PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Animal Breeding: Contributions to the Efficiency of Livestock Production

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IMPROVEMENT OF BIOLOGICAL EFFICIENCY

Animal breeding: contributions to the efficiency of livestock production

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CONTENTS

Biological efficiency is an elastic term that commonly refers to comparisons of some aspect of animal performance at individual or herd level. It is useful in reviewing the opportunities for improvement by animal breeding to stretch the term to cover the biological efficiency of whole industries and thus their ability to compete for resources. Past improvements in the productivity of livestock, especially of pigs and poultry, suggests that genetical progress tends to be contemporary with advances in husbandry, scale, and other aspects of management; that ruminants are relatively backward; and that reproductive rate has so far not contributed fully to the improvements. The conflict of objectives that follows from diversity in production methods that range from hill-farming to factory farming needs resolving. Most of the prospective contributions from animal breeding research imply an emphasis on intensive systems and on efficient food production. Since society at large has other interests as well, there is a case for initiating an articulate and scientific study of the facts, methods and principles of livestock policy with a view to identifying national priorities.

1. Fitness and competition for resources

Biological efficiency applied to livestock enterprises bears a strong resemblance to Darwinian fitness. Both are concerned with the competence of genotypes to ensure survival in a competitive and changeable world, and both imply the production, if possible, of a reproductive surplus which can be used for expanding in some way. The greater this surplus or output from a given

9-2

set of environmental inputs of food, disease control, and so on, the more efficient (Harris 1970). The main difference lies in the context. Man influences the environment to suit his own ends, alters the selection pressures through market or other preferences, and controls the use to which the surplus (or the funds it generates) is put. Biological efficiency of livestock is not intrinsic but is judged in circumstances which include markets, management systems and popular opinions as well as climates and diseases. In essence it is a measure of success in competing for resources with other animals, other herds, other industries. By implication the commonest breeds are, or have recently been, the most efficient. The rise and fall of breeds of cattle, pigs, and poultry reflect changing ideas about efficiency; and the various kinds of draft animals in developing countries – oxen, horses, mules, camels, llamas, and elephants – show how the context matters. Today it is one in which other components of production are in a state of flux. Advances in transport, animal health, deep freezing, fertilizers, protein substitutes, and above all the managerial revolution come readily to mind (de Vries 1968) and this fact will colour all that follows in this paper.

On this view the biological efficiency of any part of animal production is to be measured in the last resort by the exactness with which it is adapted to all the other components of the relevant environment. The matter can be put another way by adapting the words of Frankel (1969) who described plant breeding as the genetic adjustment of plants to the physical, biological, technological, economic and social components of the environment. By extending the task of the plant breeder to cover the adapting of plants to the institutions and desires of human societies as a whole and not only to those of producers of crops, Frankel raises the status of plant breeding from a technology to a crusade on behalf of mankind. It is the same with animal breeding (Donald 1968).

Biological efficiency in the more limited sense of feed conversion efficiency or feed utilization has attracted much attention. For recent reviews Blaxter (1965), Byerly (1967) and Holmes (1971) may be consulted. It is not the purpose of this paper to go over the same ground, nor to try to cover the subject of reproduction as have for instance Short (1967) or Bradford (1972), although it is another important aspect of biological efficiency. Instead, at this time, when economic growth may conflict with other social ambitions, it is appropriate to consider, however superficially, the influences affecting the efficiency of the livestock industry. Starting with the merit of individual animals relative to their herd mates, there is a progression of efficiencies through the herd as a whole, the breed, and the industry, finishing up with the efficient use of resources (including land, labour, capital and finance for research and advisory work) from the point of view of the nation. At each stage in this progression, there are opportunities for improving efficiency.

Economic reasons (see, for example, Allen 1972) have been well aired: inflation; rising labour costs; competitive supplies from food surplus areas, especially the European Economic Community; alternative uses for land; growing organization and skill in marketing; all the year round supplies of lamb; new patterns of movement of store stock; and export markets. While these problems beset the industry, technology is advancing and creating more problems. Wide differences in performance from farm to farm are high-lighted by the recording of cattle, sheep and pigs; artificial insemination sets about recasting the breeding of sheep and pigs as it has the breeding of cattle: and mass production methods bring about a confusion and a conflict of national purposes.

Experience with pigs and poultry, together with the enormous variation in breed, cross-breeds and products suggests that the task of improving the suitability of cattle and sheep for their economic purposes has scarcely begun. Anatomical and reproductive improvements in them are waiting to be made. There are plenty of biological inefficiencies – at least there seem to be. Barren ewes, dead calves, dystocia, over-fatness, bad udders, and liability to parasitic infection are familiar. How far they are a necessary consequence of a desirable state of heterozygosity, balanced lethality or linkage is not known. Meantime they are treated as defects to be got rid of. At the herd level, there can be inefficiencies due to mis-management expressed as under- or over-feeding, poor reproductive record, excessive mortality and mistaken breeding policy or balance of crops and stock. These have long been the concern of farm economists.

At the industrial level, there is competition for resources on a still grander scale. Sheep and cattle are in contention for land, labour and capital. Their products compete with those of pigs, poultry and fish, home grown or imported. Both occupy land that is sometimes needed for trees, parks, roads or housing. Such are the complexities that arise at this level, it is tempting to regard the term 'biological efficiency', along with 'unnecessary duplication' and 'under-developed' as convenient but defying definition.

The search for whatever passes for efficiency has naturally to be based on what is socially possible for the time being. Belated progress of a kind which would be quite out of date for pigs or poultry is now proposed for sheep (Robertson *et al.* 1972). In fact, freedom to search for higher efficiency is only partial, livestock producers and breeders being limited by the economic conditions within which they work as well as by the methods available to them. Changing the habits of banks, markets, or landlords is usually beyond the powers of individuals; and resistance to livestock producers' attitudes to efficiency can come from many more sources.

There are those to whom the very idea of efficiency is repugnant. It threatens farmers who think of production as a way of life; or as a cosy relationship of employer with employee. It is distasteful to Arcadians and Utopians alike. It worries those who fear change; and it provokes others who are against this or that kind of pollution, factory farming, fertilizers, and imported livestock. Not everyone wants this kind of improvement. It might not be regarded by some as 'in the public interest'. Technology has an appetite that grows by eating and may engender a rate of change that outpaces society at large (Ashby 1971). Breeders sometimes feel that selection pressure in one direction may lead to a relaxation in another and a loss of net merit. Fear of this may inhibit concentration on one or a few characters. The benefits of increased efficiency may not go to those who have earned them since under some economic conditions a surplus might develop or under-recoupment be imposed. Popular breeds may become obsolete and leading breeders redundant. So for one reason or another there must be a substantial number of both urban and rural people who are not interested in the pursuit of efficiency.

The contribution of agriculture, forestry and fishing to the U.K. gross domestic product in 1971 was valued in the official statistics at £1363M. The national total for all industry was put at £47 746M. It will be well therefore not to exaggerate its industrial importance nor to under-rate the consumer interest and the amenity value which are not included in these figures. Nevertheless, since it is government policy for the present to increase the gross domestic product and the efficiency of production of all kinds, it is necessary to consider where greater efficiency might come from.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

2. Rising productivity of livestock

Livestock production and the costs of it depend heavily on three processes: (1) reproduction; (2) production (of eggs, milk or wool); and (3) growth. Each of these depends on genetic and environmental variables which affect the economic efficiency of an enterprise (Dickerson 1970) so that there are numerous ways of influencing the ratio of inputs to outputs. In each class of stock, the first attempts to measure outputs were by modern standards over-simple. The choice of method has depended, naturally enough, on cost; but notable changes have been brought about.

There are well-documented increases in the performance of poultry, pigs and dairy cattle. The most striking is that of broiler growth rates (Dickerson 1970). During the period 1939–69, age of American broilers at a market size of 1.5 to 1.8 kg and feed consumed were reduced by half. Good progress is also being made with Large White pigs in Britain. Since 1958, the feed conversion ratio of Large White bacon pigs on test has come down from 3.31 to 2.68 kg per kg of live mass gain (according to the annual reports of the Pig Industry Development Authority and the Meat and Livestock Commission), that is, a reduction of 18 % in 12 years. At the same time, depth of fat on the shoulder was reduced from 46 to 41 mm on average, and area of eye muscle increased from 26.7 to 32.4 cm^2.

Over the last 100 years pigs have undergone a transformation. Since the heyday of the very fat Small White and Middle White pigs there has been plenty of time for changes in husbandry and consumer taste. The amount of fat in the pig when killed and the distribution of it has altered. The efficiency of the various types of pig in the sequence cannot be compared however because the food, the housing, the disease control have improved, and the desire to eat fat pork has gone. The time taken to effect the genetic changes in size, shape and composition was much longer than would have been necessary if modern knowledge had been put to work from the beginning. But there would have been no point in trying to apply it because improvement is determined by progress in husbandry and market demand as well as by heredity. One problem now is to coordinate these three.

The yields of dairy cows in many countries have also been rising. Milk Marketing Board data from England show that milk-recorded Friesian cows have improved in yield at the rate of about 13 l (3 gal) of milk each year since 1960. Only part of this is genetic in origin. Although a somewhat leisurely rate of change, it may be fast enough for markets and farm practices to cope with especially if there is judged to be a need for more meat but not for more milk. Yet from the point of view of costs of improvement, the slowness is frustrating. Notwithstanding all the resources of the Milk Marketing Board in organization, capital, milk recording, and data processing, the mean yield of the dairy cow population bred by a.i. increases genetically at about 0.5 % a year. Rates of 0.8 % or more can be achieved (Hargrove & Legates 1971). Whether such high rates are always desirable is open to question. In addition to first lactation yields of milk, there are usually standards of health and conformation to be met by a.i. bulls but they do not and cannot include a standard of comprehensive biological efficiency unless this assortment of characters is assumed to do service for it.

3. Observations on progress to date

(a) *Methodology*

No single cause for these changes can be safely identified in any of these examples (for a discussion of this subject, see Hill 1972). There has probably been a co-adaptation of management and livestock in each case but the various and varying contributions from better crops, skill in feeding, disease control and housing on the one hand and selective breeding on the other have not been traced. What can confidently be asserted is that without large-scale operations, without clear purpose, and without finance and technological skills to back them much less would have been achieved in the last 25 years.

The question now arises whether increases in growth rate, or yield, always mean increased efficiency of the enterprise. Average growth rate or yield of eggs or milk are outputs and not measures of biological efficiency. The justification for emphasizing individual performance is the supposition that it will be associated with growing economic efficiency of enterprises and industries.

Supporting this view is the evidence that productivity (if not always the profitability) of farms, of labour, and of herds, has been rising steadily. The other possibility is that progress in feed, housing, and disease control more than compensates for any decline in reproductive performance or health there might otherwise have been. There could come a stage as plant breeders know when still higher performance carries excessive health risks.

(b) *Conflict of objectives*

So far only in poultry breeding has reproduction been successfully emphasized. Yet control of diseases and death rates has a marked influence on biological efficiency. Vital statistics on farm animals show that there is still an unacceptably high average rate of loss particularly among young animals. Something like 10 to 20 % of the calves, pigs and lambs born are not successfully reared. Obviously it would be advantageous if those losses could be economically reduced. The approaches to this task are numerous and involve many agricultural arts and sciences. Early foetal death, twinning, lower perinatal mortality, and easy parturition warrant continued study. Because of its favourable effect on all of these – save parturition in some cases – systematic crossbreeding may grow in favour. Table 1 illustrates the point with data from Donald (1963).

Table 1. Crossbreeding dairy cattle

losses of calves out of heifers

dam	calf	no.	% died
pure	pure	197	14.7
pure	cross	110	6.4
cross	cross	185	6.5

Increasing herd sizes of dairy cows and pigs bring a new conflict of breeding objectives nearer. There are grounds for expecting this. Behaviour and fertility may be affected by the size of herd. The incidence and type of disease varies with housing, grazing and locality. The benefits of standardizing procedure, using advanced skills, capital intensive husbandry, and contracting, are greater for the large enterprise than for the small one and so are the risks that specialization will mean a fatal loss of adaptibility or outrun the ability of management to manage it.

Animals tailored to an industrial system of production are unlikely to be suitable for general purpose use. Technological advance is not just a matter of grafting new practices on farming. Some of it is but some of it leads to a type of food production known as factory farming, the type characteristics of which are large scale of operations, uniformity of method and uniformity of product. Way-of-life farming by contrast is relatively small scale, with limited control over the conditions of production and consequently a need for flexibility and adaptation to changing circumstances. Where there is a trend towards industrial forms of production intermediates can be found as, for instance, with pigs and dairy cattle where herd size is growing and feeding methods are rapidly being simplified.

Because breeding is such a slow process – but not necessarily slower than changes in standards of management or product grading – it is to be considered whether it should be started well before the need arises. In anticipation, for instance, that shorter, thicker pigs with less fat than those available today will be wanted in future, selection could begin now. And indeed a start has been made. But those who invest in such a project may be ahead of their time and fail to find a market. Farmers who bred large lean beef cattle a few years ago found few supporters. The efficiency of their cattle was academic. In such cases, the benefits of breeding would not bear a favourable relationship to the costs of achieving them. If, as Hinks (1971) calculates, it takes 12 to 15 years for the considerable costs of finding a bull capable of improving yields of milk to be recovered, those whose money is being invested will need confidence in a fairly distant future.

It does not follow that because a desirable change could be brought about by breeding it should be done that way. A cheaper and quicker method may be available through management. The incidence of diseases due to mineral deficiency, for instance, although influenced by heredity (Wiener & Field 1971) may be preventable through improved feed composition. Although in the long run there may be a case for breeding in order to avoid recurrent costs of prevention, there is the time taken to achieve the breeding result to be considered as well as the loss of progress in other breeding objectives. For the present the position is different from that pertaining to crop plants. Simmonds (1972) believes that it is easier to persuade farmers to try out a new product than a new method, let alone a new production system. If that is so, it should pay to seek improvements through products (including new varieties of plants) whenever possible. One good reason for this is that large commercial organizations are ready and willing to patent and promote new plant products. In contrast there are no sales organizations for new strains of livestock corresponding to the National Seed Development Organization for plant varieties.

To sum up, it could be said that in the matter of biological efficiency animal research workers do not know accurately where they are, nor yet where they have come from; but they travel hopefully. Complex though the problems are, the technical methods for solving them have been greatly extended in recent years and in the following sections, brief reference will be made to some. By no means the least of the reasons to be thankful for them is that they give some assurance that the rigidities of the pedigree system of breeding will not be quickly replaced by others imposed by today's technological orthodoxies.

4. Current developments

Within the next 10 to 20 years, the quest for efficiency will begin to benefit from a number of current research topics. Of these a few may be mentioned that are of particular interest to livestock geneticists. Only time will show whether any of these will prove of as much significance as would for instance an understanding of heterosis and genotype-environment interaction.

(a) Pelleted complete diets for ruminants

It is now feasible to produce pelleted complete diets for ruminants on which they will grow well and ruminate. The pellets lend themselves to dry storage and mechanical handling. At present they are probably not economic to use when made on a small scale, but the question of what is or is not economic admits of no final answer. For the present the complete diet is being used in experiments. It has the substantial advantage of enabling food consumption to be easily recorded free from most of the seasonal variation so characteristic of grass in all its forms. There is the prospect therefore of making breed and crossbred comparisons within and among countries in which inputs as well as outputs can be satisfactorily observed. Table 2 shows some early information from a comparison of Friesian and Jersey cattle (L. S. Monteiro, personal communication). Taking the evidence on its face value for the present indicates that while the fast growing Friesians make better use of their food during growth up to 18 months of age, the Jerseys have been of superior efficiency as producers of milk, butterfat and total solids.

(b) Herd performance

Performance and progeny testing is being extended in various ways. Perhaps the most important trend is to apply the basic idea to whole lives instead of first lactations or post-weaning growth and to whole herds and flocks instead of individual animals (Cartwright 1970). The Milk Marketing Board and the Meat and Livestock Commission are doing this for cattle, sheep and pigs. By this means attention will be focused on management so that weaknesses, particularly in health and viability, may be recognized and dealt with by advice or research.

Table 2. Efficiency (%) on complete diet

breed	growth, 3 to 18 months	f.c.m. lactation 1: during lactation	f.c.m. lactation 1: since weaning	lactation 1: fat	lactation 1: solids
Friesian	12.5	56.2	27.1	2.2	3.9
Jersey	11.1	57.2	29.7	2.5	4.2

Some of the complications arising when cattle are compared for efficiency of production are discussed by Joandet & Cartwright (1969), Klosterman (1972) and others. Fertility, health and meat quality are emphasized. They show also that body size and therefore growth rate have an importance which depends less on efficiency of food use than on managerial and market requirements in respect of mass and age. The main problem is to find the breeds or crosses with the size and growth that are best for a given system of production and age at slaughter. The more production systems or variations of these systems there are, the more complex the problem. The degree of success in the search for greater efficiency will depend on reducing the number of products, concentrating the search on as few systems of production as possible, and bringing managerial, health and other environmental factors to a higher degree of standardization (Korach 1964).

(c) Product quality

Progress in scientific apparatus to exploit chemical, physical and statistical knowledge has greatly increased the range of observations. Chemical analyses of milk and meat, and blood can now be done at a rate and with an accuracy unattainable a few years ago. Devices for estimating depth of fat on live animals are now commonplace. Much of the value of the information obtained in these ways would be wasted were it not that computation has become equal to the task of reducing the data. With a little imagination it is possible to foresee that the computer will be used to work out regularly the history and prospects of a cow in terms of a kind of price: earnings ratio by a new variety of stockbroker.

Livestock breeding has not reached the standards of precision in chemical quality that breeders of potatoes, wheat and barley need to meet for such products as crisps, bread and whisky. For frozen foods, special varieties are grown. Consumers seem to be less demanding about meat quality; and milk quality does not attract as much attention as might be expected. So far only pressure for less fat has been reflected in a changed composition of animals and a revised view of the importance of conformation. Formerly an important component of good conformation was a smooth distribution of a thick layer of subcutaneous fat. Lessening this fat, or breeding meat animals that will deposit it inside instead of on the outside of their bodies, is a current objective being rapidly realized. As deboning and prepacking grow in importance, still more notice will need to be taken of the ratio of edible to non-edible parts of carcasses in choosing breeds and in manipulating rates of growth and mass at slaughter (Harrington 1971).

5. More distant prospects

(a) *Crossbreeding cattle*

As the emphasis on biological and economic efficiencies of whole dairy enterprises grows, the testing methods will become increasingly preoccupied with the merits of crossbreeding, a subject recently discussed critically by Robertson (1971) and Lerner (1973). Sufficient work has now been done on dairy cattle (Pearson & MacDowell 1968) to show that first cross animals will be close to the mean of the parents in characters of high heritability such as butterfat percentage of milk in which little or no heterosis is detectable. For milk yield and body mass, heterosis of the order of 5 % of the mid-parent value will occur. As has been generally observed, where heritability is low, heterosis may be substantial. For viability and fertility it may reach 15 %. Reports of more trials on cattle continue to come in tending to support the view that crossbreeding not only permits size, growth rate, and carcass quality to be adjusted quickly but confers a bonus in the form of better reproductive performance (Mason 1966; Gregory 1972; Everitt & Jury 1972). In table 3 some data from an experiment carried out by the Animal Breeding Research Organisation with cattle are shown to illustrate how the merits of crossbreeding vary with character and how, in consequence, with management and price levels. Experience with sheep, although limited, suggests so far that similar results will be obtained from them (Donald, Read & Russell 1963; Bowman 1966).

(b) *Shape of growth curve*

It is characteristic of the growth of livestock that animals destined to have large mature size tend to be larger at each age than those destined to have a smaller mature size. This is convenient if it is desired to select animals for breeding for increased growth rate and size before their mature size is known; but it is inconvenient if fast early growth is to be associated with relatively small mature size. That would require the latter type of growth curve to cross over the former and there is not much evidence of that. Yet it is desirable to develop this property in order to combine the efficiency of fast growth in young animals for slaughter with economy in maintaining their mothers provided it is not too costly to do it and it does not hinder the worthwhile object of raising fertility. There are several possible ways of going about it. The first is to raise birth weights through maternal effect, the second is to raise the dam's milk production and the third is to use a selection index which favours candidates approaching the desired shape of growth curve. A much quicker solution to the problem may be provided by a crossbreeding programme based on small good-milking dams and large sires.

Table 3. Performance of Friesian (F), Jersey (J) and crossbred (X) heifers

	percentage of mid-parent							
	70	80	90	100		110	120	130
live mass at birth		J		X		X		F
live mass at 18 months		J				XX	F	
milk yield			J			XF		
total solids yield				J	F	X		
butterfat yield				F		JX		
solids not fat				F	X	J		
butterfat			F		X		J	

(c) *Variation between breeds*

The amazing neglect of genetic variation among breeds has ended. The breed comparisons which testing stations made possible for poultry and pigs and which contributed to a substantial reduction in the number of numerically significant breeds are gradually being extended to cattle and sheep. Here the difficulties of making sound judgements are much greater because of the diversity of farm, production, and marketing conditions to which cattle and sheep are subject. Encouragement can be drawn from collaborative ventures set up by technologists in Europe (including Britain) for breed comparisons of pigs and dairy cattle (J. W. B. King & C. J. M. Hinks, personal communication). If the results are sufficiently encouraging the means will have been created of efficiently carrying out trials of common interest to farmers in many countries whose husbandry methods grow more intensive and more alike.

(d) *Multibreed comparisons*

Finding the right breed, or crossbreed for either milk or beef production from the very large number available – over 100 pure breeds of cattle in Europe alone – is an impossible task unless some simplifying assumptions are made. Until recently research has been conducted on a few currently popular breeds. Observations are restricted to some forms of output, mainly milk or body mass, thus favouring large animals. This may not matter, but prior selection of breeds does. It is therefore of interest that Taylor (1971) is carrying out a multibreed comparison based on small groups of 8 to 10 animals from all available breeds raised on *ad lib* feeding of pelleted complete diet. This plan is designed to provide estimates of the genetic relationships between breeds corresponding to the intrabreed heritabilities and correlations used in pure breeding. These are not provided by comparisons within a few arbitrarily chosen breeds. This work is particularly timely because there is a burst of enthusiasm for new initiatives in cattle breeding since a more liberal and constructive import policy was adopted.

Imports and exports of breeding stock have an importance which exceeds the immediate cash value of the transactions. Fortunately the term 'stud stock farm of the world' has become archaic and the idea behind it is seen to be unrealistic. In its place is an appreciation that this trade in livestock, opportunistic though it may be, and an incentive to comparatively few people, has a deeper significance for the health of animal production. That significance may be for good or for ill. It is for good when it stimulates a period of constructive thinking about the merits of homebred livestock as is happening now; and it is for good when it results in the addition of useful new varieties. But it is for ill whenever the adaptation of commercial stock here is inhibited by the commitment of leading breeders to out-of-date models in order to preserve either their export or their home market. Controllers of artificial insemination of course may now play the part of leading breeders.

(*e*) *Fertility*

It was shown by Wallace (1955) and by others many times since then that efficient food use in a sheep breeding enterprise depended heavily on ewe fertility. Yet in spite of a great deal of work on the subject, raising the level of fertility in the national flocks and herds is depressingly slow. Wallace himself (1958) and later Turner, Hayman, Triffitt & Prunster (1962) showed that fertility in Romney and Merino sheep could be raised by selection although slowly, even with selection devoted mainly to it. Trials with high fertility breeds such as Finnish Landrace and

Table 4. Lambs born per ewe put to the ram

age of ewe at lambing	breed of ewe: Finnish Landrace	crossbred	Tasmanian Merino
1 year	1.4	0.8	0.0
2+3 years	2.5	1.8	0.7
number of ewes	50	64	30

Romanov which have an average litter size of 2.5–3.0 (Donald & Read 1967; Desvignes & Lefèvre 1969) show that rams of these breeds are able to raise the fertility of first-cross daughters by 30 % or more immediately since ewes of British breeds under good conditions have litter sizes ranging from about 1.2 to 2.0 lambs on average. An even more striking demonstration of the ability of the Finnish Landrace to raise fertility is shown by crossbred ewes from the low-fertility Tasmanian Merino (table 4; and R. B. Land, personal communication). So far efforts to put the Finnish Landrace to good use have had rather limited success. New high-fertility strains produced by enterprising breeders found many experts as well as meat graders and producers as yet unprepared to accept the corollaries to larger litters – better feeding of ewes, more care at lambing, and adjusting ideas about performance from an individual to a flock basis. Since not all men and their farms make combinations suitable for stock of higher performance it is desirable to find out how much extra fertility can be exploited and where. Extra fertility comes in various forms. Precocity, extended breeding season, and higher ovulation rates can each prove helpful in the right circumstances. But they all create a need for knowing much more about pre-natal and early post-natal maternal effects. Large, lively, fast-growing lambs exact a price from the ewe and she must be able to pay it in endocrinological, immunological and nutritional currency.

6. Short-term objectives

A guess at the major animal breeding objectives may now be ventured. It is influenced by the trends of current research and the effect the attendant publicity has on the thinking of producers; but it also owes something to the assumption that because there is no imminent food shortage in Europe, markets will emphasize quality.

As capital and labour costs rise, the search for more efficient production systems will include sorting out the growth rates, mature sizes and crossbreeding combinations to match the required end-products. This process has gone a long way already with poultry, and some distance with pigs. More weight will be given to anatomical and chemical composition to meet quality standards; and to raising more young for each breeding female kept. The implied advances in control of environment can be expected to reduce variation, and ensure socially acceptable husbandry.

7. Social aspects

The examples of current research which have been mentioned, along with many more will make it possible to continue the process of intensifying animal production. All this however will not be enough. More attention will have to be paid to those aspects of livestock production in Britain which affect society as a whole. That in many ways the improvement of livestock is a sociological problem has already been pointed out (Lerner & Donald 1966; Meyer 1972). Here, as in the other countries of the European Economic Community, gross national product and economic efficiency or its component biological efficiencies are not the only criteria to be kept in mind (Brooks *et al.* 1971), but defining and weighting the others is an elusive problem that creates uneasiness.

There is nothing novel about a society which carries on activities which have a value for it that is not readily definable in economic terms. Primitive societies do so. In less primitive ones as well, beef cattle have a prestige value. Indeed in Britain vast numbers of cattle and sheep, as well as horses, dogs and other animals, are kept whose economic value and commercial efficiency are quite irrelevant. These numbers could conceivably be enlarged to accommodate all livestock.

For those who do not wish to entertain the idea that food could be a by-product of U.K. agriculture the main purposes of which are thought of as employment, recreation, conservation and environment, there are several other political and social issues to mull over. Within the E.E.C. will it be sensible for Britain to try to make all phases of livestock production competitive with the same industries elsewhere? Or to breed specifically for export? What weight is to be given to the opinions of those who would place handicaps on the growth of industrial food production? Are farming and agricultural research itself to be regarded as ways of life to be preserved in the name of freedom or as desirable features of society? In particular, is livestock research to be aimed at protein or food, at efficiency of production or efficiency of farming? These are interfaces of science and society.

Geneticists often work in association with other kinds of specialist. But there is a surprising omission. There is little joint study of common problems with economists. If the old concepts about the role of agriculture have been made unserviceable, is it not timely to encourage study of the objectives of livestock production and agriculture generally against its new background? To avert unnecessary strife, ecologists, social scientists and planners concerned with amenity, and employment, as well as with economics might be glad to embark on collaborative studies with animal technologists on the future of livestock production. With factory farming, pollution, marketing, protein substitutes, land use, land values, tourism and by no means least, the art of agricultural development to choose from, there is no shortage of topics. Environmentalism may be 'a sentimental longing for the recent past' but it is a fact of life that many regard as contributing to the standard of living.

We shall be wise therefore to concern ourselves not only with the rate of change but also with the style of change, that is, the way in which the components of the ratio of inputs to outputs by which efficiency is to be measured are chosen. Where food is plentiful, amenity ranks highly. Farming is not only a way of life for farmers but is also part of the way of life of society as a whole (Bunting 1970; Bonham-Carter 1971). Behavioural change in the towns and in the country will have different motivations (Leagans & Loomis 1971). As Aschman (1965) puts it, analysis of past attitudes to livestock will not predict the new. The new attitudes will be imposed by economic pressures within the European dimension; by advances in science; and by the demand for food growing inexorably (Lerner 1973). Control and modification of them will be required in the name of the social conscience, conservation, and amenity. When enough people believe in the efficacy of revealed religion, or revealed science, or revealed environmentalism, economic values are adjusted accordingly.

8. Conclusions

Although progress at technological level can be claimed, more vigour might be applied to the business of deciding what is required of the livestock industry and then seeing that it gets done. Livestock are an essential part of the agricultural industry and cannot be considered in isolation. The search for and the creation if necessary of specially bred varieties of livestock to meet with growing exactness the requirements of industry is being retarded less by ignorance than by lack of purpose.

In the light of current knowledge, a possible strategy might be, first to promote efficient food production by industrial methods for pigs, poultry and rabbits, together with some of the cattle and sheep; secondly, to breed a few types of grassland sheep and cattle designed for organized crossbreeding; and thirdly to devise production systems to link the grasslands with the factories. Some such firmly established course of action seems desirable in order to limit the number of problems to be solved. It will be easy for all to agree that resources for research should be deployed where they will be most effective, but much less easy to defend the choice.

The advances to be made in adapting livestock would include: (*a*) more specific definitions of objectives and of efficiency; (*b*) new standards of organization, contracting, financing, discipline, grading and uniformity (H.M.S.O. 1972), difficult of achievement for those with the ideas inherent in the term way-of-life farming; and (*c*) new attitudes to environment, to the care of animals, and to pollution possibly at variance with the concept of industrial production.

Underlying the choice of both the strategy and the tactics is the belief that development is the achievement of new arts of living and working together (Frankel 1952) and requires that agriculture be an integral part of society to be adapted with and for it (Hunter 1970). To this end, there should be an independent body which issues information and constructive criticism of objectives, research, teaching, management, and administration at all levels of decision making. An articulate and scientific study of the facts, methods, and principles of a livestock policy is needed in Britain and might make some progress towards uncovering the factors modulating the process of technological innovation, and towards making intelligent guesses at the national priorities (Zuckerman 1968). The same aims have been urged by Duckham & Masefield (1970) for agriculture everywhere.

Given the diversity of vested interests in agriculture, these suggestions smack somewhat of a counsel of perfection. Yet that may be no bad thing if they lead to more clarity about purposes. Over a mass of tactical concepts, some strategies should dominate but in the recent past, political and economic guidance has been faltering. There is a tendency to forget that the phrase of convenience 'developed and developing' refers not to a dichotomy but to a spectrum over the whole of which some principles of agricultural evolution apply that could be the basis of strategy.

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