CHAPTER IX

ORGANIC CHEMISTRY

BY TREAT B. JOHNSON

Introduction

The historians, who write of human evolution, speak of the Stone Age, the Bronze Age, the Iron Age, and other Ages, meaning by such distinctions the successive periods of human activity that have been characterized by the use of these materials. A quite fitting term to apply to the period in which we are now living, and which began about one hundred years before the birth of our national SOCIETY, would be "The Chemical Age." It has been one of rapid and wonderful developments. Many pages could be written to illustrate how far-reaching and how marvelous have been the modern advances in chemical science and their applications. But all this has taken place so quietly that the average individual does not appreciate the part these new discoveries are playing; nor can we estimate with any accuracy the still greater part they are to play in the future.

It is, therefore, a duty and a privilege for us, as chemists, to reveal at this time and in this fitting place a picture of our major accomplishments and their meaning, which will be understandable to those who have not had the opportunity to study chemistry. It is next to impossible today for the layman to form any proper appreciation of how far the results of chemical science are of influence in his daily life, still more to what an extent they are likely to come to his assistance in the future. In our relations with our fellow men, and when we are rejoicing as scientists over the results of our past accomplishments, let us not forget that it is only recently that the progress of pure scientific knowledge has caught up with the old empirical methods of the industrial operations of our manufacturing organizations. Organic chemistry in America is a very young science.

The task of reviewing the progress of organic chemistry in

our country since the organization of our national SOCIETY in 1876 is not an easy one. The growth has been so rapid and so many outstanding achievements in the pure and applied fields of this branch of chemistry have been accomplished, that it is an impossibility, in an essay of this size, to evaluate the work of every investigator who has played an important role in this development. Although I have not suffered myself to overlook any facts and accomplishments that were known to me or were brought to my attention, I have, however, realized my limitations as an historian of organic chemistry. In bar of any criticism that may be brought against my survey and conclusions, I can only offer the same apology for human frailty as was expressed by Benjamin Silliman of Yale in his address on "American Contributions to Chemistry," delivered at Northumberland, Pennsylvania, August 1, 1874, on the occasion of the Priestley centennial of chemistry. I quote his words verbatim:

> In attempting to review the contributions to our science at the hands of American investigators during the century we celebrate today, it is proper in bar of criticism to say that I was called at a very late hour to the task in hand, and have become more sensible as the work opened before me of the disproportion between the brief time at command and the extent of the task assigned me. If important omissions are detected—and that there are such can hardly be doubted—the speaker must beg of his fellow workers in the common field some indulgence, as is due to human frailty; and while he is conscious of a desire to do full justice to the labors of all, he has also the knowledge that all among living laborers have not responded to his call for coöperation. If an apparently undue proportion of space has been given to some portions of the historical part of our essay, it may be said in fairness that it is far easier and more just to write history than to anticipate it, and one who lives in this latter end of the first century of modern chemistry must see to it that we leave such footprints in the sands of our time that the future historian of the science cannot fail to do us justice.

The Growth of Organic Chemistry as a Science

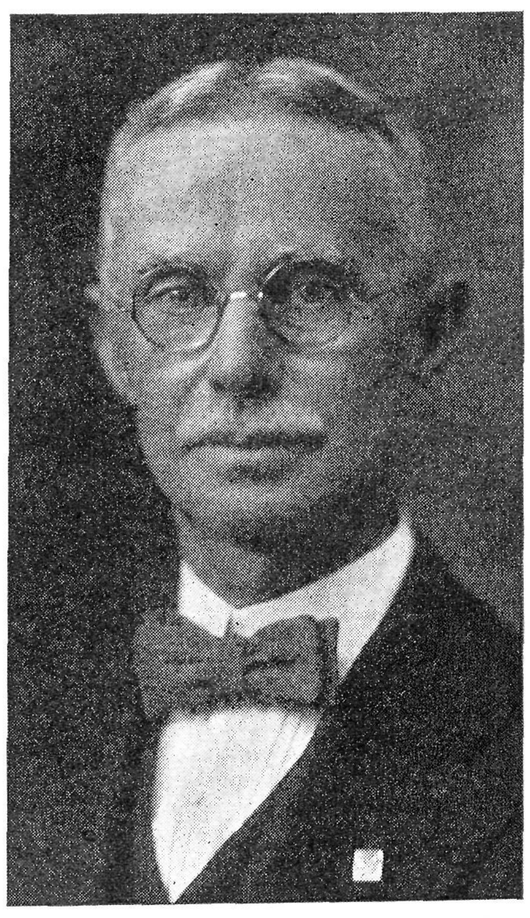
There is probably no topic which is better suited than organic chemistry to indicate the advance which has been made in this country, since the organization of our national SOCIETY, in teaching, research, and the various lines of active work of our science. In 1876 the science of organic chemistry was, indeed, very highly developed in Europe and there were many productive workers in Germany, France, England, and Russia, whose achievements preceding this date are now recognized as foundation stones of our present scientific structure. But at that time in our own country there were only five or six universities in which organic chemistry was taught as a special branch of chemistry, and in which researches in this special field were conducted. Those who were interested in the promotion of the science were unable to accomplish their aims on account of lack of funds and laboratory equipment.

ALEXANDER SMITH
(1865–1922)
President 1911

Foster

ARTHUR D. LITTLE
(1863–)
President 1912, 1913

THEODORE W. RICHARDS
(1868–)
President 1914



Gessford

CHARLES H. HERTY
(1867–)
President 1915, 1916

C. H. Herty was also Editor of *Industrial and Engineering Chemistry* 1916–1922.

In the early period of organic chemistry formula worship was a strong force influencing the researches in this subject, and the remark is made even today, by those who have not followed the modern developments, that on account of this worship the evolution of organic chemistry has been retarded and conspicuous progress is not being made. We have also been subjected to the criticism that our native publications do not stand out as constructive and original contributions to our science. The author does not believe that this is a just and warranted criticism, and he feels quite confident that there is an increasing discontent among our young investigators with the simple development of ideas inherited from the past. We have growing in our country a most promising group of young chemists, who can be expected to add to the present knowledge of our science.

The constitution or structure of chemical compounds has received more attention from organic chemists than any other subject, and this has been true ever since chemistry came to be a science. Just as soon as organic chemists recognized the significance of structural or space formulations of organic molecules, the science began to undergo a rapid evolution and an advance was made which has never been duplicated. It was the physiologist and philosopher, Du Bois-Reymond, who said:

> I know of no more astonishing production of the human mind than structural chemistry. To develop, from that which appears to the five senses as quality and transformation of matter, such a doctrine as that of the relations between the hydrocarbons, could scarcely have been easier than to develop the mechanics of the planetary system from the motion of luminous points; and Strecker's prediction of the synthesis of creatine, which was afterwards verified by Volhard, although in a less exalted sphere, was in fact no smaller achievement than the discovery of Neptune.

What a wonderful advance has been made since Du Bois-Reymond spoke these words! Organic chemists have not been pursuing a phantom for the past fifty years. The success attending the application of the doctrine of valency to the compounds of carbon helped its extension to all compounds formed by combinations with this element. Edward Frankland and August Kekulé gave us great truths. No conceptions more prolific of results have been introduced into any department of science, and this very success in the hands of the organic chemists is now making it more and more obvious that these are truths which are worth pursuing for further development from the physical side. Valency was the ladder by which the organic chemist climbed to his brilliant achievements in chemical synthesis; but notwithstanding this success, there is something to be reckoned with besides valency. One great desideratum of modern organic

chemistry is a physical interpretation of the combining capacities of the carbon atom.

Many organic chemists today are unwilling to admit, as many would have them to believe, that the chemistry of carbon has reached its limit of development. There is a growing spirit of optimism among a large proportion of our young workers that organic chemistry has not approached that condition in which it has ceased to afford a profitable field for research. The writer is one who believes that never, since the organization of our SOCIETY in 1876, has there been a time when there were more opportunities for constructive and original work than are visible at the present time.

From the systematic point of view there is no doubt that organic chemistry is the most highly developed branch of chemistry. The old idea that the only aim and end of organic chemistry is that of making new compounds, and then studying their constitution, is not the doctrine that is practiced by organic teachers in our most progressive institutions. Every science naturally develops along the line of least resistance, and in the case of organic chemistry this was synthesis. In the early sixties scarcely an organic chemist concerned himself with the relative positions of atoms or groups of atoms in space, and it was nearly twelve years after the birth of our SOCIETY that organic chemists awoke to the importance of this special relationship. In other words, while Pasteur's conception of molecular asymmetry was enunciated in 1860, it was not until 1874, when the classic papers of van't Hoff and LeBel appeared, that Pasteur's ideas assumed a development applicable to the theory of structures; and not until 1887 that Wislicenus showed that stereochemistry is no longer a chemical curiosity. The introduction of the stereochemical hypothesis was unquestionably the greatest advance in structural organic chemistry since the recognition of the quadrivalency of carbon.

Following this work of Wislicenus this subject became a fashion, has remained so ever since, and it is gratifying to write that the influence of his work spread to America (the home for a time of his youth and the scene of his early chemical labors), and that some of the most important contributions in this field today are being made by American organic chemists. We are now concerned, as never before, with explanations of physical structure, and in no field of science are these speculations to find a greater field of service than in that dealing with the problems of physiological chemistry.

The organic chemist of the last fifty years has been more than a mere interpreter of nature. A marvelous perseverance and constructive ability has been displayed. He has developed powers of synthesis beyond those of nature. Although the early aim was directed to the discovery of the arrangement of atoms within molecules, more and more attention is now devoted to the way in which the specific reaction takes place. Physiological chemistry has been revolutionized by application of new principles, and has now become a science of progress. Bacteriology is also being influenced by the same forces. The organic chemist hitherto interested himself chiefly in the end products of his reaction. By appropriating the principles of physical chemistry in his work, he has come to realize that his reactions do not proceed to end in a sense expressed by his graphical equations, but that reaction velocity and laws of equilibrium exercise a fundamental bearing on his whole work. He has learned to realize that his equation is true only when read from left to right and vice versa from right to left.

It can be truly said that the trend of organic chemistry is gradually away from a narrow conception of structural formulas as the final goal, and towards a consideration of nature as a manipulation of energy. The continuity of all classes of chemical phenomena is being more and more recognized, and as a result we are seeing the evolution of a new kind of chemistry—biochemistry. This is attracting the attention of some of our best workers in the fields of organic and physical chemistry. In no country is more progress being made today in this new field of chemical science than in America. Several of our leading American workers in organic and physical chemistry are engaged in its development and through the results of their investigations they are contributing very extensively to the advancement of medicine, physiology, and bacteriology. No one of these branches of science can advance further without the aid of chemistry. The human body is now recognized as a chemical laboratory and without the aid of the chemists qualified with a thorough knowledge of the properties of carbon its mysteries cannot be unraveled. We are at the beginning of a new era and great advances are to be expected.

The present status of biochemistry is well expressed in the words of Meldola, who wrote in 1895 as follows:[1]

> We are but dwellers in the outer gates, waiting for the guide who is to show us the bearing of modern research on the great problem of life, which confronts alike the physicist, the chemist, and the biologist.

[1] *Nature*, **52**, 482 (1895).

It was E. F. Armstrong who wrote in 1924:

> Chemistry, in particular organic chemistry, is perhaps today at the parting of the ways, and we may well be on the eve of another great advance due to the birth of new views of structure. Earnest workers in all branches of the science are making strenuous efforts to see behind the curtain and are converging to a common view—a sure sign that a renaissance is at hand.

The Period 1876–1901

The writer has necessarily confined himself to the field of academic activities, and left for other writers to review the developments which have been made in the field of applied organic chemistry and to relate the history of the marvelous growth of our modern organic chemical industry. Scientists and technologists in organic chemistry are not born, but made by half a lifetime of hard study, and in both fields we can point to several outstanding men in this country whose achievements in special lines of research have been the directing influence leading to great scientific and industrial accomplishments. Research men and teachers in academic institutions have a way of giving more than they receive, and in their collegiate activities they have many opportunities of being kind and helpful. Very often, however, little reward is offered for such assistance, and in many cases the information given has contributed to the success of important commercial developments. In some cases it is often impossible for industry to repay these men or even to show a due appreciation of their services. We have had many examples of men of this type in the field of organic chemistry in our country, and their influence has been of the very highest value to the progress of our science.

When one attempts to present a picture of the progress made in the field of organic chemistry, and to discuss the present status of this branch of chemistry he is at once confronted with the question, which naturally arises in the minds of anyone who is interested, as to who have been the outstanding personages in bringing about this pronounced change in chemical interest in this country during the past fifty years. One is immediately asked, is it a growth of recent years and of the mushroom type, or were the foundation stones of our present structure laid several years ago in the early period of our development? In other words, can we pick outstanding figures who may be classified as a group of pioneers, or was our superstructure built on the results of researches of our present generation? It is perhaps fortunate for the writer that he is in a position to visualize and obtain a prospectus of the progress of our achievements from a central

station. It was in 1901 that he received his Ph.D. degree from Yale University, or the same year that our SOCIETY celebrated its Twenty-fifth Anniversary. In consequence of this fact he is led to draw illustrations and comparisons from these two definite periods of our history and to emphasize the outstanding academic achievements of the two periods, 1876–1901 and 1901–1926. To answer the above question is extremely difficult. Only those chemists can be mentioned who stand out in bold relief. Some of our most brilliant researchers in science started their careers as workers in organic chemistry, but did not stay in this field. They shone later by the results of their outstanding performances in departments of knowledge other than chemistry.

After a careful study and consideration of certain facts, which will be referred to later, the author is led to the conclusion that the progress, of which we are all proud, has been one of evolution and that the results obtained have been accomplished successfully by the application of sound and accurate principles which were taught to us by the men active in our old institutions of learning. In other words, as is well expressed in the words of one of our esteemed pioneers—Remsen—"Progress in chemistry is not made by revolution but by evolution." Space forbids an exposition of more than a mere reference to the most outstanding achievements. The final conclusion that any reviewer can safely draw, no matter what feature is emphasized, is that American research in organic chemistry is not the product of a selected group of geniuses who have shone conspicuously, and have, thereby, won a commanding position through notable achievements, but is the result of the labors of a large number of men working, for the most part, under very unfavorable conditions and against a pressure calling for the greatest personal enthusiasm. In other words, we are observing and enjoying the results of the mass action of a large group of interested workers.

There has never been any royal road in chemical research in organic chemistry. Each step in advance has always been made more or less at random, and each investigator is comparable to a traveler in an unknown country. His path is never mapped out for him, and there are many by-paths, which are always uncharted, leading him often in the wrong direction. There is only one course that is the right one to follow, and this has to be found by many trials. Our future advance and the new contributions to knowledge are dependent on our ability to benefit by the errors that have been recorded by our earlier explorers. In this light it is indeed fortunate that the men operating in

the period covered by the years 1901–1926 can well turn to the labors of their scientific brethren who were active during the first period, 1876–1901, for inspiration and advice.

It is questionable whether any American investigator in the field of organic chemistry has contributed more of a fundamental character and has been more widely recognized outside of the United States for the originality of his theoretical concepts and conclusions than Arthur Michael. His defense of the Kekulé-polymolecule idea, and his interpretation of the mechanism of an organic reaction as proceeding according to the principles of addition, with formation of an intermediate "addition product," were conceptions which have exercised a tremendous influence on the development of chemical thought. He can justly claim first place among American chemists during the last fifty years as an exponent of original chemical theory, and any survey of our fifty years of progress would not be accurate if it did not reveal the accomplishments of his researches and refer to the influence that his work has had on the development of chemical thought since the beginning of his activities as an organic chemist. He has formulated principles, made and originated syntheses and discoveries leading to applications which have rendered the world a service much greater than is generally known. Michael has not only influenced modern chemical thought on the subject of mechanism of chemical reactions, but he has also made most important contributions of theoretical bearing dealing with such subjects as valency, the relation of thermochemistry to organic structure, desmotropism, stereoisomerism, the theory of partition principle, and the scale of combined influence. In the field of organic syntheses may be recorded as outstanding accomplishments his original method of building up carbon combinations by the direct addition of malonic esters, in the form of their sodium salts, to unsaturated carbon compounds, as is illustrated by the two following syntheses:

$$C_6H_5CH:CHCOOC_2H_5 + Na\cdot CH(COOC_2H_5)_2 = C_6H_5CH(NaC(COOC_2H_5)_2)\cdot CH_2COOC_2H_5$$

$$(CN)_2 + NaCH(COOC_2H_5)_2 = NC\cdot C(=NH)\cdot NaC(COOC_2H_5)_2$$

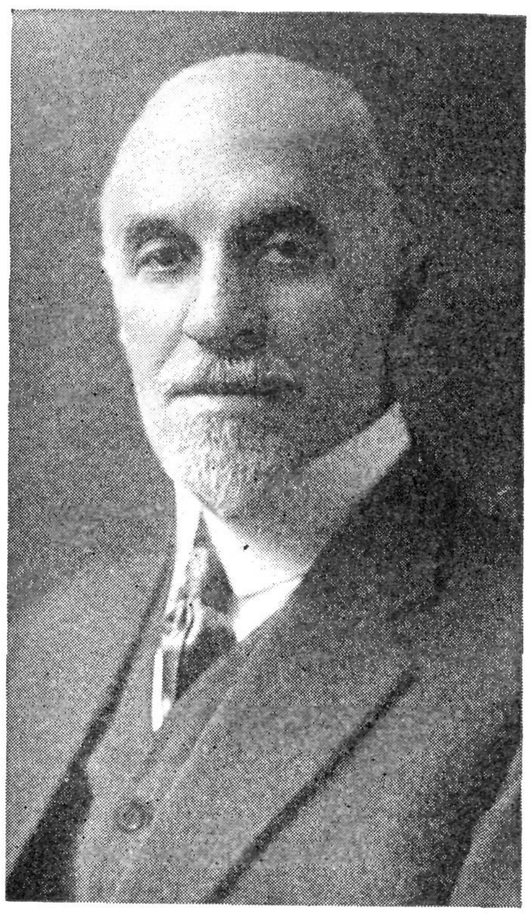
It was Michael who first showed that urea and thiourea interact with malonic ester, in the presence of sodium ethylate as a catalyst or condensing agent, to form cyclic ureides or pyrimidine condensations, and in his work on the production of salicin from synthetical helicin he won the distinction of being the first one

to accomplish successfully the synthesis of a glucoside occurring in nature.

The second American investigator who was conspicuous for his advanced views regarding the mechanism of organic reactions, and whose original conceptions attacked the very foundation of the theories regarding organic reactions, current at the time he was active, was John Ulric Nef. His denial of two fundamental assumptions, namely, that of the constant quadrivalence of carbon in organic combinations and that of the assumption of molecular substitution as representing the primary mechanism of many of our organic reactions, was considered revolutionary by many of our organic investigators; yet it cannot be denied, in the light of modern developments, that his speculations have contributed to some of our most important and fundamental work. His researches and speculations on unsaturation of organic compounds, the structure of nitro paraffins, the nature of valency, the bivalency of carbon, the structure of mercury fulminate, intramolecular addition-reactions, methylene carbon chemistry, and the theory of addition-reactions have been achievements of outstanding merit and importance. So important was bivalent carbon according to Nef that he expressed the conviction in one of his papers, "That in the chemistry of methylene is to be found exact scientific physiology and medicine and perhaps an explanation of the vital processes."

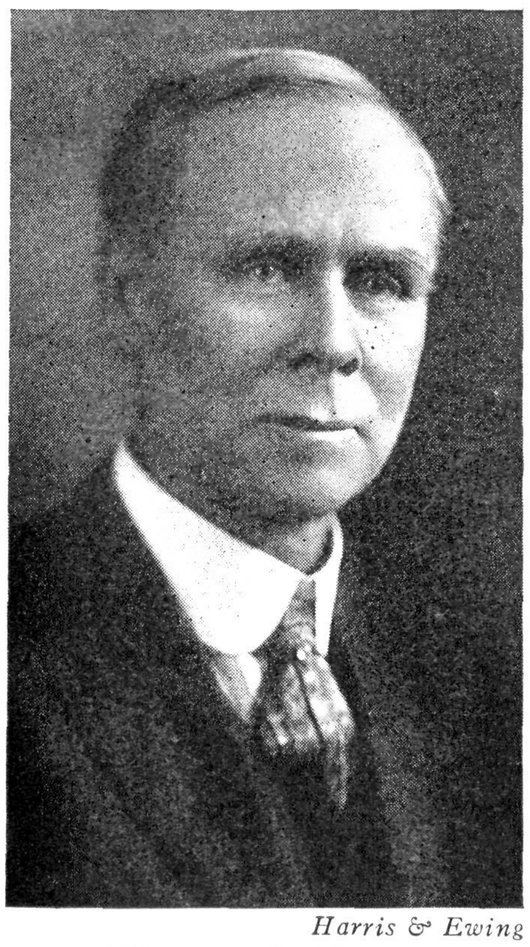
It is undoubtedly true that these two men—Michael and Nef—are the outstanding figures of the older school in the field of theoretical organic chemistry in this country. Unfortunately, their work is not so well known to our present American investigators as it should be, as most of their papers were published in German journals. Too few of us realize how much several of the German journals owe to American contributors of our first quarter-century, 1876–1901, for their past success. The two most interesting and important conceptions which have enriched organic chemistry within the last fifty years were formulated by these two American organic chemists—Michael and Nef—but their ideas were developed in German publications. Germany was the leader of the chemical world at the time they were most active, and naturally their papers were sent to those journals where they were assured prompt publication and were read by chemists in Europe who were recognized as leaders in their profession.

Neither of these two men will be remembered for his influence as a great teacher. They were, on the other hand, representative



JULIUS STIEGLITZ
(1867–)
President 1917

WILLIAM H. NICHOLS
(1852–)
President 1918, 1919



Harris & Ewing

WILLIAM A. NOYES
(1857–)
President 1920

EDWARD C. FRANKLIN
(1862–)
President 1923

W. H. Nichols was also a Charter Member; W. A. Noyes was also Secretary 1903–1907, Editor of *Journal of the American Chemical Society* 1902–1917, and Editor of *Chemical Abstracts* 1907–1909.

of a very small group of men, active in the first decade of our period of history, who were gifted with an unusual natural ability for original research and fortunately enjoyed opportunities for cultivating it. While one (Michael) excelled as a theorist and as a keen critic in the field of organic chemistry, the other (Nef), though often criticized for not presenting sound theory, excelled as an experimentalist of the first rank and supported his own speculations with original data.

Men of a different stamp, who were active in our first period, and who cannot be forgotten in this review were: Josiah P. Cooke (1827–1894), an educational pioneer who took a very prominent part in the contest of introducing science into our college courses and advocated strongly the laboratory method of teaching chemistry; T. Sterry Hunt, who was the first to define organic chemistry as the chemistry of carbon and was very active in the field of chemical speculation; and A. B. Prescott, who was made professor of organic chemistry at the University of Michigan in 1876. The latter's textbook on "Organic Analysis" was the most complete and valuable treatise on this subject that had yet been written by an American chemist.

Organic chemists in our country owe a debt of gratitude to Ira Remsen, not only for his achievements as an investigator in the field of organic chemistry and as an excellent teacher, but chiefly for his organization, support, and service as editor of the *American Chemical Journal* during its period of publication from 1879 to 1913. For his research work on saccharin the Society of Chemical Industry in England conferred upon him the medal of that Society and thus recognized for the first time in its history the discoveries of an American chemist.

The *American Chemical Journal* offered a medium for publication of original research which was greatly needed in this country. It acted as an important stimulus to American research in both organic and inorganic chemistry and received the support of the best workers in our American universities. It was one of the chief factors which served to develop or create a national interest in the contributions of American investigators; it stimulated a competition which led to a decided increase in the amount of published work in this country, and discouraged the habit of foreign investigators of ignoring and belittling American chemistry. At the time that the journal was started practically all the results of the best research work done in this country were published abroad. Today the tables have been reversed, and the fact that a condition has been developed whereby only

an occasional American investigator publishes in a foreign journal is due in no small degree to the vision, love of American institutions, and scientific interest of Ira Remsen. He has ever been a strong supporter of original research, and his pleas for a more thorough study in our country of modern organic chemistry have always been received with enthusiasm and met with prompt support.

The *American Chemical Journal,* while edited with the aid of chemists in America and abroad, was supported chiefly by workers in this country. Its pages record the results obtained by the most active organic researchers of that period. Some of the prominent organic chemists who contributed extensively to the support of that journal during its thirty-five years of activity, in addition to Remsen and his co-workers, were the following:

W. G. Mixter	Sheffield Scientific School of Yale University
S. P. Sadtler	Philadelphia College of Pharmacy
S. W. Johnson	Sheffield Scientific School of Yale University
C. L. Jackson	Harvard University
E. F. Smith	University of Pennsylvania
F. W. Clarke	University of Cincinnati
Arthur Michael	Tufts College
J. M. Crafts	Geneva, Switzerland, and Amherst College
E. J. Hallock	Columbia College
H. B. Hill	Harvard University
W. J. Comstock	Sheffield Scientific School of Yale University
J. U. Nef	Clarke University and University of Chicago
Felix Lengfeld	University of Chicago
Paul C. Freer	University of Michigan
T. B. Osborne	Connecticut Agricultural Experiment Station
R. H. Chittenden	Sheffield Scientific School of Yale University
H. L. Wheeler	Sheffield Scientific School of Yale University
T. B. Johnson	Sheffield Scientific School of Yale University
Julius Stieglitz	University of Chicago
W. A. Noyes	University of Illinois
Moses Gomberg	University of Michigan
J. F. Norris	Massachusetts Institute of Technology
J. R. Bailey	University of Texas
E. P. Kohler	Harvard University
R. S. Curtis	University of Illinois
H. A. Torrey	Harvard University
H. D. Dakin	Laboratory of C. A. Herter, New York City
L. W. Jones	Princeton University
H. W. Wiley	Bureau of Chemistry
J. H. Kastle	State College of Kentucky

Among the most outstanding contributions in organic chemistry made by these various investigators may be mentioned the following:

(*a*) The various papers by Remsen and his collaborators on the chemistry of sulfonic acids.

(*b*) Publications by Arthur Michael on the synthesis of helicin and salicin, the constitution of ethyl acetoacetate, stereoisomerism, and the law of entropy.

(*c*) The development and application of the Friedel-Craft reaction, reported in Remsen's journal in 1879.

(*d*) Synthesis of saccharin by Remsen and Fahlberg.

(*e*) The discovery of furfural as a product of the dry distillation of wood by Hill in 1881, and later contributions to the chemistry of mucobromic acid.

(*f*) Chittenden's pioneer work in the field of physiological chemistry, including yearly reviews of the progress of this branch of chemistry.

(*g*) Paper on sodium formanilide by W. J. Comstock and F. Kleeberg. This is of particular interest as the first case of a compound containing the —NHCO— grouping, whose sodium salts, under conditions which exclude dissociation, interact with alkyl halides to give nitrogen ethers, whereas the corresponding silver salts give the oxygen ethers.

(*h*) Crystalline vegetable proteins by T. B. Osborne and co-workers.

(*i*) Contributions to the chemistry of camphor and camphoric acid by W. A. Noyes.

(*j*) Molecular rearrangements and the chemistry of pyrimidines. Synthesis of the natural biochemical combinations—uracil, thymine, and cytosine—by H. L. Wheeler and T. B. Johnson.

(*k*) Salts of imido esters, theory of the Beckmann rearrangement, and studies in catalysis by Stieglitz.

(*l*) The discovery of triphenylmethyl by Gomberg. Trivalent carbon.

(*m*) New applications of the Grignard reaction, and contributions to the problem of unsaturation by Kohler.

(*n*) Application of the principle of β-oxidation and its biochemical significance by H. D. Dakin.

It was G. C. Caldwell in his address on "The American Chemist: His Past and Present" who stated in 1891 as retiring President of the AMERICAN CHEMICAL SOCIETY that:

> The most frequent contributors were Clarke, Chittenden, Gibbs, Hill, Jackson, Morse, Michael, Mabery, Mallet, Remsen, Smith, and Wiley. The most notable feature in the work of this decade is the great amount of work in organic chemistry done especially under the leadership of Remsen, Jackson, and Michael, most of which found its way to the public through Remsen's journal.

It was due to the self-sacrifice of these various men, who supported the *American Chemical Journal* in the early and dark days of American chemistry and who forced their papers into that journal for publication, that a condition was finally brought about compelling foreign recognition of our work. A notable feature in the work of this first period was the great amount of research done in organic chemistry, and we can all feel confident and proud that it was not work of which an American need be ashamed. We can all rejoice as organic chemists that our own country contributed in those early days in so large a measure to worthy research.

In completing this review of the first period of our history—1876–1901—the writer can conclude the chapter with no finer remarks than those of that great historian of chemistry—Schorlemmer—who translated the preface to Hermann Kopp's "Die Entwickelung der Chemie in der Neueren Zeit" as follows:

> To none is it allowed to enjoy for long the progress of science, and the results which the future may bring to light. The alchemists of past centuries endeavored to prepare the elixir of life, a means by which man might be kept

healthy in body and mind for an unlimited space of time. We will not discuss here the question how far this might have been an advantage for science if eminent men would have continued their researches for an unlimited period. The alchemists worked in vain. It is not in our power to appropriate to ourselves the experiences and the results which futurity alone can bring. But in a certain sense we are indeed enabled to prolong our life backward into the past by appropriating the experiences of those who were before us, and by becoming acquainted with their views as thoroughly as if we had been their contemporaries. The means of doing this is also an elixir of life. May the present attempt to contribute to this end be judged with indulgence.

The Period 1901–1926

As early as 1890, the opinion was expressed in England and on the continent by chemists who sensed the trend of developments in chemistry, that the greatest advance in future years would take place in America. Although European countries stood in the forefront at that time, it was felt that conditions were such in America that we were destined to take the lead in a not distant date in both industrial and scientific achievements. This prophecy has to a large extent been fulfilled, and the success of our achievements is due in no small degree to the research activities carried on by our organic chemists during the last twenty-five years. If one takes this second period of our history, 1901–1926, and attempts to award to it its full measure of distinction, it is very questionable whether any previous period of twenty-five years has contributed so much, in all fields of pure and applied science, that has affected so materially the progress of the whole world, and has benefited the general welfare of every human being. As a result, the status of the profession of chemistry has been raised to a much higher level, and the public now appraises our professional services with a far greater appreciation than formerly. Organic chemists in America who are qualified for advanced research enjoy the satisfaction of feeling that there is a market for their services. This condition did not prevail in 1901, as the writer can well attest from experience. We now enjoy a rare advantage, and we feel grateful for the part our national SOCIETY has played as an organization in developing and perfecting the present condition.

The progress of organic chemistry during the past twenty-five years has been helped by the recent developments in the field of physical chemistry. The new advances made in this branch of chemistry have been an assistance, and have in no way interfered with the major study of the constitutional problems under investigation by the organic chemists. In fact, the new revelations of crystal structure by application of the principles of X-ray analysis have led to results which have confirmed the

older speculations regarding the structure of organic compounds. The newer discoveries have made it possible for the organic chemist to give interpretations to many phenomena which are an improvement over those given by our earlier workers. This has in no way led, however, to a revolution of the methods of organic chemistry. While the new tools presented for our use by the physical chemists have enabled us to make greater progress in our own special field, we are still unwilling to admit that the fruitful conceptions of Kekulé do not still hold much in store for us. Neither are organic chemists inclined to take an extreme view as a result of the new advance made in our knowledge of the atom. They still believe in the atomic theory, which has proved so useful a tool in their past achievements, and that the organic chemistry of the future will be built upon the old. In other words, a greater science of organic chemistry will be developed in the next quarter-century period if we do not forget the achievements of 1876–1901 and also those of 1901–1926. The development will not be brought about by revolution, but by evolution.

Organic chemists are still confined to conditions widely removed from those which find application in the fields of the mathematical sciences. This branch of chemistry is probably still the most wonderfully elaborated section of chemical science, and like the biological sciences it must be developed for a long time on a non-mathematical basis. We have still much to accomplish by the empirical method. The organic chemist has a great deal to learn regarding the mechanism of organic reactions, and the present methods of experimental science compel the investigator to adopt a special technic and work with quantities which fail to reveal any variations in mass. Furthermore, the synthetical chemist is conscious of the possible creation of thousands of new organic combinations which theoretically may be predicted to exist. These new constructions when synthesized will open up still greater and richer fields for future research. It is, therefore, for such reasons as these that the organic chemist considers the basis of our present atomic theory a safe and secure foundation for future guidance in his investigations and speculations.

The major problem before the organic chemist is still that of acquiring a more exact knowledge of the organic molecule. What we need is a better knowledge of the methods of divining it, and to learn more regarding the energy relations and stray forces which operate to regulate and control the chemical activity of such organic complexes. Any method of attack which will

enable the organic researcher to make a new advance should be appropriated. It is not a question of deciding at this time what method of attack will prove the most profitable, but one of utilizing all the methods which can be placed at our command. It was Professor Nernst who wrote:

> The question whether chemistry has profited most by the atomic theory or by thermodynamics is a foolish one. It is like the question whether Goethe or Schiller is the greater poet. Let us rejoice that we have two such valuable methods of chemical research. We need all the aid we can possibly get and even with this aid progress will be relatively slow.

A characteristic feature of the development in organic chemistry during the last twenty-five years has been the tendency to specialization. Fifty years ago the term "chemist" indicated a scientist with an encyclopedical mind, or one who was versed in all branches of chemistry—analytical, organic, and general or physical. Today it is impossible, on account of the rapid increase in scientific data, for a man to be master of any one single branch of chemical science. Organic chemistry has found such wide application to the solution of problems in other branches of science and in industry, and has proved of such great assistance in the solution of border-line problems in fields related to chemistry, that it has acquired a greatly extended field of utility and service. It is necessary today for one to limit his research activities to a special section of organic chemistry. As a result of this intensive specialization, a condition has been created which sharply differentiates our second period from the first. In the first, 1876–1901, it was possible to pick out certain workers who were outstanding personages in the whole field of organic chemistry. In this second period, which is now drawing to a close, it is much more difficult to decide "Who's Who in Organic Chemistry," and in consequence of the large number of men who have made noteworthy contributions in some special field, the author is forced to refer to groups of workers and their achievements, rather than to emphasize the accomplishments of any individual worker. In other words, we have made progress during the past twenty-five years as a result of mass action, and it is undoubtedly true that this condition has resulted in increasing the number of promising workers in our science.

The Division of Organic Chemistry of the AMERICAN CHEMICAL SOCIETY has a membership of nearly six hundred chemists, of whom not less than twenty-five have acquired a national reputation through their research accomplishments. Of the various chemists who have been honored in this country by election to the National Academy of Sciences for outstanding accomplishments

in some branch of organic chemistry, sixteen are living. Of these, all but three—C. L. Jackson, Arthur Michael, and Ira Remsen—are still active and are contributing to our knowledge of this science, or to the development of border-line problems in the field of biochemistry. The fact that this Academy has elected so large a number of our division of chemistry to membership is conclusive evidence of the progress of this particular field of science.

The development of the chemistry habit in our country during the last twenty-five years, and the astonishing popularity and interest in organic chemistry research is due in no small degree to the energy and activities of a group of workers who have given more than twenty-five years to the service of this science and who are now entering the third quarter-century period of our chemical history. The various universities and research institutions where these workers have given such loyal service are now recognized as the important centers of academic research in organic chemistry in this country and are attracting to their laboratories a large number of young research workers. A quarter of a century ago the American university that supported an outstanding organic investigator was an exception, and as late as 1901 the ability to carry on constructive organic research was not considered as a superior attainment.

A review of this character would not be complete without inclusion of some brief references to the work of the more prominent of this older group of organic chemists. The twelve men who stand out particularly for their accomplishments are:

Moses Gomberg, of the University of Michigan, who has enriched our knowledge of the chemistry of "free radicals" and opened up a new fundamental chapter in organic chemistry by his discovery of triphenylmethyl; J. J. Abel, of Johns Hopkins University, recognized for his original work on adrenaline and his recent contributions to the chemistry of internal secretions; William A. Noyes, of the University of Illlnois, recognized for his contribution to our knowledge of the chemistry of camphor, his later work on optical rotation, and his researches in connection with the problem of positive and negative valences; Julius Stieglitz, of the University of Chicago, who has contributed to our knowledge of the mechanism of molecular rearrangements, opened the way to a precise formulation of indicator sensitiveness, and was one of the first in this country to apply physicochemical methods to the solution of problems of organic chemistry; Marston T. Bogert, of Columbia University, known for his original work

on quinazolines and his researches in the field of heterocyclic organic chemistry and synthetic perfumes; Elmer P. Kohler, of Harvard University, an investigator who has done fundamental work in theoretical organic chemistry dealing with the question of unsaturation and theory of addition-reactions and has added to our knowledge of the Grignard reaction; Treat B. Johnson, of Yale University, who has contributed to the development of the organic chemistry of nitrogen, added to our knowledge of pyrimidines and purines, and extended the application of organic chemistry to the field of biochemistry; E. C. Franklin, of Leland Stanford University, the recognized American pioneer in the development of the ammono system of organic chemistry; P. A. Levene, of the Rockefeller Institute of Medical Research, known for his important work dealing with the unraveling of the chemical structure of biologically important substances, and who, together with C. S. Hudson of the Bureau of Chemistry, has won recognition in this country and abroad for important discoveries in the field of stereoisomerism; T. B. Osborne, of the Connecticut Agricultural Experiment Station and Yale University, who is recognized as the father of protein chemistry in this country and has won international distinction for his work; and F. B. Power, of the Bureau of Chemistry in Washington, D. C., known widely for his original work in the field of plant chemistry.

Today we have as many institutions as we have states in our Union that can point to the accomplishments of promising investigators in organic chemistry. No university which does not command the services of good organic chemists and the resources of well-equipped laboratories can be regarded as secure. J. R. Bailey of the University of Texas, W. L. Evans of Ohio State University, G. B. Frankforter of the University of Minnesota, Lauder W. Jones of Princeton University, J. M. Nelson of Columbia University, W. Lee Lewis of Northwestern University, J. F. Norris of the Massachusetts Institute of Technology, J. A. Nieuwland of the University of Notre Dame, E. E. Reid of Johns Hopkins University, R. R. Renshaw of New York University, F. W. Upson of the University of Nebraska, A. S. Wheeler of the University of North Carolina, W. R. Orndorff of Cornell University, and W. M. Clark of the Hygienic Laboratory, United States Public Health Service, are conspicuous representatives of a group of organic chemists who have won recognition as efficient teachers and made contributions in research which have won approbation. We are just beginning to appreciate our opportunities and to make the most of them. Several of our younger men and most promis-

ing teachers are studying various problems of organic chemistry earnestly, thoughtfully, and carefully under the guidance of these leaders, and through their initiative we are bound to win a market for our science, develop new potential possibilities, and raise it to a much higher level.

It is to the younger generation in our universities that we must look in the future for discoveries in the field of organic chemistry of constructive value. We have now in the field several men of outstanding ability of whom may be mentioned: J. B. Conant of Harvard University, A. J. Hill of Yale University, F. C. Whitmore of Northwestern University, F. F. Blicke of the University of Michigan, Roger Adams of the University of Illinois, Morris Kharasch of the University of Maryland, Henry Gilman and R. M. Hixon of Iowa State College, Homer Adkins of the University of Wisconsin, C. E. Boord of Ohio State University, and H. A. Spoehr of California. A great many meritorious pieces of work have to be omitted. Most important contributions in organic chemistry have been made also by men outside of university laboratories, of which may be mentioned, for example, the work of H. D. Gibbs on the catalytic oxidation of naphthalene to phthalic anhydride, and that of J. M. Weiss and C. R. Downs, who successfully accomplished the synthesis of maleic acid from benzene by catalytic oxidation.

The subdivisions introduced below will serve to show the specialization which has developed in our last period as a result of the expansion of the field of organic chemistry. Other groups of workers might be arranged, but it is believed that the subdivision made embraces all the developments of major importance. In each group the names of those chemists who have contributed widely in their respective field are recorded; and younger men have been included who have recently published material of considerable merit. No attempt has been made to classify these workers according to merit, and in many cases a name has been incorporated in more than one group. In fact, there are several men who have been conspicuous for their contributions in widely different fields of organic chemistry. In the preparation of this list the author has included those chemists who have been active in applying organic chemistry to the solution of problems in biochemistry. This new development has been a characteristic feature of our productive work in recent years. The author realizes that some worthy worker in his respective field may have been omitted from this classification. Such omissions, however, are not intentional. A conscious endeavor has been

made to reveal the fact that we have in this country a very strong and active group of productive workers in organic chemistry, and the list only serves to show who have been the most prominent as contributors to our journals. The various papers published in the *Journal of the American Chemical Society* and the *Journal of Biological Chemistry* have served as a basis of selection of the most representative men.

The author would not be expressing a proper appreciation of the work of his colleagues, if he did not call attention to two large groups of men who are playing as important a part in the promotion of organic chemistry as those men who have the ability and privilege of publishing new material. He refers particularly to that large group of men which is engaged in the important work of teaching organic chemistry, and to the second group which is employed in industrial organizations in this country. Both of these groups are necessary members of a "chemistry crew" of which the research man is the stroke oar. Just as long as these various workers operate in unison and pull together the chemistry shell will move to the front and American organic chemistry will make progress. Reference must also be made to the noteworthy accomplishments of a group of organic workers who have contributed to the literature in the form of organic textbooks, chemical monographs, etc. There are several publications of this character of which we, in this country, may well feel proud.

It is the belief of the writer that more attention will be paid to the publication of special scientific monographs in the next period of twenty-five years than in the one that is just closing. This will be a necessary result of intensive specialization in our science. The author sincerely hopes that this survey may be so received that the younger members of our profession who read it may catch some of the real spirit in which it has been constructed; something of that feeling which animates, stimulates, and encourages our leading investigators, and which is the final cause that leads to a vigorous growth in any science. Let no one think that organic chemistry in America is today founded on flimsy foundations and is not to make further progress.

Subdivisions and Respective Workers

(1) ORGANIC CHEMISTRY THEORY (VALENCY AND ELECTRON PROBLEMS):
Moses Gomberg, Julius Stieglitz, W. A. Noyes, J. B. Conant, K. G. Falk, H. S. Fry, J. M. Nelson, C. W. Porter, E. C. Franklin.

(2) ORGANIC SYNTHESIS:
T. B. Johnson, M. T. Bogert, A. J. Hill, Roger Adams, H. T. Clarke,

R. R. Renshaw, Oliver Kamm, A. W. Dox, A. S. Wheeler, W. R. Orndorff, L. H. Cretcher, M. L. Crossley, G. B. Frankforter, W. J. Hale, J. B. Conant, Henry Gilman, F. C. Whitmore.

(3) CARBOHYDRATES, INCLUDING CELLULOSE:
P. A. Levene, C. S. Hudson, E. J. Witzemann, R. M. Hixon, Harold Hibbert, W. L. Evans, W. L. Lewis, F. W. Upson, F. B. LaForge.

(4) ENZYMES:
C. S. Hudson, H. C. Sherman, J. M. Nelson, J. H. Northrop, K. G. Falk.

(5) HYDROCARBONS AND CYCLOPARAFFINS:
Moses Gomberg, E. P. Kohler, J. F. Norris, B. T. Brooks.

(6) HETEROCYCLIC ORGANIC CHEMISTRY (INCLUDING PURINES AND PYRIMIDINES):
M. T. Bogert, T. B. Johnson, J. R. Bailey, Dorothy Hahn, A. J. Hill, C. O. Johns, Oskar Baudisch, C. E. Boord.

(7) PROTEINS AND AMINO ACIDS:
T. B. Osborne, H. B. Vickery, H. D. Dakin, D. B. Jones, R. A. Gortner, T. B. Johnson, P. A. Levene.

(8) MOLECULAR REARRANGEMENTS:
T. B. Johnson, C. G. Derick, Julius Stieglitz, L. W. Jones, L. O. Raiford, Arthur Lachman.

(9) REACTION MECHANISM:
Arthur Michael, E. P. Kohler, Julius Stieglitz, J. B. Conant, Arthur Lachman, Harold Hibbert, F. F. Blicke, L. W. Jones, T. B. Johnson.

(10) FATS, CHOLESTEROL, PHYTOSTEROLS, ETC. (INCLUDING ESSENTIAL OILS):
R. J. Anderson, F. B. Power, Edward Kremers, E. K. Nelson, B. H. Nicolet, A. H. Gill, F. W. Heyl.

(11) BIOCHEMICAL SYNTHESIS (CHEMISTRY OF ANIMAL AND PLANT CELLS):
T. B. Johnson, H. D. Dakin, E. C. Kendall, A. E. Osterberg, K. K. Koessler, M. T. Hanke, P. A. Levene, Walter A. Jacobs.

(12) STEREOISOMERISM:
P. A. Levene, C. S. Hudson, W. A. Noyes, Julius Stieglitz, J. W. E. Glattfeld.

(13) SULFUR CHEMISTRY (ACYCLIC AND CYCLIC):
M. T. Bogert, E. E. Reid, F. B. Dains, D. E. Worrall, T. B. Johnson, C. E. Boord.

(14) CATALYSIS OF ORGANIC REACTIONS:
Roger Adams, C. E. Boord, Homer Adkins, H. D. Gibbs, C. R. Downs, J. M. Weiss, J. A. Nieuwland, J. B. Conant, Julius Stieglitz, J. H. James, Oskar Baudisch, W. D. Bancroft, H. A. Spoehr, H. A. Taylor.

(15) METALLO-ORGANIC CHEMISTRY (ARSENICALS, MERCURIALS, GRIGNARD REACTION, ETC.):
F. C. Whitmore, W. G. O. Christiansen, W. A. Jacobs, Michael Heidelberger, C. S. Marvel, W. L. Lewis, G. W. Raiziss, C. A. Kraus, Morris Kharasch, C. S. Palmer, E. P. Kohler, Henry Gilman, Marie Reimer, E. C. Franklin.

(16) PHYSICO-ORGANIC CHEMISTRY:
J. B. Conant, J. F. Norris, C. G. Derick, C. E. Boord, Julius Stieglitz, E. J. Cohn.

(17) ALKALOIDS:
F. W. Heyl, J. O. Schlotterbeck, J. U. Lloyd, H. M. Gordin, H. C. Biddle, Walter A. Jacobs, Michael Heidelberger, J. F. Couch.

(18) PHYTOCHEMISTRY (INCLUDING PLANT PRODUCTS):
H. A. Spoehr, C. W. Porter, Oskar Baudisch, Edward Kremers, F. B. Power, R. J. Anderson, V. K. Chesnut, E. K. Nelson.

(19) IDENTIFICATION OF ORGANIC COMPOUNDS:
S. P. Mulliken, Oliver Kamm.

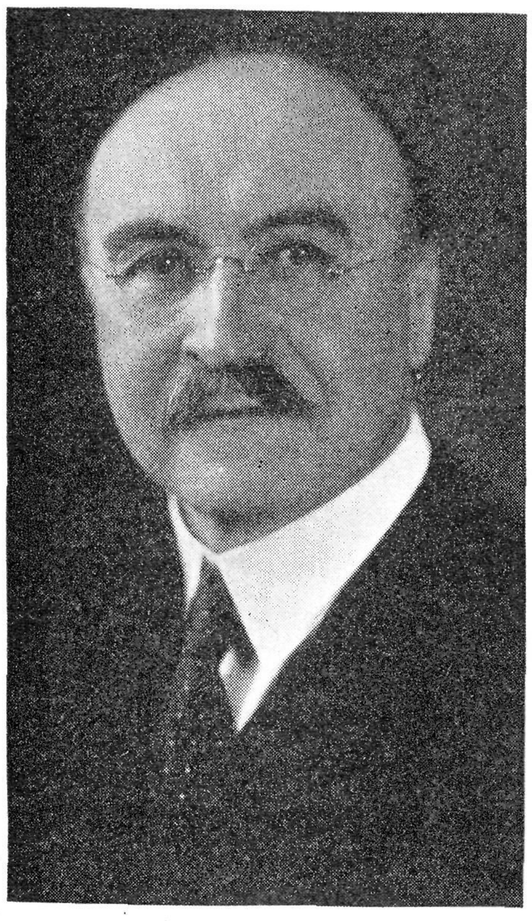
(20) TERPENE CHEMISTRY:
L. F. Hawley, W. A. Noyes, A. W. Schorger, Edward Kremers, Frank Rabak.

The Future

Outside of the applications of organic chemistry that have been made in our various industries, there are none which will exercise a greater economic influence and promotion of man's welfare and progress than the application of this branch of chemistry to medicine. Medical science has been advanced through distinct achievements in the field of synthetical chemistry. The resources of the chemist have been offered freely and the public has benefited by the discoveries made. While the physician is well qualified by education and by experience to give the public advice on matters of health and disease, how little does the public realize that the newer remedies he uses to improve sanitation, relieve pain, heal disease, and in preventive medicine are products originating or developed in the laboratory of the organic chemist! Surely the time is now at hand when the public must be given the true facts. The information should come from the highest sources of chemistry and be published over the names of men capable of presenting the facts and who are acknowledged as leaders in their profession.

IN CONCLUSION.—If the author were asked to prophesy the course of progress in the future development of organic chemistry, he could make no prediction more sound and probable than by quoting verbatim a recent statement from the pen of a former President of our national SOCIETY—William H. Nichols. The statement is taken from an address delivered by him in connection with the celebration of Prof. Edward Hart's fifty years of continuous service at Lafayette College on October 16, 1924, and is as follows:

> I will venture only one prediction. The most elaborate and delicate chemical works ever devised is the human body. Much has already been done by the chemist in delving into its secrets. Positive results have been obtained which have almost annihilated certain diseases and modified others. I predict that during the next half-century the chemist, working hand in hand with the physician, will discover the origin and nature of most of the enemies of the human body—notably that arch enemy, cancer—and not only alleviate their effects but absolutely prevent their sinister operations.

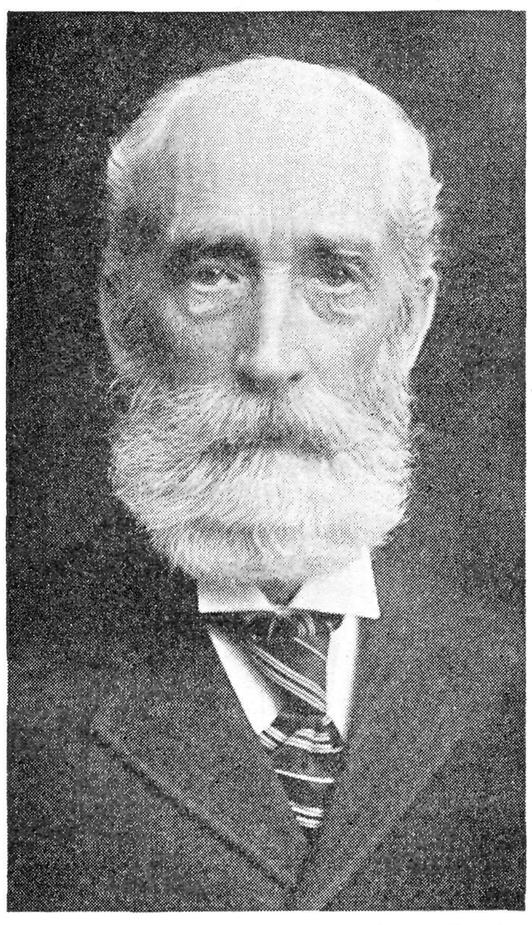


Underwood & Underwood

LEO H. BAEKELAND
(1863–)
President 1924

Harris & Ewing

JAMES F. NORRIS
(1871–)
President 1925, 1926



Alman & Co.

ALBERT C. HALE
(1845–1921)
Secretary 1889–1903

Harris & Ewing

CHARLES L. PARSONS
(1867–)
Secretary 1907–

A. C. Hale attended the Priestley Centennial in 1874.