ADDRESSES DELIVERED AT THE INAUGURATION OF PROFESSOR WM A. NOYES, AS HEAD OF THE DEPARTMENT OF CHEMISTRY AND DIRECTOR OF THE CHEMICAL LABORATORY OF THE UNIVERSITY OF ILLINOIS, OCTOBER 18, 1907

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RELATION OF CHEMISTRY TO AGRICULTURE[1]

THE subject assigned the writer on the program of exercises in honor of Dr. W. A. Noyes, who was recently appointed head of the department of chemistry and director of the laboratory at the University of Illinois, is "The Relation of Chemistry to Agriculture."

The friends of the university, who are present here on this auspicious occasion, will, as a matter of course, not expect anything new or startling in a paper of this kind. The application of chemistry to the art of agriculture is characterized by the same results which are manifest in many of the leading industries of the world after this fundamental science had thrown new light upon the processes involved. One general and most important result in this connection has been the establishment of rationalism in the place of empiricism.

It is true that in some of the methods employed in agriculture empiricism has been in advance of science. The beneficial effects of barn-yard manure upon crops

[1] This and the following addresses by William McMurtrie, Julius Stieglitz, George B. Frankforter and William A. Noyes were delivered at the inaugural exercises of Professor Noyes as head of the chemical department and director of the chemical laboratory of the University of Illinois, on October 18, 1907.

was well established in the minds of farmers before chemistry had pointed out that carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur, potassium, calcium, magnesium and iron were essential to vegetable growth. So also the addition of the more concentrated feeding stuffs, as cereals to hay, straw, roots, etc., in the feeding of domestic animals, was learned by simple observation to be useful in the production of milk, flesh, fat, work, etc., before science had established the fact that the best results could be attained only by the proper proportion in a ration of digestible protein, fat, carbohydrates and ash.

The history of nations, with the exception of one, shows, however, that these empirical observations were not universally put to practise by the tillers of the soil. The capability of a rich virgin soil to produce remunerative crops for a generation or more led to the baneful waste of most fertilizing materials in the past. As a result of this practise the population of many nations increased and civilization advanced until the bountiful sources of plant food contained in the soil became exhausted to such an extent that an adequate amount of food for the teeming populations could no longer be produced, and retrogression in every respect necessarily followed.

The population of countries stands in a direct relation to the food-supply, other things being equal. When the food supply of the territory now occupied by our beloved country was limited to hunting and fishing with a very insignificant amount of agricultural crops, this vast domain could support a population of only about three millions of people. With the advent of the white race and the gradual subjection of the fertile soils to agricultural pursuits, this territory now supports a population of eighty millions of people and the limit has not yet been reached.

It is the province of agriculture to utilize a comparatively few, special, inorganic forms of matter contained in the air and soil and change them into organic compounds, vegetable and animal, which may serve as food and raiment for mankind. Since the transformation which matter thus undergoes is of a purely chemical nature, it stands to reason that the science of chemistry was destined to free agriculture from the slough of empiricism in which it was engulfed and place it upon a sound, scientific basis. The minds of many of the most prominent chemists of the world were imbued with the importance of study and investigations leading to this end. As a result of their labors truths were gradually established and rational systems in the production of vegetable and animal matter based upon them were inaugurated. On this occasion, therefore, it will only be possible to refer briefly to the more important services which the science of chemistry has done to increase and perpetuate the food production of the world.

About three quarters of a century ago Liebig, who is generally regarded as the father of agricultural chemistry, penned the following words:

> A visible, gradual deterioration of arable soils of most civilized countries can not but command the serious attention of all men who take an interest in the public welfare. It is of the utmost importance that we do not deceive ourselves respecting the danger indicated by these signs as

threatening the future of populations. An impending evil is not evaded by denying its existence or shutting our eyes to the signs of its approach. It is our duty to examine and appreciate the signs.

After this acute observer and far-seeing philosopher had uttered these words and published his first little book, entitled "Chemistry in its Application to Agriculture," which marks a new epoch in the history of this important branch of human industry, and Wiegeman and Polsdorf had corroborated the theoretical views of the great master by furnishing the infallible, experimental proof, that the mineral or ash constituents of plants were indispensable to vegetable growth, the intelligent farmers of Germany were eager to listen to Liebig's teaching and to profit by any light which the more accurate and rational methods of science might furnish. They had been educated in the school of experience, in which they learned that the closest attention, the most arduous labor and the strictest economy were demanded to extort from their impoverished soils enough to sustain themselves and families. But not only this. The views of Liebig spread rapidly all over the civilized world, and aroused an enthusiasm among scientific investigators in every civilized country, rarely equaled in the annals of history. It is impossible in the time allotted to this paper to go into detail. Suffice it to say that the combined efforts of all these investigators have done more for public welfare than perhaps any other human undertaking. Among the important results of their labors in connection with soil and vegetable production may be mentioned:

1. The chemical composition of agricultural products, including the ash or mineral ingredients.

2. The chemical composition of soils, showing that the soil contains certain elements which serve as plant food and without which vegetable growth is impossible.

3. The establishment of the fact that the most important of the ingredients of plant food, *i. e.*, those which furnish the bulk of the ash of agricultural crops, and contained in the soil in comparatively small quantities, that they are present in two forms, available and reserve plant food, that the immediate fertility of soils depends upon the former, and that by continuous cropping without application of fertilizing materials to the soil this available plant food is gradually exhausted, until maximum or even average crops can no longer be produced.

4. The important observation that if only one of the essential elements of plant food is wanting in the soil, while all others are present in ample quantities, plants will refuse to grow.

5. The devising of methods by which the wanting ingredients of plant food can be definitely determined in an exhausted soil, so that the loss of money and labor in applying fertilizers, which would have no beneficial effect upon the production of crops, can be avoided.

6. The discovery and analysis of natural deposits of plant food, as Guano, Chili saltpeter, Stasfurt salts, apatites, coprolites, limestones rich in phosphates, etc., as well as the analysis of numerous waste products and by-products, such as bones, blood, tankage, oil meals, wood ashes, etc., all of which

have been utilized in immense quantities, the world over, for restoring worn-out soils.

7. The control of commercial fertilizers, giving the true composition and money value of the brands brought by manufacturers and dealers upon the market, in order to protect the former against frauds, so easily practised in articles of this nature.

8. The composition, production, proper treatment and preservation of barnyard manure, the most important, most easily obtainable and the best of all fertilizing materials.

9. The chemical composition of all agricultural products, giving an insight into the nature and amount of plant food removed by them from the soil, and indicating a proper rotation of crops, so that one or the other of the essential ingredients of plant food may not be too rapidly withdrawn from the soil, and thus unduly hasten its unproductiveness.

These, my friends, are some of the beneficent results which have followed the application of chemistry to the production of vegetable matter. In passing over to the consideration of the other branch of agricultural industry, namely, the production of animal matter, it may be well to call attention to a few well-known facts. Plants can live on the dead inorganic matter contained in the air and soil alone. They have the power of transforming it into living organic matter and into the more complicated combinations of which their bodies are composed. Animals can not live on inorganic matter alone. They must have in addition the more highly organized forms, which plants produce.

Hence the animal kingdom is dependent upon the vegetable kingdom for its existence.

Since animals consume plants for food, it follows that the same elements which occur in plants are found in the animal body. In fact the same compounds that occur in vegetable matter are again found in the animal body, only slightly modified.

Before chemistry began to shed its light upon agriculture, the rearing and feeding of domestic animals for human food and raiment was just as empirical as the production of plants. It is true, as already stated, that simple observation led to many good methods in actual practise, but no intelligent reasons could be given for the methods. The subject of animal nutrition was taken up by scientific investigators with as much zeal and as careful study and experimentation as were expended on vegetable production, and the results and data obtained are sufficient to warrant an intelligent use of the means at hand.

The amount of time and labor expended in changing the rule-of-thumb methods of feeding domestic animals into a rational system is very great taken in the aggregate.

1. The composition of every product of domestic animals, the composition of every part of their bodies, and the proportion of these parts among themselves in forming the living animals produced for various purposes are known to the chemist.

2. The proximate composition of feeding stuffs of all kinds has been accurately determined by thousands upon thousands of analyses made in all parts of the world. Extensive tables giving the percentage of

protein, fat, carbohydrates, fiber and ash have been placed at the command of every one engaged in this branch of agriculture. But this is not all. Just as the total amount of plant food in the soil is not completely available for the production of vegetable matter, so the proximate principles just mentioned do not entirely serve as nourishment for the animal body. The digestibility of the various ingredients varies in different plants as well as in different parts of the same plant. Hence a simple analysis of a feeding stuff does not always determine its true food value. For this reason additional investigations were found to be necessary. Just as in the determination of the available plant food of a soil the plants are brought into requisition, so here experiments had to be made in connection with various domestic animals in order to determine the amount of these ingredients which served as nourishment when taken into the system. Tables giving the coefficients of digestion of the constituents of the feeding stuffs, therefore, always accompany the tables of analyses. In addition to all this, experiments have been made with domestic animals to establish the best proportion and amount of these constituents for the purpose of maintenance and development as well as for the production of work, milk, flesh, fat, etc.

3. As in the case of commercial fertilizers, here again the work of the chemist controls the sale of concentrated feeding stuffs, so that the purchaser of these valuable commodities, which are thrown upon the market in immense quantities, is insured against adulteration.

With all of this information at his command the intelligent animal husbandman can utilize his store of feeding stuffs, and, if necessary, by purchasing others, prepare the proper rations for insuring the best and most economical results.

Chemistry has aided agriculture in many other ways. The establishment of new industries like the manufacture of glucose, which annually insures a market for the surplus production of agricultural crops, may be mentioned. Of much greater importance to agriculture has been the establishment of the beet-sugar industry, since it opened a field for the production of a new agricultural crop on an immense scale. From an almost hopeless beginning this industry has by the aid of science gradually grown into one of the leading industries of the world.

When the German chemist, Margraf, examined the garden beet it was found to contain only about four or five per cent. of cane sugar. By careful selection and analysis of mother beets, selecting only those for seed which revealed the highest content of sugar, the quality of this sugar-producing plant was gradually improved. When the writer was a student Professor Wagner, the celebrated technologist of Germany, found, upon analysis, individual beets with a sugar content of twelve per cent. He at that time expressed the hope that by continued effort in the improvement of the beet this exception might prove to be the rule. The results to-day far exceed his expectations. Individual beets have been grown with a sugar content of twenty per cent., and it is safe to say that in the best sugar-beet countries the average content of sugar of beets delivered at the factories reaches sixteen per cent. The gradual improvement in the quality of this plant can be seen from the following statistics. For the production of one ton of sugar there were required:

In 1836	18 tons of beets.
In 1842	16 tons of beets.
In 1857	12 tons of beets.
In 1871	11 tons of beets.
In 1894	7½ tons of beets.

At the present time under favorable conditions less than seven and one half tons of beets are undoubtedly required to manufacture a ton of sugar. To show how this industry has grown in importance it is only necessary to say that of the total production of sugar of the world in 1905, amounting in round numbers to thirteen millions of tons, seven millions of tons were produced from sugar beets.

Other plants are no doubt capable of a similar improvement, and in this connection the writer refers with great pleasure to the work of, and result in, corn-breeding inaugurated by Professor Hopkins, of this institution. The production of corn rich in starch for the manufacture of starch, alcohol and glucose, and rich in protein for the stock-feeder, will add immensely to the value and usefulness of this staple crop.

Chemistry has rendered a great service to agriculture in furnishing the means of combating the insect and other enemies of fruits and crops of various kinds.

The liberal use of insecticides and fungicides has saved many agricultural crops from utter annihilation and has been instrumental in greatly increasing the yield and improving the quality of agricultural products.

Weeds constitute another enemy of the farmer's crops. Where cultivation can be employed throughout the growing season weeds can, of course, be kept down. But in the growing of small grains and grasses this method of destroying them is impossible. In some countries the yield and quality of this class of crops are greatly reduced by weeds. But chemistry has apparently found a way to remedy this difficulty. The latest achievement in this respect is to spray the growing crop with the solution of a chemical which kills the weeds and does not injure the crop. The chemical employed for this purpose is ferrous sulphate in a ten-per-cent. solution. It does not injure cereals, corn or even grasses and clover, but destroys or retards the growth of the most noxious weeds to such an extent that the yield of crops has been increased twenty per cent.

One of the greatest services which chemistry has rendered to the amelioration of the farmer's vocation is the protection assured against artificial and fraudulent imitations of numerous genuine products. A few of the most vicious abuses, through which the farmer and consumer suffered alike, were the sale of oleomargarine for genuine butter, which almost destroyed the dairy industry; the sale of artificially colored distilled vinegar for cider vinegar, which caused millions of bushels of apples to rot in the orchards of the country; the sale of glucose for maple syrup and honey;

the sale of skim milk for whole milk; and the sale of skim-milk cheese for full cream cheese.

It is gratifying to refer to the aid which the governments of all civilized nations have given in recent times for the purpose of elevating and perpetuating the art of agriculture, the industry most important to the welfare of humanity. Agricultural colleges and experiment stations, agricultural departments, both national and state, have been established and richly endowed. These are filled with earnest and honest investigators, who are working diligently and faithfully to disseminate truths, already established, among the rural population and to discover new ones, by which this noble vocation may be advanced. May the good work go on.

H. A. Webber

RELATION OF CHEMISTRY TO THE INDUSTRIES

I AM gratified that an opportunity has been given me to be present on this occasion and take part in the installation of the new head of the department of chemistry of this great university. To me it is a matter of no little significance, and to all of us, interested, as we are, in the promotion of the work of the institution and its material and scientific progress, it is almost the beginning of a new era in its development. We may congratulate ourselves that the officers charged with the duty of seeking out and appointing the new incumbent, should have had such good fortune in their search, and should have chosen so well. But I know you will sympathize with me when I say that the pleasure and gratification which comes to us now must be tempered by the remembrance of the real cause which brings us together: the early and untimely removal of the late head of the department. To me it brought keen sorrow. I knew Dr. Palmer as a youth, just emerging into manhood. Earnest, enthusiastic, industrious and skilful, he came to his work with qualities of mind calculated to make him a leader among his fellows, and to cause him to quickly take a high position in his chosen profession. A persistent reader of the literature even in his student days, a deep and accurate thinker, a rapid manipulator, confident of the accuracy of his results, he was able to accomplish more within a given time than most men; and all this, combined with a vivid and useful imagination, made possible for him splendid progress in research and opened for him a career which must certainly have placed him in the forefront of the profession, and made him a leading chemist in his country and in the world.

As a teacher the same qualities made him successful. Students respect and follow successful men—men who work earnestly and produce useful results. Such results were manifest as an outcome of all the efforts Dr. Palmer put forth. While we mourn him personally as a friend and colleague, we realize the loss to the world of chemistry and the industries, caused by his death. But in this case particularly we must realize that the oft repeated adage, "The evil that men do lives after them," must be modified, and we may say, "The good he has done lives after him," in the men he has trained, in the results of his investigations, in the publications of his work now within our reach, in his influence upon the standing and position of the university generally. We may congratulate the university and its corps of administration and instruction that so many of her sons should have been so influential and instrumental in establishing the splendid position she occupies in the eyes of her graduates and the world at large.

I have been invited at this time to discuss the relations of chemistry to the industries, and in this, to me, most interesting duty, to occupy fifteen minutes. It is fair to remind you and the committee having these exercises in charge that this has, more than once, been the subject of an encyclopedia of many volumes, that it constituted one of the most important departments of our late national census, reported in several hundred quarto pages. To adequately discuss the subject, therefore, I should be forced to trespass upon your good nature and the wishes of the committee; the day would be all too short, and your patience and strength, as well as my own, would be sorely taxed. You may not expect me, therefore, to offer more than a syllabus of what might be said in the several hours or the several addresses which should be allotted to the subject.

The head of the department will, I hope, have many years to exploit it, for to be fully successful he may not avoid these relations omnipresent. The utilitarianism of our age makes it important that theory and practise, science and industry, shall go hand in hand to insure progress on either side. The good flowing from the relation in question is reciprocal. If the science of chemistry has furnished the industry with knowledge and facts and suggestions, the practise of chemistry in the industry by its needs, by its difficulties, by its successes, has furnished to the science suggestions, facts and knowledge which have been helpful, stimulating and inspiring. The best that can be said of the relations of chemistry to the industries is, the closer they are the better for both. The necessity arising from the large production of wastes in the manufacture of illuminating gas, the utilization of coal tar, which had become an intolerable nuisance, led simultaneously to the establishment of the great color industries, with consequent stimulation of all the allied industries, to the development of the chemistry of the carbon compounds in general, and furnished materials through the study of which the laws of modern chemistry could be worked out and confirmed. It is well known that many of these materials could be produced only when operating in a large way in manufacturing establishments and by methods available only in the industries. It is in this way, as well as others, that the industries have been helpful in the development of the science. But reciprocally the science and its methods, abstract research in the laboratories, have been helpful, nay, necessary to the industries. This is splendidly illustrated in the memorable address of Professor Crookes before the chemical section of the British Association for the Advancement of Science, in the meeting in Bristol, in which, sounding the note of alarm regarding the possible deficiency of the bread supply of Great Britain, due to shortage of nitrogenous plant food in the wheat fields, and advocating the proposed parliamentary legislation for the establishment of national granaries in which supplies of wheat could be stored for protection against national famine, he described methods and apparatus used by himself in abstract research and later by Lord Rayleigh in the search for argon, methods and apparatus whereby atmospheric nitrogen and oxygen could be made to combine with each other with expenditures of energy so low as to make the utilization of atmospheric nitrogen a commercial possibility at costs as low as or lower than the element could be supplied in combination in niter from the celebrated deposits of Chili, until then the sole source of economic supply after the exhaustion of the guano deposits of the world.

The combination of nitrogen and oxygen of the atmosphere through the intervention of the electric arc and the silent electric discharge or under the influence of electrical tension has become commercially an accomplished fact, and other means for fixation of atmospheric nitrogen in forms available for plant food have been worked out, notably the process of Caro and Frank, whereby nitrogen is made to combine with calcium carbide to form calcium cyanamide, since proved to be as efficient for plant food as calcium nitrate or ammonium sulphate. The research laboratory was the direct means for producing these brilliant and immediately useful results. So also the biological studies of Berthelot, which led to the discovery of the nitrogen-fixing bacteria of clay soils; of Wilfarth and Hellriegel, which led to the discovery of nitrogen-fixing bacteria of the root nodules of leguminous plants, notably of clover; of Muntz, which led to the discovery of the nitrifying bacteria of soils, through the agency of which the nitrogen of organic matters and ammonia is changed to the nitric combinations, in which alone it is available for the uses of vegetation. All these have done their share to reduce and remove the threatened danger which Professor Crookes justly saw and which has now been unquestionably removed by the discoveries, then far from commercial attainment, he at the same time described. Abstract research is still essential to progress in the industry, even as it was in his day recognized to be by the great Napoleon, who, realizing that political supremacy is largely, if not wholly, dependent upon industrial supremacy, called to his aid, after the establishment of the celebrated continental blockade, all the great minds of the institute and the academy, to devise and develop means whereby the needs of his empire could be wholly met by internal resources, and out of this grew many of the great industries of France and the world generally: the beet-sugar industry, the madder crop, the production of indigo, the development of the textile industries, particularly in linen and wool. This necessity of industrial supremacy to the assurance of the political supremacy has been recognized by other great statesmen and leaders. What Napoleon saw, the great German Kaiser of the present day saw when he urged and insisted upon the establishment of the engineering doctorate of the universities of his empire, and Senator Morrill saw when he urged upon the Congress of the United States the enactment of the great land-grant law for the establishment of the colleges of agriculture and the mechanic arts, from which this and other great universities of the land have grown. This is, furthermore, what Congressman Hatch saw when he proposed to and urged upon the congress the enactment of the law providing for the establishment and support of the agricultural experiment stations to be devoted to scientific research and the more intimate study of the problems of agriculture pressing for solution; and it is what van Rensselaer, Cornell, Packer, Pardee, Johns Hopkins, Harrison and Rockefeller saw and felt when they made generous provisions for the great universities and schools of technology for training young men in the sciences in their relations to the industries and the arts of human life. It is such genius and its applications which insures the world's progress.

Genius has been defined as "capacity for hard work." It is far more. It is a keen and active imagination combined with industry, energy and ambition to bring to fruitful realization the product of a trained imagination. This leads us to some of the needs of modern education in its relations to our subject. Genius as thus defined and described must be developed in the student of this age. The imagination must be trained and directed, the judgment strengthened. Thus genius becomes a keen and trained imagination, combined with good judgment and an industrious habit, with energy to bring to fruition the work of the imagination. So we should educate our students to the importance of a clear and exact knowledge of the work of others as recorded in literature, for progress means building upon the work of others. They should then be trained in the judicious and scientific use of the imagination suggested by the great Tyndall, whereby they may be able to see how the accomplishments of others may be extended and utilized. Then the power of observation must be developed, and hence the need for and usefulness of the research laboratory, happily recognized more and more as the years pass, in the systems of education and in the organizations of the great industries.

It is interesting and inspiring to one concerned with educational matters to see how far the research laboratory is being attached to and made part of the manufacturing plants of this and other countries. It has been claimed that the research laboratories have been the foundation stones upon which the great structure of the German chemical industry has been reared, and the claim can not be questioned. It was inspiring, upon a visit to one of the great chemical works of Germany, where more than 3,000 hands were employed, to see an entire, large, well-arranged, well lighted and ventilated building devoted wholly to abstract research in lines related to the industry, occupied by hundreds of chemists engaged in the work for which the building was provided. And it was even more interesting to follow the results of the research carried on in the several laboratories of that great building.

In this connection we may call attention to the brilliant work lately reported by Professor Harries, of the Technical High School of Charlottenburg, Germany, in the study of the constitution of caoutchouc, or india rubber. By oxidation of the pure gum with ozone he was able to produce what he named its diozonide, and this by proper treatment was converted into levulinic aldehyde, which in turn was oxidized to levulinic acid. This, Professor Harries reminds us, can be obtained more readily and cheaply from starch than from any other material, and he suggests that by a series of deoxidations and condensations, starch may be converted into caoutchouc, which has become so useful and almost indispensable in the industries and yet is provided in such comparatively limited quantity in nature that there is almost a dearth of it in the world's market to-day. It would be interesting, indeed, if we should come to depend for our india rubber supply upon the cornfields of Illinois, the prairies of the Mississippi basin and the manufacturing laboratories, rather than, as in the past and now, upon the jungles of Africa and South America. Yet the production of india rubber from corn starch would be no more remarkable than the production of alizarine and indigo from coal tar. The research laboratory is the source from which artificial alizarine and artificial indigo sprang; the same source may be the starting point of the production of india rubber from indian corn.

What may we expect from the recent announcement of Professor Ramsay that under the influence of the radium emanation copper may be broken down with the production of potassium, lithium and calcium, thus suggesting a new source for potassium compounds, so useful to farm crops?

Other products and questions await the magic touch of the research chemist. Who for instance, will take care of and utilize the comparatively large quantities of selenium and tellurium, thus far so little studied and now so largely issuing as a by-product of the manufacture of vitriol and the refining of copper? Here is abundant supply of raw material to be had from the industry by the research chemist for the asking. Again, who will supply the volatile combustible required to make up the shortage of supplies of petroleum products needed for use in the internal combustion engines, upon which the future must largely depend for inexpensive power? Who will furnish other products sorely needed in the world if not the research chemist? In this connection I am again constrained to quote the inspiring words written by the editor of the *Wall Street Journal* under the caption "Science as a Financial Asset." Among other things this accomplished editor said:

Science as a source of strength in promoting private wealth and public welfare is the one thing that draws the line of demarcation between ancient and modern times. That was a belated mediæval, not a modern, outburst of popular wrath against which Lavoisier's friends appealed for his life on the ground of his scientific service to the French state. The powers then in control then replied that the republic had no use for chemists. Far more like modernity is the declaration of a German chemist that "scientific research is the greatest financial asset of the fatherland." Germany's economic progress proves that he was at least nearer right. The sciences in general have been among the greatest emancipating forces, because they have helped to overcome man's fear of nature, which kept him from utilizing the forces of the world about him, and because they disclosed elements of the highest value to the world in their most practical forms. It has been well said that if we were to take away what the chemists have contributed, the whole structure of modern society would break down at once. Every commercial transaction in the civilized world is based on the chemist's certificate as to the fineness of gold, which forms our ultimate measure of values. Faith may remove mountains, but modern society relies on dynamite. Without explosives our great engineering works must cease and the Panama Canal, no less than modern warfare, become impossible! Chemistry has made possible the transportation systems which span the leading countries of the world.

It has made it possible to turn to man's service the wealth of the mineral world. By analysis of plants and soils, the waste materials of the world have been brought to the growing of crops. Indeed, every great industry, whether it be farming, manufacturing, transportation or mining, would almost immediately relapse to barbarism if the secrets of the chemist and physicist, the geologist and mineralogist, could be gathered up and cast into the sea.

This estimate of the work of the research chemist has our hearty sympathy and it brings much of inspiration and encouragement. It justifies all that the rulers and legislators have done for this and similar institutions and loudly calls for generous support in the future. It expresses appreciation of the work done in this university, which has made such magnificent progress under the direction of its present very efficient head and the splendid promise for its immediate future. All here present will, I am sure, heartily join me in wishing for the university and for its department of chemistry no diminution of the splendid prosperity which has attended the efforts of its excellent administration in the recent past.

WILLIAM MCMURTRIE

CHEMICAL RESEARCH IN AMERICAN UNIVERSITIES

GATHERED here to-day to celebrate the installation of one of our prominent American investigators as director of chemistry in the University of Illinois, we should not do justice to the occasion if our thoughts did not turn to the serious meaning of this event for the future of chemical research in our universities. I have thought to devote the few minutes, during which I shall have the pleasure of addressing you, most usefully to the consideration of some conditions affecting the future of chemical research in our American universities.

Before this audience I need make no lengthy plea of justification for the demand for research work in chemistry in our universities, either on the ground of economic considerations or from the standpoint of our highest ideals, as expressed in the struggle of the human race for enlightenment on itself. As Professor Theodore W. Richards recently said in his inaugural lecture at the University of Berlin:

> All the manifold experiences of the human mind are intimately connected with the presence of that which we call material, enlivened by that which we call energy; and the ultimate deciphering of the great mystery of life will depend just as much on the understanding of these as upon the study of the mind itself. Thus modern chemistry should be regarded not only as bringing to medicine and the useful arts its obvious and multifarious contributions, but as occupying also an essentially important place in the realm of intellectual speculation.

After Dr. McMurtrie's address it is unnecessary to say much about chemistry in the field of economics. It is a trite fact now that the industrial and commercial supremacy of Great Britain is threatened most dangerously by the wonderful growth of manufacturing in Germany. Englishmen, noting this in the face of the fact that they themselves are rather favored in the matter of natural resources and wealth, are attributing the great strength of their competitors almost entirely to their splendidly trained army of chemists. A significant fact is that this onward march of the German industries is characterized by much of the same fearlessness and supreme confidence of victory as was its march on the unprepared armies of France forty years ago; and for much the same reason—again, it is splendidly organized—organized in the matter of trained scientists, chiefly chemists; its industrial adversary is not—as yet. Chemistry, in some form or other, enters into the production and manufacture of almost all the great articles of commerce—from the raising of wheat and corn on soils scientifically analyzed and fertilized, to the making of steel and all iron materials, from the preparation of brilliant dyes to that of common leather, from the drugs of our sick days to the food products of our daily life—all can be developed best under the direction or with the help of able chemists, and, what is equally important, all, without exception, are capable of vast improvement under the seeing eyes of the chemist, trained to observe closely, to reason accurately, to think originally, to experiment rigorously—trained, in a word, to do research work. German universities and polytechnic schools are turning out such chemists, doctors of philosophy, by the hundred—men trained to investigation, so that they can improve and develop new ways for actual work of manufacturing, instead of merely using and transmitting traditions. No branch of industry in Germany need want for such men—their numbers and usefulness are seen best from the fact that a single great factory, the Badische Anilin und Farbenfabrik, had in its employ one hundred and fifty such chemists in 1900. There can be no doubt in the mind of any political economist that a country so thoroughly equipped with scientifically trained chemists and with schools for developing them must have an enormous advantage over competitors that lack both or have them only in lesser degree. But such men can receive their final training at universities only from men who are investigators in their branch of work: the critical attitude of mind, the inspiration to originate, the training to convert the new idea into the new result can come only from men who have thought for themselves and worked out their own problems—from research men in our universities.

American universities are feeling the pressure of a growing demand from our industries for such trained investigators, and with this outside pressure and the inner call to do our share toward the elucidation of the great problems of humanity the last years have also witnessed a rapidly growing and insistent demand for research men to fill important university positions; not every university in recent times has been as successful and fortunate as is the University of

Illinois in meeting this need; indeed, there is a very decided shortage of men of proved ability to do and direct investigative work in chemistry, and we may well ask why this should be so and what remedy we have for such a condition in this country. Turning only for a moment to chemical research as it was here twenty-five years ago, the better to understand present conditions, we find at that time only here and there in our universities a man of note carrying on systematic investigations in chemistry: Remsen at Johns Hopkins, the Gibbses at Yale and Harvard, Cooke, Hill, Jackson, Morley, Long, Michael and Ward, only a handful of men devoting their lives to chemical research as an article of faith. Universities at that time did not demand that their chemistry professors should be investigators, and they were, as a rule, instead, technical experts, analytical chemists—thorough, capable, honest men, but engaged in as extensive and as profitable commercial work as the head of any commercial laboratory. As a matter of fact, we had then practically only one real university, devoted to graduate work as distinguished from college work, and that was Johns Hopkins, our pioneer American university; although, as stated, graduate and research work were also carried on to some extent at Harvard, Yale and a few other places. The greatest recent impetus to all branches of research, including chemistry, came in this country, in my opinion, from the founding of Clark University with research as its chief and almost exclusive field and from the founding, only two years later, of the University of Chicago with its strong graduate school, strong not only in its faculty, but, unlike Clark, also in its student body. By one great effort at once a great college as well as a university, its founding stimulated the development of the graduate schools in the older universities of the east which were also both colleges and graduate schools; the western universities have more slowly strengthened their graduate work or have just started to give graduate instruction, that is, to do real university work. With the development of our universities, in the last fifteen years of eager growth, chemistry in this country has given us the work of men like Richards, of Harvard, a second Stas on atomic weights, and in this same subject we still have Morley and also have W. A. Noyes, now of Illinois; in organic chemistry we have Nef of Chicago, with great new ideas powerfully influencing work abroad as well as here, Remsen and his students continuing the work of former years, and again, Noyes; in physical chemistry we have A. A. Noyes in Boston, Franklin at Leland Stanford, Bancroft, Hulett, our enthusiastic friend Kahlenberg at Wisconsin fighting nobly for a lost cause; in inorganic chemistry, Edgar F. Smith, Morse and again Remsen. There are about as many names again which could be mentioned and then our list of really prominent research men in chemistry at American universities would be exhausted—I am not including technical research men. With the older men, there are barely twenty men in all, directing strictly original research work in our American universities, work involving new ideas as well as the preparation of new compounds and salts. The supply is far too small to meet the demand, and in view of the importance of the subject, this condition, unless improved, presents a distinct menace to our educational and economic development. A second significant fact is that with the exception of two or three men working under particularly favorable special conditions, the productiveness of our research men is by no means commensurate with the output of an equal number of men in Germany. An impartial scrutiny of the situation shows unmistakably serious defects in our American conditions which must be removed if chemical research is to flourish here as abroad and if able men are to be attracted in sufficient numbers to a life devoted to research and research instruction.

Contrasting the conditions in German universities with ours, we find the American professor, as a rule, overburdened with an excessive amount of routine work, consisting of lecturing, laboratory instruction and administrative duties. Some teaching must be considered as essential for the welfare of the investigator: in presenting his subject before a critical student body, he is held to an iron logic, he must ever go to the very foundations of our science and, detecting a weak point here, a missing link, a circle proof, a traditional rut there, his mind continually receives ideas for critical work on the very essence of chemistry. But every profound investigation requires a degree of abstraction and absorption as great as that demanded for creative art. And for such work the best powers of the brain are obviously needed: but, after lecturing two hours or giving laboratory instruction for half a day and attending to innumerable petty administrative details, that best power is gone for the days, and each year is made up of just such days or worse in most of our American universities; the mental alertness, the critical and creative faculties, are wasted on routine work, which to a large extent could be done as well or better by a different type of man. Now, in Germany, as I knew it, the great investigators lectured at most once a day, their laboratory instruction was limited to research students, the instruction of all the other students in the laboratory being left wholly in the hands of other men, able men of rank and training, not inexperienced assistants. Then, only a little over half the year was given to academic work, almost half the year being left, not for recreation—a few weeks sufficed for that—but for that intense, absolutely undisturbed work required for the creating mind.

A second important factor in the productiveness of our American chemists as compared with those abroad is found in the problem of research assistants; the creative imagination of the investigator in chemistry must always be held in check, as Richards has said, by experimental realization of the logical outcome of his flights of fancy; but chemical experimentation is one of great minuteness, infinite attention to details and endless preparation. Where the German investigator can have, when he needs them, several assistants, ranking from a newly fledged doctor of philosophy to an associate professor when necessary, a single research assistant in chemistry has until recent years been a rare specimen in

America and even now the species is not flourishing—it is being starved to death, by low salaries. From presidents who are chemists down to the least of us, we all have our troubles in securing just one of them; the demand for two would perhaps prostrate the authorities. And yet it would be the economic thing not to limit our investigators to one assistant, for men like Nef, Richards, the two Noyes, can direct half a dozen assistants as well as one, and by the present system their productive years are, to a large extent, simply being wasted. But, unless we secure conditions for a large measure of success and productiveness, chemical research in our universities will never attract our best Americans in sufficient numbers to satisfy the minimum demand of our country for able investigators in academic and in industrial lines—and that is the point of my argument.

The last condition I ought to refer to in this connection is one that has caused a wide-spread sentiment of uneasiness in all our universities—the question of the financial side of an academic existence. This serious question, common to all branches of academic research work, is receiving careful attention from our ablest university presidents, and I will leave it entirely in their wiser hands. It is an important factor in regard to the very point raised, the necessity of attracting our able young manhood to supply the country's need of investigators.

I have tried to point out what I consider the three most essential needs for the development of American chemical research on a plane worthy of our country, on a plane which will enable it to do its share towards the intellectual progress of our race and which will also prepare it for the great commercial struggle of the future: relief of the investigator from an untoward burden of routine and administrative duties; the exploitation of the talents of these gifted men by the employment of a proper staff of research assistants; a proper remuneration, that worry for the future of his family—he cares, as a rule, little for himself—may not impair his usefulness.

The University of Illinois, in selecting a man with the ideals and the capacity of William A. Noyes to develop its work in chemistry, has definitely joined the ranks of those universities which are committed to the attempt to give the highest kind of instruction in chemistry, instruction which will turn out, not artisans, but artists—chemists. In bringing Dr. Noyes here, the university has, as I understand it, wisely kept in mind as far as possible the three conditions for successful work which I have tried to outline. The University of Chicago greeted with the greatest satisfaction the selection of your excellent president to be the head of this institution; we knew he would strengthen Illinois, that he would undertake to raise its standards to those of the best universities of all countries; we rejoiced, not only unselfishly in the satisfaction of seeing the promise of a noble work, but also selfishly; for the higher the ideals of our neighbors, the higher must be the plane of our own lives—in institutional life as in private life. In the same way, I would say on behalf of the chemists of the University of Chicago that we heartily welcome the promise of a strong department of chemistry here; many links of friendship already bind our faculties; our joint efforts to advance the ideals of chemical research and instruction will surely cement still closer these ties!

JULIUS STIEGLITZ
THE UNIVERSITY OF CHICAGO

TEACHING OF CHEMISTRY IN STATE UNIVERSITIES

A NEW epoch in chemistry has begun in the United States. Development along the lines of pure, industrial and applied chemistry is everywhere evident. The interest now taken by our universities, by our great industries and especially by our national government, bears evidence of wonderful progress. During the past decade, however, the Americans have asked themselves why other countries which can not be compared with our own in wealth and natural resources have surpassed us in nearly every phase of manufacturing and industrial chemistry. Indeed we can not understand how it has come about that the United States, by far the richest country in the world, is so far behind Germany in nearly all lines of manufacturing chemistry.

To one familiar with the European and especially the German industries, the answer seems comparatively simple, depending upon only a few principles, some of which I wish to briefly preface at this time. Germany leads the world in chemical industry, because of her persistent scientific study of every phase of industrial work. For nearly a century her watchword has been "science, industry and economy." She has spent all of her energies along applied chemical lines, and has brought to bear every possible resource which could be utilized in the furthering of her manufacturing conquests. She has long since realized the fact that to take an active part in the industrial world power, she must match her science against the wealth and natural resources of other rich countries like our own. That she has succeeded is borne out by a glance at her export statistics.

By far the most important factor in the development of the chemical industries in Germany has been her universities. The German universities have perhaps cost the nation more than any other one institution, except her army. Unlike German militarism, however, the universities have been the best financial investment the nation has ever made. For two hundred years these great universities have been the nerve centers, yea, even the very brains, of the whole nation. During the last century they have played a unique and important part in this wonderful industrial development. Without them, her mineral industries would not be worth a passing consideration. Without them, her coal-tar, her beet-sugar and scores of other great industries would, in all probability, barely exist to-day. Without them, Germany would still be a fourth instead of a first class industrial power. Without them, I doubt if the nation could have lived through the fierce storms which have, from time to time, swept over the empire. Without losing the dignity of the university, without losing the highest ideals of scholarship, they have joined the purely scientific with the commercial side of the nation, bringing about conditions which have completely changed the life, the financial and social conditions, of the nation. This wonderful change has been brought about as Van't Hoff has well said, "entirely by a hearty cooperation between the scientific laboratories of the nation and the technical and industrial work."

But other nations have universities. Why have they not done for their respective countries what the German universities have done for Germany? The United States, for instance, has more universities than Germany. Why then is the United States behind Germany in this industrial race? The answer, I believe, may be found in the fact that the American universities and colleges as a whole have not until recently fully realized the fact that the old idea of scientific culture in this present materialistic age is not what is demanded by the nation. University men now fully realize that scientific training of the old culture type, and more especially in chemistry, is worthless to the nation and worthless to the individual except in so far as the mental discipline goes. But simple discipline is not the sole aim in the study of any science. It must embrace experience and a true knowledge of the subject, such as will enable the individual to apply the principles in practical life. It is only when this training is applied that its full value is appreciated by the individual himself and by the nation. Didactic chemistry as taught twenty-five or thirty years ago can no longer be accepted by the universities of to-day. A glance into the history of chemistry will show that no scientific investigation has ever been made, either in the so-called field of pure or in that of industrial chemistry, which has not had its influence on the material development of the world. In fact, a discovery in chemistry or, as a matter of fact, in any other science which does not leave its impression upon the world, which does not help to bring humanity nearer ideality, from both the social and industrial standpoint, which does not directly raise the standard of civilization, is not worthy of being called a discovery. Our universities and colleges as a whole do not at the present time fully appreciate this fact. Our universities are just learning that the scientist and technologist are not born, but made by half a life-time of hard study, and that the universities alone are able to offer this scientific training. The teaching of science in our universities, therefore, is paramount in the industrial and material development of our country.

In taking up the teaching of chemistry in the United States, I can not, I think, do better than to give a brief outline of the conditions under which chemistry has been taught in some of our state universities during the past twenty-five years.

It is a striking but lamentable fact that until the last few years the practical chemist of the United States was essentially a self-made man. He had perhaps taken a course or two of chemistry in his university or college, but rarely had he studied chemistry from the applied standpoint. Therefore, after graduating he was compelled to begin as an apprentice and to spend several years in learning the things which should have been taught to him in his university course. University work twenty-five years ago meant, in a large majority of state universities, the study of Latin, Greek, mathematics and history, with a smattering of modern languages. Seldom did a university curriculum include the study of science except so far as it represented simple didactic training. Applied chemistry was not considered worthy of being placed in the college curriculum.

I distinctly remember my first impressions of chemistry, as offered in one of our state universities. We studied general chemistry by the old didactic methods. Our first lesson was to commit to memory the atomic weights of the common elements. (Imagine a man in the University of Illinois spending the first week of his general chemistry course in committing to memory the atomic weights.) We had no laboratory experiments except those performed by the professor, and these were performed in such a way that the underlying truths were entirely lost to the student. In fact, the only experiments in this whole course which left an impression upon the class, were those with hydrogen and oxygen which some of the students prepared for the professor while he was out of the lecture room. And I think I am not doing the kindly professor an injustice when I say I firmly believe that these experiments were the first to leave lasting impression upon him. Not a word in that whole course in chemistry was said which conveyed to the minds of the students the idea that chemistry was for any other purpose than to be simply dabbled with in college laboratories; not a word was said which conveyed to the minds of the students the fact that the laws and principles which we were studying were the foundation stones of our great industrial structures; not a word which impressed upon us the fact that we were studying the very substances from which our own bodies are made, from which the whole universe is made; not a word concerning the possibilities of the new chemistry; not a word which would indicate that there was anything more in the whole realm of chemistry than that found within the covers of a small elementary text. My surprise was all the greater when a few years later, I sat before a man with a thorough knowledge of industrial and practical chemistry.

The above is a fair sample, I think, of the methods of teaching chemistry in a majority of our state universities twenty-five years ago. In fact, very little progress had apparently been made since the introduction of laboratory work into the United States some twenty-five or thirty years earlier. In 1850 there were, so far as I can learn, only four or five institutions in the country which could boast of a chemical laboratory, and these were equipped in the most primitive way. Yale College had a small laboratory barely large enough to accommodate a dozen students. Amherst had just opened a small laboratory and Lawrence Scientific School likewise had a very imperfect one. There were, perhaps, two or three other institutions which had so-called chemical laboratories. There were, however, no systematic courses of study such as we find in our universities to-day, and no courses in applied and industrial chemistry. Students who were desirous of a systematic study of chemistry and more especially along technical lines, were forced to go abroad. With the exception of these few institutions the teaching of chemistry was entirely didactic. It is not surprising, therefore, that little or no progress should have been made during the next twenty or thirty years in the teaching of chemistry.

I do not mean to say that there were no great teachers of chemistry during these pioneer days. Such a statement would be incorrect, for there were men who stood out in chemistry during the fifties, sixties and seventies, as prominently in our own country as Liebig and Wöhler did in Germany during the early part of the century. Such men as Silliman and Cook stood out preeminently during the fifties and sixties, while men like Elliott, Remsen, Chandler, Morley, Mabery, Mallet and others have given the institutions with which they were connected such a standing as to place them on the same plane with the older institutions of Europe.

In this early epoch, practically none of the state universities of the center and middle west had reached a point where they could offer to the student good practical courses in chemistry. One reason, I think, was a lack of well-trained teachers, but the chief reason was doubtless an economic one. The state universities turned out few skilled chemists because there was no demand for such men in the center and middle west. The great industrial institutions were not compelled to resort to science and to the reclamation processes in order to earn large dividends. The trained chemist had not yet entered on the industrial stage. He did not hold the great industries in his hand as he does to-day.

Furthermore, the state universities were scarcely able to train such men had there been a demand. They were struggling to keep up with the rapidly growing population of the state, and little more could be done than to teach general chemistry in crowded and poorly equipped laboratories. In fact, the state universities of the center and middle west twenty-five years ago were supported by the state as belonging in the same class as reform schools and institutions of similar nature. The state had not yet come to realize that the university is its best investment, not only from the mental and moral but also from the strictly commercial point of view.

The state universities, I think, occupy a position quite different from any of the other educational institutions. They are a part of the great commonwealth, they belong to the people of the state and hence must, if they fulfill their obligations to the state, not only train men and women for civic but also for purely scientific and industrial life. Neither must be neglected. During the past decade practically all of the state universities have come to realize this fact, and nowhere in the world has there been such rapid development along the lines of both pure and applied chemistry as in these institutions. The teaching of chemistry in these rapidly developing states has naturally and properly taken an industrial trend. There is not a single state university to-day which is not, besides doing research work, materially assisting in the industrial development of the state from which it receives its support. It is no longer difficult to obtain appropriations to well equip laboratories, as is evident from the splendidly equipped laboratories of the University of Illinois.

Of all these great unversities which have become not only great educational but also important industrial factors within the bounds of the states from which they receive their support, the University of Illinois stands among the first. Situated in the center of a great industrial population where trained men are always at a premium, its opportunities are boundless. It is bound to play an even more important part in the chemical development of the country in the future than it has in the past. With the man at the head, whom we have gathered here to-day to honor and bid a god-speed, I do not believe it is possible to predict too much for this university not only in purely didactic but also in industrial and applied chemistry. None of the branches of chemistry which must be taken up by this state university are new to him. He is the peer of Elliott or Remsen in didactics and of Silliman and Chandler in industrial chemistry. No man in the whole country is better fitted to take up the broad lines of chemistry now demanded by the state university. I congratulate the University of Illinois and the whole state in securing Dr. Noyes as standard bearer, and with such coworkers as Parr, Grindley, Bartow, Lincoln and Curtiss, this university will stand second to none of the state universities in preparing young men and women for the work demanded by this great state and by the whole nation.

George B. Frankforter
University of Illinois

THE CONTRIBUTION OF CHEMISTRY TO MODERN LIFE

I THINK that few who have not paid especial attention to the subject realize how completely the world, as a place to live in, has been transformed during the past century. This transformation rests for its basis almost entirely on our fund of scientific knowledge, and especially upon the knowledge of physics and chemistry and biology which has been accumulated by scientific workers during the past seventy-five years. I wish to say something to you, this afternoon, of the part which chemistry has had in bringing about this wonderful change in our surroundings.

Our science goes back to the dark ages and before for its beginnings, but we, as chemists, haven't much reason to be proud of our intellectual pedigree. From the fifth to the fifteenth century, those who were known as chemists, or rather as alchemists, spent their time in searching for the philosopher's stone, which should change all things to gold, or for the elixir of life which should give eternal youth. The object which they sought was a sordid one, and while its attainment was quite generally believed to be possible, we have reason to think that many of the alchemists used the little knowledge which they possessed to deceive others more ignorant than themselves. We have been accustomed to say that our fuller knowledge has shown the folly of the alchemist's dream. Five years ago a distinguished chemist, in a public address, spoke of the doctrine of the transmutation of the elements as dead and every chemist who heard him agreed with his statement. But such revolutionary and startling discoveries have been made since then that a transmutation of the elements must now be considered as an accomplished fact.

This new discovery of transmutation did not come, however, along the paths the alchemists were following. Those paths were mostly blind alleys leading nowhere, though, now and again, some new fact about the way substances act on each other was discovered. And in spite of its obscure and mystical symbols and literature, and although the methods of experimentation were often more allied to magic and astrology than to science, alchemy left us a valuable inheritance of experimental knowledge. Many who took up the pursuit of alchemy from a desire for gold doubtless continued to work from a pure love of experiment.

In the sixteenth century some of those who had busied themselves with alchemy conceived the idea that chemistry might be of service to medicine. For one hundred years or more, the most notable of the chemists followed chiefly this new direction. They did not, however, discard the belief in the transmutation of metals. It was an age when authority still counted for very much and it seemed to them impossible to disbelieve the many circumstantial accounts of transmutation which had come down to them, often from sources that seemed thoroughly reliable. But, either because they despaired of success or because they found other things to do which seemed of more value, the chemists of this period turned their attention more and more away from alchemy and towards medicine and pharmacy. We may well doubt if their labors were much to the advantage of the suffering humanity of their time. Their crude empiricism and their wild and often mystical speculations as to the processes which go on in the body in health and disease were a poor basis for medical treatment. Doubtless many a poor patient fell a victim to their imperfect knowledge.

Thus far our science, such as it was, had followed utilitarian ends. The alchemist sought for gold—the medical chemist for new medicines. An embarrassing question often asked of a scientific man who has spent months or years of work over some problem is "What is the use?"—"Of what value will be the solution of the problem, if you succeed?" The contrast between the product of this thousand years of utilitarian science and the material results which have accrued during the two and a half centuries of better ideals is a sufficient answer, even from the material point of view—but I wish to protest against measuring the value of scientific work on the basis of dollars and cents.

About three hundred years ago there began to appear men who took an interest in the study of natural phenomena for the purpose of gaining a deeper insight into the nature of the world about them. There were, at first, very few men of this new type, and progress was slow in comparison with that of later times, but it was rapid when compared with the time of the alchemists. For these men were actuated by an entirely new and different spirit—the desire to *know* and the desire to gain knowledge that it might become freely the property of the whole world—and the knowledge they sought was not like that of the alchemist, whose aim was selfish and personal and whose greatest fear was that his secret discovery might become common property and so lose its value.

During the two centuries that followed there was a slow accumulation of chemical knowledge which passed freely among the few who had become imbued with this new spirit of investigation. During this period there was developed, too, the first really important generalization of the science—the theory of phlogiston which gave a qualitative explanation of the phenomena of combustion. This theory lived for more than a century and was useful in its time, but when the fundamental facts about combustion were discovered by Priestley and Cavendish and Lavoisier the theory was no longer needed. It was not displaced by a new theory, for the knowledge of the simple facts about oxygen and its relation to combustion was enough.

At the dawn of the nineteenth century Dalton gave to the world the next great generalization of our science—the atomic theory. This theory has been the central idea which has permeated the science and guided its development since that time. It has given to us a vivid picture which interprets and classifies for us the bewildering mass of experimental facts acquired by the work of thousands of chemists.

But while we find that this central guiding principle in the science was given to the world early in the century, there were as yet but few workers to cultivate the rich fields lying before them. There were no schools of chemistry, no great laboratories for instruction and research, such as we find to-day. But there were a few brilliant workers—Sir Humphry Davy in England, with his discovery of the alkali metals; Gay Lussac in France, with his laws of gases and discovery of iodine; Berzelius in Sweden, with his incredible achievements in the development of analytical methods and determination of equivalent weights. And for each of these there was another who gained from him an inspiration for scientific achievement—Faraday from Davy, Wöhler from Berzelius and Liebig from Gay Lussac. But Liebig did much more than go back to Germany to work in a laboratory of his own with perhaps an assistant or two. He founded in Giesen a laboratory for the training of investigators and it is scarcely possible to overestimate the importance of the influences which went out from that laboratory. To that laboratory came a company of enthusiastic young men gathered from all over the world. These men gained from their association with Liebig something of vastly greater importance than a knowledge of chemistry—they carried away an inspiration for research and an enthusiasm for the laboratory method of instruction. Largely from that laboratory as a center, chemical laboratories for the training of students spread throughout Germany and the world.

The fundamental principle of laboratory

instruction is that the student comes into direct personal contact with the things about which he is to study and so gains first-hand knowledge. While chemists were the pioneers in this method of instruction, physicists and biologists soon saw its advantages and introduced it in those sciences. The principle has now permeated almost every line of teaching and we hear, to-day, of the laboratory method in history and psychology as well as in the physical sciences.

By the middle of the nineteenth century the methods to be used in training a band of chemists were being rapidly developed. And it came to be more and more clearly recognized that the training is not merely to give to the student a knowledge of chemical facts—it must give to him the power to think for himself and to strike out into new and untried paths. It is this power of individual initiative which is given to the students in the German laboratories that has placed Germany in the front rank in chemical manufacture as well as in research and instruction.

Some of the most important applications of chemistry in the industries were developed early, along experimental lines having little or no connection with scientific work. One hundred and fifty years ago, those who were smelting ores of iron and copper and lead and zinc knew very little of the work of the chemists of their day. And the same was true of those who were tanning leather, dyeing cottons, woolens and silks, burning bricks and pottery and china, making glass and working in many other chemical industries already well developed.

The soda industry was one of the first large chemical industries to be developed on a scientific basis. When we consider that the soda for our soap is now practically all made from salt, it seems hard to believe that one hundred years ago soap was made almost exclusively from the potash of wood ashes or from natural soda, the supply of which was very limited. I think we are forced to the conclusion that our great-grandmothers used very much less soap than we do. The first factory for making soda from salt was built by Le Blanc in France in 1791, but, partly because of the political conditions at the time of the Revolution, partly for other reasons, the factory was not a success. Le Blanc himself died a few years later, in extreme poverty, and it was not till 1823 that Muspratt established the industry successfully in England. From that time the Le Blanc process held undisputed sway till the early seventies. Since then it has fought a losing battle with the ammonia soda process, and to-day there is not a Le Blanc factory to be found in America. Now the ammonia soda is, in turn, being displaced rapidly by electrolytic soda. This sort of competition is typical of that which occurs in many chemical manufactures. In the case of Le Blanc soda it has been a most powerful incentive toward the improvement of the process. It has resulted in developing improved mechanical appliances for carrying out the operations, in the recovery of the hydrochloric acid and its use in the manufacture of chloride of lime and in the recovery of sulphur from the calcium sulphide. I visited a Le Blanc factory in

England two years ago, where they told me that their sulphur for making the sulphuric acid used in the process came from Spain in the form of pyrites and that 85 per cent. of it left their factory as pure sulphur. In all this development the chemist has taken an ever-increasing part —in the development of new processes and the direction of old ones, and in that analytical control of raw material and finished product which has become indispensable in all kinds of manufacture.

The soda industry in its various branches was begun and has developed as the result of chemical work applied directly to the solution of technical problems. Since then it has often happened that work begun with the sole purpose of adding to our fund of scientific knowledge has led to important technical industries. The founding of one of our greatest industries began in this way, at the middle of the nineteenth century. In 1856 William Henry Perkin, then a young man of eighteen, was working in London as the private assistant of Professor A. W. Hoffmann. He was not satisfied, however, merely to spend the day on Hoffmann's researches and he fitted up a rough laboratory in his father's house where he could work in the evenings and in vacation time. Here, with a purely scientific interest, he tried some experiments which he hoped might lead to a synthesis of quinine. He got, instead, a dirty brown precipitate which must have seemed very unpromising. He became interested in it, however, and repeated the experiment with aniline. This gave him a black and still more unpromising product, but on examining it further he found in it a beautiful purple coloring matter which proved to be what we now know as the "Mauve dye." At that time, only fifty years ago, such a thing as an artificial dye was unknown, and we must marvel at the wonderful insight and energy of this boy who grasped the significance of his discovery and made it the beginning of the great industry of coal-tar dyes. After further study of the new compound and after practical tests in the dyeing of silk he gave up his position as Hoffmann's assistant and began the manufacture of the new dye. He was fortunate in having a father who had enough faith in the undertaking to risk almost his whole fortune on the venture, for it would have been hardly possible, then, to secure from outsiders enough capital for so hazardous an enterprise.

At that time benzene, the raw material for the manufacture, was not to be had in the market, of definite quality, and its distillation from tar had to be developed. Further, after the dye had been prepared it was quite different from the dyes then in use and methods for its application to silks and other goods had to be worked out. All these difficulties were finally overcome and within two years the mauve was supplied for the dyeing of silk. As soon as success was assured, others turned their attention in the new direction. Three years later magenta was discovered in France and soon after other dyes were prepared by Perkin, by Hoffmann and others. Hoffmann's discoveries of dyes are especially interesting because he thought that Perkin was making a mistake when he left him.

And Perkin himself was much afraid that by entering a technical pursuit he would be prevented from following the research work in which he was so much interested. He determined, however, that he would not be drawn away from research, and in that determination and its imitation by others I think we may see the secret of much of the success of this industry. In no other industry are so many highly-trained chemists employed and in no other is the work so closely related to research in the pure science.

Twelve years after the discovery of mauve, Graebe and Liebermann succeeded in preparing alizarin, or turkey red, from the anthracene of coal tar. This discovery, again, was the result of pure scientific work undertaken without reference to its technical importance. The first method of preparation, too, was by a difficult process which was too expensive to be commercially feasible. As soon as the scientific problem had been solved, however, the question was taken up from the commercial standpoint and Perkin soon found an economical method for the manufacture of the dye. At that time large quantities of madder root were raised in Holland and elsewhere for the preparation of alizarin. It was soon found that the dye could be made much more cheaply from anthracene and within a few years the artificial alizarin drove the natural product from the market and the Dutch farmers were compelled to raise other agricultural products. So important is this dye that the value of the amount manufactured in 1880 is given as $8,000,000. It is estimated that it would have cost $28,000,000 to manufacture the same amount of the dye from madder root. This means that the world saves $20,000,-000 a year in the manufacture of this single dye, an amount that would pay for the maintenance of a good number of chemical laboratories.

The development of this manufacture was so rapid that by 1873 Perkin and his brother found that it would be necessary to double or treble their factory to supply the demand. Perkin was then only thirty-five years of age and his love of research had survived his seventeen years of experience as a manufacturer. Partly for this reason, partly because he did not wish to assume the responsibility of the larger factory, he sold the works and after that time he devoted himself to scientific research, with distinguished success. The jubilee of the discovery of mauve and the founding of the coal-tar industry was justly celebrated last year as one of the great events of the century, but Perkin's scientific achievements and the way in which he stood for high ideals in research are, I think, of even greater value to the world.

The manufacture of mauve was quickly successful and after the scientific discovery of the structure of alizarin, commercial production soon followed. With indigo, the case has been somewhat different. The scientific problem was in itself more difficult and the course of events has illustrated with especial clearness the difference between the scientific and the technical solution of the same problem. Baeyer began his work on indigo in 1865. During the five years following he prepared a number of important derivatives, which contributed much toward the clearing up of the relation between indigo and other compounds. In 1870, he found that some of the work he was doing seemed to cover much the same ground as some work which Kekulè had undertaken and out of scientific courtesy he allowed the matter to lie dormant for eight years. In 1878, as Kekulè had published nothing further of importance, Baeyer returned to the problem and in 1880 he obtained a successful synthesis of indigo. With the brilliant success of alizarin in mind patents were taken out, and it was generally expected that the manufacture of the artificial dye would soon become of commercial importance. But these hopes of immediate success were not realized. Two principal difficulties were encountered. The original methods of synthesis involved a considerable number of difficult transformations between the raw material, toluene, and the finished dye, indigo. These transformations required a very large amount of careful scientific study before the conditions could be found under which they could be carried out in ways that would be economical of time and material. But when this side of the problem had received a partial solution as the result of fifteen years or more of work, a second difficulty presented itself in the magnitude of the interests involved. It is estimated that the world uses about 5,000 tons of indigo in a year. Now, even with the perfected methods it takes about four pounds of toluene to make one pound of indigo and the present production of toluene is only about 5,000 tons a year. The whole of the toluene produced would give only about one fourth of the amount required to supply the world's demand for indigo. Furthermore, the toluene now produced finds a ready market for use in the preparation of other dyes and other compounds. Any attempt to use a considerable amount of toluene for the manufacture of indigo would be met, therefore, by a rising price which would quickly make the production by this method commercially impossible.

Fortunately, another synthesis of indigo was discovered by Heumann in 1890 which made it possible to prepare indigo with the use of naphthalin as a raw material. As the supply of naphthalin is ample for the purpose, the second difficulty was overcome. But the new process required the solution of a whole set of new problems and it was not till seven years later that the Badische Anilin and Soda-Fabrik considered that the process was sufficiently well developed to justify preparation for the manufacture on a large scale. So carefully had they worked out every detail, however, that during the three years that followed they were willing to expend four and a half million dollars in building the factory and apparatus for this one enterprise. As the world uses in a year twelve to fifteen million dollars' worth of indigo, the manufacture on a large scale is justified, and there is every indication at present that the artificial indigo is slowly displacing the natural product. The farmers in India are already feeling this new competition and it is doubtless only a question of a few years before they will be compelled to devote their attention to other crops. The hope has been expressed that the land released in this way may be used for raising food products, which may give some relief from the famines so common in that country.

In 1856, in the same year in which Perkin discovered mauve, Henry Bessemer presented to the world at the Cheltenham meeting of the British Association the first account of his new process for the manufacture of steel. Previous to that time steel had been made by a roundabout, tedious process. The carbon was burned out of pig iron in puddling furnaces so constructed that only comparatively small amounts could be handled at once and the most arduous hand labor was required. From the wrought iron obtained in this way steel was prepared by packing the bars in charcoal and heating them for several days until they had reabsorbed the requisite amount of carbon. Bessemer conceived the idea that by blowing air through melted iron it would be possible to burn out the carbon and silicon in the iron, while the heat resulting from their combustion would keep the iron liquid. He thought, too, that if he could stop the blast at the right moment, before all the carbon was gone, he would have steel. He showed that in this way several tons of iron could be converted into steel in fifteen or twenty minutes, whereas the old process took half as many days. Such a revolutionary process attracted a great deal of attention, and he succeeded in selling the right to use the process to a number of manufacturers for a considerable sum of money. When they attempted to make steel by the new method, however, every one of them failed. It was found practically impossible to stop the blow at the right point to secure a uniform product. But Bessemer was not disheartened by the failure and for the two years and a half following he worked continuously, building new furnaces and tearing them down, until he finally solved the difficulty. It was found possible to determine when the burning out of the carbon in the iron was practically complete by watching the flame as it issued from the converter. Then, by adding the right amount of an iron containing manganese and carbon, the proper composition for steel could be secured. When Bessemer tried again to introduce his perfected process he met with a very cold reception from the manufacturers. They said they were not to be deceived a second time. He was finally compelled to build works and establish the manufacture for himself. He succeeded beyond the most sanguine expectations, and the revolution in the manufacture of steel which dates from that time is common knowledge.

Agriculture still remains the most important industry in the world. From the time that primitive man began to till the soil to the middle of the nineteenth century the farmer received but little aid from chemistry. The work of the last seventy years has changed all that. As late as 1840, it was generally supposed that plants grew chiefly from the vegetable humus in the soil. Many of the fundamental facts on which to base a more correct view had been known long before, but it was Liebig who first grouped these facts together and pointed out clearly that plants are nourished by the inorganic constituents of the air and soil and that it is the potash and lime and phosphorus and inorganic nitrogen of the soil which are vitally essential to their growth. On this simple foundation has grown up our great modern fertilizer industry, which brings to our farmers the phosphates from the south, the potash salts from Germany, and the nitrates from South America. The supply of the last is limited in consideration of the present demand, and there has been a good deal of speculation as to what our farmers will do when the beds of nitrates are exhausted. There is plenty of nitrogen all about us in the air, however, and several methods have already been developed for utilizing this inexhaustible supply.

I might speak further of the part that chemistry plays, to-day, in the making of paper, in the tanning of leather, in the boiling of soap, in the manufacture of glass, in making paints and varnishes and india rubber, in the making of cement and in the refining of petroleum, but I will not take your time with further details. In these and in many other industries the work of the chemist has become an indispensable factor. Fifty years ago there were very few chemists in America and those few were almost exclusively engaged in teaching. To-day it is estimated that there are 8,000 chemists in the United States and a very large proportion of these are employed in industrial work. But it is not in technical lines only that great advances in chemistry have been made. I believe the advance which has been made in chemical research is of much greater importance. I have spoken of the fact that Liebig gave to his students the love of research and that they acquired in his laboratory the power of individual initiative. In many of the chemical laboratories of our colleges and universities and technical schools are to be found to-day earnest workers who are seeking for new truths and who inspire their students with the power to think independently and to do original work. Whether the student's life work is to be in the field of pure science or in its technical applications, this power is the greatest gift that a teacher can impart.

While the material advantages which have come to us from chemistry are very great and may be justly emphasized, its greatest achievement is, after all, the part which it has had, together with other sciences, in transforming the way in which the world *thinks*. In its laboratory method it has replaced the old idea of authority by the idea of first-hand knowledge. It leads the individual to seek for himself the fundamental basis of his knowledge and it leads him not merely to pass that knowledge on to the next generation, but to transform it into a new and truer form. And as this scientific spirit permeates society it more and more destroys deceit and fraud, wherever found. WILLIAM A. NOYES

UNIVERSITY OF ILLINOIS