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# CHEMISTRY IN THE SERVICE OF SCIENCE[1]

By Dr. A. T. LINCOLN

CARLETON COLLEGE

The approach to the Hall of Science at the Century of Progress is so arranged as to present to the visitor some of the concepts of the phenomenal development of chemistry as a symbol of the contribution of science to the human race. By means of the strikingly beautiful murals there is depicted the growth and development of chemistry and its applications to industry, commerce and medicine. It is the natural tendency for the individual scientist to believe that the particular branch of science in which his interest lies is of basic importance in its contribution to human knowledge and thereby to human progress. The chemist, however, can claim with some justice that in his field—chemistry—all the sciences find their common meeting ground. The chemist has to perfect himself more and more in mathematics as one of his most valuable tools. An eminent mathematician has said, "The striking progress in modern physics and physical chemistry has arisen from inquiries as to the data which specific mathematical tools could be made to yield when applied to physics and chemistry." He applies to his chemical problems the principles described by physics; he isolates, purifies and makes available for use the minerals and ores located by the geologist; he is now interpreting biological phenomena in terms of chemical changes and he is helping to pave the way for a clearer understanding and thereby a more accurate control over the physiological processes occurring in our own bodies. The automotive industry is really a chemical industry because everything used in it is chemical. This may be said of practically all the fundamental basic industries, a fact which further emphasizes the importance of chemistry as the handmaid of all the sciences.

## Service to Astronomy

To the man in the street little connection is apparent between shaking the test-tube and star-gazing,

[1] Presented at the second annual meeting of The Minnesota Academy of Science, Rochester, Minn., April 21, 1934.

but the interrelation is nevertheless real and important. The progress of the astronomer is largely due to the help of the chemist and physicist. Nevertheless, the astronomer has himself assisted in the advance of these two closely related sciences.

Through the remarkable versatility of the spectroscope a wide variety of physical and chemical discoveries have been applied. Among these may be mentioned: (1) By pressure the shift toward red or violet spectral lines is utilized as a means of measuring the pressure of stellar atmospheres; (2) with temperature there is a variation of the relative intensities of lines which gives a clue to stellar temperatures. By the photometer, now displaced by photographic methods, the magnitude of tens of thousands of stars has been determined. The thermopile, radiometer, interferometer and photocell are among the many instruments that have contributed to a much completer knowledge of the stars.

Among the special contributions of the chemist are the new dyes, new alloys and new glasses which the astronomer is continually requiring for the more refined features of his researches. The dyes are not the variety that graces our dinners or ballrooms, but dyes that will improve the sensitiveness of the photographic plate in various wave-lengths, especially in the infra-red. A new dye has recently been discovered which makes it possible to prepare infra-red emulsions of higher speed than hitherto. They are sensitive to the region of 7,500 A° to 8,600 A°, much beyond the range of visible light from about 3,900 A° at the violet end to 7,600 A° at the extreme red, through rendering exposure of 1/100,000 of a second common, and even 1/1,000,000 of a second are frequently used, while a special dye, xeno-cyamine, gives a sensitivity up to 11,000 A°. What with a combination of the telescopic lens and a sensitized emulsion, infra-red photography makes possible photographs of mountains to a distance of over 300 miles and at sea removes the fog hindrance to good pictures. Infrared photography of the heavens as a supplement to the existing methods presents great possibilities. With infra-red filters a record of stars that radiate this light may be made while cutting off the visible spectrum and reducing the scattering of their rays on their way to the earth.

New alloys while useful in every industry are aiding in the progress of astronomy, wherein they are used for telescope mirrors, optical gratings and in many other ways. This demand for bigger and bigger telescopes is being met by the glass-maker, who is producing the glass of the desired composition to reduce expansion and contraction to the minimum with changes of temperature. Telescopes focus the object by means of a reflecting mirror at the bottom of the telescope tube. This glass disk is silvered on the accurately ground paraboloidal front surface.

The big 60-inch mirror, 8 inches thick, and weighing about one ton, has been superseded by the 100-inch mirror, which is 13 inches thick and weighs nearly five tons. And now within the last week or so a new 200-inch disk has just been poured of Pyrex glass, which is intended for the new reflecting telescope at the California Institute of Technology. Since expansion and contraction of glass with change of temperature changes the figure and decreases the definition of stars, use is being made of fused quartz, the coefficient of expansion of which is very small. These disks up to 12 inches in diameter are being utilized.

These are some of the numerous problems that the chemist has been asked to assist in solving, and the possibilities in the future for additional contributions of the chemist are possibly even greater.

### SERVICE TO BIOCHEMISTRY

One of the fields of science in which the service of chemistry is extensively utilized is that of biological sciences and so intimate is the interrelation of the two that their joint activities have been designated by a combination of the two terms into a single word —biochemistry. As biology has been divided into two divisions, botany and zoology, which includes physiology, so the service of chemistry to these sciences is designated plant biochemistry and animal biochemistry.

*Plant biochemistry:* Hardly a phase of plant development can be considered but that the problems involved become highly chemical in character. The chlorophyll which is sometimes designated "the president of the powerful photo-electrical system" through the energy of the sun by a process designated as photosynthesis causes various chemical reactions with the liberation of oxygen as one of the by-products.

For work on this green coloring material of plants honors have recently been conferred upon two great chemists: Richard Willstätter, a noted German worker, to whom was given the Willard Gibbs Medal, and James B. Conant, an American chemist, who was recently elevated to the presidency of Harvard University. Many others have worked with this complex chemical of such fundamental importance to all life. A complete formula has been worked out only within the last few years, and even yet not all the atoms and bonds are located beyond dispute.

The hemin or red coloring matter of the blood is closely related to chlorophyll, and was probably derived from it ages ago. It has iron in place of the magnesium of the chlorophyll. Willstätter recently stated the principal characteristic of animal chemistry as oxidation, catalyzed by the magnesium of the chlorophyll. With the aid of the chlorophyll granules in plants, employing the energy of sunlight, carbon dioxide is converted into sugar and from that into starch and cellulose—food, reserve food and structural materials, respectively. Animals ultimately subsist on plants, which in turn utilize the service of chlorophyll. "It may not be too much to call chlorophyll the most important organic chemical, for it has made life, as we know it, on this earth." Within the chloroplast wonderful chemical changes take place—starch is formed in some cells, while others are charged with sugar. Accompanying these there is possibly the flux of nitrogen and formation of proteins. Then associated in family connections are the carotenoids, the chlorophyll-phytol seeming to be a derivative of carotene. The pale yellow oily substance derived from carotene is our vitamin A, which the chemist now knows how to manufacture.

The impetus biology has given organic chemistry recently is demonstrated in a number of fields. The attempt to elucidate the structure of vitamins A and C and cognate problems is perhaps one of the most striking. The relation of vitamin A to natural polyene pigments of the carotene and related groups, which have been considered biochemical, now becomes purely a chemical problem of outstanding interest and is treated at present as such. Vitamin C has recently been identified with ascorbic acid and the structural formula assigned.

The mechanism of the intake of minerals by the plant root cells, which are able to maintain within the tissues a higher salt concentration than exists in the surrounding medium, involves problems well within the range of the physical chemist. The assimilation of nitrogen, the intake and effects of potassium as well as of phosphorus, not to include the secondary plant nutrients boron, copper, iodine and sodium, are fascinating chemical problems yet unsolved. The chemistry of plant juices is receiving marked attention from the latex of the rubber plant and the turpentine of the pines to the important classes of volatile essential oils. The extensive problems of plant breeding involve the formation and distribution of certain plant constituents.

Then the plants from which are derived our medicinal drugs comprise another fruitful field of chemical research, not to emphasize the control of the diseases and particularly the elimination of the enemies of plants by the preparation of insecticides, germicides and fungicides which have specific properties, particularly their harmlessness to man. The development of pyrethrum poisons is a conspicuous example.

*Animal biochemistry and medicine:* To follow animal as well as plant metabolism is one of the most fascinating of the chemist's tasks, as there is thereby afforded infinite opportunities. While biochemistry is at present becoming a mere name, this field is one in which the worker must have clinical as well as thorough chemical training, for it lends itself to an exercise of the imagination which is almost infinite, but a strong guard will have to be exercised over this fancy.

One of the great services of chemistry to biology and medicine is the protein research resulting largely through the work of Fischer, Kassel, Osborne and Sörensen in the discovery of the thirty-odd amino-acids, the building stones of the proteins. More recently the applications of physical chemistry have resulted in the outstanding contributions through the use of physico-chemical methods to this most complicated and important field.

The whole animal kingdom depends for the production of the amino-acids upon their synthesis by the plant cell. Hence animals depend for these vital proteins upon the plants which produce them through the photosynthetic process. The number of theoretically possible protein compounds that might be synthesized from the 31 amino-acids is almost limitless, but each protein has its biological reactions that characterize the particular species and distinguish it from all others. This specificity is practically limitless, and it is perfectly marvelous that nature always does manage to synthesize the same protein time after time through generation after generation of plants, a given organism reproducing its own characteristic patterns with never a variation, even in all members of the species. This is an impressive illustration of the exactness of the regulation of the vital reactions in nature.

The interrelations between the amino-acids, the numerous types of proteins, nucleic acids, the digestion and metabolism of proteins comprise one of the important fields in which the problems are becoming purely chemical in character. Their solution requires the methods of that branch of physical chemistry termed colloidal chemistry. This may be emphasized by two recent marked examples—that of the study of epilepsy and of insanity, both of which are problems in the colloid chemistry of the brain cells. In the study of epilepsy Irvine McQuarrie has recently emphasized that "as a general rule, the factors which tend to increase cell membrane permeability (superhydration) are those recognized as favoring the occurrence of epileptic seizures; whereas those which are thought to decrease permeability (dehydration) favor their cessation—the mineral and water balances in relation to the occurrence of epileptic convulsions are tentatively interpreted as indicating the existence of an inherent defect in the physiological mechanism for regulating the semi-permeability of the brain cell membranes."

Claude Bernard's theory of anesthesia and narcosis as developed by Wilder D. Bancroft indicates that coagulation produced by certain drugs is counteracted by the peptizing effect of the compounds such as sodium thiocyanate on "the coagulated protein colloids of the central nervous system including the brain and spinal cord and the sympathetic nervous system." Bancroft suggests "that many of the 'functional disorders' may be nothing more than an abnormal degree of dispersion of the nerve colloids," and certain effects show "that such colloidal reagents will produce symptoms that are not unlike many of those of insanity." It has been shown that "coagulating agents cause changes in the brain colloids from normal through irritability and insanity to sleep, anesthesia and death. Dispersing agents cause changes in the brain colloids from normal, through insanity to death."

The problems presented by photosynthesis, action of infra-red radiation, catalysis due to minute quantities of elements, such as magnesium in chlorophyll, and the realization of the existence of complex colloidal systems in the various organisms lend added interest to the fascinating problems of biology and medicine, which chemistry is aiding in solving. The first stages of cooperation are soon followed, however, by the pure problem of synthetic organic chemistry and the application of physical chemistry.

In addition to the few problems mentioned above, many others of great interest are crowding to the front for solution which include the verification of the identity of calciferol with the naturally occurring vitamin D, the precursor of which is the irradiated ergosterol with antirachitic properties; glandular secretions; and the long lists of important local anesthetics, hypnotics, antiseptics, as well as the bactericides, and the interesting dyes which have specific toxic action on enzymes and on the catalytic activities of tissues—all of which offer almost unlimited scope to the organic chemist.

*Bacteria and yeasts:* There are two groups of biological operators which during their life processes produce enzymes which are definite chemical products some of which are recognized toxins and others antitoxins. The relation of these through their chemical reactions is assuming greater importance. This is due to the fact that apart from their medicinal values both of a curative and also of a poisonous character there are multitudes of bacteria and yeasts that can be cultivated and utilized in the production of chemical compounds. These include the nitrifying bacteria that convert nitrogen into compounds usable by the plant, the various processes such as the souring of milk, the manufacture of cheese and the preparation of silage, as well as the disposal of sewage; and the use of yeast in bread-making as well as in the fermentation of sugars. These fermentation processes are assuming great importance in the chemical industries for the manufacture of acetic acid, methyl and ethyl alcohol as well as many of the higher alcohols and ketones.

### Service to Geology

The period of discovery of the location as well as the classification of the metallic and non-metallic constituents of the earth is nearly closed. This has been geology's large contribution. The evaluation of these deposits by the analytic chemist is a service readily recognized. Then there has followed the application of physical chemistry to the solution of the intricate problems of the origin of the various deposits such as van't Hoff's classic researches in the Strassfurt salt deposits and the more recent phase rule studies of the Trona Lake salt deposits and the recovery of potassium chloride therefrom. The origin of ore deposits and the availability of the values contained therein of metals as well as of the non-metallic deposits such as salt, gypsum, aluminum compounds, asbestos, clays and those materials usable in the preparation of abrasives, refractories and insulators, emphasize the intimate relationship of chemistry to economic geology.

International relationships may be affected by the distribution of the deposits upon which the activities of the nation may depend in peace as well as in war. For the independence of her industries the United States has practically all the minerals and industrial raw materials that would be needed even in time of war, except possibly asbestos, graphite, nickel, antimony, cobalt, potassium, chromium and platinum, whereas many nations, such as Germany, have few of the real essentials or "key" minerals and are therefore dependent upon foreign nations for these.

The nitrogen industry is a good illustration. Prior to 1914 practically all the nitrogen needed by the nations of the world was obtained as Chile saltpeter, sodium nitrate, from the Chilean government. During the war the supply required by Germany for her fertilizers and the manufacture of explosives was cut off completely. She developed a process for the fixation of atmospheric nitrogen and thus became independent of all the nations. Practically all nations are now drawing their supply of nitrogen from the air and the Chilean government, having depended largely upon the Chile saltpeter for the governmental revenues, is now in a critical financial condition due to the loss of its nitrate export trade.

In 1933 the world's production of synthetic nitrogen was 1,700,000 metric tons, or 50 per cent. less than the total production capacity for all forms of fixed nitrogen. This was 80 per cent. of the peak of 1929 production and 90 per cent. of the peak of 1929 consumption.

This development has been largely at the expense of Chilean nitrogen, which was 70,800 metric tons for 1932–1933, or only 15 per cent. of the 464,000 metric tons produced in 1929–1930 and only 4 per cent. of the production of all forms of nitrogen in 1932–1933. The excess Chilean nitrate stock is at least equivalent to a two-years' requirement. Agriculture theoretically should consume enormous quantities of nitrogen, but the rich soils of our midwestern plains and elsewhere will maintain a normal rate of production of grain for years to come without the aid of commercial fertilizers. A fertilizer is only a necessity under intensive cultivation, and the large proportion of the 400 million acres of crop lands is not so cultivated. It is evident that the time when an enormous quantity of nitrogen must be used is doubtless much further distant than has been indicated by propaganda put out during the past lamented "New Era."

In the petroleum industry the interrelationship of the geologist and chemist is most marked. The geologist has located a large number of the principal petroleum fields, and the survey has been so thoroughly done that he is practically at the end of his trail. The crude oil has been handed over to the chemist for refinement and synthesis of a multitude of new products and a potentiality of many others, the research work in this direction having hardly started. The United States production of 851 million barrels of 42 gallons each represents about 62.1 per cent. of the world's production. From this approximately 17,000 million gallons of gasoline were produced in 1931. The efficiency in this cracking process has meant an increased yield of some 300 per cent., within the last few years. More advance has been made in the quality of lubricating oils, of which about 1,200 millions of gallons were produced in 1931, to fulfil the ever-increasing stricter requirements of the rapidly moving parts of machinery, such as airplanes, steam turbines and spindles, than during the previous 30 years. The multitude of new compounds being produced has added hundreds of new words to our vocabulary. These substances are replacing the older solvents, and new uses for them must be found. New plastic materials are being produced in larger quantities; new synthetic resins for the paint and varnish industry are being developed, while 4,000,000 gallons of alcohol are produced yearly from the oil industry, whereas a billion could be produced in direct competition with agricultural production from molasses, potatoes, sugar beets and corn. Then there is the recent successful attempt by England to produce synthetic motor fuels by the hydrogenation of coal in direct competition with the petroleum industry.

### SERVICE TO AGRICULTURE

The chief business of chemistry in its relation to agriculture has been "to make two blades of grass grow where one grew before." For nearly the last hundred years the fundamental idea has been prevalent that the human race would disappear through starvation. Malthus predicted it, as did also Sir William Crookes, who prophesied we would not be able to grow enough wheat to sustain the human race. But now we hear on all sides that "too much food is being produced at prices too low to maintain the farmers, etc."

By the extensive research that has been carried on during the past fifty years, the growth of plants as well as animals has been chemically controlled. By balanced rations they have been properly fed and nourished. By breeding the protein content, the oil content or the starch content of wheat, oats, corn and other crops have been improved in such a way that their quality for various specific purposes has been greatly improved. Through proper fertilization and controlled conditions of growth, extra yields have been enormously increased.

Likewise the breeding of stock—horses, cattle, hogs, sheep—has been so developed as to produce better horses, better milch or beef cattle, better pork with the proper distribution of fat and lean in the bacon, as well as hens that will have a laying capacity of 300 eggs or more per year.

Not only have these conditions all required their special chemical controls, but both plants and animals have had to be very carefully protected from disease. This protection is a highly specialized field of chemistry in which by the development of various insecticides, germicides, fungicides, bactericides and disinfectants a strenuous warfare is being carried on for the preservation of the plants and animals. As we have seen in the realm of medicine, chemistry is the chief handmaid, as it were, in this never-ending fight. For the apparent increase in the enemies of both plants and animals, the grasshopper plagues, the impending chinch bug invasion, the menace of the cornborer and numerous other pests indicate that the victory is a long way from being won.

*Natural versus synthetic products:* As indicated, the chief purpose of agriculture has been the production of food for the human race. Now that that object can be so easily attained and there can be produced such a superabundance of food products, the questions arise: What is the farmer going to produce? What is he going to do with his land? The AAA says, "Take the land out of production," but does not go much further; yet Secretary Wallace does tell us that by the removal of 20,000,000 acres of land from the production of cotton there will be some millions of the inhabitants who will have to be removed from these lands and transported to some other more favorable section of the country, while the land they leave will revert to government parks to be visited by the traveling public in search of pleasure grounds. The few inhabitants residing there will have as their occupation the selling of gasoline, sandwiches, candy bars and hard liquors. The same picture presents itself with reference to the removal from active cultivation of wheat land, corn land, pasture land, since the reduction of production of these crops and the decrease in the cattle and hogs will further decrease the demand for land on which to produce these various products. This is not a very pleasant prospect for the land owner nor for many others.

## Farm Products as Potential Raw Materials for the Chemical Industry

Cotton has been for many years one of our principal textile materials and some 17 million bales of 500 pounds each have gone each year into the production of cloth of various kinds and for numerous uses. But even this had to be processed by the chemist, according to certain washing, bleaching and dyeing processes. With the development of the tire industry more of the cotton fiber has gone into cordage for the construction of tires. Some of the poorer cotton fiber known as "linters" went into the manufacture of explosives like nitrated cotton. Now much more of it is being utilized by various synthetic processes for the preparation of rayon and a new type of paints or lacquers such as Duco, and particularly in the plastic industry. Then from the seeds there result hulls and meal utilized as feeds and fertilizers, the cotton seed oil which is used as edible oils, such as salad oils, the hydrogenated products such as Crisco, and for the manufacture of soap, a by-product from which—glycerine—has many uses, particularly as a basic material for the production of explosives (nitroglycerine), medicine, anti-freeze and synthetic resins (glyptal) used in the preparation of enamels and varnishes and plastics.

Similarly, corn, which was chiefly grown for feed, is now becoming the basis of a larger number of commercial products, such as starch for the textile trade, corn oil, a salad oil, dextrines for paste, corn syrup and many others. Then there is the cellulose of the corn husks and stalks, a potential material for paper pulp and building insulating boards; and the zein of the corn silks, a vegetable protein resembling cellulose, insoluble in water, with potential uses in the plastic industry.

From oat hulls there has been developed an important chemical solvent, furfurol, from which an important type of plastics is prepared in large quantities for the manufacture of victrola records and similar products.

*New crops:* By improved breeding the sugar content of sugar beets has been greatly increased, thus making them a competitor of sugar cane in the production of sugar. There are a number of possible new crops that are potential sources of chemical raw materials, such as soybeans, the oil from which is becoming a strong competitor of other oils used in the paint industry. "The diversity of industrial uses to which its several derivatives are already put is little short of amazing." In 1931, 2,226,000 acres of soybeans were used for hay, and 1,271,000 acres produced 18,885,000 bushels of seeds, and over 13,000,000 pounds of oil, against the approximate 9,000,000 pounds imported, which was about 50 per cent. of the importation of the previous year (1929).

Levulose, one of the digestion products of sucrose (cane sugar), is a valuable food, one and a half times as sweet as cane sugar. Its use promises marked benefit to the health of mankind as a preventative or a treatment of diabetes. It occurs in many plants and particularly in the weed, the Jerusalem artichoke or wild sunflower, to the extent of 8.64 per cent. to 19.47 per cent. The average in Iowa is about 14 per cent. and in Minnesota ranges from 6.72 per cent. to 10.3 per cent. With breeding this can be greatly increased, as has been demonstrated. An experimental plant for the production of levulose is in operation at the Iowa State College of Agriculture at Ames, Iowa.

The tung-oil trees are suited for producing paper, and ramie or China grass offers the strongest natural fiber for clothing and paper. The long leaf and loblolly pine in ten years are suited for pulp. The hybrid poplar produces short pulp fiber. There are large varieties of nut trees, fruit trees, vegetables, sweet potatoes, peanuts and many others, the cultivation of which can be greatly extended for the production of food. By new processes the chemist is busy with research on these new products so as to make them a valuable source of revenue to the farmer and to give him new opportunities by providing him with new crops. This results in broadening the old-time farming into a new agricultural industry—"the growing of chemicals through biological means and to chemcial ends."

In 1900 there were 20 million horses employed and in 1921, 21 million, but in 1931 there were only 13 million or a loss of 8 million horses in eleven years due to the change from horse power to gasoline. This elimination of the horse reduced the consumption of food farm products equivalent to the food consumption of 40,000,000 people. An apparent advance in the technology of farming caused an immediate direct result, the greatest disaster that could have happened to the farm.

Then, too, by using 27,000,000 automobiles, the American people, instead of walking and using their own energy, consumed 15 per cent. less meat per capita in the same period, with the result that the number of cattle decreased in the United States from 40 million head in 1920 to 30 million head in 1931. These 10 million cattle, which have been lost, annually would consume as much food as 50 million people. There was during this period a loss of about 17 per cent. in the demand for farm products. The present use of automotive power means that approximately 20 per cent. of all farms in America are no longer needed, and if no control is applied the next most probable state of the American farmer will be even worse. The value of the American farm has, according to the United States Department of Agriculture, gradually decreased according to the index number of 156 in 1921 to 116 in 1929 to probably as low as 70 in 1932.

By individual technology the farmer has not strengthened his position financially, since between 1910 and 1931 he purchased seven billion dollars worth of automobiles, trucks and tractors. These were not bought from his income, for farm mortgages increased during that same period eight billion dollars. The outstanding debt against their equipment remains, and about 90 per cent. of the equipment itself has reverted to rust and decay.

Stated in another way: Only 200 million acres, instead of the 350 million acres now under crop cultivation in the United States, are necessary to furnish all the food and raiment that all living things in this country require. This excess acreage is largely inclusive of what is termed submarginal lands or land incapable of yielding an average crop without entailing a large expense. William J. Hale says:

> It is needless to recall the many panaceas proposed for the farmers' ills or to recount the many acts of congress carrying appropriations of billions of dollars, designed to ameliorate his sufferings. All attempts thus far in governmental action have come to the same sad end—failure; and all future attempts, eliminative of chemical and biological direction, are destined to the same untimely end. There can be only one practical solution—scientific management with financial assurance of real contracts. Those who would promote the greatest industry that Heaven can ever give to mortal man must rid themselves of all political and fantastic taint; they must envisage here a chemical industry operating biologically for the betterment of society.

### THE CHEMICAL INDUSTRY

To fulfil the requirements of the various industries for chemical aid in the development of their special interests the necessity for chemical control has so increased that these various fields have virtually become specialized departments of applied chemistry with the chemist and his process in full control. This has meant that the fields of chemistry have become more extensive, that they have been developed to a greater depth in order to solve the numerous new problems which call for hosts of new materials with specifically designated properties increasing more and more in rigid specification. This has resulted in chemistry building up the materials for the various industries resulting in the development of the new chemical industry which is becoming bigger and bigger and assuming more and more importance in the development and advance of our civilizations.

Machine production has been such an economic force that it has moved our very social and political foundation. Chemical production is a new factor in our industrial economy that up to the present has been almost completely overlooked. It has increased enormously since 1920, while mechanical energy used in manufacturing since 1909 has really declined. This indicates that the humming wheels of the machine age are slowing down as the decrease in the use of power during the past half century has lost much of its initial momentum. Mr. William Haynes has recently emphasized the fact that when the first effects of the industrial revolution felt in America in 1790 were recognized, about 15 to 39 horse power each from the water wheels was the sole source of industrial power, and the total population of 4 million consumed about 70,000 horse power distributed through 3,500 mills. In 1870 the total horse power used in all factories, mines and for transportation was nearly 7 million or 100 times as much for a population of about 38 million—that is, the mechanical energy per capita had increased 10 times. Since 1870 the increase has been only about 5.6 times. The rate of increase reached the peak in 1909. From 1866 to 1889 the increase was 54 per cent., from 1889 to 1899 it was 39 per cent., from 1899 to 1909 it was 53 per cent., from 1909 to 1919 it was 35 per cent., and from 1919 to 1929 the increase had fallen to 25 per cent. During this last period 1920 to 1930 there was an actual increase or gain of 1,280,000 workers in our manufacturing industries. The horse power from 1914 to 1927 consumed in all industries increased from 22 to 38 millions, while the chemical industry increased from 992,703 to 1,840,049 or nearly double the gain of the national all-industry average. The value of the all-industry products was increased from 34 billions to 62 billions, while in 1914 the value of the American chemical products was $1,299,085,000, and in 1929 that had increased to $3,315,228,000. That is, both the value of the goods produced in our chemical industries and the energy consumed have increased nearly 3 times against the all-industry increase of only twice.

In the industries to-day the development of chemical operations has reached the point where none of our factories can operate without chemicals. In a few cases we have emphasized this as in the case of agriculture which is dependent upon fertilizers and insecticides, and the textile industry which requires bleaching materials and dyes. These examples could be greatly extended, to say nothing of transportation, communication—the telephone, telegraph and radio—medicine, the electrochemical industry, and even the arts—all must have their essential chemical supplies.

As gunpowder disrupted the seemingly impregnable alliance of kings, barons and bishops which sustained the feudal system; just as the machine inaugurated the industrial revolution which opened up such vast resources for production, so chemistry is moving the foundation of our present system. "The chemical revolution will bring lower costs, a growing multitude of new products and the increasing replacement of familiar wares by superior synthetic articles." The chemical revolution will make possible greater and broader consumption which will "enable us to transcend splendidly the progress of the past century."

# OBITUARY

## GILMAN A. DREW

### 1868–1934

THE death of Gilman A. Drew at his home in Eagle Lake, Florida, on October 26, after a lingering illness, will recall to the minds of American zoologists first of all the great services that he rendered to their science by his work at the Marine Biological Laboratory over a period of twenty-five years from 1901 to 1926. At the end of that time ill health forced him to give up his work at Woods Hole, and he retired to his orange grove in Florida. He was active in the work of his grove and in connection with agricultural affairs in Florida until about two years ago.

Drew was a student of W. K. Brooks at Johns Hopkins University, and his assistant for two years after obtaining his Ph.D. degree in 1898. There he acquired his interest in mollusks and laid the foundation for his subsequent investigations. His publications were not many in number, but they were remarkable for their finished technique and accurate delineation and description. He had the mind of the naturalist rather than of the analytic experimentalist or philosopher; and he combined studies of anatomy, behavior and embryology in gaining a total view of the life history of the species under consideration.

His study of the breeding mechanisms and behavior of the squid, Loligo, is one of the most finished and complete studies of reproduction in any animal. In this he began with breeding behavior, which is faithfully described; and proceeded thence to an examination of the structure and mechanism of the extraordinarily complicated spermatophores of the male, the method of their use and their correlation with remarkable structural peculiarities of the female which provide a double insurance of fertilization. He described very minutely the manner in which a long series of structural and functional mechanisms of the reproductive apparatus of the male produce these beautiful adaptive structures, timed to discharge a fertilizing flow of spermatozoa long after their attachment by a special cementing segment on the appropriate spots of the body of the female. He shows in a most complete way how structure, function and behavior combine to produce the perpetuation of the species. If Drew had never done any other work, this alone would mark him as one of the really accomplished naturalists of his time. It is unfortunate that this work is not better known to students of animal behavior.

Drew was also a stimulating and resourceful teacher. He was professor of biology at the University of Maine from 1900 to 1911; but his best opportunity was in the course in marine invertebrates at Woods Hole, which he directed from 1901 to 1909. In the field trips he was one of the most active of all the party; in spite of his lameness, with his one powerful leg and his trusty crutch, no one could go farther or better than he on land, over boulders, or in the shallow water collecting. In the laboratory he was equally active. A book for students which he published on this subject has enjoyed a wide reputation.

Drew became assistant director of the Marine Biological Laboratory in 1909, and after two years he resigned his professorship in the University of Maine to devote his whole time to this work. It would be difficult to do full justice to the value of his services during the seventeen years devoted to administration, within which the great material developments of the laboratory took place. In the splendid modern buildings of the Marine Biological Laboratory the marks of Drew's minute supervision, ingenuity and in-