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BOTANY OF THE FUTURE[1]

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DEFINITION

THE speaker has been assigned the task of discussing botany of the future. Perhaps we should first define the term botany. If one were to ask an educated layman or even a specialist in plant science, he would undoubtedly get the glib definition that botany is the science of plants. This is an extremely broad definition, but is it the content of the term that the layman or specialist really has in mind? Is not the layman inclined to think of botany in the limited sense of collecting, classifying and naming plants? However this may be, in this paper botany will be used in the broad sense of the dictionary definition including all plant science.

There are two implications in this assignment that the speaker must limit. First, "Botany of the Future" implies a prophetic effort, and second, botany is a science made up of several distinct disciplines, each too big for the complete mastery by one person. The speaker claims no prophetic power and feels none too competent in his own limited field of plant physiology. It will have to suffice to give a brief history of botany, with especial emphasis on the more recent trends, and from these decide on some of the probable future trends in botanical research and development with merest reference to the meaning of botany to other sciences and to man.

THE STRUGGLE TO MAKE BOTANY AN INDUCTIVE SCIENCE

Before and immediately following the beginning of the Christian era the Greeks and Romans wrote much about plants. Their statements were based on casual observations, no experiments and much speculative thinking. Their descriptions of plants were often so

[1] Address before the American Association for the Advancement of Science in the conference on Science and Society, Ottawa, June 28, 1938. This address with the literature citations is to be published in full later by the association.

inaccurate that later workers could not identify the plants by the descriptions. Perhaps the confused state in which they left the idea of sex in plants illustrates best their inability to gain knowledge of plants by studying plants themselves. In this connection they discussed some of the palms in which the stamens and pistils are borne on separate individuals. In such cases accurate observation and certainly a minimum of experimentation would have established the existence of sex.

The slight contributions of these early Greek and Roman writers to real knowledge of plants do not justify the mention of their work in the present connection. On the other hand, the Aristotelian deductive and speculative method of approaching plant problems and some of his concepts dominated botanical thought throughout the Middle Ages and prevented the development of an inductive approach. Sachs (Sachs *ibid.*) points out the influence that Aristotelian methods of thought and dogmas had upon Linnaeus, the father of systematic botany, who worked during the eighteenth century.

Even the influence of Aristotelian thought upon Linnaeus would not justify its discussion in this connection. The speaker feels, however, that the discussion is justified by the fact that the botanical workers even to-day are too much given to speculation and to theories and too little to well-planned and searching experiments that will gain from plants themselves the information sought. We will refer to this point again later when discussing the topic, "Theories often impede progress."

History of Certain Phases of Botany

Let us now outline briefly the history of the development of only two of the many phases of botany. This will give us an insight into the nature of botanical research and the type of problems met. It will also give us a background for understanding some of the larger botanical problems of to-day and the immediate future.

Plant nutrition. Any considerable understanding of plant nutrition had to await the development of modern chemistry. It is true that prior to this Malpighi and Hales had gained evidence that much of the dry weight of green plants comes from the air. During the last half of the eighteenth century a series of discoveries set, at the same time, the background for an understanding of plant nutrition and for the development of modern chemistry. Priestley discovered "vital air," oxygen, and showed that green parts of plants sometimes give off oxygen. Lavoisier and Cavendish discovered the composition of carbon dioxide, water and nitric acid, and the former discovered the nature of respiration in animals. In the meantime Ingen-Housz, even under the misleading influence of phlogiston chemistry, had discovered two reverse types of processes in green plants which we now know as carbon-synthesis, or photosynthesis, and respiration.

But Saussure in 1804 laid the real foundations for plant nutrition when he established and extended by quantitative methods the findings of Ingen-Houss that green portions of plants in light absorb carbon dioxide from the air and transform it into some sort of organic material and set oxygen free in the process. He also showed that living tissue carries on respiration which eliminates CO_2 and consumes oxygen. Saussure proved also that the greater part of the dry weight of plants came from the CO_2 of the air and from water absorbed from the soil. One can hardly overemphasize the significance of the discovery of these two basic cosmic biological processes. Carbon-synthesis supplies the world with practically all its organic matter, including food, fiber and shelter, and some sort of respiration is a universal manifestation of living matter. Saussure also proved that the relatively small amounts of salts absorbed with the water play an essential rôle in plant nutrition. Thus he established in outline, practically as we know it to-day, the inorganic nutrition of green plants.

The next great advance in plant nutrition was the discovery of the chemical elements other than carbon, oxygen and hydrogen that are essential for plant development. The greater contributors to this knowledge were Boussingault, the French agricultural chemist, Liebig with his clear forceful statement of his theory of mineral nutrition of green plants, the various tenets of which were later tested out and corrected by Lawes and Gilbert at Rothamsted Experimental Station, and Nobbe and Sachs of Germany, who contributed much to the knowledge of mineral nutrition of green plants by their nutrient solution studies. Out of all the work on plant nutrition up to the early part of the second half of the nineteenth century came the doctrine of the ten essential elements for plant nutrition, namely, carbon, hydrogen, oxygen, calcium, potassium, magnesium, iron, phosphorus, sulfur and nitrogen. Further studies by agricultural chemists led also to the fertilizer doctrine of three essential fertilizer elements, N, P and K.

These two doctrines of essential chemical elements and of essential fertilizer elements were both due to suffer modifications by extension because of researches carried on during the present century. The early students of plant nutrition failed to discover various essential chemical elements for plants that are needed in very small amounts because they failed to purify sufficiently the nutrient salts used or because of other errors in experimentation. Anyway in addition, boron, copper, zinc and manganese have been established recently as essential for the nutrition of some, if not all, plants, and a number of other chemical elements benefit the growth of one plant or another when supplied in small quantities in the form of salts. Soils have also been found in which certain plants grow very poorly, due to deficiency or lack of availability of one or another chemical element besides N, P and K. Amongst the recently found soil deficiencies are iron, sulfur, boron, copper, zinc and manganese.

What are some of the future problems in plant nutrition?

We have progressed far since the time of Saussure in learning the effect of conditions upon the rate of carbon fixation, and we have learned something about enzymes and much about the chemistry of the pigments involved in photosynthesis, but we have still to learn the exact details of the reactions and are therefore unable to duplicate carbon-synthesis outside the plant. In respiration also we have learned much about substances oxidized, about various organic substances produced by respiration and fermentation and something of the enzymes involved in these processes. The detailed understanding of carbon-synthesis and respiration are big chemical problems of the future.

Botanists are just now reinvestigating the essential chemical elements for plant nutrition as well as chemical soil deficiencies by sufficiently accurate methods to arrive at proper answers. This, however, is a minor future problem in plant nutrition. The big problem in this connection is the exact functions performed by the various chemical elements in plant nutrition and growth. We know much about symptoms caused by the lack or deficiency of the several elements. It is also easy to assign at least one function to elements like nitrogen, phosphorus and sulfur because they are built into organic compounds essential for life, but it is more difficult to find the function of potassium, copper, boron, etc. When we know all the functions of all the essential chemical elements for plant nutrition we will come near knowing all about plant life.

Chemical control of plant development. The study of chemical control of growth and development of plants is one of the latest fields of botany to get attention. Practically all the significant experimentation in this field comes within the last quarter of a century and the greatest progress within the last decade.

Perhaps the most interesting chemical modification of plant development is that caused by organic substances of the hormone type (Boysen-Jensen). In 1893 Julius Sachs announced the theory, based on rather general observations and experiments, that every plant organ (leaf, root, stem, flower, etc.) was initiated in plants by some stimulating substance (chemical) produced by the metabolism of plants. It is interesting that this theory was announced for plants some years before the discovery of the first animal hormone, secretin, by Bayliss and Starling (1902), while definite experimental knowledge of plant hormones came many years later. Sachs's theory had little experimental evidence to support it until Boysen-Jensen (1911) published his work showing the significance of chemical substances in the oat coleoptile in determining its growth and tropic response to light.

Following Boysen-Jensen's early work much knowledge has accumulated upon the effect of organic chemical regulators upon plant development (Zimmerman). Amongst the effects are: causing of tropic responses of plant organs to light and gravity, probably by the unequal distribution of the chemicals in the two sides of the organ; inducing cell elongation; initiating roots and other cell proliferations; inducing leaf epinasty; and completely or partially inhibiting growth of plant organs.

In contrast to the control of animal metabolism and development by endocrines the chemical control of plant development seems to be far less specialized; a number of chemicals that are very different in molecular size produce the same effects on plants, also chemicals that are not known to be produced by plants themselves act like plant hormones. The first point is illustrated by the fact that the four unsaturated carbon-containing gases (carbon monoxide, ethylene, acetylene and propylene), also certain indole, naphthalene and phenyl aliphatic acids, as well as the salts and esters of these acids, have similar effects on plant development; they initiate roots and cause other cell proliferations in plants, and they induce epinasty of leaves and act as growth inhibitors. While there seems no doubt that several of the effective substances mentioned above are not synthesized by plants at all, or at least not in sufficient amounts to modify growth, such a conclusion must be reached only after careful investigation in case the substance is effective in extremely low concentration. Either on the weight or molecular concentration basis ethylene is the most effective chemical known for modifying the development of certain plants. Recently, contrary to earlier assumption, it has been shown that most living plant tissues produce ethylene and that ethylene is a plant hormone which regulates development and induces ripening.

While several organic substances have been found to be effective in inducing roots, we have much yet to learn about organic compounds that initiate and regulate growth of buds and flowers. We know that some plants are induced to flower by long daily illumination, while others flower only on short daily illumination, also underground storage organs develop on certain plants only under short daily illumination. There is reason to believe that these and many other light effects are caused by the amount or type of organic regulators synthesized and maintained by plants under the influence of light.

The very important discoveries made in chemical regulation of plant development during the last few years have been of great assistance to investigators in other lines of botany and to practical propagators. The number of problems that are now opened up in this field, and the great number of investigators now engaged in the work indicate that this is to be a very productive field of plant research in the immediate future.

This is a very brief history of the development of only two of the many general problems that have been met in botany. Because of limit of time these two examples will have to serve as pictures of the nature of the problems met in botany and the methods used in their solution. These brief sketches also bring us face to face with some of the big problems to be met in the field in the immediate future.

BOTANY SPLITS INTO MANY DISCIPLINES

During the last part of the nineteenth and the first part of the twentieth century botany split into many separate sciences on three distinct bases: (1) on the basis of the phase of plant life studied (systematics, morphology, anatomy, physiology, cytology, genetics, phytochemistry, etc.); (2) on the basis of plant groups studied (bacteriology, mycology, algology, etc.); and (3) on the basis of the economic use made of various plants (agronomy, horticulture, floriculture, forestry, etc.). Let us make the situation more complex and shock the zoologists by claiming certain phases of entomology as a part of botanical science; one would not progress far in plant culture without the control of insect pests, and insects are necessary for pollination of many flowers and play an important, sometimes an intricate, rôle in transmitting virus and other plant diseases. Each one of these disciplines has discovered many facts about plants and established certain principles concerning them. As a result there exists to-day a great body of knowledge about plants that is not broadly enough correlated. There are indications that the next great step in the study of plants is the correlation and development of these several sciences into a comprehensive botany.

COMPREHENSIVE BOTANY OF THE FUTURE

The splitting of botany into many disciplines is evidently an artificial procedure. It does, however, separate the problems out so they can be readily defined and made capable of attack even by one individual. No considerable progress is made, however, in any problem of a given discipline of botany until the worker finds need of the help of other disciplines for the complete solution of his problem. Likewise, progress in his own problem is sure to throw light upon problems in several other fields of botany.

Of course all science has essential interrelations and may therefore be considered a unit, but the interrelation between the several disciplines of a subject like botany are so intricate and so numerous that the development of the several disciplines in closest relation with each other is suggested. The project method of attacking plant problems is becoming more common in agricultural and other plant research institutions. In the project method several individuals who know the more important technics for the solution of a problem work together, that is, they attack the problem from a variety of angles working each line alone but consulting frequently for mutual help and inspiration. There is also a move toward organization of institutions that cover many phases of the subject. If such institutions are to be most effective they must bring together individuals trained in all the main disciplines of botany as well as a large sprinkling of individuals trained in the several branches of chemistry and physics which, after all, in the broad sense, furnish a great part of the technic for botany. There is of course no advantage in the project-institute type of organization over the departmental type of organization unless the scientists representing the different disciplines work together, but the cooperative spirit in botany is also increasing.

I predict that the next great advance in botany is a synthetic one, in which all the disciplines will develop in intimate relation with each other, resulting in a unified comprehensive botany of the future.

EXAMPLES OF BOTANY ADVANCING PRODUCTION

Now let us consider a few cases in which botanical research has aided production. The illustrations are chosen, not because of the magnitude of their effect on production, but because the relation between the research and improved production is so direct that it can not be questioned. These illustrations must be considered, however, as only a few of the thousands of ways in which botanical research has increased the power of man to produce food and other commodities needed by him.

Plant pests. Some years ago a disease of cabbage—cabbage yellows—threatened to wipe out the cabbage industry. Dr. L. R. Jones, of Wisconsin, saw a 20-acre field in which only a few heads were perfect and without disease. He said, "These plants are probably resistant to yellows." He grew seeds from these, and through many years of selection and intensive study produced resistant forms that grow perfectly in diseased soil.

Just prior to 1900 a leafhopper was introduced into Hawaii from the South Sea Islands that threatened to completely wipe out cane production in the Hawaiian Islands. Several years of study and work by entomologists led to the introduction from the native home of the leafhopper insect parasites that completely controlled the pest. We have already claimed certain phases of entomology as a part of botany, so the last illustration is quite to the point.

These are but two of many cases of control of diseases or insect pests on useful plants. What is more important, a background of scientific information and principles has been established that will insure the control of plant pests in the future.

Crop nutrition. In northwestern United States it was discovered that the soil was deficient in sulfur. By adding sulfur compounds to the soil, alfalfa yields could be raised as much as five-fold. The discovery that pineapples grown in various soils of Hawaii were starving for iron because the iron in the soil was insoluble and that the iron had to be fed through the leaves as an iron sulfate spray made possible the development of the large pineapple industry in Hawaii. Recently, non-productive peat soils of Holland and the United States have been found to be deficient in copper. By addition of copper the soils become highly productive vegetable lands. Many other similar examples could be mentioned of increased production that resulted from supplying soil deficiencies.

Breeding better plants. Breeding and selection has done much to improve useful plants. Dr. William Saunders and his son, Dr. Charles Saunders, by 15 years of breeding and selection of wheat, produced Marquis wheat, the present spring wheat of western Canada. This wheat has about six days' shorter growing season than the Red Fife, which it displaced. It thereby misses fall frosts, which results in an increase in yield of nearly 30 per cent.

Hybrid maizes which resulted from basic genetic studies and which are just now coming into cultivation in the United States are a striking example of breeding increasing crop yield. Java's cane-breeding work, stretching over a period of more than 20 years, has produced the new P.O.J. canes that, under identical cultivation methods, produce three times as much sugar per acre as any of the canes entering into the original crosses. More than 15 tons of sugar per acre per crop have been produced. With these new canes and with improved methods of cultivation now known, two islands, Cuba and Java, besides growing much other food for their people, can produce with profit all the sugar the world can eat at two cents a pound at the mills.

It would require volumes to tell the complete story of the service of botany to man economically, medically and esthetically, but these statements will have to suffice for this paper.

Effective Methods for Botanical Research

We have just discussed the effectiveness of the project basis of organization for botanical research and the desirability of having in close association in botanical departments or institutions all types of technics necessary for the complete solution of plant problems. Let us mention some other methods or points of view that are now proving effective in botanical research and that need special consideration in the future development of the subject.

Equipment for plant research. The complexity of the future problems in botany will call for a great variety of technics and for greater and greater accuracies in measurements. To meet these needs the botany laboratories of the future will require much very accurate physical, chemical and biological apparatus. In addition, there should be apparatus for the growth of plants on a considerable scale and under a great range of controlled conditions as to light, temperature, humidity, etc. A research man should not be forced to guess at his results because of the inaccuracy of the apparatus. It is more productive to have fewer scientists and better equipment if finance is a limiting factor. One must also remember that equipment is paid for once, requiring of course a slight operating expense and occasional renewal, while salaries are a continually recurring charge against a project.

Dangers of over-organization for botanical research. The real discoveries in botany are made by the scientist coming into face-to-face contact with the plants and plant materials being studied and these contacts should be made with unburdened and alert minds. There is no doubt that over-organization and over-direction often interfere with this simple direct relation between the botanist and the material he is studying. Assuming of course that the workers are prepared for and adapted to their work, it is not direction but constructive suggestions and inspiration that they need from their fellow workers in order to make greatest progress.

Theories often impede progress. The method of attacking problems by the use of hypotheses makes every step of research directive and logical. The problem to be solved is stated; on the basis of established knowledge several hypotheses are set up, any one of which may be the solution of the problem; and finally each hypothesis is tested out by logically organized experiments. In case none of the first set of hypotheses proves to be the solution of the problem, the process is repeated until the solution is found. The very logic of the procedure may lead the investigator into a pitfall. Will he, before he has sufficient experimental evidence or because of numerous inferential agreements, dignify one of the hypotheses to the position of an established theory? There is no doubt that some investigators have a "theory psychosis."

Recently Farr and Eckerson discovered the real composition and structure of cellulose as it exists in the cotton fiber and other cell walls. It seems impossible that this discovery could have been delayed so long, considering that the cellulose industries in the United States alone produce more than a billion dollars worth of cellulose materials each year, and further, considering that botanists have been examining cell walls of plants with microscopes for a full century.

During the period 1852 to 1858 Nägeli developed his micellar theory of the structure of cellulose walls. According to his theory the cotton fiber is made up of cellulose particles or crystals too small to be seen with the microscope, but of such shape and arrangement as to account for the changes in the dimensions of the cell walls when swollen in water, and for the image produced when polarized light is passed through the wall.

Finally, Farr and Eckerson looked at developing cotton fibers through the microscope, and believed their eyes. They found that the cotton fiber consists of microscopically visible spheroid particles of cellulose cemented together by pectin-like substances such as cause fruit juices to form jelly.

I need not emphasize the significance of this discovery to the understanding of plants, because practically all plants produce cellulose walls. The importance of it is quite as evident to our billion dollar cellulose industry.

This is one of many cases in plant research where theories have impeded progress. Theories and hypotheses are useful in shaping experiments, but the truth about things must be learned by studying the things themselves in a face-to-face approach.

Accidental discoveries. Of course the botanist must proceed in his research on the logical basis mentioned above; there is no substitute for thoroughly planned and carefully executed experiments for solving the problem under consideration. On the other hand, the investigator should always be on the lookout for unexpected reactions that do not fit into the hypothesis under consideraion or that may not even be relevant to the problem under study.

A few years ago Dr. Pupin gave his retiring address as president of the American Association for the Advancement of Science, covering his years of research on air communication. From his address it seemed that most of his big discoveries were chanced upon when he was looking for something different.

Pure research in botany a misleading concept. The distinction between pure and applied knowledge or research probably originated with the Greeks. Slaves did the work for the Greeks; dealing with practical things or even with the objective was not the field for thinkers. The masters were metaphysicians, and, while they talked much about the nature of existence, they failed in the main to study the things that existed. Best progress in research with plants requires that one forgets this distinction between pure and applied research and pursues the studies wherever they will add to knowledge.

Perhaps there is no field of science in which we can as little afford to draw a line between pure and applied research and knowledge as in botany. Boussingault, the French agricultural chemist, and the Rothamsted Experimental Station early added much to our knowledge of plant nutrition and to-day agricultural experiment stations and similar institutions in the study of practical problems are continually adding important basic knowledge to nearly every phase of botany. Finally, the conditions met in a laboratory are limited and principles established in the laboratory need to be tested and modified as to limitations and breadth of significance by tests under the more varied conditions in the field and in nature. In this way only will we arrive at a complete knowledge of plants in all their relations.

Economic and Sociological Implications of Botany

Citizens take a serious interest in botany. Throughout the history of man, plants have been amongst the most intimate objects of his environment. Also they have been the sole ultimate source of his food and clothing and the source of much of his shelter. In spite of this the average man has had little essential knowledge about plants. The serious and intelligent interest of people in botany is now increasing very rapidly.

Many of our farmers and others interested in plant production have been trained in agricultural colleges and still more in agricultural high schools. This training has given them some basic knowledge of plant nutrition and soil fertility, plant breeding, fungal and insect pests and various other phases of botany.

The increasing interest in gardening, especially ornamental gardening, is indicated by the rapid growth in the membership of garden clubs. No doubt the initial interest of such amateur gardeners manifests itself mainly in growing and knowing the names of plants for beautifying home grounds or in the arrangements of flowers for artistic effect in the house. On the other hand, many of these amateurs are interested in collecting and cultivating ecological groups of plants, such as rock plants, or systematic groups, such as lilies, begonias and iris. Many also are breeding and producing new forms of the groups that interest them. The number of books published for amateur gardeners is increasing rapidly and improving from year to year as to basic knowledge on propagation, plant nutrition and soil fertility, control of plant pests, breeding and other phases of the subject.

Because of the agencies mentioned above as well as others, more people are continuously becoming interested in and acquiring basic knowledge about plants. Plants develop in accordance with fixed laws, consequently serious study of them leads to factual thinking, a thing so desirable to the citizens of a republic.

Botany affects economics. Adam Smith's prediction of the eighteenth century that increase in population would overtake the capacity of the earth to produce food for the population and Malthus's further development of this idea both preceded any considerable knowledge of plants. A century and a half after this prediction the problem is not, Can we produce enough food for the population of the earth, but How can we dispose of what we do produce with production curtailed far below capacity? What changed this sad picture of a century and a half ago with a very cheerful one so far as ability to produce food for subsistence is concerned?

Neglecting for the moment other unexpected changes such as decrease of birth rate with rise in standards of living (the latter contrary to the postulates of the two economists), there are two big advances that have brought about his change: (1) invention of farm machinery which increased enormously the power of the individual to produce food and (2) the growing knowledge of botany in all its phases which has made production much more effective. With farm machinery now developed and with information about plants already established, every population on earth could be adequately fed with production at a fraction of capacity. There is still something to be done in improving farm machinery, and botany is still in its infancy; there is also a large part of the productive land of the earth, especially in the tropics, untouched by the plow. Because of the development of farm machinery and the great advance in knowledge of plants, feeding the world is no longer a problem of production but one of distribution.

Philosophy Interprets Science

It is sometimes enlightening to get the view-point of men who are outside and looking in upon a process. Such onlookers have the advantage of perspective free from the possible confusion of details, but their lack of knowledge of details and the interrelations of details may lead them to a very wrong interpretation of the process as a whole. In this case let us consider the present-day interpretation of science and scientific research by philosophers. As a basis for the discussion we cite three recent philosophical books written severally by Hutchins, Durant and Benjamin.

The speaker gets the impression from these books that scientists are random or aimless collectors of data. In Section 7 of this paper we have discussed the use of hypotheses in scientific research and emphasized the fact that the use of hypotheses makes every step of research purposeful and directive. Philosophers certainly could not get the idea that research is an aimless collecting of data by studying research as it is conducted to-day. Where did they get this idea? Their descriptions of the scientific method are very similar to research methods outlined by Francis Bacon during the early part of the seventeenth century. It is granted that Francis Bacon was one of the world's greatest minds with his tremendous scope of knowledge and profound and accurate thinking; it is also true that he had little insight into the great complexity and profundity to be met in scientific problems and little realization of the methods that were to prove most effective in solving these problems. Is it too much to ask of philosophers that they evaluate the scientific research on the basis of a careful study of what is going on in science to-day?

President Hutchins speaks with devastating effect of scientific knowledge as empirical knowledge. We find two definitions of empirical in the dictionary; one derogatory, the other complimentary. In the first sense it means superficial or based on insufficient observations, and in the second or the derived sense it means based on experience or experiments. If one stops to think, he will see that all real knowledge, *i.e.*, knowledge that has its counterpart in mind and matter, must be knowledge gained by experience or experiments. The scientist might even boast of his knowledge as empirical in the latter sense.

From reading these books one also gets the idea that scientists fail dismally to correlate their results into a logical system of thought. To a degree this has been true in botany during the period of great specialization through which the subject has passed recently. Fearing the ills of specialization Hutchins has suggested a common college course for all students so that when they get into their special fields they may have common knowledge as a basis for mutual understanding. This gives one a picture of confusion of tongues brought about by specialization. To one working in the field of botanical research to-day this idea of the confusion of tongues due to specialization appears far from an actual picture of the situation. Not only is every research man interested in and conversant with the results being obtained in many other phases of botanical research, but many problems are being investigated cooperatively by two or more specialists of diverse training combining the technics and knowledge of disciplines necessary for solving the problems. As botanical research advances larger generalizations are reached which in turn solve more practical plant problems and throw more light on the nature of life itself.

These philosophical writings give one the impression that the scientific mind shows certain immaturity as against the maturity of the philosophical mind. The botanist writes his story of plants as far as he can on the basis of established facts and laws; he struggles to add to known laws and facts about plants so that the true story may be continued; but he always recognizes that the complete story can be written, if ever, only after an enormous amount of additional research. The philosopher seems to demand the complete story, although most of it is a fairy tale.

One gets the impression from these philosophical writings that the main interest of scientists is improving practice. It is now rather generally conceded not only by scientists but by thinking practical men that the quickest and surest way of solving practical problems is to establish basic principles that underlie practical problems.

Then may I say in closing that the main aim of botany of the future is not the development of better methods for plant production and utilization of plant products, for these will come as an inevitable result if the study is rightly conducted. The main aim is the formulation of a system of knowledge of plants based on experimentally established facts—if you please, a factual philosophy of plant life.

OBITUARY

RAEMER REX RENSHAW

THE death of Dr. Raemer Rex Renshaw on September 23 in New York City saddened his many friends and colleagues. As senior professor of organic chemistry at New York University since 1924, he was well known and respected for his personal and intellectual qualities. His passing came as a sad loss to his university and to American chemistry.

Raemer Rex Renshaw was born in Sierraville, California, on August 31, 1880. In 1902 he was graduated from the University of Oregon with the bachelor of science degree. He received his master of science degree from the same institution the following year, while holding the position of instructor. In 1904 he left Oregon to become university fellow at Columbia University, and later was granted the degree of doctor of philosophy by that university, in 1907.

After completing the work for his doctor's degree he continued his career of service to American chemical education with professorships successively at Wesleyan University, Iowa State College, Harvard University and, since 1920, at the chemistry department of New York University at University Heights in New York City.

During the world war, Dr. Renshaw held the rank of captain in the Chemical Warfare Service. He was active in the work of scientific societies as chairman of the Organic Division of the American Chemical Society in 1924, chairman of the New York Section in 1929, and secretary of the Chemistry Section of the American Association for the Advancement of Science during the period 1929–1931.

His researches were reported in a large number of publications and covered, among others, the following topics: Aminophthalic acids; lecithins; cholin and betaine and their sulfur, arsenic and phosphorus analogues; diglycerids; trimethylarsine selenid; carbohydrates; dyes containing the furane ring; onium compounds; acetylcholin and its physiological functions.

Dr. Renshaw's patient understanding of students, his inspiring encouragement of his younger associates and his general kindliness will long be remembered by those who knew him.

H. G. LINDWALL

NEW YORK UNIVERSITY

JOHN ORR HAMILTON

PROFESSOR JOHN ORR HAMILTON, for twenty-nine years head of the department of physics in the Kansas State College of Agriculture and Applied Science, died on August 9, 1938, from an attack of angina pectoris. Though he had been relieved in part from institutional responsibility, his death came as a sudden shock to a host of friends among the faculty, students and alumni.

Professor Hamilton was born at Princeton, Indiana, on September 4, 1867. Following teaching experience and study elsewhere, he was in 1900 graduated from the University of Chicago, having given special attention to mathematics and physics. He was first connected with the Kansas State College in 1901, going there as assistant in physics. For several years the department included electrical engineering, and Professor Hamilton's interest was always strong in the everyday application of physics to industry, including agriculture and the household. He was the author of a text on "Physics of the Household," a "Laboratory Manual for Engineering Physics" and "Weather Studies."

In 1912 radio station 9YV was licensed, and the physics department began a daily broadcast of the weather reports. This was in Morse code and available to any who could read it, and is believed to have been the first regular radio weather service inaugurated. During the world war, Professor Hamilton directed the training of men in signal service work.