# SCIENCE

VOL. 81 FRIDAY, JUNE 14, 1935 No. 2111



SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. MCKEEN CATTELL and published every Friday by

THE SCIENCE PRESS

New York City: Grand Central Terminal

Lancaster, Pa. Garrison, N. Y.

Annual Subscription, $6.00 Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the Association may be secured from the office of the permanent secretary, in the Smithsonian Institution Building, Washington, D. C.

# BOTANY AND HUMAN AFFAIRS[1]

By Dr. A. F. WOODS

UNITED STATES DEPARTMENT OF AGRICULTURE

"BOTANY and Human Affairs" is a rather broad subject to present in twenty-five minutes. But I am advised by Director Gager that various special phases will be discussed in detail by other speakers, so that I may confine my remarks to a more general treatment of the larger aspects of the subject, creating, if you please, a background for the real pictures to come later in this program.

All animals, including man, are dependent for food directly or indirectly on some form of green or chlorophyll-bearing plant life. The study of these organisms, that make man's life possible, is of as great fundamental importance as the study of man himself.

Botany in its broad sense is the systematized knowledge we possess of the vegetable kingdom as a whole. It includes all that is known about plants, their history through the ages, as we get it in geology and paleontology, the description and classification of all known forms of living plants; the study of their origin, life relationships and development (embryology, genetics); their structure; (histology and cytology and morphology) their physiology, their composition, modification, mutation and evolution; their cultivation, propagation and breeding; their diseases, their relation to each other and to other organisms and to the factors of their environment. From the economic aspect it is evident that this includes much of agriculture, forestry, horticulture, pharmacognosy, floriculture and cognate subjects.

At the lower end of this great kingdom of plant life we find the beginning of what we know as living

[1] Address delivered at the opening program of the twenty-fifth anniversary exercises of the Brooklyn Botanic Garden, May 13, 1935.

organisms, those complex molecules that we call protoplasm, that are able under favorable conditions to sustain and reproduce themselves from the inorganic elements of their environment, the so-called autotrophic microorganisms. These are the simplest types of living organisms. Some of them are so small that they are invisible under the highest powers of the microscope. Others are more like fungi or algae without chlorophyll, though some of them do contain chromogen materials. The energy that they need for their life processes they are able to draw from the inorganic materials of their environment, from combinations of nitrogen, phosphorus, sulfur, chlorine, potassium, calcium, magnesium, iron, copper, manganese and possibly a few other elements. This ability to extract energy from inorganic compounds, utilizing it for the reduction of carbon dioxide to organic compounds, is limited to a very few species, but they are of very great importance in soil formation and in soil fertility. They include such genera as *Nitrosomonas, Nitrosococcus,* which oxidize ammonia to nitrite, *Nitrobacter,* which oxidizes nitrite to nitrate, and species of the genus *Thiobacillus,* which oxidize sulfur and its compounds, utilizing also light energy. Others oxidize iron and manganous compounds and others oxidize hydrogen. Some of these contain pigment and may be algae rather than true bacteria.

Then comes the great group of microscopic parasitic and saprophytic *heterotrophic Bacteria.* We know now as a result of the facts brought to light by those who study these forms of plant life that they bring about fundamental transformations and changes necessary to the existence of higher forms of life. In association with other plants or plant remains some of them oxidize atmospheric nitrogen into nitric acid and ammonia in forms available to higher plants. Some of them have formed cooperative or symbiotic relations with higher plants, as for example with Leguminosae, the alfalfas, clovers, peas, beans, which are among our most valuable soil-building and feed and food crops. They prepare the food material for higher plants. They separate these materials again when the plant or the animal that feeds on them dies. Others have become parasitic, causing disease and destruction to higher plants or animals. Crown gall or plant cancer, pear blight and various rots and wilts, some extremely destructive, are examples of plant diseases caused by bacteria. Tuberculosis, anthrax, tetanus, typhoid fever, cholera, pneumonia are among the well-known and destructive animal diseases caused by bacteria.

In this same general group of parasitic and saprophytic organisms are the fungi, yeasts, moulds, rusts, smuts, toadstools, mushrooms, bracket fungi, and hosts of others, some helpful and valuable, others harmful and causing destructive diseases of plants and animals. This group is especially prolific in species causing plant diseases. Some of the most destructive and best-known examples are the black rot of grapes, bitter rot of apples, apple scab, peach and plum rot, the fusarium wilts of cotton, flax and cow peas; the root rot of corn and the scab of wheat and barley; the rusts and smuts of wheat and other cereals and a great variety of other plants; the mildew rots of grape, potato and hops; the heart rots of trees and various root rots; chestnut blight and Dutch elm disease.

Most of these fungi have complicated life histories living in different forms on totally unrelated plants. One form, or stage, of the black rust of cereals, for example, lives only on certain species of barberry (*B. vulgaris* group), from which it moves again to the cereal host. The blister rust of the white pine passes part of its life on gooseberry and currant leaves. The unraveling of these life histories is the most effective means to a knowledge of effective control.

The black rust of wheat of the bread varieties can be controlled in part by destroying the common barberry (*B. vulgaris*) in the regions where these wheats are grown. The blister rust of white pine can not be prevented, except by destroying the gooseberries and currants in the vicinity of white pines. These are simply two well-known examples of hundreds of other similar associations, some with plants and some with insects, highly important to our welfare to understand. Dr. Geo. M. Reed, of the Brooklyn Botanic Garden, is doing some outstanding work on smut diseases of cereal grains. These diseases are very destructive and difficult to control. Dr. Reed has discovered the existence of physiological races or varieties of smuts. Varieties of the parasite that look exactly alike under the microscope may be quite different in their ability to infect a particular strain or variety of grain. These facts must be taken into consideration in breeding for resistance to smut infection. The smuts cause enormous losses in a great variety of cereals. The work that is being done here by Dr. Reed in cooperation with the United States Department of Agriculture is of very great scientific as well as of very great practical value in giving us increased power to protect our most important food crops.

The average annual loss to our crop plants caused by diseases alone averages 10 per cent., or more than $500,000,000 a year. All our botanical research in this field costs less than one tenth of one per cent. of the annual saving from the application of its results. A careful estimate made in 1928 covering about 40 years of research by the Bureau of Plant Industry of the U. S. Department of Agriculture in cooperation with other agencies in the general field of applied botany showed an annual saving and gain of more than $500 for every dollar expended.

Let us move upward now on the ladder of life from the lowest forms of plant life to those organisms that are more commonly known as plants, *viz.*, those organisms that are green. They differ from the bacteria and fungi in that they are able to live normally only in the light. They draw their energy from the sun, utilizing it to combine carbon-dioxide with water, forming starch, sugar and cellulose, freeing bound oxygen in the process which adds materially to our slowly waning atmospheric supply. They then bring about combinations of sugar and nitrate or ammonia forming albuminoids and proteins, which are the basis of protoplasm, both in plants and animals. Plant and animal life, except the small group of bacteria able to obtain their energy from inorganic sources would be impossible without this fixation of carbon and transformation of energy carried on by green plants. Some of these green plants are so small that they are invisible to the unaided eye, single cells no larger than some of the bacteria. These are the simple algae, furnishing foods for other forms of microscopic aquatic animal life, which in turn are the food of forms of increasing size and complexity, and finally for oysters, lobsters, crabs and fish and other forms of aquatic animal life. Others are banded together into great masses of surprising beauty, like the sea weeds. Others are the grass of the field, which "to-day is and to-morrow is cast into the oven" or dies down to enrich the soil for the corn and wheat, the vine and the fruit tree or the great trees of the forest.

Plants are the great soil-builders and protectors of soil from wind and water erosion. Where we have destroyed vegetation planlessly and thoughtlessly we are rapidly losing our soil by wind erosion in dry periods and by water erosion in wet periods. In the last few years the topsoil on millions of acres west of the 100th meridian has been blown away in dust storms. Millions of acres have been covered by wind-blown sand. This is largely the result of overgrazing and consequent destruction of the plant cover or destruction of the plant cover by breaking up the sod to prepare the land for wheat or other crops. The danger has been appreciated by botanists and agriculturists for many years. But their warnings have not been heeded. Experiment stations established in this dryland area two decades ago have studied these problems and have pointed out safe uses for these lands, but lack of general appreciation of the danger has prevented general adoption of the methods recommended. The situation is now so serious that the whole nation is awake to it. Our botanists, ecologists and agriculturists are striving to find soil-binding plants and methods of checking erosion and in a measure repairing the damage. Botanical explorers are visiting various parts of the world to find additions to our store of drought-resistant and soil-binding plants to aid in this recovery program. Many valuable wild and cultivated species are being introduced. Botanic gardens furnish extremely valuable help in this and other plant introduction work.

In the areas formerly forested a similar process of unwise destruction of the forest cover has been going on for many years. Land of little or no value for agriculture has been denuded of its trees through destructive lumbering followed by fire. The exposed soil has been washed into the streams, choking their channels. Heavy rains are followed by floods. Navigation and power resources are destroyed. The aquatic plants are destroyed, followed by the animal life, fish and game when their primary food source is gone. The whole balance of nature is thus upset. What was once a source of wealth, and under proper use would have continued to be such, is rapidly becoming a barren waste and a source of danger. The indiscriminate dumping of sewage and industrial wastes into streams, lakes and the ocean is rapidly destroying aquatic vegetation of all types beneficial to aquatic animal life and the source of their food supply. Oysters, clams, crabs, fish and waterfowl disappear with their food supply. The public does not yet understand this danger to our great natural aquatic resources, and destruction still goes on. Here is a great field for the botanist and zoologist to do effective research and educational work. It is encouraging to note that the Secretary of War has appointed a committee to look into this pollution problem.

A program of erosion control has been recently inaugurated in a large way, and reforestation, range control on the public domain and land use programs are now matters of national concern. Intelligent plans are being made to correct these maladjustments as rapidly as possible. Botanical knowledge and research are the keys to the solution of these great problems. In this new era botany in its broad sense will be called upon to play an increasingly important part in the reestablishment of biologically balanced areas. The ecologists and physiologists have a large part to play. The plant explorers have important contributions to make. The phytopathologists must be on the job. There is work for the expert systematists, the algologists and bacteriologists, as well as foresters and agronomists. In all this work botanic gardens and arboretums will prove to be of increasing value.

With careful study and planning we shall be able in many cases to improve on the former natural vegetation. In many cases we shall use our rapidly increasing knowledge of genetics to breed and fix better varieties and strains of plants better adapted to special uses —plants that are more resistant to drouth and cold, more firmly and deeply rooted, more resistant to disease and insect pests, and of better or more desirable quality for uses to which they may be put. All these things are now being done by botanists. Gradually through botanical study we have learned some of the secrets of making new varieties and species and establishing and even patenting some of them.

The plant breeder could not exercise this power to produce and establish new varieties with the efficiency now attained had not the student of genetics made available a large fund of information in this special field of research. The story is a long one, starting with the discovery of the sexuality of plants by Camerarias in 1691. Probably the most important discovery was that of Gregor Mendel more than a century ago in regard to the law of the distribution of unit characters in the progeny of hybrids. With improved technique and equipment it is possible now to connect certain characters of the progeny with the genes (the heredity units) of the chromosome controlling those particular characters. It may be possible in the future to more definitely control the combination of different genes to produce the new varieties of plants, having the combination of the characters desired. This is now accomplished by crossing large numbers of individuals having the unit characters desired, then selecting and recombining until the desired result is obtained. By taking advantage of the Mendelian formula, the fixed strains of the desired type if produced may be segregated in three generations, provided further crossing is eliminated. By using these methods the rust and drouth resistance of macaroni wheats (*Triticum durum*) have been successfully combined with *T. vulgare,* the ordinary bread wheat. At the wheat-breeding station at Omsk, Russia, the bread wheats have been successfully crossed with a wild grass, *Agropyron elongatum,* transmitting drouth, rust and alkali resistance to the progeny. Wilt resistance of the citron has been bred into the watermelon. The resistance of certain Asiatic chestnuts to chestnut blight has been bred into the American chestnut. Almost every variety of cultivated crop has been improved in one or more particulars by plant breeders. Some fine work of this kind is in progress here. Dr. Graves, of the staff of this garden, for several years has been collaborating with the Federal Department of Agriculture in producing hybrids between the American and Japanese and Chinese varieties of chestnuts, with a view to producing a tree which will not only be immune to chestnut blight, which has almost exterminated the American chestnut, but will also be a valuable timber tree. The results strongly indicate that this much-desired objective will be accomplished. Botanic gardens and arboretums are especially valuable as sources of breeding material and as centers where such studies can be carried on. They are among the most important sources of living plant material and are invaluable centers of technical and practical information in every phase of botanical study in its broadest sense. We need more of them and we should give them better financial support. Aside from their generally recognized practical value, they have great civic and educational value especially to the community in which they are located. Another line of development is the artificial production of mutation (inheritable variation not the direct result of crossing) by exposing the reproductive cells to x-rays and similar types of radiation. Profound changes are produced in this way.

Dr. Gager, the director of the Brooklyn Botanic Garden, shortly before coming to Brooklyn conducted extensive pioneer studies on the effect of the rays of radium on the various life processes of plants, and since coming to Brooklyn he has collaborated with Dr. Blakeslee, of the Carnegie Institution of Washington, in exposing reproductive cells to radium rays. The result of this work was to produce probably for the first time inheritable changes in living organisms by exposing their living cells to penetrating radiation. It is epoch-making work and is a field worthy of most careful study. Then there is the newly discovered mode of germplasmic origin of new characters *aristogenes,* of which at present we have no control.[2]

By varying the length of exposure to light and by modifying the wave-lengths of the light used or by increasing or decreasing the intensity of the total light and modifying the periods of exposure we can produce profound changes in the time of flowers and fruiting. This method of control has already proved to be of great value in plant breeding in the control of flowering periods and it may have much wider use, especially in plant introduction and adaptation. Changes in chemical composition, especially the vitamin content, may be brought about by light control. This vitamin content of plant tissue is especially important. The vitamins appear to be of the nature of vegetable hormones, certain of them controlling growth in animals; others control lime assimilation, reproduction and resistance to disease. This is one of the most productive and active fields of plant physiological, biochemical and biophysical research at the present time. It is opening a new field of nutrition and health preservation and control and prevention of some of the most serious diseases of man and other animals, such as tuberculosis, beriberi, scurvy, rickets, xerophthalmia, pellagra, rheumatism and others.

[2] SCIENCE, n. s., 80: 2087, 604, December 28, 1934.

The ultra-violet rays are principally involved in vitamin formation. These rays are largely eliminated by ordinary glass. Leafy field crops, like lettuce, grown under ordinary glass, should therefore receive supplementary ultra-violet light treatment if their vitamin content is to be up to normal. Special glass transmitting these rays is now available but at considerably increased cost. Special ultra-violet light radiation equipment is also available.

The environmental, nutritional and genetic factors controlling the production in the plant of other valuable organic constituents—gums, oils, fats, alkaloids, rubber—are still very imperfectly understood and offer a productive field of great scientific and economic value. Here again botanic gardens and arboreta afford the most helpful aids to such investigations. Time does not permit multiplication of examples of how botany, a knowledge of plant life, in one way or another enters into almost every aspect of our welfare. The time allotted might easily be consumed in the more detailed presentation of some narrow field, but I have selected the more general and less technical presentation so that those of you who are not botanists may get the broader perspective of the relation of botany to human welfare.

In closing this presentation I wish to give you an illustration of the importance of intensive study of problems that may appear at first sight to have no possible value to humanity. Botanists, as well as other scientists, are frequently criticized for devoting too much time and money to what the critic considers to be quite useless and worthless but which may later prove of very great value. There are numberless examples. I have time to call your attention to but one in which the Bureau of Plant Industry of the U. S. Department of Agriculture found uses for an apparently unimportant discovery made by Karl Wilhelm von Nägeli, a brilliant Swiss botanist. Von Nägeli, desiring to study under the microscope the activities of living plant cells, selected for the purpose what is popularly known as "frog spittle" or "green slime," a fresh-water alga belonging to the genus *Spirogyra*. This alga grows in ponds and slow streams and looks to the naked eye like fine, long, green silk threads. The microscope shows that the thread is made up of large cylindrical cells attached end to end, having spiral bands of chlorophyll. The protoplasm and nucleus show clearly. It is thus easy to see the living cell in operation. This, of course, was the reason for selecting this plant for study. It might not have appealed very strongly to the visiting committee of farmers and business men or the president of the university had they happened in at that time. They probably would have been more disgusted than was Nägeli himself when he could not get the alga to grow in his carefully prepared synthetic solutions, containing everything needed by the alga in just the right proportions. Day after day he tested and retested to find the reason why the *Spirogyra* died in his aquarium but would live in the water brought in from the pond containing the same nutrient salts. In his synthetic solutions made up from distilled water and from tap water, the *Spirogyra* after a few hours turned brown, broke up into short pieces and in twelve to twenty-four hours was dead. To make a long story short he finally traced the cause of death to minute traces of copper taken up from the bronze faucet in his laboratory as the water passed through it. The amount of copper was so small that it could not be detected by any chemical method known. But the chlorophyll band in the *Spirogyra* cell reacted to one part of copper in 50 million parts of water. It thus proved to be the most sensitive test known for copper. He described his researches and published them in a little pamphlet which remained untranslated and almost forgotten for more than half a century.

The next chapter in the story opens with a letter received by the Department of Agriculture from a cress grower, who complained that he and other growers were being put out of business by some disease attacking the cress. As this was quite an important industry in which many millions of dollars were invested, we sent Dr. George T. Moore to investigate. He found that the trouble was caused by *Spirogyra* smothering the cress. He thought right away of the work of Nägeli and made arrangements to add copper, 1 part to 50 million, to the water in some of the beds. It worked exactly as Nägeli has described. The Spirogyra was destroyed without injury to the cress. The cost was negligible. This led to a further study in the use of copper in destroying algae of various kinds in water reservoirs. Certain forms of alga growth make water almost impossible to use at certain times of the year, due to bad taste and odor imparted to it. Methods were worked out making it possible by treatment with copper to remove any of these contaminating species at small expense. The methods developed have now become standard sanitary engineering practice.

The next development grew out of the observation that in these copper-treated waters certain species of bacteria were greatly reduced in numbers. These belonged to the *colon* group. Tests were therefore made on typhoid, para-colon, Asiatic cholera and related species. It was found that these could be destroyed in a few hours by the introduction of small amounts of copper sulfate or metallic copper without the slightest danger to those using the water. Certain types of fish, however, were killed. This led also to the testing of chlorine for these types of bacteria.

Chlorine was found to be effective in destroying bacterial pollution without injury to fish but did not destroy algae. Both methods have now become standard practice in sanitary engineering.

The next development grew out of the observation that mosquito larvae were killed by these traces of copper, 1 part to 10 million. Colonel Gorgas requested that we send one of our men with him to clean up the zone in the Isthmus of Panama through which we were to dig the Panama Canal. The late Karl Kellerman was assigned to the job and used the copper treatment exclusively in destroying algae and mosquito larvae when it was not practicable to use oil.

The use of copper in water supplies was followed by a study of copper in animal nutrition. The results of that study show that it is absolutely essential along with iron for haemoglobin formation in the red-blooded animals. Its absence in the diet brings on secondary anemias that result in death if copper is not supplied. A trace of copper also proved to be essential in the growth of plants. What the next chapters will be I do not know. But I do know that Nägeli's work on "frog spittle" paved the way for work of very great value to humanity many years after he had passed away.

We must encourage and support research in all fields. It is the only key to progress. Botanical research has made it possible to produce food sufficient for earth's teeming millions if they will stop fighting and intelligently use the knowledge already gained.

In conclusion, I am sorry that the last annual report of the Brooklyn Botanic Garden did not come to my attention before I prepared my address for this evening. A discussion of that report would be a forceful presentation of botany and human affairs. The Brooklyn Garden is outstanding among the gardens of this country in its public relations contacts and in its cooperation with civic agencies of city, state and nation, in educating the public to appreciate the value, to the community, of botany in its many aspects and relations. Director Gager has been selected as chairman of the subcommittee having in charge this aspect of the plans for the National Botanic Garden at Washington.

# THE ABSORPTION OF SOUND IN GASES[1]

By Professor VERN O. KNUDSEN

DEAN OF GRADUATE STUDY, THE UNIVERSITY OF CALIFORNIA AT LOS ANGELES

THE experiments I shall here describe, which began with studies in architectural acoustics, have led to the discovery of important, although peculiar and unsuspected, laws concerning the propagation of sound in the atmosphere and other gases.[2] The results obtained also conform remarkably well with predictions of modern theories of the dispersion and absorption of sound in gases. In this latter connection the results exhibit a new technique for investigating the nature of energy transfers during molecular collisions.

The classical theories of Stokes and Kirchhoff on the absorption of sound in gases were based upon the effects of viscosity and heat conductivity, and until recently it has been assumed generally that these effects accounted for the observed attenuation of sound in the air and other gases. These classical theories, which require the attenuation to increase with the square of the frequency, explain, qualitatively at least, why, when listening to distant echoes of speech, we hear only the low-frequency vowels and do not hear the high-frequency consonants, which are absorbed in the air before reaching our ears. However, certain acoustical phenomena, which nearly every one must have observed in his early youth, are not even qualitatively explained by these classical theories. Thus, the sound of an approaching train or a wagon coming over a cobblestone road can be heard more distinctly and at a greater distance when a storm is gathering (usually characterized by a drop in temperature and an increase in humidity) than when the air is warm and relatively dry; and the sounds of ordinary speech can be heard at distances of more than a mile on cold, dry days. Reliable observations of such Arctic explorers as Stefansson indicate that at $-80°$ F. conversations as far away as five or six miles have been heard and understood, and that other sounds, as the barking of dogs or the chopping of wood, have been heard at distances as great as fifteen miles. These long distance transmissions of sound through the atmosphere are usually explained by assuming that the temperature of the air increases from the ground upward—often referred to as an inverted temperature gradient—which would cause the sound waves to be refracted downward and thus spread out essentially in two dimensions over a wide horizontal zone; whereas, under the more common condition of

[1] At the request of the editor of SCIENCE this non-technical article has been prepared by the author of the paper presented at Pittsburgh to which was awarded the prize for a notable contribution presented at the annual meeting of the American Association for the Advancement of Science.—ED.

[2] The experiments are described more completely in papers in the April (1935) issue of the *Journal of the Acoustical Society of America*, and in previous issues of this journal.