THE IMPORTANCE OF PLANTS[1]

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NOTHING I have to say here is new; all of it has been known for many years, some of it for a century or more. Yet I believe that the repetition from time to time of facts of fundamental import has its place. Even scientists can on occasion review with profit the broad significance of the material on which they spend their lives. One group of facts of the character I mention concerns the place occupied by plants in the life of man and the economy of nature.

PLANTS THE BASIS OF LIFE

Plants are the basis upon which all other life depends. In the last analysis they supply us with all the food we eat, they maintain the oxygen content of the air and they are the primary source of those important accessory foods, the vitamins. Without plants we would starve to death, die of suffocation and expire from a combination of deficiency diseases. In addition, plants are the chief means by which the energy of the sun is and has been in ages past caught and stored for us in usable form. Without plants fire would be unknown because there would be no wood or coal or petroleum to burn, and electricity—except as a natural phenomenon—would be at most limited to areas freely supplied with water power.

The essential relation of plants to the food we eat, the air we breathe and the energy we dissipate with such reckless abandon is based on two of their characteristics. These are their ability to store the energy of the sun's rays in sugar, starch, cellulose, oils, fats and other constituents of the plant body, and their ability to construct from simple and elementary substances types of chemical compounds necessary for the existence of animals, including ourselves.

The first of these powers, limited from a practical standpoint to plants which possess the green pigment chlorophyll, is the familiar process of photosynthesis in which the plant transforms water obtained from the soil and gaseous carbon dioxide from the air into sugar and oxygen. In the course of photosynthesis, which occurs only in the light, energy from the sun is stored in the product sugar and in the starch, wood, oils and fats or other organic substances constructed by living things from this sugar. The energy we obtain by burning coal, lignite, peat and petroleum was stored by the activity of plants in the dim past. It represents our capital stock of usable energy and once dissipated can not be recovered. The energy in wood, sugar, plant and animal oils and fats released by burning or by the metabolism of living things is that part of the sun's energy stored in our time. This can be regenerated within a reasonable period by the activity of plants now growing. Other sources of power, water power, wind power, power from the tides, are minor in comparison with the energy which has been and is being stored by the photosynthesis of plants.

The major features of this essential process were discovered and elaborated by Joseph Priestley, Ingenhousz, Boussingault and others over a period of about 100 years beginning in 1771 and are taught in every course in botany and biology. The details of how chlorophyll works are, however, still unknown, and the basic and essential character of the process is not yet a part of our national thinking. If it were, the small group of men who are attempting to discover how photosynthesis occurs—that is, how plants store the sun's rays—would receive more encouragement and assistance than they do, and in the discussions of the future of synthetic rubber made from petroleum we would see some consideration given to the wisdom, from the long view, of using petroleum in quantity to make something which can be produced from the air and water by the activity of plants.

Perhaps the significance of photosynthesis for our mechanical age could be more clearly grasped if it were possible to prepare a balance sheet on the world's store of available energy and the rate at which it is being dissipated. This can not be done. We can say that the coal and petroleum burned annually represents a net loss of potential energy, and we can also say that in time, though not in what time, we will have to depend upon the energy fixed annually by plants unless some other source at present not at our command, for example, atomic energy, is discovered and methods for its utilization devised.

How much energy is fixed annually by plants? Abbot has estimated that the energy given off by the sun amounts to the equivalent of 4×10^{23} tons of coal annually, of which the earth intercepts a small fraction, the equivalent of 2×10^{14} tons of coal. According to Berle, plants fix each year 2.7×10^{11} metric tons of carbon, which is the equivalent of somewhere near 3×10^{11} tons of coal. If these figures are approximately correct, then about 0.5 per cent. of that part of the sun's energy which falls on the earth is caught annually and stored by plants.

Another set of data leads to somewhat the same con-

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clusion. Transeau calculated that 1.6 per cent. of the sun's energy was utilized by a field of corn in Illinois during the 100 days of its growing season. Since for much of the rest of the year a corn field lacks vegetation it would appear that something less than 1 per cent. of the sun's energy annually reaching corn land in Illinois is fixed. In some parts of the tropics and other sections of the world where vegetation is active the year round this proportion would be larger; on the other hand, in the arctic, in deserts and a considerable part of the ocean it would be much less. We may be justified, therefore, in assuming that the annual energy fixation of plants approximates the equivalent of 3×10^{11} tons of coal.

This astronomical figure is at first sight quite comforting, particularly when we learn that in energy value it is over 200 times the coal and oil burned in 1938. The difficulty is that most of this annual income is not used. Wood, alcohol produced in fermentation and plant waste plays but a minor part in furnishing heat or mechanical energy because of their inconvenience, expense or lack of adaptability to modern machinery.

Berle has reported a method by which motor fuel equal in many respects to petroleum can be produced from cellulose, starch, sugar and other carbohydrates, thus offering the possibility of replacing our stock of usable stored energy by utilizing part of the current day-to-day income. Carbohydrates only can be used by Berle's method; lignin, protein, oils and fats are unsuitable as crude materials. However, if all the carbohydrates in all the plants were used as Berle suggests, and this is obviously impracticable, we would have but 6 times the present annual consumption of petroleum and less than 2 times the equivalent of the annual world consumption of petroleum and coal. If all the world used coal and petroleum as we did in this country in 1942, the total energy fixed by plants would be but 25 times that dissipated and all the carbohydrates made each year would yield about one third the amount the world would need.

Two years ago the National Science Fund asked a representative group of outstanding scientists to list the problems with which scientific research should be concerned in the post-war era and on which special emphasis should be placed. Future sources of energy stood third on the list. Its importance was surpassed, in the judgment of these men, only by the analysis and study of human behavior and the general field of medical problems.

I shall not linger long on the second characteristic of plants so necessary for the existence of other life on this planet; that is, their ability to construct from simple and elementary substances types of chemical compounds essential for animals. Their capacity for making sugar from carbon dioxide and water, constructing amino acids from inorganic nitrogen and organic-carbon compounds and for synthesizing vitamins enables us to live. Plants are able chemists and there is no substitute for them.

PLANTS AND RESEARCH IN SCIENCE

It would seem perhaps appropriate to terminate a discussion of the importance of the plant kingdom after having pointed out the essential relation of plants to our sources of energy and the dependence of all life on their existence. However, plants do more than fill our stomachs, warm our bodies and help us to go quickly from here to there. For example, plants are useful for the investigation of problems in science. For this purpose they have certain advantages. They can be grown in large numbers, and we have no compunction in destroying them in quantity if it is desirable for the purposes of the research. Their firm, well-delineated cell walls, general structure and methods of reproduction make them well adapted to the investigation of certain kinds of problems, and their infinite variety in morphology and physiology offers opportunity to select an organism best fitted to serve as experimental material for attack on a particular question.

The study of plants played a major part in the development of our knowledge of cells and the formulation of the cell theory. Cells were first described by Robert Hooke in 1665 from charcoal, cork and other plant tissues. The discovery of the nucleus is generally ascribed to Robert Brown, botanist, who made his announcement in 1831. The first careful description of cell division we owe to the botanist Hugo von Mohl, who introduced the term protoplasm in its present sense. Chromosomes were figured by the botanist, Anton Schneider, in 1873 and first adequately described by Strassburger in 1875.

In many other directions we find that research with plants has led to fundamental discoveries. The investigations of Payen and Persoz in 1833 on the diastatic activity of germinated barley opened the door to the field of enzymes. Mendel's laws, the foundation of our understanding of heredity and genetics, were discovered by experimenting with peas. The idea of hormones was first presented by the botanist Sachs in 1880. The essential nature of the so-called minor essential mineral elements, for example, manganese, copper and zinc, was demonstrated by Bertrand and his coworkers for the black mold *Aspergillus niger* considerably before their importance in animal nutrition was recognized. The discovery of the nature of virus diseases to which belong the agents responsible for smallpox, yellow fever, influenza, poliomyelitis, virus pneumonia, foot and mouth disease, hog cholera, rabies and many other afflictions of man, animals and plants began with experiments by Iwanowski in 1892 on the mosaic disease of tobacco and was completed by Stanley in 1935 by the isolation from tobacco afflicted with mosaic of the active agent as a nucleo-protein of high molecular weight. The influence of day-length on reproduction was demonstrated for plants by Garner and Allard some years before the correlation of reproductive activity in animals and day-length was investigated.

Perhaps nowhere is the importance of work with plants for scientific objectives of general application demonstrated better than that which has been carried on with yeast. Pasteur's investigations on fermentation contributed in a major way to the germ theory of disease and to his later discoveries in the field of medicine. Investigations on the chemical changes induced in carbohydrates by yeast have had an immense influence on our knowledge of respiration and the intermediary metabolism of carbohydrates in animals, including man. At least two vitamins, pantothenic acid and biotin, were discovered from a study of yeast.

Many other examples could be cited illustrating the importance of research on plant material. What I have said, however, will suffice to show that the study of plants has given us in the past, as it will in the future, concepts of general significance in biology, a knowledge of principles applicable to other living things, including ourselves.

RECREATIONAL VALUE OF PLANTS

I scarcely need call your attention to the recreational value of plants. The opportunity to enjoy flowers, shrubs and trees acts as an antidote for the artificiality and tension of city life, relieves the drabness and monotony so frequently associated with existence in a small town or in the country, and satisfies a deep-seated desire in all of us. It can not be expressed in units of value, though it has been recognized in art, poetry, architecture and design since the beginnings of recorded history. I see it evidenced by the thousands of films exposed by a part of the million or more, people who visit the New York Botanical Garden annually; by the letters which come to my desk from those who feel impelled to tell me "the great pleasure it is to wander through flower gardens and conservatories and to spend quiet, peaceful, restful hours in the grounds," to quote from one of them; by the nearly 150,000 people who in 1938 attended the International Flower Show in the Grand Central Palace in New York City between Monday noon and the succeeding Saturday night with an admission charge of $1.10; by the universal interest in gardening and the numerous organizations associated with it, Garden Clubs, Rock Garden Society, Iris Society, Dahlia Society, Herb Society, Rose Society, Begonia Society, Succulent Society and so on; by the elaborate gardens maintained by the wealthy and the plants raised on window sills in country kitchen and city apartment.

Some one has said that gardening and a love of gardens are essential components of a full, sane and rounded life, and traffic with the soil and the green things that grow from it is one of the noblest and most healthful associations man may adopt. To own a bit of ground, dig it with a spade, plant seeds and watch them grow is a most satisfying thing, and fondness for such activity often comes back to a man after he runs the round of pleasure and business. As Henry Ward Beecher once wrote, every book which interprets the secret lore of fields and gardens, every essay that brings us nearer to an understanding of trees and shrubs and even weeds is a contribution to the wealth and happiness of man.

A garden gives the possessor fruit, vegetables and flowers; it also teaches patience and philosophy, pacifies and heals the body and the mind. This is recognized in the employment of gardening in occupational therapy by hospitals and prisons, a practice which has been used successfully and is increasing. This was not always so. Oscar Wilde, writing of his own experience in an English jail, said:

> But neither milk-white rose nor red
> May bloom in prison air
> The shard, the pebble and the flint
> Are what they give us there
> For flowers have been known to heal
> A common man's despair.

At the New York Botanical Garden some years ago we received an anonymous gift of money from an individual who stated that it was sent because the opportunity of enjoying the plantings in the Garden had prevented self-destruction. If one person was impelled to express his appreciation in this fashion there must have been many others less articulate or with smaller need who have felt the influence of plants in times of stress. I believe that in the brave post-war world many are now planning, gardening will be recognized and given an important place because of its occupational and spiritual values.

May I add a word of caution. We need nothing but our senses to enjoy the beauty of flowers, but the deeper satisfaction of knowing them and growing them requires a breadth of knowledge and experience surprising to the uninitiated. So long as any man out of employment is considered to be a capable gardener, and seed catalogues are looked upon as adequate texts, gardening is likely to be a series of disappointments which only the persistent will survive. Gardening as a profession requires training, practice and a body of special information, as other professions do, and the amateur, whether individual or corporate, does well to look to the professional for guidance and for help. The Royal Botanic Gardens at Kew and at Edinburgh as well as similar institutions on the continent have long recognized gardening as a profession and have conducted courses of instruction in theory and practice. In this country few institutions have as yet concerned themselves with this aspect of education, though in the post-war period there is going to be a considerable need for it.

ECONOMIC IMPORTANCE OF PLANTS

Every one recognizes the economic importance of the common field crops, wheat, oats and corn, of the vegetables and fruits and of lumber. These are items in our everyday living. Not every one realizes, however, how many other products are obtained from plants. They are the source of linseed oil, corn and coconut oil, turpentine, lacquer, varnish and resin, coffee, tea and other beverages, perfumes, flavorings and spices, drugs and insecticides, paper, cordage and clothing, cellulose for artificial silk and a hundred other useful products. The plant extractives industry alone, including drugs and flavorings, probably amounts in the United States to between 100 and 160 million dollars annually. It took a war, a war which cut us off from normal supplies, to make us appreciate how much our economy and our comfort and convenience depend upon many of these plant products from distant places. Rubber and quinine are two of the most generally known, but there are many others, for example, the sponge of the luffa gourd, the insecticide pyrethrum, chicle for chewing gum, the drug ergot, agar agar and cork. And yet in spite of the varied materials we now obtain from plants the potentialities of the plant world are but partially explored. What might be called economic botany is largely an inheritance from our untutored ancestors who obtained their information over the centuries by trial and error. Very little systematic effort has been made to explore the plant kingdom with the idea of exploiting products as yet unknown or unused. The wide contacts brought through this war to hundreds of thousands of our young men, many of them already trained in science, may result in new and important uses for plants. The opportunity exists because not only are familiar plants incompletely investigated, but there are considerable areas of the earth botanically unexplored and thousands of species of plants still unknown to science. Any one of them might become as important to us as *Penicillium notatum.*

I can not close this discussion of the economic aspects of plants without referring to their importance in disease and decay. It is not my intention, however, to discuss bacteria, yeasts and molds as causes of disease in other plants and in animals and man nor to elaborate on their relation to decay except to call attention to the importance of the fungi in rotting wood and cloth, molding food, short circuiting electrical instruments and deteriorating optical equipment in the tropics. Although those of us who live in the temperate zone are acquainted with the fungus rots of telephone poles, railroad ties and house timbers and the minor losses from mildewed curtains or moldy food, we have little conception of the destructiveness of molds in the moist tropics. Their control is a matter of major concern.

Another way in which plants contribute to our economic system is through the association of microorganisms in the formation of various products, for example, cheese which depends upon the activity of the lactic acid and other bacteria and various molds; beer, wine and other fermented liquids produced by yeast; sauerkraut, vinegar, soy sauce and many others less well known or desirable. Bacteria, yeasts and molds as we learn to know them better are increasingly used for producing specific chemical compounds which are beyond the skill of the laboratory worker or which can be made more cheaply by the microorganism. Alcohol, acetic acid, acetone, glycerine, citric acid, gluconic acid and riboflavin are some of these compounds. The most recent and illustrious addition to this list is of course penicillin.

"Botany," said Thomas Jefferson, "I rank with the most valuable sciences whether we consider its subjects as furnishing the principal substances of life to man and beast, delicious varieties for our tables, refreshments from our orchards, the adornment of our flower-borders, shade and perfume of our groves, materials for our buildings or medicaments for our bodies."

Jefferson wrote these words in 1814. Priestley had but recently demonstrated that plants produce oxygen; the uniqueness and importance of photosynthesis was still to be recognized; coal and petroleum were still to be developed; vitamins and amino acids, the relation of plants to them and their importance in animal nutrition were unknown; rubber was a plaything; the relation of bacteria and molds to disease and decay was still to be discovered and penicillin was a long way in the future. Thomas Jefferson estimated the importance of plants on the basis of the knowledge about them available in 1814. What would he have said to-day?