BIOLOGY

Artificial Photosynthesis

The secret of how the green leaf captures energy is near solution, and a revolution in power and food is believed near. Recent discoveries in photosynthesis point way.

By WATSON and HELEN DAVIS

➤ THE SOLUTION of one of the major mysteries seems near: How the green leaf captures the energy of sunshine and stores it up in the making of food.

This great problem once solved should lead to "artificial photosynthesis," that is, doing what the plant does without the aid of life.

Potentially this can mean:

A vast increase in the food or raw material supply.

A revolution or a virtual substitution for agriculture.

Factories located in tropic or desert areas, powered by sunshine.

Relocation of civilization in parts of the world removed from the present power sources of coal, oil and water power.

This is a bigger accomplishment than the release of atomic energy, although it does not seem capable of being used as a weapon.

Man has long envied the green leaf its ability to use sunlight to power its miniature chemical factory. Although each leaf makes use, apparently, of only a small percentage of the energy in the sunlight that falls upon it, the chemicals that leaves build out of water and carbon dioxide, using the sun's energy to put them together, support all the life on earth.

Natural Laws Followed

Chemists have investigated many processes carried out by living tissues and found that, one after another, they have proved to happen according to natural laws.

No particular need for a living force, such as used to be imagined, has been found once the conditions for the reaction have been fully understood. Therefore, they have believed that the final great secret of photosynthesis would one day be found.

Once found, they are sure it can be used by man-built factories to produce food and materials beyond the capacity of today's farms and gardens.

Early chemists, such as Liebig, Baeyer, Willstatter and Stoll, studied the problem of how the plant makes starch and sugar. They succeeded in learning that the plant needs water and carbon dioxide as materials to build its chemicals, and that it requires sunlight to carry out this reaction.

Using the chemical knowledge that was available to them at the time, the beginners in the study of photosynthesis wrote out equations for the simplest method they could think of that might result in the compounds they observed in the plants.

Plants were known to make a great deal of cellulose, which is wood. Cellulose is related to starch, which plants also make. So close is this relationship that cellulose may be written by the chemist as a polymer of starch, and described by the same formula: $C_6H_{10}O_5$. Combined with one molecule of water, starch becomes sugar: $C_6H_{12}O_6$.

The simplest chemical that combines carbon, hydrogen and oxygen in the same proportions is formaldehyde, CH_2O, the familiar disinfecting liquid. Therefore, said the early chemists, plants combine water and carbon dioxide to make formaldehyde.

Mistake Was Hindrance

This was a mistake, and it has hindered the understanding of photosynthesis for a hundred years. Nature is a much better chemist than early adepts in the art realized.

Simple compounds of two or perhaps three chemical elements that show a decided change in properties when they are brought together can be followed through various reactions with comparative ease. Not so in living combinations, where complex changes proceed, of their own accord, very fast.

If a chemist of long ago had been granted any wish, no matter how impossible, he might well have wished for a method of following some single atom through the changing compounds of the life cycle in some animal body or some plant.

In the early years of the present century that wish was granted. Radioactivity, first discovered in 1898, provides the seemingly impossible method by which a single atom can be tracked down. Other new discoveries about chemical behavior can be used to refine the methods of identifying the compounds in which the radioactive atoms are found.

Correct Early Errors

Photosynthesis is now being followed by these techniques that would have seemed impossible half a century ago. Many early mistakes are being corrected as a result.

It seemed obvious to early students of plant life that the oxygen, which they knew was given off by the plant, came from the carbon dioxide when the carbon of that gas was added to water to form formaldehyde. However, when chemists could use and trace different kinds of carbon atoms and different kinds of oxygen atoms, they were astonished to find that the reaction is quite different.

Three distinct processes are found to be concerned with photosynthesis. The first of these splits the water molecule in two. This is the source of the life-giving oxygen that the plant throws off into the air. This process is triggered by the mysterious green chemical, chlorophyll, lately the advertisers' darling.

Splitting the water molecule sets free hydrogen, which reacts with the carbon dioxide. This is the second process in the chain of photosynthesis reactions taking place in a green leaf. Next the hydrogen and the carbon dioxide are reworked by the living cells of the leaf. What this third process makes of them is not formaldehyde.

Each of these three processes by which the green leaf accomplishes its unique work is the object of intense study by groups of scientists at the present time. Some are measuring the energy necessary to build up and to break down each of the chemicals formed by the leaf cell.

Other groups are studying the cycle of oxidation and reduction that has to do with the plant's releasing oxygen. Other ways of doing this are known to chemists, and they are comparing one method with another to see whether, for future use, man can outsmart the plant and build a more efficient process.

The most fascinating part of photosynthesis, from the chemist's standpoint, however, is to learn how the plant goes about building up its starches and sugars. What does it start with, now that the simple formaldehyde is pretty well ruled out?

Radiocarbon as Tracer

For about 15 years, a group at the University of California in Berkeley, working under Drs. Melvin Calvin, Andrew A. Benson and James A. Bassham, have been using the radioactive form of carbon to follow the compounds created in the living leaf.

By making the time shorter and shorter between the moment radioactive carbon meets leaf and the moment chemist extracts the product with its tell-tale radioactivity, this scientific team has just discovered two of the earliest compounds in photosynthesis.

Far from being simple compounds, they are two rare and complex sugars, each combined with a group containing phosphorus. A radioactive form of phosphorus aided in making this discovery.

Phosphorus is an element that forms peculiar compounds, which are apt to interfere with chemical reactions of other elements, if present. When phosphorus is present in small amounts, as in many substances created by life processes, analytical chemists are tempted to ignore the troublesome element, and class it among the "impurities."

However, this strange, fiery substance, which can be so deadly in its elemental form, proves to be a chemical of life in photosynthesis. Capable of combining with great energy, it provides a reasonable clue to reactions theoretically impossible when only carbon, oxygen and hydrogen were in the picture. And combined with the rare sugars, ribulose and sedoheptulose, it ties in with other chemicals, such as deoxyribose, known to lie very close to the heart of all life chemistry.

Ribose is a sugar formed of five carbon atoms to the molecule, instead of the six that make up the more familiar glucose. Ribulose and deoxyribose are close chemical relatives of the five-carbon sugar.

Heptulose is similarly akin to heptose, a seven-carbon sugar. To find such complicated forms appearing among the first products of carbon dioxide and water is very startling. The phosphorus, of course, was present in the plant tissues all the time. Early plant chemists just did not look for it, or forgot to mention if if they did.

Built To Be Torn Down

The appearance of these sugars with their odd numbers of carbon atoms is another evidence that nature works in mysterious ways, for they seem to be built up only to be torn down again.

Somewhere, however, in the cycle of building up and tearing down, a repeating reaction has been achieved by which incoming carbon can always be seized, incorporated into the moving machinery, and finally passed on to replenish the structures of the whole plant, which is always growing, changing, repairing itself, furnishing sustenance to all the so-called higher forms of life.

Yet the source of all this vital energy is being narrowed down to non-vital causes. Out of the living leaf scientists have extracted small green granules that they have named chloroplasts. They are complex structures, but they are not even as much "alive" as the enzymes.

Living Structures Eliminated

Drs. Daniel I. Arnon, M. B. Allen and F. R. Whatley of the University of California in Berkeley report in *Nature* (Aug. 28) how they made chloroplasts carry on photosynthesis without the aid of more complicated living structures.

These scientists have, moreover, found chemicals that will stop each of the processes of photosynthesis singly or in combination, so that the man in the laboratory can separate or combine the plant processes at will, and see what happens.

With the knowledge of how to do this, other scientists working in similar fields are making haste to apply these findings to their own photosynthesis problems. The goal of controlled photosynthesis is almost in sight.

Science News Letter, December 18, 1954

The eyes of an *ostrich* often weigh more than twice as much as its brain.

Japan leads the world in fisheries production, with an average of almost 3,000,000 metric tons of *fish* a year, the United States is next with 2,500,000 and Russia is third with 2,000,000.

GENERAL SCIENCE

1954 Carnegie Report

Annual report tells of discovery of fall of Mayapan, which is likened to destruction of Troy. Also notes progress in astronomy, sex reversal and probing fossil records.

➤ DISCOVERY OF the sacking and burning of Mayapan, the last great city of the pre-Columbian Maya civilization of Yucatan, Mexico, about 1450, resulted from excavations announced in the annual report of the Carnegie Institution of Washington.

This confirmation of events described in old pre-conquest records "parallels in many ways the archaeological verification of the Homeric account of the destruction of Troy," Dr. Vannevar Bush, president, told the trustees at their annual meeting.

In the ruins of the same city, a mural painting done on plaster in colors was unearthed. Heads of monsters were painted in green, red, yellow, white and blue against a black background.

Houses of ordinary people, which were previously neglected because of concentration upon the striking Maya temples, were found in Mayapan in such numbers that the city must have been large in the ancient days, even in terms of present-day Yucatan.

Mammalian Sex Reversal

The first sex reversal accomplished in the mammal male was reported by Dr. Robert K. Burns of the department of embryology.

This is declared to be of great importance for the study of sex differentiation in higher animals. Using the opossum, in which embryonic animals are accessible in the mother's brood pouch, he obtained by injection of sex hormones the reversal of the primary sex organs of male opossums.

Spot Proteins in Fossils

Fossils as old as 360,000,000 years can still be analyzed for their building blocks of protein, amino acids, Dr. Philip H. Abelson, director of the geophysical laboratory, discovered.

This discovery opens the opportunity for investigating the bodily chemistry or biochemistry of creatures long extinct.

Some of the amino acids, identical with those in present-day proteins, that were found included alanine, glycine, valine, leucine, aspartic acid and glutamin acid.

Because experiments showed that the rate of breaking-down of the amino acids increased with temperature, scientists may be able to use fossils as a recording geological thermometer for sediments.

Spiral Arms Young

Observations with the 100-inch telescope of Mt. Wilson Observatory upon stars both in the inner and the outer region of our Milky Way and in the similar Andromeda galaxy showed that the stars in the outer spiral arms were formed late in the history of the galaxies, from the huge clouds of dust and gas existing there.

The stars nearer the center of the galaxies are believed to be nearly as old as the galaxies themselves.

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