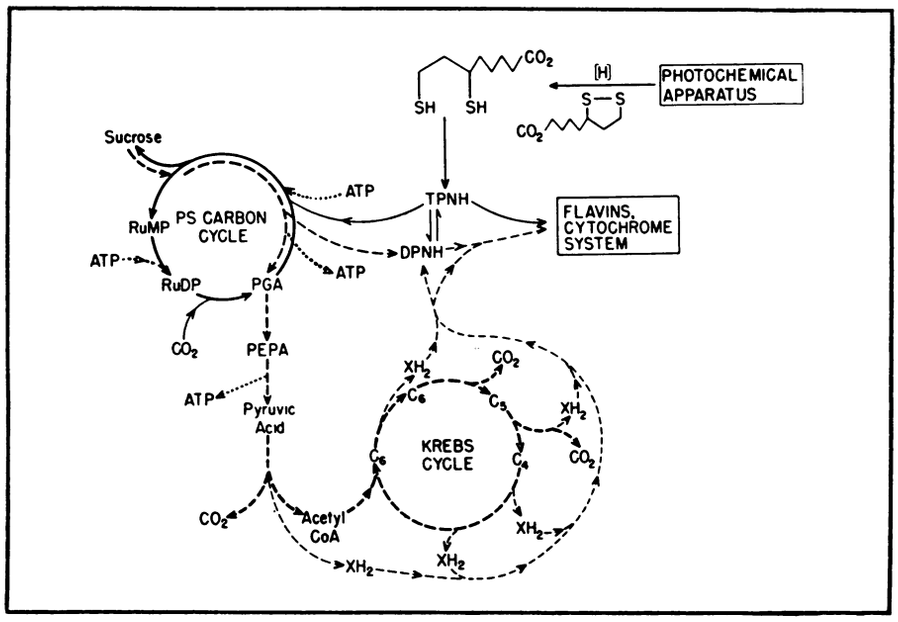

PHOTOSYNTHESIS CYCLE—The relationship between the photosynthetic cycle, the Krebs cycle and the reducing agents available in the cell is shown in this diagram of Dr. Melvin Calvin of the University of California, Berkeley.

BIOCHEMISTRY

How Green Leaf Works

➤ THE GREAT RACE among scientists to be the first to give the most complete account of photosynthesis, the food-manufacturing process of the green leaf, comes closer to a finish.

Dr. Melvin Calvin of the University of California, Berkeley, told the National Organic Chemistry Symposium of the American Chemical Society at Purdue University, Lafayette, Ind., how light acts as a valve to control the relationship between two kinds of chemical cycles in plants.

Both cycles are fundamental in maintaining this planet's life.

One is the cycle of sugars. It forms the food that supports life. By alternately building up and tearing down sugars with five and seven carbon atoms, plants add one carbon atom at a time, stepwise, to the structure of the leaves, stems and roots they build in the sunshine. Thus they manufacture food. This fundamental way in which plant tissues are built up has been understood only about a year.

The other life cycle, now linked to the sugar transformations, is known by the name of its discoverer, Dr. Hans A. Krebs of England's Sheffield University. He was honored for discovery of the "Krebs cycle" by the Nobel prize in 1953. In this cycle, citric acid is recognized as a fundamental chemical in many life processes. This is the same substance that is found in lemons and other citrus fruit. It plays a part in sugar utilization by muscles.

Working with radioactive carbon and phosphorus, Dr. Calvin and his research group have now found that citric acid, a tricarboxylic acid, appears in photosynthetic products as soon as the light is turned off.

Citric acid goes through a complicated but fairly well understood series of chemical transformations in which the elements phosphorus and sulfur take part.

Sulfur is a close chemical relative of oxygen, the vital element breathed by both animals and plants. These two elements can often change places in molecules without a very noticeable change in properties of similar compounds.

Dr. Calvin now suggests that sulfur may be the undiscovered trigger that kicks off the circling reactions that make photosynthesis a continual process in the green plant.

Delicate balance between two alternate kinds of sulfur compounds associated with the sugar and the tricarboxylic acid cycles in living plants may be affected by the sunlight's energy. Light may therefore act as the valve allowing carbon to progress along one pathway while it is shining, shifting it to another in the dark.

Identity of the substance that seizes hydrogen is the final mystery in the photosynthesis puzzle.

Plants take three steps to build complex organic compounds from water and carbon dioxide with light's aid. As each step has been understood by scientists, it has been found more roundabout than early chemists had imagined. Yet the mechanisms found working in green leaves have proved simple.

The first step taken by the plant's chemical factory is to split water into its two elements, oxygen and hydrogen. The oxygen is given back into the air.

In the second step hydrogen helps break up carbon dioxide, changing the carbon to a compound more adaptable to the rapidly changing cycle of organic compounds that the plant continually builds up and breaks down.

In the third step, the beginning of the shifting cycles of organic compounds, the leaf calls upon the phosphorus supply in its tissues to form transitory substances that start the cycles going.

Early Stages Known

The early stages of photosynthesis have been quite thoroughly worked out. Radioactive carbon and phosphorus isotopes have been introduced into plant tissues. The tell-tale atoms show what becomes of these elements. The sequence of compounds formed has been learned by shortening the time between injection of the isotopes and analysis of the radioactive products made by the plant. But the very earliest substance made, the compound that triggers the first attack on the carbon, has remained a mystery.

Hydrogen is the part of the broken-up water molecule that the plant holds. No bubble of hydrogen gas as such is ever let loose by the green leaf. The plant's chemical factory takes the hydrogen ion, with its electrical combining charge, and combines something with it to form an unstable compound. This compound turns into one kind of substance in the dark and another kind when light shines on the leaf.

The energy the plant uses for these transformations has been measured. To make the chemical change from one molecule of carbon dioxide, such as the plant would absorb from the atmosphere, to a readily reacting form of organic compound usable in the plant's tissues, the plant will ultimately call into use four electrons, obtained from splitting water, plus three molecules of a compound chemists call ATP. The letters are an abbreviation of the compound's long name, adenosine triphosphate.

Since the importance of phosphorus compounds has been recognized, this substance has been known to take an important part in photosynthetic reactions. If the trigger chemical proves to be a known sulfur compound, scientists will know how the mysterious green leaf goes about its work.

When this great advance is achieved, it may lead to the chemist's imitating the green leaf and setting up a factory to manufacture sugars, carbohydrates and other foods, beating the plants at their own game.

It is also likely that other complex chemical cycles will be discovered in living plants. As is so frequently the case in scientific advances, the puzzling out of one kind of complexity leads to still others. Probably other cycles besides the sugar cycle and the Krebs cycle will be found, operating to produce the great variety of substances manufactured by living matter.