Chemistry

From the American Chemical Society meeting in Seattle, Wash.

Photosynthesis: In the beginning

During earth's early days photosynthesis may have released hydrogen instead of oxygen gas. And this process probably was conducted by a simple version of chlorophyll — the molecule that orchestrates contemporary photosynthesis.

So theorize Janet A. Mercer-Smith of Los Alamos National Laboratory in New Mexico and David C. Mauzerall of Rockefeller University in New York City. The researchers report that in tests with "primitive chlorophyll" models they have gathered evidence to support their primordial photosynthesis theory — one that clashes with an origin-of-life theory that has been popular for more than 50 years.

In contemporary photosynthesis, chlorophyll pigments absorb sunlight and initiate a series of chemical reactions whose net result is the following: $H_2O + CO_2 \rightarrow O_2 +$ carbohydrates. This process not only supplies most of the oxygen (O_2) for our atmosphere, but also forms the basis of our food chain.

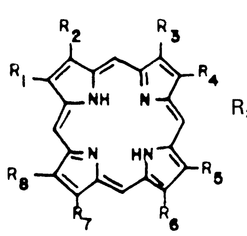
Fossil records suggest that microorganisms now capable of conducting some type of photosynthetic process first appeared about 3.5 billion years ago. However, there also is evidence that suggests significant quantities of oxygen did not appear until about 3 billion years ago. So what biochemistry were those microorganisms performing for one-half billion years?

According to one popular origin-of-life theory — the J.B.S. Haldane-A.I. Oparin "primordial soup" theory — those first microorganisms initially did not take advantage of their food-photosynthesizing skills. Instead, they lived off nutrients formed abiotically, during electrical discharges into hot springs, for example. Eventually, though, these yeast-like organisms began to multiply and to use up their available food sources. A "biological energy crisis" developed, "forcing" the organisms to learn the food-supplying, oxygen-evolving process of photosynthesis in a relatively short period of time.

An alternative theory, supported by the work of Mercer-Smith and Mauzerall and originally proposed by the late Samuel Granick of Rockefeller University, is that a primitive form of photosynthesis actually originated quite early — perhaps with life itself. According to this theory, the construction of chlorophyll in green plants today recapitulates the history of photosynthesis. In other words, plants synthesize their own chlorophyll from simpler pigments called porphyrins; these porphyrins may have been "primitive chlorophylls," conducting a primitive form of photosynthesis in the primordial soup.

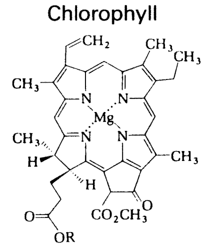
Mercer-Smith and Mauzerall constructed "primitive chlorophyll" models such as uroporphyrins (see structure below). Previous work by other researchers, including Cyril Ponnamperuma of the University of Maryland, has shown that such porphyrins could have been formed from the primordial soup. When illuminated in an environment lacking oxygen that simulates the early atmosphere, these porphyrins, Mercer-Smith discovered, oxidize (take electrons from) simple organic compounds also believed to have been part of the primordial soup. Next, the porphyrins donate their extra electrons to protons ($2H^+$), and hydrogen gas (H_2) is evolved.

Eventually, Mercer-Smith suggests, magnesium cations (Mg^{++}) — perhaps from seawater — were incorporated into porphyrins, leading to the modern-day chlorophyll molecules that evolve oxygen during photosynthesis.



UROPORPHYRIN III: $R_{1,3,5,8} = CH_2CO_2H$; $R_{2,4,6,7} = CH_2CH_2CO_2H$

Chlorophyll



Technology

Fill 'er up — with coal dust

Powdered coal shows promise as an inexpensive fuel for future automobiles, according to researchers at General Motors Corp. The trick is to combine a gas turbine engine with a coal-dust delivery system. Recently, Richard J. Stettler and his colleagues at the Advanced Product Manufacturing and Engineering Staff in Warren, Mich., designed, installed and tested two such systems, one in a Cadillac Eldorado.

A specially designed conveyor belt carries coal dust, which has the consistency of powdered sugar, from the storage tank to the engine. A blast of compressed air feeds the coal into the turbine's combustor, where the fuel ignites and produces the hot gases that drive the turbine to power the car. Although the prototype system works, Stettler says a more reliable automotive gas turbine engine is needed. In addition, sulfur and ash residues interfere with the operation of the system. This is one problem that halted earlier experiments with coal-fired turbines in locomotives. Now, with electric utilities demanding cleaner powdered ("micronized") coal to fire power plants, coal producers are beginning to market fuel that is clean enough to be used in turbine-powered cars.

Stettler says the main advantage of using coal is its much lower cost compared with gasoline or diesel fuel. Furthermore, using coal in its solid form, rather than after conversion to a liquid fuel, saves energy.

Centering on magnetic recording

The University of California at San Diego will be the site of a new center for magnetic recording research, the first such academic center outside of Japan. The university will contribute $1 million, land for a building and four new faculty members who specialize in magnetic recording research. A group of companies, including IBM Corp., Control Data Corp., Eastman Kodak Co. and others, will provide $11 million during the next five years to start the center. This technology has important applications in data storage for computers and information processing systems.

Silicon carbide for hot chips

The possibility of implanting electronic "chips" directly into high-temperature environments like jet engines is one step closer with the development of a practical manufacturing process for high-purity, silicon carbide semiconductors. The integrated-circuit chips now usually found in computers and numerous other machines are made from silicon doped with traces of other elements. However, temperatures above 600°F destroy these microscopic electronic webs. Electronic packages built on a silicon carbide base should be able to endure temperatures as high as 1,600°F.

Although the search for a practical silicon carbide production process began in the 1950s, the problem of building a crystalline silicon carbide layer on a silicon base halted earlier efforts. The problem arose because silicon and silicon carbide have different crystal structures and the spacing between atoms of the two materials is significantly different. Two years ago, physicists at the National Aeronautics and Space Administration's Lewis Research Center in Cleveland found an answer. They proposed that laying down a very thin buffer layer of tiny, irregular silicon carbide crystals would act as a bridge between the two different crystal structures. The researchers have now used silicon carbide, produced using the process they developed, to build diodes and other electronic devices.

"Such electronics ... could give us the ability to place electronic packages and switches inside experimental turbine engines to monitor and control the engine to a degree never before possible," says NASA's William Nieberding.