Details of photosynthesis revealed in new study led by UCSD and Caltech biophysicists

May 1, 1997

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DETAILS OF PHOTOSYNTHESIS REVEALED IN NEW STUDY LED BY UCSD AND CALTECH BIOPHYSICISTS

It's probably the single most important chemical reaction in the biological world. Indeed, all life derives its energy from photosynthesis.

Now, a team of biophysicists at the University of California, San Diego and the California Institute of Technology has captured in atomic detail the changes that take place when light strikes the site where the primary events of photosynthesis takes place--a protein called the reaction center.

The results, published in the May 2 issue of the journal Science, are offering a new and detailed explanation into how this complex chemical reaction takes place.

"This work helps answer some basic questions about photosynthesis," said George Feher, research professor of physics at UCSD.

Knowledge of the precise chemical pathways that create photosynthesis is significant since it's literally the first step in the process of life.

"The problems the planet faces have to do with famine and energy, and both of these are related to photosynthesis," said Feher. "So it's a very basic process. People who are worried about relevance, shouldn't be in this case."

At the heart of the photosynthetic machinery is a membrane protein called the reaction center which carries out the basic chemical reactions. In these centers, packets of light called photons are captured by molecules of chlorophyll. When these molecules are excited by light, they release electrons which are shuttled from one electron acceptor molecule to another, the last two being quinone molecules. These processes ultimately set in motion a charge separation across the membrane which the organism uses to synthesize adenosine triphosphate (ATP), a high-energy compound. The entire reaction takes place in a fraction of a second.

During the past two decades, Feher's research into this process has focused on certain photosynthetic bacteria called Rhodobacter spheroides. Bacteria are simpler to study than green plants since bacterial photosynthesis is a one-step process that does not result in oxygen evolution.

Among other things, Feher and his collaborators have analyzed the reaction centers in these bacteria, using biochemical and spectroscopic techniques to determine their electronic structures; his collaboration with D. C. Rees and his group at the California Institute of Technology has focused on the three-dimensional structure of these centers.

In previous work, the research team determined the precise structure of the center in its neutral state--before electrons were set in motion in the presence of light.

This new work describes in atomic detail changes that take place in the three-dimensional structure after it is exposed to light. This was accomplished by exposing a reaction center crystal to a light source, and then immediately plunging the crystal into liquid nitrogen at temperatures of 90 degrees above absolute zero. In this manner, the activity was literally frozen in time.

Afterward, the researchers compared the neutral structure with the light-adapted structure. In some cases, the changes were quite dramatic.

"We found significant structural changes in the light-adapted structure," Feher said.

Among other things, the secondary quinone in the light-adapted structure was visibly shifted from its position in the neutral structure. Also, a region called the "headgroup" appeared to be twisted about 180 degrees from its former position, as if turned a half revolution by a propeller.

From the dramatic structural changes, the researchers were able to explain the kinetic behavior of the electron transfer reactions inside the reaction center after it was exposed to light. An additional outcome of this study was the higher resolution, ie. precision, with which the structure was determined. This enabled the researchers to locate water molecules within several channels leading to the secondary acceptor quinone. Water is a natural conveyor of protons, which when combined with the shuttled electrons at the secondary acceptor quinone, create dihydroquinone. This latter chemical leaves the reaction center, carrying the protons that trigger a proton gradient across the membrane that results in ATP production.

Feher noted that the results from his studies of bacterial photosynthesis are likely to be applicable to the similar process in green plants.

"Nature usually doesn't invent things twice completely differently," he said.

Also participating in the study, in addition to Feher and Rees, were M. H. B. Stowell, and T. M. McPhillips, at Caltech; S. M. Soltis, with the Stanford Synchrotron Radiation Laboratory; and E. Abresch, with the physics department at UCSD.

(May 1, 1997)