The need for definition of terms such as "Darwinian" and "natural selection" and "chemical" and "biological evolution" was pointed up by H. H. Pattee (Stanford University) who suggested that evolution according to the Lamarck concept was possible at the molecular level and that evolution cannot occur in the primitive molecule according to the Darwinian concept.

T. H. Jukes (University of California, Berkeley) noted that understanding and interpreting the DNA code may make an important contribution to an understanding of evolution.

H. Gaffron (Florida State) was concerned with the role of light in evolution. He suggested that the early photosynthetic mechanism may have produced free oxygen. The wavelengths of light used may have been quite different from those used today.

The meeting was sponsored by the Institute for Space Biosciences of Florida State University and the National Aeronautics and Space Administration. Facilities and arrangements for the meeting were provided by S. W. Fox and his associates of Florida State University. The proceedings were opened with an official welcome from the president of Florida State University, G. Blackwell, and F. Quimby, head of the Exobiology Program of NASA. The meeting included 31 participants from the United States, England, Germany, Russia, Japan, and India. Several suggestions were made that such meetings should probably be held with greater frequency, and that this one was a most profitable experience.

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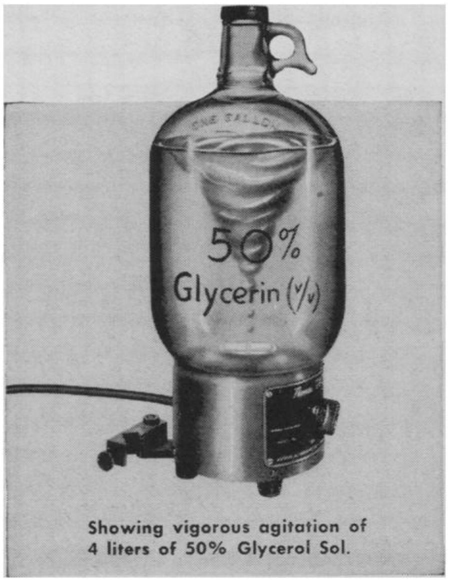
Photosynthesis

Photosynthetic mechanisms of green plants was the subject of a symposium held at Airlie House in Warrenton, Virginia, 14–18 October 1963. The major theme of the meeting was the determination of the sequence of electron transport steps in chloroplasts, especially as related to two experimentally separable light reactions. The problem was approached by the techniques of difference spectroscopy (B. Kok, K. Witt, J. Olson, W. Bonner, and B. Chance), analysis of fluorescence and delayed light emission (L. Duysens, W. Butler and N. Bishop, J.



Rosenberg and J. Franck, W. Arnold, and others), electron paramagnetic resonance (E. Weaver and H. Beinert), sensitive analysis of oxygen or carbon dioxide exchanges (J. Myers, C. S. French, M. Hommersand, Govindjee, Blinks and many others), by study of genetic mutants (R. P. Levine, N. Bishop, and H. Gaffron), a new type of liquid sampling for mass spectrometer analysis (G. Hoch), and study of the biochemistry of isolated chloroplasts (D. Arnon, A. Trebst, and others). From the results of such varied experiments during the past few years, some major points have been established with certainty.

There appear to be two photosystems. One (designated "II" by L. N. M. Duysens) contains part of the total of chlorophyll *a* and a high proportion of the accessory pigments; the other ("I") contains most of the long wavelength absorbing and nonfluorescent chlorophyll *a*. System II is closely related to the dehydrogenation of water and the evolution of oxygen; activation of system I causes electrons to move to the low potential (highly reducing) end of the chain.

Pigment connected to system I transfers its energy to a special chlorophyll *a* (P700), behaving as a one-electron redox intermediate (B. Kok). The photo-oxidized pigment, in turn, oxidizes cytochrome *f* (H. Witt and B. Chance both showed this reaction occurs even at 77°K). The newly found copper enzyme plastocyanin (S. Katoh and A. Takamiya) might be part of the very same charge transfer complex. From these data and others, a well thought of but not universally accepted scheme for electron transport would be similar to the one proposed by Hill and Bendall, with the following sequence:

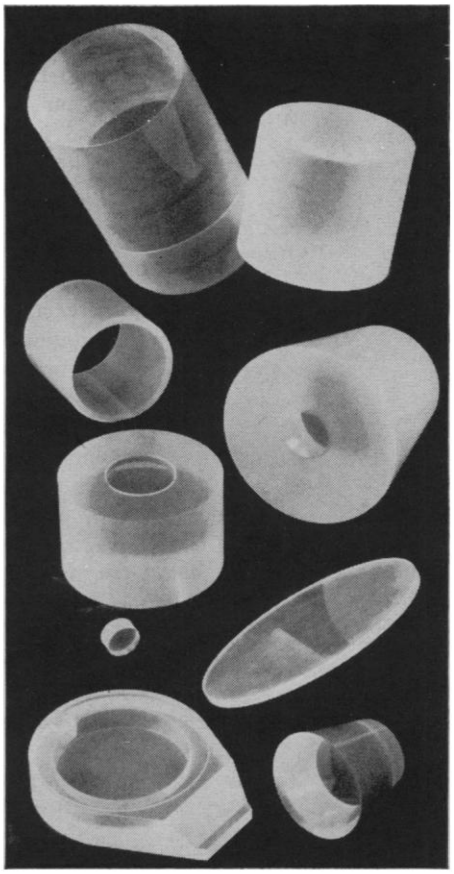
$$\begin{array}{l} \mathrm{H_2O} \xrightarrow{\text{system II}} \\ \quad \text{pigment Q} \longrightarrow \text{cytochrome } b_6 \longrightarrow \\ \quad \text{plastoquinone} \longrightarrow \text{cytochrome } f \longrightarrow \\ \quad \text{pigment 700} \xrightarrow{\text{system I}}, \\ \quad \text{ferredoxin} \longrightarrow \text{transhydrogenase} \longrightarrow \\ \hfill \text{NADP} \end{array}$$

The last three steps are found only in the reduction of nicotinamide adenine dinucleotide phosphate (NADP); other redox compounds are reduced without the need for the two sequential terminal enzymes (A. San Pietro and H. E. Davenport). Pigment Q (for quencher) is an unknown component (proposed by L. Duysens) which is supposed to function in the second light act in a way analogous to P700 in the first, but on a different potential level. The kinetics of pigment Q have been followed from the effects of different lights on the fluorescence of chlorophyll *a* (L. N. M. Duysens and W. Butler). H. Witt identified pigment Q with plastoquinone but his assumption was not unanimously supported—Duysens considered plastoquinone to be an early but not a primary product of the second photoreaction. Biochemical evidence for plastoquinone participation seemed quite firm on the basis of extraction and re-addition experiments (R. A. Dilley, A. Trebst, and H. Witt), but they are not enough to show its exact location. Trebst indicated at least two sites for pigment Q participation, based on differential extraction; Dilley, Crane, and Henninger reported a complex set of specificities for different electron acceptors on adding back varying mixtures of the seven or eight quinones that they isolated from chloroplasts. An entirely different approach, the study of genetic mutants of the electron transport path in *Chlamydomonas*, is beginning to yield information consistent with the general pattern of electron transport previously noted (R. P. Levine).

Although cytochrome b_6 played a large role in Hill's original theoretical proposal and would provide a logical site for ATP formation, evidence for its participation in chloroplast electron transport is as yet almost nonexistent. W. Bonner reported that the cytochrome b_6 absorption spectrum essentially disappears as chlorophyll develops in greening leaves. Only J. Olson, using *Euglena* chloroplasts previously extracted by aqueous buffers, could see a spectroscopic sign of b_6 reduction; here its reoxidation in the dark was very slow.

Most of the schemes currently considered are based on a sequential participation of the intermediates between the two photoacts. Even this was challenged by J. Franck and J. Rosenberg and by B. Kok, who considered the present evidence compatible with the possibility that both photoacts operate rather directly upon only one component or at least in one complex. A third possibility indicated by G. Hoch is that the primary products of each photoact have a rather similar potential; their energies are coupled to raise one of the products to the required (oxidative) strength.

Significant for their absence were decisive data relating to the site of phosphorylation (in the middle of the chain or at the low potential end), the

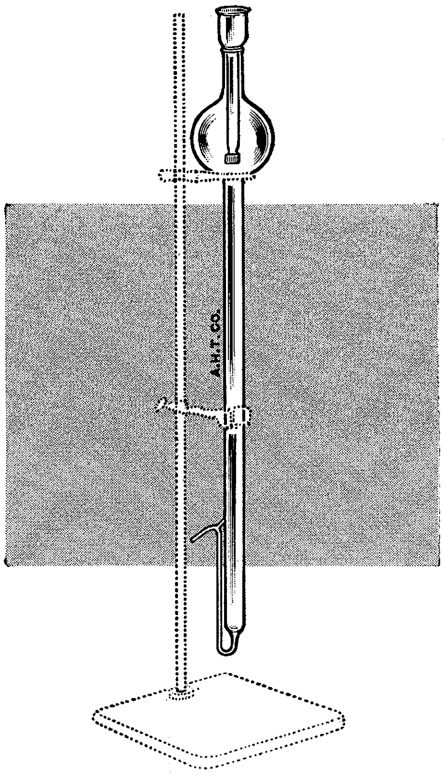


hypothetical existence of a primary electron acceptor for light step I with midpoint potential on the order of −0.55 volts ("X" above), and the details of the oxygen evolution process.

The phenomenon of enhancing one wavelength of light by a second, which led directly to the original concept of two separate pigment systems, was reviewed by Govindjee. J. Myers pointed out that at this level the major remaining problem is that of the mechanism of the division of incoming quanta between the two systems. Two alternative models proposed by Myers ("spillover" versus "separate package") were treated in mathematical terms by T. Bannister and M. Vrooman. It is interesting to note that three separate approaches—polarography with whole cells (C. S. French), measurement of traces of oxygen evolution from isolated chloroplasts as a result of single light flashes (C. P. Wittingham and P. Bishop), and mass spectrometry (G. Hoch)—show that the product of light reaction I is stored and is consumed by the consequences of photoact II.

The improved mass spectrometric techniques of G. Hoch and O. Owens clarified many aspects of the longstanding controversy on the relation between respiration and photosynthesis. Evidently low light intensities inhibit the normal dark respiration, and higher light intensities induce a new and higher oxygen uptake. The earlier inhibition is accomplished by system I alone, and may represent a competition between chloroplasts and mitochondria for phosphate and adenosine diphosphate (ADP); that is, photosynthesis may inhibit respiration for approximately the same reason that respiration inhibits glycolysis.

Turning to reactions of isolated chloroplasts and the nature and function of purified components, K. Fry and A. San Pietro described evidence implicating iron as the electron carrier in chloroplast ferredoxin. D. I. Arnon told how the cyclic electron flow (supporting phosphorylation) can occur by adding large amounts of ferredoxin under anaerobic conditions, in the absence of the second photoreaction. S. Katoh noted the action of plastocyanine, a new copper enzyme, in the electron flow of chloroplasts and G. Forti examined the reactions of extracted cytochrome *f*. Interaction of chloroplasts with added redox components was detailed very thoroughly for numerous soluble quinones (A. Trebst), for indophenol dyes (D. Keister), and



for compounds of natural origin (C. Black and H. Habermann).

In considering the mechanism of the phosphorylation steps, A. Jagendorf and G. Hind reported rather large amounts of a temporary, light-induced, nonphosphorylated intermediate in chloroplasts. The nature and function of this pool both require more clarification. Changes in chloroplast geometry (measured by light scattering) are evidently dependent on the presence of high energy intermediates of the phosphorylation process (L. Packer). Jagendorf and Hind reported similar changes, under quite different conditions, but depending again on the presence of high-energy intermediates. R. Lumry commented on the feasibility of an interconversion of chemical and mechanical energy in the chloroplasts. In reviewing the concept of coupling of electron flow and phosphorylation, M. Avron described a series of uncouplers, noted his recent discovery of a protein coupling factor, and pointed out conditions where coupling is much tighter than heretofore observed.

The general chemical structure of chloroplast membranes (designated "thylakoids") was considered by W. Menke. Among other things the amino acid composition of the fundamental protein of lamellae was found to be remarkably uniform among a very wide range of algae and higher plants. Analytical data, including small angle x-ray scattering, proves that the lamellar structure consists of lipid layers sandwiched between two layers of loosely connected globular proteins. The nature of the lipids present was noted by A. A. Benson. The concept that lamellar structure requires the presence of pigment molecules was severely challenged by L. Bogorad on the basis of electron microscope pictures of a series of mutants in a blue-green alga, all of which had one or more pigments missing and yet develop recognizable lamallae. The microphysical techniques of R. A. Olson lead him to believe that only the long wavelength absorbing, far-red fluorescing form of chlorophyll *a* (presumably the "P700" of Kok, intimately concerned with photoact I) is rigidly oriented with respect to the lamellar structure.

Pioneering efforts at subfractionating chloroplasts for the purpose of obtaining photoactive minute particles or chlorophyll-protein complexes were reported by A. Takamiya *et al.*, M. B. Allen and J. C. Murchio, and J. S. Kahn. Some relevant photochemical

(nonenzymatic) reactions were described briefly (L. Vernon, A. San Pietro and associates). Two aspects of the chemistry of isolated phycobilins, in relation to absorption and fluorescence emission spectra were noted—J. Bergeron on the dimerization of the protein and E. Fujimori on the effects of *p*-chloromecuribenzoate (PCMB). Both authors extrapolate their results to the situation in the intact cell; Bergeron concluded that the fluorescence of blue-green algae at 680 mμ is in part due to phycocyanin itself. After a detailed review of their work with the dimers of chlorophyll, S. S. and M. Brody suggested that the dimer is present and functional in vivo.

The path of phosphorus in *Chlorella* cells was noted by S. Miyachi. The recent kinetic studies of A. Bassham on the path of carbon in photosynthesis show clearly that in vivo the initial carboxylation reaction must lead in part to directly reduced intermediates (either a triose or a hexose phosphate) instead of producing two phosphoglyceric acid molecules as the isolated enzyme does. This concept was reinforced by inhibitor studies of M. Gibbs and by his convincing demonstration that aldolase is absent from blue-green algae. Both authors favored a more direct role for some enzyme-containing sulfhydryl in the initial carboxylation and reduction, and both speculated on the participation of ferredoxin without the use of reduced nicotinamide adenine dinucleotide phosphate (NADPH). N. E. Tolbert and C. P. Whittingham and R. Hiller reviewed the existence of the two-carbon "glycolate pathway" in photosynthesis, again a region not envisaged in the classical schemes of M. Calvin. Both groups pointed out that: (i) the conditions favoring major turnover in the glycolate pathway are just those found ordinarily in nature (high light, low carbon dioxide, and high oxygen), and (ii) it is already known that a very major fraction of oxygen uptake by green leaves in the light occurs through glycolic acid oxidase, a known enzyme in the pathway. The actual site of origin of the original two-carbon intermediate (phosphoglycolic acid, according to Tolbert) is still unresolved.

B. Vennesland reviewed the closely woven concepts of Warburg as to the interrelationships between respiration, carbon dioxide fixation, phosphorylation, the nature of the light reaction, and oxygen evolution. These concepts were found to be consistent with the data obtained directly by Vennesland with isolated chloroplasts, but do not explain many other data presented at this meeting and elsewhere. The ideas of Warburg vary considerably from those of most other workers in photosynthesis, and no reconciliation between them appears possible at the present time.

A great many of the papers attempted to present a brief review and overall perspective of the work from each particular laboratory over the past 2 or 3 years. In view of this, and the rather extensive coverage of active laboratories at the meeting, the volume to be published by the National Academy of Sciences–National Research Council in the near future should be a valuable record of the state of photosynthetic research in the early 1960's.

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Silica

Various aspects of present and future research on silica were discussed at the annual symposium of the American Ceramic Society (New England Section) at Massachusetts Institute of Technology, 29 October.

C. Frondel (Harvard), in his introductory remarks, considered areas where research is still needed for the understanding of the various polymorphs of silica. He revealed that quartz as an entity has been well known for over 2000 years and reviewed the three periods in which the investigation of silica polymorphs has been especially intense. Currently the details of the crystal structure and chemical composition of the silica polymorphs and silica glass are under intense study. Water in silica minerals may occur as tetrahedral OH groups. He noted also that the silicon-oxygen bond lengths vary considerably both in silica and silicates and that symmetrical SiO_4 tetrahedra are only approximations of the true structure. Recent investigations have settled affirmatively the controversies regarding the existence of tridymite in the pure state;