

PHOTOSYNTHESIS

Parallel Photosystems

from a Correspondent

THE process by which green plants capture the energy of the Sun and convert it into chemical energy stored in the form of carbohydrates may involve three separate light reactions, and not two as previously thought.

In photosynthesis, water is split into oxygen and hydrogen ions by light energy from the Sun, and the resulting electrons are used to reduce carbon dioxide to carbohydrate. So far, the most popular model for explaining this transfer of electrons to carbon dioxide involves two separate light reactions acting in series (see D. A. Walker, *Nature*, **226**, 1204; 1970). Photosystem two (S2) is associated with the oxidation of water and the concomitant evolution of oxygen. Photosystem one (S1) accepts electrons from the primary photoreductant of S2 by way of electron carriers and promotes them, by a second light reaction, to the redox level of ferredoxin, an iron containing protein, and thence by enzymic reaction to nicotinamide adenine dinucleotide phosphate (NADP).

Arnon and his colleagues have, since the mid-sixties, considered this scheme to be incorrect and have argued that the two photosystems (S1 and S2) act in parallel rather than in series, when bringing about carbon fixation (*Nature*, **207**, 1367; 1965). They have presented evidence that S2 alone is capable of reducing NADP and that the function of S1 is to produce adenosine triphosphate (ATP) by cycling electrons through a system of linked redox carriers. According to the Benson-Calvin scheme for carbon fixation in photosynthesis, both NADPH₂ and ATP generated in the light are required for converting carbon dioxide into carbohydrate (D. A. Walker, *Nature*, **226**, 1204; 1970). From the energetic point the parallel scheme did not seem entirely satisfactory, for it required that only one photon of red light was available to raise an electron from water to NADP.

In a recent article from Arnon's laboratory (*Proc. US Nat. Acad. Sci.*, **67**, 1404; 1970) additional evidence is presented for the parallel scheme and it suggests that S2 consists of two photo-reactions S2a and S2b. These two photo-reactions are thought to act in series linked by a chain of electron carriers including cytochrome *b*₅₅₉ and the copper containing protein plastocyanin. Photoreaction S2b finally brings about the reduction of NADP by donating its excited electron to ferredoxin. The evidence of Arnon *et al.* for this new scheme comes from studies of fragments of spinach chloroplasts rich in either S2 or S1 activity. The S2 particles were able to photo-oxidase cytochrome *b*₅₅₉ and, moreover, could in the presence of plasto-

cyanin bring about a light induced evolution of oxygen from water and a reduction of ferredoxin and hence NADP. In further agreement with their model they found no evidence that S1 mediated reactions such as the oxidation of the S1 trap (P700) or its associated cytochrome (cytochrome *f*) were involved in the photoreduction of NADP with water.

Although Arnon has been able to place his parallel scheme on a firmer basis energetically by introducing a third photochemical act, the model still does not explain many of the well established observations of other laboratories. For example, it is difficult to reconcile the parallel scheme with the work of Duysens and Ames (*Biochim. Biophys. Acta*, **64**, 243; 1970) who reduced and oxidized cyt. *f* by using light which selectively excited S2 or S1 respectively. Nevertheless, if the claim that S2 can operate independently of S1 in reducing NADP is correct then there is undoubtedly a need to modify the well established series formulation of electron transport in photosynthesis. Only time will tell if the model presented by Arnon and his col-

leagues will be a satisfactory modification.

MARINE FISH

Galway Plankton

from our Marine Vertebrate Correspondent

STUDIES of the planktonic stages of marine fish have been a feature of fisheries research in the North Atlantic for many years, but they have usually been carried out with a view to tracing the early stages of fishes of direct commercial importance. Detailed local studies of the plankton, such as those conducted by the Plymouth laboratory of the Marine Biological Association, are much fewer but they have considerable relevance in that they present an overall picture of the fauna in the surface layers of the sea. An intensive survey of the plankton in Galway Bay and of the west coast of Ireland has been conducted by the staff of the Department of Zoology, University College, Galway, of which the fourth part on the larval and post-larval stages of fishes taken in the plankton be-

Structure and Migration of the Solvated Electron

THE reactions of the solvated electron are the subject of two articles in next Monday's *Nature Physical Science*.

The study of the solvated electron has its origins in the work begun by Kraus at the beginning of this century on the blue solutions formed by dissolving alkali metals in liquid ammonia and amines. Electrical conductivity and other measurements have established that the solvated electron is responsible for the blue colour of these solutions, but, although Platzman predicted some of the properties of the hydrated electron in 1953, it is only in the past decade that the solvation of electrons by polar solvents has been generally recognized.

Reactions of the electron can now be measured routinely, but its structure remains uncertain. Several theoretical models have been developed all of which are quantitatively unsuccessful, particularly in predicting the asymmetry of the optical absorption band. Qualitatively the electron is usually regarded as occupying a cavity in the liquid in which the surrounding molecules are polarized, thus creating a potential well, but it is uncertain whether these vacancies pre-exist or are created by the electron. Work on electrons trapped in viscous super-cooled liquids and glasses supports the former alternative. Furthermore, the absorption band of these trapped electrons can be selectively bleached, by exposure to the appropriate wavelength light, showing that it consists of several overlapping bands which arise through the electron occupying vacancies of different sizes.

Catterall (*Nature Physical Science*,

229, 10; 1971) now suggests that the width of the absorption of the solvated electron in dilute metal-ammonia solutions may also be explained by the occupation of cavities having a (Gaussian) distribution of sizes. From studies of relaxation rates in magnetic resonance experiments Catterall concludes that the electron occupies small vacancies in the liquid, and that the large volume expansion resulting from dissolution of metals in ammonia arises through breakdown of the normal liquid structure surrounding the trapped electron rather than through the creation of large vacancies.

The magnitude and temperature dependence of the diffusion constant of the solvated electron are also important because they indicate whether or not the solvated electron diffuses like a normal solvated ion. Conductivity measurements (Barker *et al.*, *Trans. Faraday Soc.*, **66**, 1498; 1970) show the electron to have a diffusion constant of 4.8×10^{-5} cm² s⁻¹ at 25° C and an activation energy for diffusion of 20 kJ mol⁻¹. In contrast, Cercek reports (*Nature Physical Science*, **229**, 12; 1971) a value of 8.4 kJ mol⁻¹, which is about half that for the self-diffusion of water, and suggests the electron does not diffuse normally. His value is calculated from the activation energies of the reactions of the hydrated electron with a number of solutes having values in the range 9 to 11 kJ mol⁻¹, and assumes these are caused only by diffusion. Logan (*Trans. Faraday Soc.*, **63**, 1712; 1967) has, however, shown that the lowest measured activation energy cannot always be equated with that of the diffusion process.