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Conference report

PHOTOSYNTHESIS SESSION OF THE BRITISH PHOTOBIOLOGY SOCIETY MEETING

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1. INTRODUCTION

This one day meeting was organized by W.P. Williams and was held at Chelsea College of Science and Technology. The photosynthesis session was chaired by M.C.W. Evans and was attended by about seventy persons including Dr. Robin Hill from Cambridge. All the sixteen presentations dealt with various aspects of the light reactions and fell into the general areas of oxygen evolution and photosystem II (3 papers), membrane phenomena and energy conservation (6 papers), electron transport components (2 papers), photosystem I and bacterial electron transport (4 papers) and one paper related to heavy metal effects on photosynthetic electron flow in terms of environmental consequences.

As a framework for reviewing the papers presented the following brief account of electron transport is given. In green plants the non-cyclic sequence of electron carriers responsible for transferring electrons and protons from water to nicotinamide adenine dinucleotide phosphate ($NADP^+$) can be designated as follows:

$$H_2O \rightarrow M \rightarrow Z_2 \rightarrow Z_1 \rightarrow \underset{\text{(PS-II)}}{P680} \rightarrow Q_1 \rightarrow B(R) \rightarrow PQ \rightarrow \text{Rieske} \rightarrow \text{Cyt f} \rightarrow PC \rightarrow$$

$$D_1 \rightarrow P700 \rightarrow A_1\ (\text{chl?}) \rightarrow A_2\ (X) \rightarrow P430\ (B) \rightleftharpoons P430\ (A) \rightarrow Fd \rightarrow FNR \rightarrow NADP^+$$

where: M is the oxygen evolving enzyme, Z_2 and Z_1 are electron donors to the reaction centre of photosystem II (PS-II), P680; Q_1, a quinone, is the first "stable" electron acceptor of PS-II; B (or R) also a quinone and is a two-electron carrier; PQ is the plastoquinone pool; Rieske is the Rieske iron center; Cyt f is a *c*-type cytochrome; PC is plastocyanin; D_1 is an electron donor to the reaction center of PS-I, P700; A_1 is suggested to be a chloro-

phyll (chl) molecule; A_2, P430(A) and P430(B) are iron-sulphur centres; Fd is ferredoxin, and FNR is ferredoxin-$NADP^+$ reductase. In photosynthetic bacteria, there is mainly a cyclic electron flow, the reaction centre will be referred to as just P and electron acceptor quinones as Q_1 and Q_2. Here electrons return to P via cytochromes *b* and *c*.

2. PHOTOSYSTEM II AND ϕ_2 EVOLUTION

Allison Stewart (from the Biochemistry Department, Cambridge) reported on the preparation of an active PS-II particle from a thermophilic blue-green alga *Phormidium laminosum*; her method involved the use of the detergent LDAO (lauryl dimethylamine oxide) at a critical ratio of 3.5 : 1.0 (LDAO : chl), and the use of Sephadex columns to remove free chlorophyll. Her preparation was able to evolve oxygen and had an absorption maximum of 674 nm with 100 chlorophyll *a* molecules per P680. Nugent (University College, London) gave details about a low temperature ESR signal resulting from a component on the water splitting side of PS-II. He tentatively identified this signal to be from Z_2^+ and, thus, suggested it to be the low temperature form of the very fast ESR room temperature signal II_{vf} studied extensively in Sauer's laboratory at Berkeley. H. Metzner (Tübingen, West Germany) presented his arguments against the decomposition of *unbound* H_2O in photosynthesis; his data seemed to be consistent with *bound* H_2O being the immediate precursor of O_2. Moreover, he argued that his flashing light experiments with D_2O- and H_2O-containing samples gave data which did not indicate the direct breakage of OH-bond in O_2 evolution. However, Metzner does agree with the consensus of opinion, that the *ultimate* source of all electrons in photosynthesis is free H_2O, but his recent experiments on the effects of 10 μM CO_2 on chloride-free system leads him to believe that CO_2 may play a role in O_2 evolution in addition to the well established role of CO_2 on the Q, B(R) and PQ side of PS-II extensively studied in the laboratories of Govindjee and of Stemler.

3. MEMBRANE PHENOMENA AND ENERGY CONVERSION

There is increasing evidence that the lipid matrix of the thylakoids plays an important role in regulating photosynthetic electron flow. In particular the fluidity of the lipid phase will affect the way in which intrinsic membrane proteins will interact. W.S. Chow of Imperial College, London, presented data which indicated that the fluidity of the thylakoids could be qualitatively estimated by measuring the polarization of fluorescence of the membrane probe, diphenyl hexatriene (DPH). Increases in lipid rigidity were induced by such treatments as ageing and addition of cholesterol. He reported this increase in membrane fluidity paralleled the inhibition of salt-induced chlorophyll fluorescence changes and the ability of the membrane to stack and unstack in various ionic media. John Bennett (University of Warwick) presented his interesting and intriguing observation that the chloro-

phyll *a*/chlorophyll *b* light harvesting pigment—protein complex (LHC) of thylakoid membranes becomes phosphorylated on illumination. Phosphorylation only occurs as long as coupled electron flow is operative and involves a peptide of approximately 1000—2000 molecular weight protruding at the membrane surface and readily lost by trypsin treatment. A particularly significant finding is that this phosphorylation process enhanced the PS-I/PS-II fluorescence ratio mentioned at 77 K suggesting a possible mechanism for the in vivo control of energy transfer between the PS-II and PS-I pigment beds (that is, spillover). Nigel Holmes (University of Bristol) reported on his experiments using wild type and mutant bacteria which have different levels of light harvesting antenna complexes. He concluded that the electrochromic shift observed with these systems was due to carotenoids associated with the light harvesting complexes absorbing in the region of 800—850 nm (B800—B850) and not associated with B870.

David Crowther (Brookhaven National Laboratories, New York) presented data and a scheme for cyclic electron flow in green plants based on measurements of the time dependence of the 518 nm absorption change (an electrochromic shift indicative of transmembrane potentials with thylakoids) and changes in 9-aminoacridine fluorescence (indicative of changes in Δ pH across membranes) under various conditions (the presence and absence of diuron, dithionite, valinomycin and nigericin). He also gave evidence for the role of cytochrome b_6 in a process operating close to the quinone. John Mills (Glynn Research Labs., Bodmin) gave a very interesting paper in which he presented evidence that the "switching on" of the chloroplast coupling factor in vivo requires the presence of a reducing agent and implicated the importance of thioredoxin in this process. The following paper by Alison Telfer of Imperial College, London, also dealt with chloroplast coupling factor. She reported that the "binding" of CF_1 to the membrane was controlled by electrostatic parameters. Removal of CF_1 from the surface or its rebinding to the surface was sensitive to the cation composition of the medium. When electrostatic shielding of surface negative charges was high this extrinsic membrane protein bound to its specific membrane site and facilitated coupled electron flow. This conclusion was based on the effectiveness of various valency cations to allow rebinding to occur, the order being $C^{3+} > C^{2+} > C^{+}$. She showed that methyl viologen acts as divalent cation as well as an electron acceptor. J.B. Jackson (University of Birmingham) obtained a P/e ratio of 0.5 in contrast to 1.0 in *R. capsulata* cells under optimal dark time between light flashes, H^+ efflux was measured with and without venturicidin, and ATP was measured by injecting luciferin-luciferase into the system. Jackson's results suggest that either there is only a 50% conversion efficiency under optimal conditions or the expected H^+/e and H^+/P ratios of 2.0 are in error.

4. ELECTRON TRANSPORT COMPONENTS

Paul Wood (University of Bristol) stated that mitochondria contain 2 cytochromes *c* (c_1 and *c*) between UQ, cyt *b*, Fe—S complex and cyto-

chrome oxidase, but, purple non-sulfur bacteria have been shown to have only one cyt *c* (c_2) between various carriers and P. This comparison led him to look for an additional cytochrome *c* in photosynthetic bacteria. Using *R. sphaeroides* membrane preparations he succeeded in obtaining two ascorbate-reducible cytochromes *c* in equal amounts: the usual cyt c_2 and another one with a molecular weight of 30,000. His experiments suggest that both cytochromes *c* participate functionally in *R. sphaeroides.* From studies on the reactions of quinones in vitro, Peter Rich (University of Cambridge) concluded that a bimolecular collision process in which a pair of electrons is transferred in two successive steps

$$PQH_2 \underset{H^+}{\rightleftarrows} PQH^- \underset{e^-}{\rightleftarrows} PQH^{\cdot} \underset{H^+}{\rightleftarrows} PQ^{\cdot} \underset{e^-}{\rightleftarrows} PQ$$

should be seriously considered in photosynthesis as an alternative to a 2-electron transport in one jump in view of the absence of a need to propose binding of quinones to proteins to explain the in vivo redox potentials of quinones.

5. PHOTOSYSTEM I AND BACTERIAL ELECTRON FLOW

R. Cammack (King's College, London), based on ESR measurements on *Phormidium laminosum* in 20% glycerol, summarized the present concepts about the electron carriers on the $NADP^+$ side of PS-I. In *Phormidium*, centre B was reduced in preference to centre A. He made the point that there is a magnetic interaction between the centres B and A and that there is no strict sequence between the centres A and B. The centres B (and A) have the following G values: 2.07 (2.05); 1.94 (1.94), 1.89 (1.86) when both the A and B centres were reduced. A new peak appeared with a G-value of 1.92 whose function is not clear.

Hilary Evans (Preston) summarized her results on the centres A and B obtained by Mössbauer spectroscopy — a technique that can look directly at the state of iron in the samples. She established that the centres X, A and B, observed by EPR, must all contain Fe. She further concluded that the centres A and B *do not* interact in apparent contrast to the conclusion of Cammack. Peter Heathcote (University College, London) attempted to identify A_1 by treating, at room temperature, Triton prepared PS-I particles with dithionite and by strong light during freezing; this method partially reduced $A_2(X)$. A new symmetrical ESR signal having a G value of 2.0 of 14 Gauss width was observed. In PS-I particles, prepared by digitonin treatment, a similiar signal with additional structure was obtained with the major G values at 2.0100, 2.0080, 2.0048. This signal was, however, converted into a smooth signal of G value 2.0037 upon treatment with Triton. The latter signal and the 14 Gauss width may suggest monomer chlorophyll to be A_1, but the signals obtained in digitonin particles, as well as in French-press treated particles, suggest further complications and the nature of A_1 remains unknown. A. Vermeglio (from CEA, Saclay, France) presented data on the action of

o-phenanthroline on the quinone side of photosynthetic bacteria. If this compound inhibits between Q_1 and Q_2 then after the 2nd flash there should be no effect on the absorbance change in Q_1 or Q_2 as the centres would remain as PQ_1^-. However, absorption changes in the semiquinone region were not observed after the 2nd flash and Vermeglio concluded that *o*-phenanthroline acts between Q_1 and Q_2 when Q_2 is in the oxidized state. However, if Q_2 is kept in the reduced state, then this compound does not prevent electron flow from Q_1 to Q_2 suggesting that an interaction between Fe (between Q_1 and Q_2?) and Q_2^- does not permit an interaction of the inhibitor with Fe.

6. ENVIRONMENTAL AND POSTERS

Homer (Preston) presented preliminary results on the various photochemical characteristics of Canary grass leaves from lead-tolerant and non-tolerant races. His results indicated that lead may act to block electron flow on the oxidizing side of PS-II. In addition to the verbal presentations there were several posters covering topics such as phase transition in the blue-green algae (W.P. Williams, Chelsea), cation effects on the thylakoid membrane and chlorophyll fluorescence (N.R. Baker, Essex), the redox properties of Q (P. Horton, Sheffield) and the enhancement of photosynthesis by uncouplers (L. Rosa, Oxford).