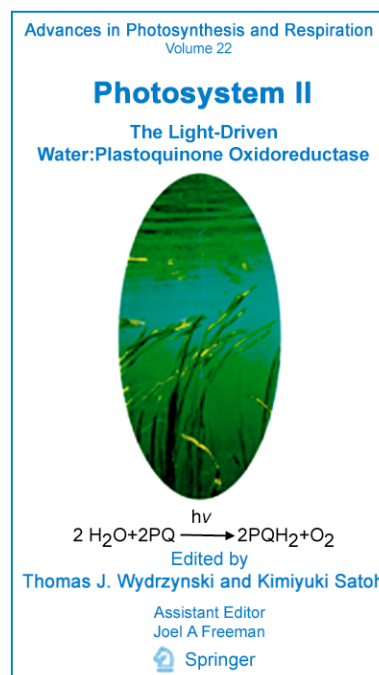


BOOK REVIEW

Advances in Photosynthesis and Respiration (AIPH), (Series Editor: Govindjee, University of Illinois, USA). **Volume 22: “Photosystem II. The Light-Driven Water: Plastoquinone Oxidoreductase,” 2005** (Editors: Thomas J Wydrzynski, Australian National University, Australia and Kimiyuki Satoh, Okayama University, Japan; and Tech. Asst. Editor: Joel A Freeman, Springer); Published by Springer, The Netherlands, ISBN 1-4020-4249-3; Hardbound pp 775 (plus 8 page Index), Price, Euro 295 (approx. INR 18,000/-). A 25% discount is given for International Society of Photosynthesis Research (ISPR) members.

‘If the story is big, the details are of huge importance’. The story of how oxygen gets out of water, which can easily be seen as stream of bubbles oozing out from the leaves of water-plants like *Hydrilla* or *Vallisneria* in sunlight, during photosynthesis, and how molecular oxygen gets converted to water in respiration are extremely important subjects in biology. The main objective of this volume appears to give readers, the nitty-gritty details of the unique biochemical process of splitting of water into oxygen by plants and thereby maintaining atmospheric oxygen, that sustains life and to evaluate the intricacies of the complex enzyme that does this feat.

Photosystem II (PSII) of oxygenic photosynthetic organisms has a unique “enzyme”, a light-driven water: plastoquinone (PQ) oxidoreductase, also named as a “metallo-radical enzyme”. Although PSII was discussed in the previous volumes of AIPH¹, this volume provides comprehensive and critical view on structural, functional and dynamic profiles of “PSII enzyme”—a core complex of mass 260×10^3 kDa. While the previous volumes on PSII were broad and discussed O₂ evolution, the present volume emphasizes on the applications of biophysical, biochemical and molecular biological techniques in deciphering the structure and function of “PSII”. The volume contains 34 chapters contributed by 75 experts including the volume editors and the Series Editor. These chapters have been categorized into 7 parts viz., Introduction; Compositions of constituents; Catalytic organization; Spectroscopic details of



structure and function; Molecular dynamics; Assembly and stability; and Origin and evolution of PSII. Catalytic organization of “PSII-enzyme” is a new feature of this volume.

Introduction (Part I) defines the scope of the volume and provides a vivid account on the conceptual development of PSII and PS II reaction center (RC). Part II, in five chapters, briefs photosynthetic energy metabolism, starting with capture of photons by antennae of PSII, and PSII RC and their functional regulation to environmental fluctuation². The divergent light-harvesting strategies and differential responses to nutritional stresses of a variety of structurally-unique antennae that occur in different plant types, besides green plants light-harvesting complex superfamily with Chl a/b and Chl a/c antenna³ have been well discussed. The structural details of two core antenna-proteins ‘CP43’ and ‘CP47’, which serve as intrinsic components of RC and oxygen-evolving complex of PSII have been highlighted. Their mutations and structural modifications which provide vital clues on the functioning of PSII, have also been thoroughly presented.

The D₁ and D₂ proteins of PSII RC ‘hold’ all the co-factors required for photosynthetic water oxidation. Organization of these proteins is vital for the metallo-radical photochemistry and thus their structural and mutational studies, in recent years have provided wealth of information on the mechanism of water oxidation and its regulation. Mn-cluster ligated to RC-proteins is shielded by extrinsic proteins of PSII, mainly a 33 kDa Mn-stabilizing protein which functions as an enhancer of O₂ evolution and also protects the Mn-cluster. Analyses of the structural details and functional roles of these clusters are of extreme importance and may hold key to providing the novel information on how oxygen gets released from water during photosynthesis. PSII complex contains as many as 20 odd proteins. Genomic and proteomic analyses, in recent years have not only revealed the structural arrangements and regulation, but also their variations in different oxygenic photosynthetic organisms, enabling better understanding of ‘light-driven water oxidation’ process in plants.

The part III comprising nine chapters deals with the functional organization and sites in PSII for electrons and protons transfer. The photophysical properties of protein-pigment complexes, kinetics and energetics of primary charge separation in PSII, the ‘iron-quinone acceptor complex’, and the regulation of “two-electron” gate at acceptor side have been rigorously presented. The structural information from spectroscopy, kinetic studies combined with mutagenesis and modeling provide readers an in-depth understanding of energy transfer in PSII. The PSII-RC contains two redox-active tyrosine residues, present in the D₁ and D₂ proteins, at the homologous locations and play pivotal role in enzymic oxidation-reduction at the donor side of PSII. The kinetics, energetics and mechanism of this oxidation-reduction process have also been discussed in detail.

Water oxidation in photosynthesis to evolve ‘molecular’ O₂ involves light-induced catalysis by four Mn-atom clusters and the associated Ca²⁺ and Cl⁻ ions. A variety of spectroscopic methods to investigate the structural and functional features and oxidation states of Mn have been described. The reactive Mn-cluster with its associated Ca and tyrosyl radical requires a special protein-environment for its function on electron and proton transfers. The nature of ligation of proteins to the catalytic Mn-cluster has been probed, using magnetic resonance as well as

vibrational and optical spectroscopy. The quasi-stable intermediates in catalytic turnover of the water-oxidation complex (WOC) involves four S-states (S₀-S₃), the Kok–Joliot oxygen clock. This clock holds key to complete understanding of photosynthetic oxygen evolution. The co-factors Ca²⁺, Cl⁻ and more importantly, bicarbonate anion still seem to ‘hide’ the “mechanism” of function of ‘light-driven water: PQ oxido-reductase’. Alternatives to ‘Kok’s oxygen cycle’ have been at times considered.

Bicarbonate involvement at the acceptor and donor sides has been widely reviewed⁴. The bicarbonate, besides binding near the non-haem iron on the acceptor side may also be bridging the redox active Mn and Ca in WOC, as well as helping in the assembly of Mn-clusters. Also, electron flow from water to PQ in electron transport pathway, a curious alternate pathway, operates involving β-carotene, a cytochrome b559 and monomeric chlorophyll (Chlz) under illuminated condition. This pathway may function as a protective mechanism under some physiological situations.

Next 6 chapters, in part IV, deal with complementary aspects of elucidating structural basis of PSII-co-factors using vibrational electron paramagnetic resonance, electron microscopic technique, light-induced FTIR difference spectroscopy and laser Raman spectroscopy. These techniques helped in probing the distance and orientation of co-factor molecules and to get a picture of PS II core antenna holocomplex. The 3-D crystal structure of PSII has been resolved at 3.6 to 3.8 Å, with the hope to fathom changes in ‘manganese valencies’, deprotonation and ‘S-states’ of water oxidation cycle. The refined X-ray crystal structure that shows amino acid ligands as well enables visualizing both physical and physiological functioning of PSII. The part III and IV are useful for courses on plant biophysics and physical biochemistry, apart from advanced biology and membrane biology courses.

Part V deals with ‘Molecular Dynamics of PSII’ with a chapter on energy trapping and equilibration for obtaining ‘regulated efficiency’. The role of carotenoids is not limited to photoprotection, but also in PS II assembly. The oscillatory behaviour of ‘Kok–Joliot cycle’, including ‘hits’ and ‘misses’; and the energetic, kinetic and mechanistic aspects of O-O bond formation have been reviewed along with the different ‘models’ proposed.

The penultimate section, part VI, addresses biosynthesis, assembly and steady-state maintenance of the photosystem and its catalytic Mn-clusters. PS II is prone to photodamage, but gets repaired uniquely. It requires low light for its assembly. The role of inorganic co-factors like Mn and Ca in the photo-assembly has been elucidated. These analyses give hope for preparing artificial water oxidizing complexes. Photo-inactivation and reactivation of PSII have agricultural importance, and hence are vigorously investigated world over. The repair and reassembly of photo-damaged PSII, a nine-step co-ordinated process have been discussed well. Studies on these aspects may provide means for developing stress-tolerance crops. Two chapters are devoted to gene expression including light-regulated transcriptional and translational control and post-translational processing of PSII. These studies hold promise for developments in agricultural biotechnology.

The origin and evolution of photosynthetic O₂ are very fascinating topics. Part VII deals with these and also on the comparative chemistry between cytochrome oxidase, where O₂ is converted to water with PSII O₂-evolution chemistry. This section also includes mimicking bacterial reaction centers, design of proteins for electron and proton transfer, and finally making artificial photosystems that would, hopefully, make O₂ and 'hydrogen' from water for clean energy.

An attractive feature of the volume is that it has 16 colour plates and many diagrams. Each chapter provides elaborate account of topics discussed, their current state of understanding and futuristic perspectives. This reminds that "the possession of knowledge does not kill 'your sense' of wonder and mystery; there is always more mystery". In short, readers shall acquire substantial knowledge on the delicate features of the unique 'PSII-enzyme' and appreciate the contributions of a range of techniques from spectroscopy to molecular biology to elucidate it. The authors, Editors and Series Editor have carried out an impressive task in bringing out this fascinating book. The volume is aptly dedicated to Jerry Babcock, who directed the use of fundamental chemistry towards working of cytochrome oxidase and PS II.

The colleges and universities in India and other parts of the world are looking for introducing new integrated inter-disciplinary programmes. This volume shall provide sufficient support to courses on biophysics, photophysics, photochemistry, physical

biochemistry, biotechnology, and nanotechnology. It would encourage research in the interfacial areas, where the physicists and chemists would find plant biologists providing enough insights in unraveling the mysterious process of Nature. Further, the search for "extremophiles" that turn to provide a new direction in the research, as has been done in X-ray crystallographic studies using thermophilic cyanobacterium, has been elegantly shown in this volume. Although the individual reader may find this volume little expensive, it is a worth addition to the collection for the libraries of Departments, Institutes and Universities as well. The readers 'cutting across the fields' shall find this book rewarding and that the uninitiated readers may find a wealth of 'information' on how atmospheric oxygen evolves from green plants and algae. The two eminent Editors, Thomas Widzynski and Kimiyuki Satoh deserve applause for the painstaking efforts on bringing out this magnificent volume. This volume appears to possess a quality, unsurpassed by previous volumes. For the Series Editor, Prof. Govindjee, on his idea of bringing out an excellent AIPH series on photosynthesis and respiration is 'not only rains but pours'; this volume adds a colourful feather on his cap⁷.

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