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Book reviews

Light emission by plants and bacteria. Edited by Govindjee, Jan Amesz and David C. Fork. 1986. Orlando, FL, USA: Academic Press, Inc. XXI + 638 pp. ISBN: 0-12-294310-4. Cloth US$: 85.00.

The book is a compendium of articles written by acknowledged experts on the theme of light emission by whole plant cells and bacteria as well as by sub-cellular preparations derived thereof. It belongs to the *Cell Biology* series of monographs published by Academic Press. Although it touches upon all types of light emission by living organisms, such as photo-, thermo-, and bioluminescence, the majority of the articles deal with the photoluminescence of the photosynthetic pigments in vivo. The book is dedicated to the memory of a pioneer, Warren L. Butler.

Chapters are grouped into six general sections: introduction (130 pp.); light absorption, prompt and delayed emission in vivo (223 pp); bioluminescence (35 pp); light emission from rhodopsins (18 pp); special features of different organisms: relationship of fluorescence to biochemistry and physiology (160 pp); and practical applications (32 pp). There is, also, a foreword contributed by Gregorio Weber, a preface by the editors, a short account of W.L. Butler's early scientific career by William A. Cramer and a subject index.

Chapters in the "Introduction" set up the stage and introduce the symbolic language of what is about to ensue. Quite appropriately, the book opens with a historical account of ideological and technological developments in bacterial and plant fluorescence contributed by L.N.M. Duysens. It touches upon topics recurring throughout the book: spectroscopy of photosynthetic pigments in vivo, kinetics of chlorophyll (Chl) *a* fluorescence, relation of Chl *a* fluorescence yield to photosynthesis, light adaptive processes, as well as upon technological advances for the generation of picosecond excitation flashes, the detection of fleetingly short-lived light signals and their subsequent electronic processing. The same topics are treated by J. Lavorel, J. Breton and M. Lutz, who extend their coverage to include techniques and applications of luminescence and resonance Raman spectroscopy. W.A. Arnold provides historical glimpses on his discovery of delayed light (with B.L. Strehler) as well as on his thermoluminescence studies. J.R. Norris and G. van Brakel introduce the currently prevalent exciton trapping and charge separation model for bacterial reaction centers and digress to describe briefly the potential of magnetic resonance in extracting information about reaction center free radicals. The "Introduction" ends with a chapter contributed by G.S. Seely and J.S. Connoly addressing the spectroscopy of dispersed and aggregated photosynthetic pigments in vitro.

The section entitled "Light absorption, prompt and delayed emission in vivo" pertains to the photogeneration and subsequent fate of electronically excited states of photosynthetic pigments as measured in fractionated photosynthetic systems, such as thylakoids, chromatophores and pigment-protein complexes. N. Murata and Kimuyuki Satoh line up spectral evidence in favor of a small number of specific protein-Chl associations in vivo and discuss such phenomena as the Q_A-linked (Q_A is the primary quinone electron acceptor of photosystem II) and ΔpH-linked quenching, the cation control of antenna size and the State I–State II transitions. I. Moya, P. Sebban and W. Haehnel supply a lucid description of techniques and results of fluorescence quantum yield and lifetime measurements, including pulse fluorometry, phase fluorometry and single photon counting. Results support again the notion of heterogeneity of Chl *a* in vivo, although the spectrally distinct forms may not have actual physical existence. R. van Grondelle and J. Amesz survey the random walk and pairwise excitation exchange models and show how information about the size of the random walk domain can be extracted from exciton-exciton annihilation measurements. H. van Gorkum correlates light-induced kinetics of Chl *a* fluorescence to electron transport down the line from the primary electron acceptor Q_A of photosystem II to the plastoquinone pool that exists between the two photosystems.

In the same section, the properties of Chl triplets generated by intersystem crossing, singlet fission of radical recombination are discussed by A.J. Hoff, who adds an interesting description of the diagnostic power of zero magnetic field resonance techniques (the so-called optically detected magnetic resonance) for reaction center radicals. Delayed fluorescence and thermoluminescence are treated by P.A. Jursinic and by P.V. Sane and A.W. Rutherford, respectively. These singlet-singlet Chl *a* emissions, which trace their origin to charge recombination events involving either the reaction center radical pair (Chl^+-$Pheo^-$ or $BChl^+$-$BPheo^-$, where Pheo stands for pheophytin, BChl for bacteriochlorophy,, and BPheo for bacteriopheophytin) or longer-living metastable states of electron transport intermediates, witness among other things pigment heterogeneity in photosystem II.

Chapters appearing in the section "Special features of different organisms: relationship of fluorescence to biochemistry and physiology" examine the light-harvesting and fluorescence properties (spectra, yields, lifetimes, polarization and kinetics) of photosynthetic bacteria (purple, green and blue-green), of the little known cryptomonads, of algae (red, green and brown), and of higher plant organelles and leaves. J. Amesz and H. Vasmel describe here the properties of the non-oxygenic purple and green photosynthetic bacteria with reference to their taxonomic classification. D.C. Fork and P. Mohanty do the same for phycobilin-containing cyanobacteria, red algae and cryptomonads. Govindjee and Kazuhiko Satoh propose a hypothesis that traces the origin of all present day photosynthetic organisms to a common ancestor and they postulate a Chl *c*-containing prokaryote as the forefather of the Chl *c*-containing brown algae, diatoms, dinoflagellates and cryptomonads. Particularly interesting is the assignment of the fast and slow kinetic phases of Chl *a* fluorescence to ground state electron and proton transport processes. In the last chapter of the section, J.M. Briantais, C. Vernotte, G. Krause, and E. Weis address the properties of higher plant leaves and chloroplasts, including an excellent discussion of the cation-induced fluorescence changes.

While photoluminescence of the protein-comlexed closed or open tetrapyrrole photosynthetic pigments is the major concern of this volume, ancillary light emissive cases are also given some space. Thus, J.W. Hastings discusses the different, enzymatically driven, mechanisms that generate electronically excited chromophores and cause emission of bioluminescence in bacteria and in dinoflagellates. In the first case, it is the mixed-function oxidation of an aldehyde and of a luciferase-bound flavin that generates an excited flavin, while the luciferase substrate in dinoflagellates is a linear tetrapyrrole. Rajni Govindjee and T. Ebrey describe the properties and review the origin of the fluorescence emitted after photoexcitation of bacteriorhodopsin, the widely studied retinal chromoprotein of *Halobacterium halobium*. The emitter is undoubtedly bacteriorhodopsin itself, not a photocycle intermediate, but its exact nature is unknown. Models postulate a weakly-populated excited state, that is different from the one that triggers the photocycle, an excited state tautomer, or even the existence of two ground states for bacteriorhodopsin. The fluorescence properties of rhodopsin, the eye retinal chromoprotein, are briefly reviewed also.

It is true that our technical skills in measuring plant photoluminescence and our ability to interpret it has reached such an advanced stage that we may now begin to think of practical benefits. The possibilities of practical applications are surveyed in the closing but exceedingly interesting chapter contributed by G. Renger and U. Schreiber. Instruments are now commercially available that are suitable for field measurements of the fast light-induced transients of Chl *a* fluorescence. These data enable quantitative estimations of chemical factors, such as atmospheric pollutants, herbicides, soil salinity, as well as of environmental stresses, such as heating, chilling and intense light, that crucially influence phytoproductivity. In addition, qualitative productivity and pollution surveys covering wide areas can be made aerially with the LIDAR (= laser-induced detection and ranging) technique, also based on measurements of photoluminescence.

Photons enter the space matter occupied with a lot of questions of ask, and leave it carrying a lot of answers. The better equipped one is, theoretically and technologically, the more meaningful are the questions one may ask and the more complete are the answers one may get. Optical spectroscopy of photosynthetic pigments in vivo has played a key role in the elucidation of the mechanism of photosynthesis. Indeed, our knowledge about this highly complex, two-tier (excited state and ground state) biological process advanced virtually at the heels of technological innovations concerning the generation, the detection and the electronic processing of photic signals. This progress has been recorded in several memorable volumes of the recent past, few of which I would like to mention here, as I count the present one to be the latest addition to the group. I hasten, nevertheless, to add that the list is personal, biased and far from comprehensive. With these qualifications then, I would mention the three-volume treatise of E.I. Rabinowitch entitled *Photosynthesis and Related Processes* (Interscience 1945, 1951 and 1956); the *Photophysiology* series of monographs, edited by A.C. Giese (Academic Press 1964–1971); the volume *Bioenergetics of Photosynthesis*, edited by Govindjee (Academic Press 1975); the monograph series entitled *Primary Processes in Photosynthesis*, edited by J. Barber (Elsevier 1978–); and the two-volume *Photosynthesis*, edited by Govindjee (Academic Press 1982).

What is new in the present volume that may be worth the attention of the interested scientist? There is a great deal of newer detail, of facts, of information that deepens our understanding of the mechanism of photosynthesis. Speaking more generally, the volume makes apparent that a far clearer physical basis now exists, by which plant photoluminescence may be interpreted, than it existed a decade ago. This derives from progress made regarding the structure of photosynthetic reaction centers, the mechanisms of charge separation and recombination, the resolution of the core and peripheral light-harvesting pigment-protein complexes and their mutual topological relations, as well as from a more complete knowledge of ground state electron transport.

Extensive bibliographies, at the end of each chapter, relate the chapter material to original publications and may serve as a guide for further reading. Cross-referencing among chapters imparts cohesiveness to the book material. It also demonstrates mutual author awareness and witnesses a degree of editorial steerage. The fact that some topics (notably fluorescence kinetics, cation effects and State I–State II transitions) are treated in more than one chapter adds, rather than detracts from the quality of the book since it affords the reader perspective from different optical angles.

In summary, it is a quality, highly informative volume that manages to steer the reader from what is solidly established to the fluid frontline of contemporary research. Authors succeeded, in general, in striking a proper balance between lucidity of presentation and the assignment of credit. This should not be taken to imply that the book is easy to read. It is clearly intended for the specialist and the serious student of photobiology. To this audience, I recommend it strongly.

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