Preface for the ESP Series in Photochemical and Photobiological Sciences

"Its not the substance, it's the dose which makes something poisonous!" When Paracelsius, a German physician of the 14th century made this statement he probably did not think about light as one of the most obvious environmental factors. But his statement applies as well to light. While we need light, for example for vitamin D production, too much light might cause skin cancer. The dose makes the difference. These diverse findings of light effects have attracted the attention of scientists for centuries. The photosciences represent a dynamic multidisciplinary field that includes such diverse subjects as behavioral responses of single cells, cures for certain types of cancer and the protective potential of tanning lotions. It also includes photobiology and photochemistry, photomedicine as well as the technology for light production, filtering and measurement. Light is a common theme in all these areas. In recent decades a more molecular centered approach has changed both the depth and the quality of the theoretical as well as the experimental foundation of photosciences.

An example of the relationship between global environment and the biosphere is the recent discovery of ozone depletion and the resulting increase in high-energy ultraviolet radiation. The hazardous effects of high-energy ultraviolet radiation on all living systems is now well established. This discovery of the result of ozone depletion put photosciences at the center of public interest with the result that, in an unparalleled effort, scientists and politicians worked closely together to come to international agreements to stop the pollution of the atmosphere.

The changed recreational behavior and the correlation with several diseases in which sunlight or artificial light sources play a major role in the causation of clinical conditions (e.g., porphyrias, polymorphic photodermatoses, *Xeroderma pigmentosum* and skin cancers) have been well documented. As a result, in some countries (e.g., Australia) public services inform people about the potential risk of extended periods of sun exposure every day. The problems are often aggravated by the phototoxic or photoallergic reactions produced by various environmental pollutants, food additives or therapeutic and cosmetic drugs. However, if properly used, light-stimulated processes can induce important beneficial effects in biological systems, such as the elucidation of several aspects of cell structure and function. Novel developments are centered around photodiagnostic and phototherapeutic modalities for the treatment of cancer, arthrosclerosis, several autoimmune diseases, neonatal jaundice and others. In addition, classic research areas such as vision and photosynthesis are still very active. Some of these developments are unique to photobiology, since the peculiar physicochemical properties of electronically excited biomolecules often lead to the promotion of reactions that are characterized by high levels of selectivity in space and time. Besides the biologically centered areas, technical developments have paved the way for the harnessing of solar energy to produce warm water and electricity or the development of environmentally friendly techniques for addressing problems of large social impact (e.g., the decontamination of polluted waters). While also in use in Western countries, these techniques are of great interest for developing countries.

The European Society for Photobiology (ESP) is an organization that aims to develop and coordinate the very different fields of photosciences in terms of public knowledge and scientific interests. Owing to the ever increasing demand for a comprehensive overview of the photosciences the ESP decided to initiate an encyclopedic series, the "Comprehensive Series in Photochemical and Photobiological Sciences". This series is intended to give an in-depth coverage over all the very different fields related to light effects. It will allow investigators, physicians, students, industry and laypersons to obtain an updated record of the state-of-the-art in specific fields, including ready access to the recent literature. Most importantly, such reviews give a critical evaluation of the directions that the field is taking, outline hotly debated or innovative topics and even suggest a redirection if appropriate. It is our intention to produce the monographs at a sufficiently high rate to generate a timely coverage of both well established and emerging topics. As a rule, the individual volumes are commissioned; however, comments, suggestions or proposals for new subjects are welcome.

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Volume Preface

The interaction of living matter with electromagnetic radiation in the near-ultraviolet (NUV), visible (Vis) and near-infrared (NIR) regions is a most important topic in life sciences. The radiation from a huge extraterrestrial fusion reactor, the sun, not only provides the unique Gibbs energy for the development and sustenance of almost all forms of life on our planet but also plays a key role in several regulatory functions such as synchronizing biological clocks and information transfer processes (e.g., vision, photomorphogenesis, phototaxis, communication via bioluminescence signals).

It is, therefore, not surprising that the sun played a central role in mankind's cultural development and religious admiration throughout the world, ranging from the great Aton hymn of the old Egyptians, to the worshippers of the sun in India and to the highly advanced ancient Indian societies (Mayas and Incas) in the Western hemisphere.

Among the different light-induced processes, photosynthesis is fundamental and unique because it enables the biological transformation of solar radiation into (electro)chemical Gibbs energy. Furthermore, it is the most abundant chemical reaction on the earth's surface (land and oceans), with an estimated turnover of 300–500 billion tons of CO_2 per year, converted into carbohydrates and subsequent products. The crucial role of photosynthesis can be best summarized in only four words: "Life is bottled sunshine" [Wynword Read, *Martyrdom of Man*, 1924].

Studies on photosynthesis date back to the early days of the development of natural sciences. The fundamental principles of energy transformation in general and photosynthesis in particular, described by the first and second law of thermodynamics, were outlined in the nineteenth century by R.J. Mayer and L. Boltzmann, respectively (Chapter 1). Nowadays, the unraveling of the underlying structural and functional organization of photosynthesis focuses on intensive research activities. The high scientific relevance of topics related to the subject is best illustrated by the impressive list of about 20 Nobel laureates that were awarded the Prize for their work performed in this field, starting with Richard Willstätter in 1915 and Hans Fischer in 1930 and their pioneering studies on the chemistry of chlorophylls as the key pigments of the photosynthetic apparatus [for an excursion into the history of photosynthesis research, I recommend the excellent book *Discoveries in Photosynthesis* (Govindjee, J. T. Beatty, H. Gest, J. F. Allen, eds.), Springer, 2005].

The overall process of photosynthesis consists of several reactions, which take place in quite different time domains, covering a range from femtoseconds (light absorption) up to hours (long-term acclimation) and even days or months (plant growth). Within this wide time region the light-driven reactions leading to the primary metabolites ("energy rich" bound hydrogen and ATP) are the fastest reactions, which are accomplished within milliseconds and referred to as "Primary Processes of Photosynthesis". Research on this topic is not only a fascinating part of pure science but it can also offer nature's masterpiece for solar energy exploitation as a blueprint for the technical development of devices aiming at contributing to solutions of mankind's Gibbs energy demands.

This edition of two volumes is restricted to topics on the "Primary Processes of Photosynthesis". As several books in this field already exist (see, for example, *Advances in Photosynthesis and Respiration*, Series editor Govindjee, Springer), one might ask: Why publish another two? The major reason for doing so is the enormous progress achieved in molecular biology and X-ray diffraction crystallography of membrane proteins during the last two decades, which has enabled, in combination with developments of sophisticated spectroscopic methods of very high time resolution, much deeper insight into the mechanisms and structure of the apparatus down to the level of atomic dimensions. Furthermore, significant advances in the methodology of theory (quantum chemistry, molecular mechanics) offer a new basis for a better understanding of structure–function relationships, including the role of dynamic processes.

This publication is an ambitious attempt to provide a synoptic state-of-the-art picture of the primary processes of photosynthesis by casting together the mosaics of detailed knowledge described by leading experts in the field. Twenty two chapters have been written by 42 authors from Europe, USA, Japan and Australia. The wealth of information appears to be best presented in two different volumes (Parts 1 and 2). Part 1 describes the photophysical principles, photosynthetic pigments and light harvesting/adaptation/stress. It is divided into five sections: Section I is an introduction to the field, giving an overview on the primary processes of photosynthesis in a single chapter presented by G. Renger. Section II also contains a single chapter, by T. Renger, which provides the basic theoretical background of the underlying photophysical principles (excitation energy and electron transfer) for light harvesting and the electron transport chain. Section III describes the properties of the main pigments in two chapters, *i.e.* the chlorophylls in Chapter 3 by H. Scheer and the carotenoids in Chapter 4 by Koyama et al. In Section IV, five chapters deal with light harvesting, and regulatory control of excitation energy fluxes. Chapter 5, presented by Law and Cogdell, provides an insight into the structure and function of the antenna system of anoxygenic photosynthetic bacteria, and in Chapter 6, presented by Mimuro et al., the properties of the antenna system of oxygenic cyanobacteria are described. Morosinotto and Bassi, in Chapter 7, and van Amerongen and Croce, in Chapter 8, summarize our knowledge on the antenna systems of Photosystem I and Photosystem II, respectively, of higher plants. Chapter 9, by Gilmore and Li, presents information on the regulatory control of the antenna function in plants. Section V describes, in a single Chapter 10 by Vass and Aro, the effects induced by light stress.

Part 2 is divided into three sections: Section VI (the numbering is continued from Part 1) is devoted to the structure and function of reaction centers in anoxygenic photosynthetic bacteria and the two photosystems of oxygen evolving organisms. Lancaster in Chapter 11 and Parson in the complementary Chapter 12 summarize the current state of knowledge on the structure and the functional pattern, respectively, of reaction centers in anoxygenic bacteria. Analogously, structure and functional pattern of Photosystem I (PS I) and Photosystem II (PS II) in oxygen-evolving organisms are described in the following five chapters presented by Fromme et al. (Chapter 13: structure of PS I), Setif and Leibl (Chapter 14: functional pattern of PSI), Zouni (Chapter 15: structure of PS II), G. Renger (Chapter 16: functional pattern of PS II) and J. Messinger and G. Renger (Chapter 17: oxygen evolution). Section VII on electron transport chains and photophosphorylation contains four chapters: anoxygenic bacteria are described by Verméglio (Chapter 18), oxygen-evolving cyanobacteria by Peschek (Chapter 19), the cytochrome b_6f complex by Cramer et al. (Chapter 20), and in Chapter 21 Junge summarizes our knowledge on photophosphorylation. In Section VIII, Larkum describes, in Chapter 22, the evolution of photosynthetic organisms.

All the chapters in these two parts provide a modern and updated view of the corresponding topics. Accordingly, this edition is not only a most valuable text for graduate students but it is also addressed to all scientists who are interested in the field of the primary processes of photosynthesis. It is my sincere hope that these two books will entice young people into this exciting research area with the aim of addressing successfully the challenging problems of high relevance that are still awaiting a satisfactory answer.

I have many people to thank. First of all, the authors for their efforts to offer the reader excellent chapters and for their positive responses to my suggestions. Without their invaluable cooperation there would be no books. My thanks also go to Susanne Renger and Solweig Nothing for their continuous help in the preparation of electronic versions of figures and typing of manuscripts, respectively.

I am most grateful to my wife Eva for all her enthusiasm in supporting this work and her invaluable help during periods of frustration and disappointment by sharing her optimism in finally reaching the desired goal.

I wish all readers a pleasant and stimulating journey through the fascinating "world" of the primary processes of photosynthesis.

Gernot Renger