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Walter Harm  
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**IUPAB Biophysics Series**

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The International Union of Pure and Applied Biophysics

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The International Union of Pure and Applied Biophysics

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# Biological effects of ultraviolet radiation

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## FOREWORD

The origins of this series were a number of discussions in the Education Committee and in the Council of the International Union of Pure and Applied Biophysics (IUPAB). The subject of the discussions was the writing of a textbook in biophysics; the driving force behind the talks was Professor Aharon Katchalsky, first while he was president of the Union, and later as the honorary vice-president.

As discussions progressed, the concept of a unified text was gradually replaced by that of a series of short inexpensive volumes, each devoted to a single topic. It was felt that this format would be more flexible and more suitable in light of the rapid advances in many areas of biophysics at present. Instructors can use the volumes in various combinations according to the needs of their courses; new volumes can be issued as new fields become important and as current texts become obsolete.

The International Union of Pure and Applied Biophysics was motivated to participate in the publication of such a series for two reasons. First, the Union is in a position to give advice on the need for texts in various areas. Second, and even more important, it can help in the search for authors who have both the specific scientific background and the breadth of vision needed to organize the knowledge in their fields in a useful and lasting way.

The texts are designed for students in the last years of the standard university curriculum and for Ph.D. and M.D. candidates taking advanced courses. They should also provide a suitable introduction for someone about to begin research in a particular field of biophysics. The Union is pleased to collaborate with the Cambridge University Press in making these texts available to students and scientists throughout the world.

Franklin Hutchinson, Yale University  
Watson Fuller, University of Keele  
Lorin Mullins, University of Maryland  
*Editors*

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## PREFACE

The killing of cells by ultraviolet (or UV) radiation, in particular by wavelengths present in sunlight, has been studied for more than a century. The ultraviolet's mutagenic action was experimentally established not long after discovery of the mutagenicity of ionizing radiations by H. J. Muller in 1927. Concomitantly, UV action spectra for the killing of cells and viruses and for mutagenesis indicated that these effects were due to energy absorption in nucleic acids, substances then known to be part of the chromosomes, and as it turned out later, those actually carrying the hereditary information. Aside from such early roots, however, UV photobiology is a relatively recent area of research, comprising in essence the achievements of the past 20 to 30 years. Its development during this period paralleled the rapid progress in genetics and molecular biology, resulting mainly from the experimental use of microorganisms and viruses.

Basically, research in UV photobiology has employed the radiation as a tool to damage organisms in a fairly specific manner, at least more specific than ionizing radiations do. Investigating the consequences of such damage not only permitted conclusions regarding the UV-absorbing material and the ways in which the damage interferes with vital cellular processes, but also led to the observation of recovery effects. Work by A. Hollaender in the middle 1930s gave the first evidence for them, but their general significance was not recognized until the later forties and early fifties. The study of recovery phenomena indicated that, in contrast to earlier concepts, the eventual fate of an irradiated organism is highly conditional, rather than being fully determined at the time of energy absorption. Not only did these achievements offer explanations for otherwise irreconcilable discrepancies between the results obtained in different laboratories, subsequent studies on recovery phenomena also revealed their molecular basis: the existence of a variety of sophisticated and highly efficient repair processes enabling the cells to cope with otherwise unbearable conditions. They are of great importance in protecting organisms against radiation damage from our natural UV source, the sun, as well as against damage from a wide variety of other agents. Moreover, it is now evident that some of the reaction steps involved in repair play at the same time a significant role in general cellular maintenance processes and such basic phenomena as genetic recombination and DNA replication. The use of UV radiation has been basically involved in these important discoveries.

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When Franklin Hutchinson, the chairman of the Editorial Board of this series of biophysics textbooks, approached me with regard to writing a book on *Biological Effects of Ultraviolet Radiation*, I accepted with mixed feelings. On the one hand, I was grateful for the opportunity to summarize the results, as well as my own views and thoughts, in an area of research that I have been associated with for the past 25 years, and in which my writing had so far been only in the form of original papers and review articles. On the other hand, it was obvious that the task of covering a field in which interpretations and concepts are still in a considerable flux, and to which hundreds of scientists contribute the results of their research almost daily, is a difficult one. My final decision was facilitated by the editor's request that the textbook be short, comprising essentially what he felt I carry around in my head. Although the latter turned out to be too optimistic in many instances, I was aware that the more time-consuming parts of the job would be: (1) the decision as to what one can consider of sufficient importance to provide graduate and advanced undergraduate students, or scientists established in other areas of research, with a useful background for entering this field; (2) the presentation of the material in a form easy to comprehend, particularly with regard to those potential readers unfamiliar with the inherent genetic and quantitative approaches. My apologies, if I have not always succeeded in these respects.

Among the rewards for writing a textbook is the author's satisfaction in presenting the facts, concepts, and his own thoughts in his field of competence in a didactically most desirable form. Full justification of the effort, however, requires the existence of a definitive need for such a book. The implicit criterion that the book must differ significantly from others on similar topics is not difficult to meet in the present case. There exist several volumes with contributions from research symposia and excellent review articles on various aspects of UV photobiology, published in journals, in periodicals, or in the form of multiauthored books. They are invaluable as a source of information for the advanced scientist but necessarily inadequate as introductory texts. A recently published work, *The Science of Photobiology*, edited by K. C. Smith (Plenum, 1977) covers the whole discipline of photobiology, including photosynthesis, photomorphogenesis, bioluminescence, and many other fields, and contains excellent contributions from many authors in their specific areas of competence. But only the chapter "Ultraviolet Radiation Effects on Molecules and Cells" coincides to a major extent with the contents of this book. Among textbooks, *Introduction to Research in Ultraviolet Photobiology* by J. Jagger (Prentice-Hall, 1967) puts its main emphasis on the techniques involved in UV-photobiological research. *Molecular Photobiology* by K. C. Smith and P. C. Hanawalt (Academic Press, 1969) covers a similar area, as does this book. However, almost 10 years have passed since publication of *Molecular Photobiology*, and in their contents the

*Preface*

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two books complement one another in several respects. Unquestionably, the emphasis on biological problems in the present book reflects the author's own research preference and his original training as a biologist.

The first three chapters of the book are designed to provide the reader with the background in chemistry and physics essential to an understanding of the biological effects, to which all of the remaining 10 chapters are devoted. The reader may feel that Chapters 7 and 8, dealing with recovery, repair processes, and related phenomena observed after UV damage, are treated in more detail than seems appropriate in comparison with other chapters. Perhaps this amounts to overemphasis of my own research area. But in all fairness, one can probably say that during the past 10 to 20 years hardly any other branch of UV photobiology contributed more to our general biological knowledge than the study of repair and recovery.

It is my pleasure to acknowledge the help of many colleagues, and the publishers of their work, for the kind permission to use their graphs or other illustrations in this book. The names are too numerous to mention them all here; acknowledgments are given at the appropriate places. Particular thanks are owed Dr. Franklin Hutchinson for the encouragement to my writing, and my colleague Dr. Claud S. Rupert, with whom I have had for the past 15 years close scientific relations in several areas covered by the book. These resulted in a number of joint publications as well as in an earlier attempt at writing together a comprehensive monograph on UV photobiology of microorganisms. We abandoned this effort, simply because the literature was turning out results faster than we were able to digest them for the purpose of writing, taking into account all other commitments and problems at a newly established university campus. Nevertheless, this apparently futile exercise was of considerable help in the preparation and writing of the present text, notably the first three chapters, which cannot deny the physicist's influence.

My thanks also include Dr. Michael H. Patrick for critically reviewing several chapters of the book, and Mr. H. Thomas Steely, Jr., a graduate student in the Molecular Biology Program at The University of Texas at Dallas for reading the manuscript and giving me his views as a potential user of the textbook. I am particularly indebted to Sally Rahn for secretarial help and for the typing of the manuscript.

Walter Harm

August 1979.