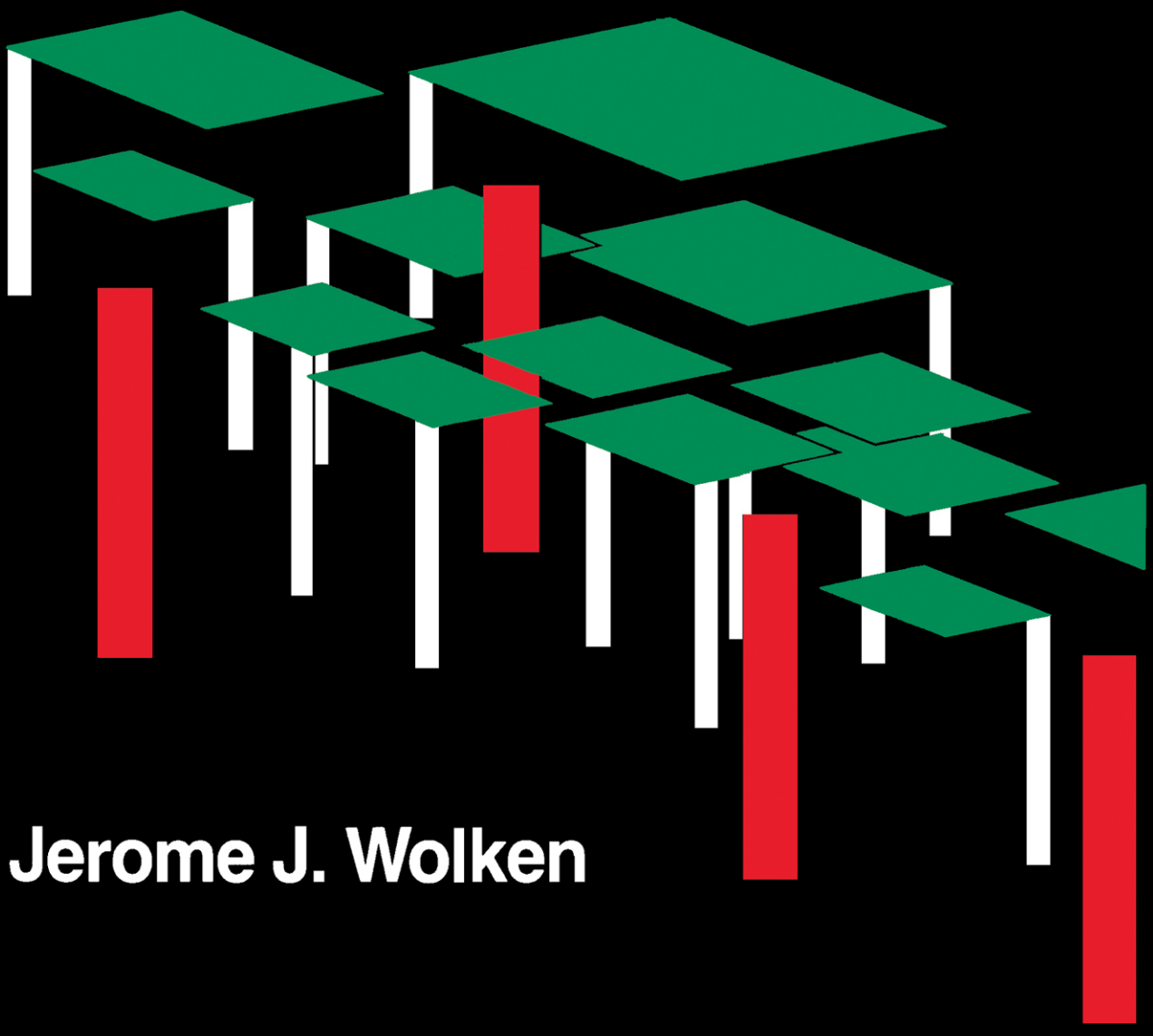
# Photoprocesses, Photoreceptors and Evolution



Jerome J. Wolken

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**The World is full of mysteries. Life is one.**

J. B. S. Haldane (1966)

# Contents

# Preface

In this monograph I have summarized a part of my experimental work on photoreceptors and photoprocesses of plants and animals. I have emphasized the important role that visible radiation has played in the development of photoreceptor systems, hence, in the evolution of life on earth.

I began these studies some two decades ago by asking questions about the effects of radiation on the behavior of living organisms: What kind of photoprocesses go on when cells are excited by light? What kind of photosensitive pigments are used in these photoprocesses? What type of photoreceptor structures evolved?

To put these studies into historical perspective, I chose as a starting point the year 1859, the publication date of Charles Darwin's "*The Origin of Species by Means of Natural Selection.*" In the more than a century which has elapsed since Darwin's publication, our ideas about the origin of life and evolution and our understanding of living processes have come a long way: from the understanding of the genetic mechanisms beginning with Mendel in 1866 to the elucidation of the genetic molecule of life, DNA, by Watson, Crick, and Wilkins in the 1950's.

To gain some feeling for this period of history, during 1970 I repeated in part Darwin's voyage on the Beagle (1831–1836) to South America and then to the Galapagos Islands where I observed firsthand the terrain and the plants and animals that continue to thrive on these islands. This experience inspired me to begin writing this monograph.

In 1971, on sabbatical leave from my university, I proceeded to University College London, where Thomas Huxley (1825–1895) lectured. Among those attending his lectures was Charles Darwin, and Huxley remained a friend and supporter of Darwin throughout his life. Darwin later lived on Gower Street, where a plaque reads, "Darwin lived here 1838–1842," and where more recently J. B. S. Haldane and J. D. Bernal speculated about the nature of life and its origin.

I then proceeded to Paris to obtain some feeling for the work of Pasteur. At the Pasteur Institute, I examined the records of his experiments which led

to the refutation of the concept of the spontaneous generation of life and to his studies of crystals of biological origin. The Museum of Natural History in the Jardin des Plantes also provided an opportunity to examine the two volumes of Lamarck's "Philosophie Zoologique" (1809) on the inheritance of acquired characteristics.

While in Peru I became fascinated with the Incan sun god mythology. This led me back to South America in 1973 and to travels through Mexico to compare the ruins and temples to the Sun of the Incas to those of the Mayans, Toltecs, and Aztecs.

All of these experiences permitted me to indulge and relive a part of history.

I have set about trying to arrive at some basis as to why life on earth as we know it is possible, and whether it was the radiation from the sun and the development of photoreceptor systems that has made life possible. Therefore, the underlying theme which I have tried to develop in this monograph is that visible radiation has played a profound role in the evolution of life on earth. Whatever the environmental conditions were which shaped the molecules necessary for life, once the molecules were formed into specific structures they became ordered within a cell and became functional. Certain molecules were particularly favorable for biological processes and specifically for light absorption. Once functional, they helped determine the behavior of the organism through a variety of light-driven reactions.

Photobiologists have greatly advanced our knowledge of photoprocesses in living systems. This book was not written for these specialists, but for those students and scientists who want to obtain some idea and understanding of the photobiological world. I have emphasized directions researchers have taken to understand the phenomena, particularly my own approach. I hope the text raises questions in the minds of the readers, and so will point out many areas yet to be explored. Above all, I hope that it will present a glimpse of the beauty, the excitement, and mysteries that can be found in the world of light we live in.

**Jerome J. Wolken**

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Some of the experimental work was presented in my previously published books and in scientific journals. I would like to thank the publishers Appleton-Century-Crofts, New York; Charles Thomas Publishers, Springfield, Illinois; Van Nostrand Reinhold Company, New York; and Academic Press, New York for permission to reproduce figures and tables from my previous publications in this book.

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I would also like to thank and acknowledge those who have contributed photographs for use in the figures: Professor Sidney Fox, University of Miami, Miami, Florida (Figure 2.2); Dr. P. Guérin de Montgareuil, Atomic Energy Commission, Cadarche, France (Figure 2.4); Dr. K. Mühlethaler, Eidgenossische Technische Hochschule, Zurich, Switzerland (Figure 5.6); Professor David Dennison, Dartmouth College, Hanover, New Hampshire (Figure 6.2b); Professor Richard Eakin, University of California, Berkeley, California (Figure 9.3); and Dr. T. Kuwabara, National Institutes of Health, Bethesda, Maryland (Figure 10.7b). Data taken in part or adapted from other sources are acknowledged in the legends for figures and tables and in the references.

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# I
# Introduction

Most cultures offer mystical and mythical accounts of the supernatural creation of life. The Judeo-Christian tradition has an account in the first book of Moses, Genesis, Chapter I, of the creation of earth in six days:

> In the beginning God created the heaven and the earth. And the earth was without form, and void; and darkness was upon the face of the deep. And the Spirit of God moved upon the face of the waters.
>
> And God said, *let there be light*: and *there was light*. And God saw the light, that it was good; and God divided the light from the darkness.

And, we are told, that beginning on the third day of creation, God brought forth living creatures: first plants, then fishes and birds, then land animals, and finally man. This biblical story dominated man's thinking on earth history from the Middle Ages to nearly the close of the eighteenth century.

Light—the sun—has from man's earliest records and biblical times been associated with life. Long before the advent of Christianity, ancient civilizations throughout the world were sun worshippers. The rituals and beliefs of ancient civilizations placed the sun and fire gods in preeminent positions. But the beliefs enshrining these gods and myths are the very beliefs that now underlie our convictions of the balance of nature and the uniqueness of life.

How remarkable that the science of today should develop on the intuitions of the past; for the deeper we delve into the origin and evolution of life, the more clearly life emerges as a light-mediated phenomenon.

Ideas about the creation of life and evolution have occurred to many civilizations throughout human history. They appear in Greek writings beginning with Aristotle in the fourth century B.C. with the view that life evolved gradually out of primeval slime.

The Kabbalists, a mystical group of Hebraic origin in the fifteenth and sixteenth centuries, held a philosophy that linked light with creation. Light was a force to bring order and structure. They believed that in addition to the direct light being absorbed there is a reflected light—a blue energy which permeates the universe and which forms a field around living beings. This reflected light can reascend through a whole series of steps very much like fluorescence. Needham (1956), a well-known biochemist and historian of science, believes it may well turn out that the "correlative thinking" of the Kabbalists had more influence on scientific minds in the dawn of modern science than has generally been credited to them.

Evolution was not a new idea when Darwin presented it in 1859. For the idea was already expressed in the middle of the eighteenth century by Diderot and in the writings of Maupertuis (1756), of Buffon (1797–1807), and of Erasmus Darwin (1794), the grandfather of Charles Darwin. Pre-Darwinian evolutionary theories presupposed a short geological time span which would not allow sufficient time for gradual evolution to operate. When geologist Sir Charles Lyell (1830–1833) amassed evidence for the long duration of earth history, he became convinced that geological phenomena could best be explained by natural forces acting over eons of time—a view that came to be termed Uniformitarianism. The first and second volumes of his "Principles of Geology" concerning the modern changes of the earth and its inhabitants appeared in 1830 and 1832, respectively. The great impact of Lyell's "Principles of Geology" on the scientific world at that time is evidenced by the fact that Darwin carried this book with him on his voyage on the *Beagle*. When Louis Agassiz (1840) showed that glaciers were a large-scale earth-moving agency, especially during the glacial ages, the Uniformitarianism school began to develop and to dominate the science of geology as well. Immanuel Velikovsky (1955) conjectured that the solar system is not immutable. He rejected the uniformitarian view of slow continuous change and advocated a thesis of cataclysmic events which interrupted the evolutionary path. He viewed the development of life on earth as a discontinuous process and produced evidence that twice in man's recorded history (1400–1500 B.C. and 700–800 B.C.) there were massive perturbations caused by the near collision between the earth and the comet Venus, and later by the near pass of Mars. Recent discoveries, for example, of volcanic ash layers interlayered