

PREFACE

Biology, the study of life, is a vast and complex subject and one in which knowledge is expanding rapidly. In writing this book, we have considered the needs of instructors and students confronted by a great range of topics. It has been our aim to provide a reliable, clear guide to all of the major areas usually addressed in a full-scale introduction to biology.

Interactions within and between organisms are many and varied, and biological processes occur at many levels of organization. We have given particular attention to concepts that are central to understanding processes at these different levels. Among them are cellular energetics (especially basic thermodynamics, the chemiosmotic model, and photophosphorylation); cellular physiology (especially the mechanisms of resting and action potentials and of muscle contraction); genetics, including both Mendelian genetics and the varied mechanisms of recombination in prokaryotes; the mechanisms of evolution; and the interactions among organisms that structure ecological communities. In our treatments of these topics we often show both the processes involved and how they adapt organisms to their environments. We have taken great care throughout the book to achieve high standards of clarity and accuracy, even though the need to simplify many of the presentations has required us to leave out some details necessary to a more advanced and complete understanding of the subject.

In dealing with some topics—such as photosynthesis, bacterial genetics, neurobiology, and ecology—we have elected to cover more material than is found in most introductory texts. In so doing, our aim was to arrive at greater clarity of presentation by thoroughly explaining inherently demanding material before moving on to related topics. We would have liked to have the space to show both the historical development and the experimental or observational basis of the major ideas of each of the subdisciplines of biology; we have compromised by emphasizing these approaches only in certain parts of the book. Microbial genetics and the molecular biology of the gene were selected as topics for a more detailed historical treatment, and we hope that this will impart some sense of the adventure of “doing” science. The experimental evidence underlying current knowledge is scattered throughout the text—see

especially Chapter 8 (Photosynthesis), Chapter 11 (Nucleic Acids as the Genetic Material), Chapter 16 (Plant Development), Chapter 21 (Animal Development), and Chapter 31 (Origins).

A review of hundreds of course outlines showed there is no single order of presentation of biological material that meets the needs of all teaching situations. Indeed, we had minor disagreements about sequencing of chapters in the book, and both of us have presented a number of topics in sequences different from those we use in our own teaching. But, as a result, all the chapters are written in a way that will allow instructors to select their own favored path through the material. Within the six different parts of the book, many of the chapters do build upon previous chapters in the same part to allow a more comprehensive development of the material. Throughout the book, numerous cross-references direct the reader to helpful information elsewhere.

Chapter 1 gives a brief overview of the history of our planet and then considers the nature of science, and of biology as a particular science. A few fundamental terms and concepts, referred to throughout the book, are introduced here.

Part I, The Cell, begins with an introduction to those principles of chemistry that are *essential* for an understanding of general biology. The selection of chemical topics is strictly limited to those used explicitly in this book. The structures and functions of prokaryotic and eukaryotic cells and of their membranes are treated thoroughly. The last three chapters of Part I introduce the basic concepts of energy and enzymes and develop them to provide a thorough background in bioenergetics.

Part II, Information and Heredity, introduces chromosomes, nuclear division, genetics, and molecular biology, concluding with considerations of cell differentiation and immunobiology. The material in Part II requires only the chapters on elementary chemistry as background. Mendelian genetics is presented before microbial and molecular genetics, but the chapters could be used in different sequences without difficulty.

In accordance with the wishes of a majority of instructors, animal physiology is presented separately from plant

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and fungal physiology in Part III, *Multicellular Life*. Part III begins with a chapter that introduces the general aspects of multicellularity and provides an overview of the fungal, plant, and animal kingdoms to orient the student. Those instructors who wish to teach individual plant and fungal chapters together with the corresponding animal chapters will find it easy to do so. Part III focuses on such topics as reproduction, development, transport, nutrition and digestion, and osmotic balance and excretion.

Part IV, *Integration and Behavior*, deals first with animal hormones, neurobiology, sensory systems, and muscles and other effectors. Building on this material, it proceeds to a consideration of animal behavior, with a concluding emphasis on social behavior.

Part V, *The Diversity of Life*, begins with an essay on paleobiology and the origin of life, followed by an introduction to the principles of taxonomy and phylogeny. The bulk of Part V consists of chapters on the major groups of organisms, emphasizing the richness of living things—their evolution, structure, physiology, and life cycles. Some courses treat the diversity of life before the topics we have covered in Parts III and IV. Part V can readily be used in this manner.

Part VI, *The Strategy of Evolution*, deals with mechanisms of evolution, speciation, and ecology, approached from both population and community viewpoints. The book concludes with a chapter on biogeography. As with Part V, the material in Part VI can easily be taught earlier in the course if the instructor so desires.

An enormous amount of effort has been invested in creating or selecting over 1000 illustrations for this book. In writing captions for them we have opted in many cases for a thorough discussion, in the belief that only a very clear understanding of the figures will aid comprehension of concepts. Because the main concepts in the book are presented in figures and captions as well as in the text, students with a visual orientation should find this book appealing.

Previews, Summaries, Readings, and Study Questions are incorporated into each chapter to help students master the material. Dozens of concept boxes occur throughout the book, enriching the basic textual material. Great care was given to making both the glossary and index functional tools. A comprehensive Student Study Guide and Instructor's Manual—both prepared by a small team of biologists

assembled by P.S. Associates—accompany this book, and 120 Transparency Masters selected from the line art in the text are available to adopters.

We have been fortunate in having had unlimited access to written material and illustrations in the book *Life on Earth*, Second Edition, by E. O. Wilson, T. Eisner, W. R. Briggs, R. E. Dickerson, R. L. Metzenberg, R. D. O'Brien, M. Susman, and W. E. Boggs (Sinauer Associates, 1978). Most of these authors have also served as manuscript reviewers for our book.

Many scientists contributed, as reviewers, to the development of this book. Their help was invaluable, for the breadth of material dealt with here far exceeds the range of our personal expertise. The reviewers have helped weed out inaccuracies and misconceptions and have helped us to organize the material both to facilitate student understanding and to bring the treatment into line with current thinking by leading investigators. Those who participated in the reviewing process are listed at the end of this Preface. To all we extend our warmest thanks for their time, care, and (in most cases) tolerance. Without their help this book would be a different one, and an inferior one. In particular we thank Nancy Clark, Preston Cloud, Mark Dubin, Robert May, Robert Metzenberg, David Shappirio, and David Woodruff for reviews of exceptional thoroughness and for providing highly detailed and explicit recommendations for improvement. Jean DeSaix read the entire manuscript, lending continuity to the effort.

We have enjoyed working with the personnel of Sinauer Associates Inc. and Willard Grant Press. Andy Sinauer and Carl May contributed in numerous ways. They read and edited key chapters for clarity and accessibility to beginning students, ferreting out ambiguities invisible to us. Their influence is also reflected in topic and illustration selection in many parts of the book.

November 10, 1982

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CHAPTER ONE

THE SCIENCE OF BIOLOGY

At some time around 18 billion years ago, a mighty explosion is thought to have occurred; and all matter that was then present began to spread apart at a great rate. The universe is still expanding today. The noise of the original explosion—the “big bang”—can still be “heard” in the form of a cool light radiation permeating all of space, a trace that can be detected by any radio telescope. The big bang sent gases hurtling in all directions—perhaps to expand until the end of time, perhaps to collapse together from gravitational attraction and repeat the process in a never-ending cycle of bang and collapse. For countless years after the bang, clouds of gases formed by chance and collapsed upon themselves through gravitational attrac-

tion, forming the galaxies, which are great clusters of hundreds of billions of stars (Figure 1). Among the billions of galaxies is our own, the Milky Way.

A brief history of Earth

Somewhat less than 5 billion years ago, toward the outer edge of the Milky Way, our solar system (the sun, Earth, and our sister planets) took form. A popular current view is that most, if not all, planets were built up into clumps of solid matter by the gravitational attraction and aggregation of cold dust particles. As Earth grew slowly by this process, the weight of the outer layers compressed the interior of the planet. This pressure and the energy from radioactive decay heated the interior until it melted. In this liquid, the settling of the heavier elements led to a fluid iron and nickel core with a radius of approximately 3700 kilometers. Around the core lies a 3000 kilo-

FIGURE 1 THE BIRTHPLACE OF STARS

The central portion of the great nebula in the constellation Orion is thought to be a “nursery” for new stars. Here the density of the nebula’s gases is above the critical limit necessary for star formation.

meter-thick mantle of dense silicate materials. Over the mantle is a lighter crust, over 40 kilometers thick under the continents but thinning to 5 kilometers under the ocean floor.

Earth's original atmosphere, consisting largely of hydrogen, was lost because it could not be held by the gravitational field; that is, our planet was once a sterile, rocky ball with neither atmosphere nor oceans. Gradually, gases from the mantle and crust formed a new atmosphere. Water vapor from the interior condensed into seas. Lightning and other energy sources converted atmospheric gases into simple organic molecules, and these dissolved in the seas (Figure 2).

The pattern of sea and land in those distant times was very different from what it is today. The crust of Earth floats on the semifluid mantle; currents of man-

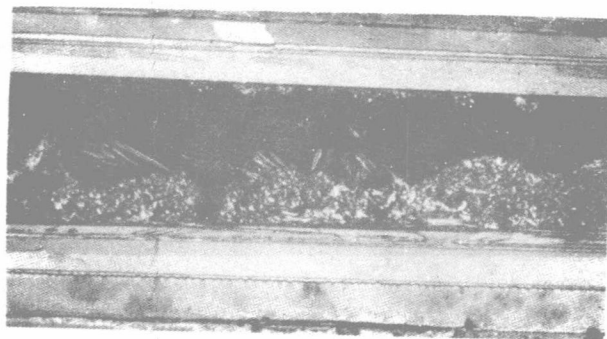


FIGURE 2 EARLY ORGANIC MOLECULES

These crystals of urea represent just one of the many organic substances formed when electricity is sparked through a mixture of gases similar to those that must have existed in the atmosphere of primitive Earth.

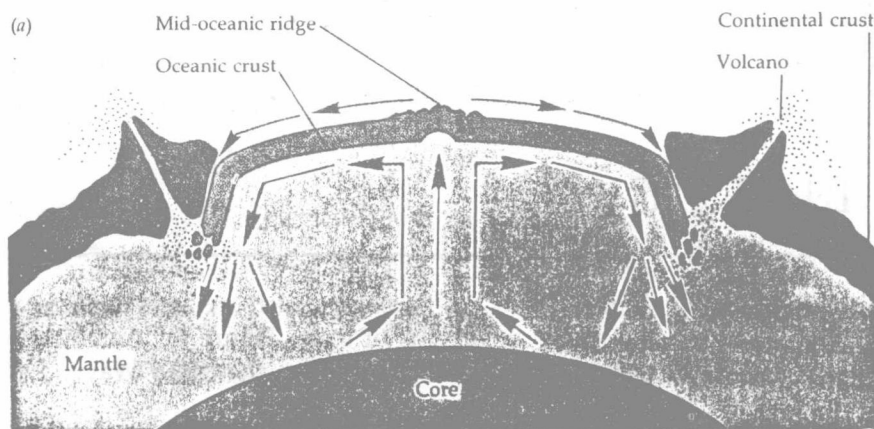


FIGURE 3 EARTH'S DYNAMIC SURFACE

(a) Mantle material pushing upward from the core of Earth forms the mid-oceanic ridges. As the material deflects to either side beneath the ridge it carries the relatively thin oceanic crust with it, resulting in a spreading of the sea floor. Tremendous heat and pressure build up where spreading oceanic crust dives beneath the heavier continental crust, and this causes volcanos near the continental margins. (b) Areas of sea floor created in the last 75 million years are shown in color; in contrast, very little new continental area (black) has been formed during this time.



the material flow up from the core, expand to the sides, and sink again into the interior, with the crust riding on the flowing mantle (Figure 3). One such upwelling is occurring beneath the mid-Atlantic Ridge, with a flow to the east and west of about a centimeter per year. Therefore, the Americas are slowly drifting away from Europe and Africa. The drifting of the American continental plates against the Pacific Ocean plate has given rise to the Rocky Mountains and Cascades in North America and the Andes in South America. Since Earth's beginning, its crust has been in constant motion. Seabeds have been lifted up and folded into mountain ranges, then gradually eroded down into plains, which have been flooded again by the ocean.

Thus, the stage on which the drama of life was to be played was a water-covered planet with shifting land masses. Some time around 4 billion years ago, the first actors appeared on stage. The oldest rocks we can find on Earth (over 3.5 billion years old) bear traces of living things (Figure 4). Eventually, the primitive oceans teemed with life; but the land, which was bathed in deadly ultraviolet radiation, remained nearly as sterile as the moon. Life was confined to depths below 5 meters in the ocean or to muds and shaded areas, which were protected from ultraviolet radiation by the absorbing shield of water.

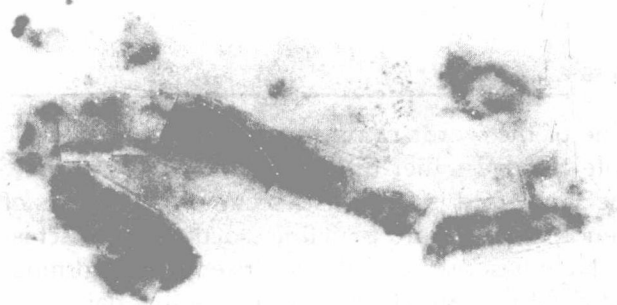


FIGURE 4 THE EARLIEST LIFE

The filamentous structures seen here are from the Warrawoona Group formation in Western Australia. This rock, a chert, is 3.5 billion years old, so these structures may represent a form that was among the earliest living things.

As life continued, the atmosphere gradually changed: photosynthesis by some of the creatures in the oceans, along with nonbiological events in the upper atmosphere, contributed to the production of oxygen gas. The oxygen, in turn, gradually contributed to an ozone layer in the upper atmosphere; and the ozone blocked some of the most damaging wavelengths of ultraviolet radiation coming from the sun. When this happened, life was able to spread to shallow coastal waters and eventually to the dry land itself, without the deadly prohibition of radiation damage.

Life evolved and the land was colonized long before the continents reached their present (and still-changing) positions. The positions of the continents in relation to one another and their movements apart have had an important influence on the geography of life on Earth. Throughout the history of the planet, there have been dramatic changes in global climates. Great ice ages developed, tying up huge quantities of water in glaciers and lowering sea levels and the temperatures of both land and sea. During warmer epochs, the ice completely disappeared, and mild climates prevailed even at high latitudes. The last few million years of Earth's history have been ones of great climatic changes, and it was during this period that *Homo sapiens*—the species that produced science—evolved.

Science as a form of human behavior

As far as we know, science is a uniquely human activity. No other animal practices science. But what is science? Science, contrary to much popular opinion, is not a collection of facts about the world. Science is a *process*, a form of human behavior. Science is what scientists do. It is a specific way, or a number of ways, of discovering things about the universe.

The goal of science is to discover information about the world so that our predictions about the future become more accurate and, hence, more useful. This book is essentially a statement of what kinds of predictions about the future biology can make today. Tomorrow's predictions will be somewhat different.

In general, the process of science goes something