FIFTH EDITION

BIOLOGY

RAVEN
JOHNSON

BIOLOGY

Fifth Edition

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BIOLOGY, FIFTH EDITION

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Preface

Biology was published in 1986 and, in the dozen years since its initial publication, has sold almost half a million copies. These have been exciting years for the science of biology, marked by great advances in many fields. The twin impacts of gene technology and evolutionary thinking have literally transformed the science of biology. In the last year alone, great strides were made in understanding AIDS and developing therapies for cancer, in sorting out the role of productivity in promoting ecosystem stability, and in tracing human origins in Africa. Much of the excitement inherent in scientific advance is reflected in controversial reports that have received considerable publicity. Recently, for example, we saw the reported cloning of an adult sheep, the suggestion of ancient life on a Mars rock, and the Nobel Prize recognition of a claim that mad-cow disease is caused by infectious proteins called prions.

The need to keep *Biology* current with these rapid advances is an obvious reason why we revised this text again this past year. A second and equally important reason is that the way biology is being taught has also undergone a sea change. There is far more emphasis today on the teaching of concepts than there was a dozen years ago, and this has led us to make significant changes in how we present material. Technology plays a greater role in teaching than it used to, both with interactive CD-ROMs, and more recently with the wealth of information that can be accessed via the internet.

The Approach of this Revision

Our approach to revising *Biology* has been guided by five considerations, each of which has influenced in a significant way how we have revised each chapter of this book:

1. **Focus on concepts.** Throughout the text we attempted to emphasize even more strongly the ideas of biology, the conceptual framework that is the core of what we want students to learn. Our efforts to reorganize the contents of each chapter into conceptual modules, discussed on the facing page, were in large measure driven by our desire to more strongly emphasize concepts, and particularly to bring out clearly the conceptual skeleton of the chapter.
2. **Reinforcing ideas.** The most effective way to learn biology is to frame the consideration of new material in terms of what has already been taught. Thus the idea of chemiosmosis, introduced in the discussion of membrane proteins in chapter 6, is subsequently used to explain a key aspect of how cells harvest energy in chapter 9, and form ATP in photosynthesis in chapter 10. The mechanisms used by cells to control the cell cycle, outlined in chapter 11, play a central role in the discussion of molecular mechanisms of cancer in chapter 17. What you learn of viruses in chapter 29 plays a key role in understanding AIDS in chapter 56.
3. **Emphasizing relevance to students.** Because so much of what is going on in biology today directly affects the lives of students, we attempted to present very clear explanations of these key issues. The physiological nature of drug addiction, the way in which cigarette-induced mutations disable cell-cycle control mechanisms, the effects of alcohol on fetal development—these and other issues are discussed explicitly and in detail.
4. **Keeping up with new developments.** The ability of biologists to study cells in molecular detail continues to revolutionize biology. Much of what is important in cell and molecular biology today had not even been anticipated a few years ago.
5. **Careful editing.** The fifth edition has gone through a scrupulous review process employing experienced instructors as well as a large cadre of expert scientists to eliminate inaccurate information or misstatements.

Guiding Themes

Evolution is the core of the science of biology, and from the first words we wrote, has always been a central theme of *Biology*. Evolution provides a context for understanding broad biological phenomena, such as the marked differences in anatomy and physiology among the vertebrates. It also provides a context for exploring the details of quite specific processes, such as the rapid evolution of the HIV virus during the course of an AIDS infection.

Exploration—the way in which scientists investigate the unknown—is a key element of our presentation of biology. Throughout this revision we provide detailed explanations of how experiments have led to our knowledge of life's processes. We chose the cover of this edition to highlight this exploration. Hidden within the image are many elements not immediately obvious at first look. Examine the cover closely for faces!

Structure-and-function provides an orientation for examining how cells and multicellular organisms *work*. The cause-and-effect relationships that underlie anatomy and physiology are a core element in organizing how we present much of the material in this text. Understanding such mechanisms provides an important element of integration as students learn biology.

What We Did in this Revision

Learning Modules

A key element in our attempt to direct student focus toward concepts has been to reorganize the internal structure of each chapter into a series of discrete learning modules, each occupying one or two pages (a few use more), and ending with a summary. The concept outline that appears at the beginning of each chapter thus represents the conceptual skeleton of the chapter, allowing students to readily grasp how the concepts relate to one another and to the overall theme of the chapter.

This sort of modular organization has been used for several years in a variety of biology texts. It has proven a very effective way to point students toward the key ideas on which they need to focus. At first glance it might appear too confining an approach for a majors text like *Biology*, but we were surprised to find how naturally the material fell into this organization. The material was in almost all cases already arrayed into conceptual blocks, as this is the natural way to teach biology—making the individual treatments fit on one or two pages neatly was largely a matter of adjusting the sizes of figures. In practically no case was material cut to make a treatment *fit*. Far more often, we found ourselves adding new material. So the entire previous edition is still here, and even more. It is just presented in easy-to-grasp pieces. Traditionally, page layout happens late in the production process, long after the authors are finished with the manuscript. Beginning each major topic at the start of a page, the hallmark of this modular organization, would be practically impossible under that arrangement. In this revision, by contrast, each page of each chapter was layed out by the authors as we revised that chapter. Content and presentation were no longer independent, but rather part of the same creative process. We feel it has made for a much more effective teaching tool, while not in any way compromising content.

Expanded Coverage

In this revision we have greatly expanded our coverage of botany to eight full chapters. One four-chapter part, Plant Form & Function, covers elements of plant anatomy and physiology, and another, Plant Growth & Reproduction, covers plant reproduction and development, including a chapter devoted specifically to plant molecular biology. We have also greatly expanded our coverage of ecology, adding significant coverage of many current issues. Population and community ecology, weak points in previous editions, have been particularly strengthened.

In every other chapter of the text, we have added material where significant advances have taken place, from our understanding of how the cell cycle is controlled, to recent findings about the course of human evolution. Few chapters escaped significant improvement in coverage.

New Art Program

When *Biology* was first published in 1986, it was the first full-color majors text ever, although that is hard to comprehend in today's world of splashy five-color texts. In intervening years we have added to the art, improving individual pieces but inevitably introducing a variety of styles and conventions. In this revision we have gone back and started from scratch, introducing an entirely new art program. Every figure in the text has been reconsidered and redone, so that all illustrations are now consistent in style as well as content. Biological molecules and cell structures, for example, now are consistently color-coded to aid in student comprehension. Cross-sections of biological membranes look the same wherever they are encountered, and so do other elements of cell and body structure. This approach enrolls visual learning as a powerful ally in the teaching process.

Technology

In the last decade, and particularly in the three years since the last edition of *Biology*, sweeping changes in the use of technology have greatly altered how biology is taught in our classrooms. While the initial loudly-trumpeted advent of laser discs had little impact (thousands of extra images added little worth to biology teaching, just as a painting is rarely improved by giving the artist more paint), fully interactive CD-ROMs that allow students to explore freely and carry out meaningful experiments are now making real contributions to biology teaching in classrooms all over the country.

You will find a new CD-ROM tutorial available with this fifth edition of *Biology*. The *Essential Study Partner* (ESP) is available **free** with the fifth edition of *Biology* and contains high quality 3-D animations, interactive study activities, illustrated overviews of key topics in the text, and supplementary quizzing and exams that students will find extremely valuable. This is a study tool that your students must have, so they receive it free.

An even greater—in fact, explosive—impact is being had by access to the internet. Every text now has its own web site. Our web site, http://www.mhhe.com/biolink, provides a wealth of opportunities to the student and teacher. These include readings, sample tests, and other elements traditionally provided in study guides, as well as a wide range of other enrichments. The three most important, in our judgment, are monthly **updates** written by us that provide the student with current information about rapidly-changing areas of biology, **internet links** provided with each chapter that let students see the range of internet opportunities available, and **enhancement chapters** written by us that allow students and instructors to explore rapidly changing areas of biology in more depth. The three enhancement chapters included with this edition are *Conservation Biology*, *Dinosaurs*, and *The Revolution in Taxonomy*. We did not wish to lengthen an already-long text, and so have placed these chapters on our website, http://www.mhhe.com/biolink, where anyone using our text will have access to them.

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Acknowledgments

We have been teaching biology together for 26 years, and are consistently surprised, each and every year, by how much fun it is. This book has been part of that fun, written in the spirit that biology ought to be engaging and interesting as well as comprehensive and authoritative. This fifth edition of *Biology* would not have been possible without the contributions of many others. Stuart Fox made major contributions to the animal biology section, James Traniello to the animal behavior chapters, and Don Briskin & Margaret Gawienowski to the chapter on plant molecular biology. Kingsley Stern provided detailed reviews of the botany section, and teachers around the country made numerous suggestions that have improved the book substantially. Every one of you has our heartfelt thanks.

A major feature of this edition has been the reformatting of the presentation into conceptual modules. This formidable task would not have been possible without the effort of Megan Jackman, our on-site developmental editor. Her intelligence and perseverance played a major role in the high quality of this book.

As any author knows, a textbook is made not by a writer but by a publishing team, a group of people that guide the raw book written by the authors through a year-long process of review, editing, fine-tuning and production. This edition was particularly fortunate in its book team, led by Elizabeth Sievers, a developmental editor who proved both a delight to work with and a reliable guide to the complicated process of getting the book out on time and in the best possible shape.

As always, we have had the support of wives and family who have seen less of us than they might like because of the pressures of getting this revision done. As this is the fifth edition of *Biology*, they have become accustomed to the many hours this book draws us away from them, a hidden price of textbook writing of which they are fully aware.

Acknowledgments would not be complete without thanking the generations of students who have used the many editions of this text. They have taught us at least as much as we have taught them.

Finally, we need to thank our reviewers. Every text owes a great deal to those faculty across the country who review it. Serving as sensitive antennae for errors and sounding boards for new approaches, reviewers are among the most valuable tools at an author's disposal. Many improvements in this edition are the direct result of their suggestions. Every one of them has our sincere thanks.

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Significant Changes to the Fifth Edition

In keeping with the goals of this revision, you will find significant changes throughout the text. In reviewing the table of contents, you will see that we've expanded the text from 55 chapters to 60 chapters. This change was in direct response to reviewers who said that we shortchanged some key areas in the fourth edition. We expanded the coverage of the viruses and simple organisms (Part VIII) from four to five chapters. We expanded the coverage of plants from five to eight chapters. We expanded the coverage of animal diversity, devoting entire chapters to both arthropods and echinoderms. We also expanded the coverage of animal form and function, devoting entire chapters to both respiration and circulation.

We changed the format and organization of the text to follow a "learning modules" approach. The material is presented according to key concepts that are numbered for ease of identification. The student can get an overview of the chapter content by reading the key concept statements and the headings that follow each statement. A walkthrough of the learning modules is presented on the next page.

Other significant changes to the content are listed below:

How Genes Work (chapter 15)

Ribosomal RNA now includes the E site; the treatment of transcription is greatly expanded, covering a two-page spread; and the discussion and illustrations of translation have been updated to include the action of the ribosomal E site.

Cancer (chapter 17)

This chapter now includes a new section on how cancer is caused by chemicals, including a new table of chemical carcinogens in the workplace; a new table of cancer-causing genes in humans; new findings on lung cancer, including how smoking damages the gene *p 53;* and a new section with up-to-date information on curing cancer with molecular therapies targeted to different stages in the cell cycle and with a genetically-engineered virus.

Populaton Ecology (chapter 23)

Many new additions to this chapter include: the levels of ecological organization are listed and defined, a discussion of metapopulations has been added, demography has been expanded to a two-page spread that includes a new section of life tables, a new two-page spread on life history tradeoffs and adaptations has been added, the discussion of *r*-selected and *K*-selected adaptations has been revised, and human population growth has been updated with new figures and a new table.

Community Ecology (chapter 24)

New additions to this chapter include: resource partitioning, including character displacement in Darwin's finches; a two-page spread on biodiversity and community structure, including species richness and species diversity discussions and trends; biogeographic patterns of species diversity; island biogeography; an expanded and revised section on succession; and preserving biodiversity.

Viruses (chapter 29)

The lytic and lysogenic cycles are discussed in the text; the new finding of the mechanism of how cholera-causing bacteria are transformed by a bacteriophage has been added; the HIV infection cycle has been updated to include the latest findings on co-receptors and the latency period; a new section has been added on the future of HIV treatment, including art and discussions of the variety of methods that are being researched; and the section on prions and viroids has been updated to include prion formation and mad-cow disease.

Plant Molecular Biology (chapter 40)

This entire chapter is new and includes up-to-date discussions, art, and photos covering the size, organization, and mapping of plant genomes; plant tissue culture methods and applications, and genetic engineering in plants.

Animals (chapter 41)

New additions to this chapter include a new phylogeny of the animals, and an illustrated table of the major animal phyla, a section discussing and illustrating four key transitions in body plan, an updated classification of the cnidarians, and a discussion with a photo of the newly discovered animal phylum Cycliophora.

The Immune System (chapter 54)

A new section on the evolution of the immune system discusses and illustrates the progression from invertebrates to vertebrates and the types of immune cells that have evolved; an illustrated table of the cells of the immune system has been added; the discussion of B cells has been revised and includes a clear layout of the humoral immune response, a discussion of how the diversity of antibodies is produced by somatic rearrangement, and the uses of the antibodies in medical diagnoses; an up-to-date AIDS epidemic chart has been added; and a new finding of how DNA vaccines may get around antigen shifting is included.

Cellular Mechanisms of Development (chapter 57)

A new section on the reversal of determination discusses the recent animal cloning experiments, and a new section on aging discusses and illustrates recent theories of aging.

A Guide to the "Learning Modules"

You will find the chapters in this edition organized in conceptual units. Each chapter presents three or four general concepts that together explain the key ideas that the chapter addresses. Each of these concepts is presented as a numbered statement, and is explored in a series of learning modules; each module is typically a one or two page spread (some use three or four pages) ending with a statement summarizing that module. The numbered general concepts explored in specific supporting modules provide the student with a clear outline of how the various topics covered in the chapter relate to one another, revealing in a direct way the conceptual skeleton of the chapter, so students don't miss the "big picture."

Here's How It Works

Each chapter opening page contains a Concept Outline that presents an overview of the conceptual units in the chapter. A portion of the Concept Outline for chapter 6 is reproduced here. The Key Concepts are numbered and the supporting topics are listed under the key concepts and provide the student with an overview of contents discussed in the chapter.

6

Membranes

Concept Outline

6.1 Biological membranes are fluid layers of lipid.

The Phospholipid Bilayer. Cells are encased by membranes composed of a bilayer of phospholipid.

The Lipid Bilayer Is Fluid. Because individual phospholipid molecules do not bind to one another, the lipid bilayer of membranes is a fluid.

6.2 Proteins embedded within the plasma membrane determine its character.

The Fluid Mosaic Model. A varied collection of proteins float within the lipid bilayer.

Components of the Cell Membrane. Cell membranes are embedded with a variety of proteins.

Examining Cell Membranes. Visualizing a plasma membrane requires a powerful electron microscope.

Kinds of Membrane Proteins. The proteins in a membrane function in support, transport, recognition, and reactions.

Structure of Membrane Proteins. Membrane proteins are anchored into the lipid bilayer by their nonpolar regions.

The numbered concepts begin the discussion of a general concept with a conceptual unit covering usually one page or a two-page spread. The first topic under the concept 6.1, "Biological membranes are fluid layers of lipid," is reproduced here.

6.1 Biological membranes are fluid layers of lipid.

The Phospholipid Bilayer

The membranes that encase all living cells are sheets of lipid only two molecules thick; more than 10,000 of these sheets piled on one another would just equal the thickness of this sheet of paper. The lipid layer that forms the foundation of a cell membrane is composed of molecules called **phospholipids** (figure 6.2).

Phospholipids

Like the fat molecules you studied in chapter 3, a phospholipid has a backbone derived from a three-carbon molecule called glycerol. Attached to this backbone are fatty acids, long chains of carbon atoms ending in a carboxyl (—COOH) group. A fat molecule has three such chains, one attached to each carbon in the backbone; because these chains are nonpolar, they do not form hydrogen bonds

The concept module "The Phospholipid Bilayer" ends with a summary statement shown below, as do all of the topics, whether they cover one page or two or more pages. This makes it very clear to the student where a topic begins and ends.

phospholipid molecules that make up the lipid bilayer, the membranes of every cell also contain proteins that extend through the lipid bilayer, providing passageways across the membrane.

The basic foundation of biological membranes is a lipid bilayer, which forms spontaneously. In such a layer, the nonpolar hydrophobic tails of phospholipid molecules point inward, forming a nonpolar barrier to water-soluble molecules.

The organization of the material into conceptual units is carried through to the end of the chapter. The chapter summaries at the end of the chapter are organized as a "Summary of Concepts" according to the "Concept Outline" found at the beginning of the chapter. Each numbered concept is followed by summary statements of the material found in the conceptual unit.

Summary of Concepts

6.1 Biological membranes are fluid layers of lipid.

- Every cell is encased within a fluid bilayer sheet of phospholipid molecules called the plasma membrane.

6.2 Proteins embedded within the plasma membrane determine its character.

- Proteins that are embedded within the plasma membrane have their hydrophobic regions exposed to the hydrophobic interior of the bilayer, and their hydrophilic regions exposed to the cytoplasm or the extracellular fluid.
- Membrane proteins can transport materials into or out of the cell, they can mark the identity of the cell, or they
- Osmosis is the diffusion of water. Since all organisms are composed of mostly water, maintaining osmotic balance is essential to life.

6.3 Bulk transport utilizes endocytosis.

- Materials or volumes of fluid that are too large to pass directly through the cell membrane can move into or out of cells through endocytosis or exocytosis, respectively.
- In these processes, the cell expends energy to change the shape of its plasma membrane, allowing the cell to engulf materials into a temporary vesicle (endocytosis), or eject materials by fusing a filled vesicle with the plasma membrane (exocytosis).

A section entitled "Discussing Key Terms" is far more than a list of key terms in the chapter. This section discusses the significance of the term within the context of the material covered in the chapter.

Discussing Key Terms

1. **Lipid bilayer** The foundation of the plasma membrane is a sheet composed of two layers of phospholipids, with the lipids oriented so that their hydrophobic ends face the interior of the sheet. The interior is thus very nonpolar, creating an effective barrier to the passage of polar substances.
2. **Transmembrane proteins** Numerous proteins are anchored in the plasma membrane by nonpolar segments that pass through the nonpolar interior of the bilayer. Some transmembrane proteins transport substances into and out of the cell, others act as receptors for chemical signals from other cells or the
4. **Osmosis** Net movement of water across a membrane. When two aqueous solutions are separated by a membrane that restricts the free passage of solutes, water diffuses across the membrane in the direction of higher solute concentration.
5. **Endocytosis and exocytosis** In endocytosis, portions of the plasma membrane invaginate and fuse, trapping a volume of extracellular liquid and its contents within a vesicle. Similarly, in exocytosis, a vesicle merges with the plasma membrane and discharges its contents to the exterior.
6. **Active transport** The movement of certain substances

Aids for Students and Instructors

Technology

We offer students and professors various technology products to support the fifth edition of *Biology*.

Essential Study Partner (ESP) CD-ROM This CD-ROM tutorial supports and enhances the material presented in the fifth edition of *Biology*. The ESP is offered free with the text and will enhance student learning with the use of high quality 3-D animations, activities that require the student to be active in the learning process, module and unit quizzes that take the student back into the material on the CD to review immediately, and illustrated overviews of key topics. Students will find the ESP to be a very valuable study tool.

Visual Resource Library CD-Rom

The WCB/McGraw-Hill *Visual Resource Library* CD-ROM for *Biology* contains nearly all of the illustrations found in the fifth edition. The CD-ROM contains an easy-to-use program that enables users to quickly view images, and easily import the images into PowerPoint to create multimedia presentations or use the already prepared PowerPoint presentations.

In addition to this text-specific *Visual Resource Library* CD-ROM, we offer two additional CD-ROMs, *Visual Resource Library* for Botany and for Environmental Science. Instructors can enhance classroom presentations by using images from these two CD-ROMs.

The Dynamic Human CD-ROM Version 2.0

This guide to anatomy and physiology interactively illustrates the complex relationships between anatomical structures and their functions in the human body. Realistic 3-D visuals are the premier feature of this exciting learning tool.

Explorations in Human Biology CD-ROM; Explorations in Cell Biology and Genetics CD-ROM

These interactive CDs, by George Johnson, feature 33 different interactive modules that cover key topics in biology.

Virtual Physiology Laboratory CD-ROM

This CD-ROM features ten simulations of the most common and important animal-based experiments ordinarily performed in introductory lab courses. The program contains video, audio, and text to clarify complex physiological functions.

Life Science Living Lexicon CD-ROM

by William N. Marchuk, Red Deer College

A Life Science Living Lexicon CD-ROM contains a comprehensive collection of life science terms, including definitions of their roots, prefixes, and suffixes as well as audio pronunciations and illustrations. The Lexicon is student interactive, providing quizzing and notetaking capabilities. It contains 4,500 terms, which can be broken down for study into the following categories: anatomy and physiology, botany, cell and molecular biology, genetics, ecology and evolution, and zoology.

Exploring the Internet on the Raven/Johnson Web Site http://www.mhhe.com/biolink

This text-specific site has been developed exclusively for users of the fifth edition of *Biology*. When visiting the site, students can access additional study aids including quizzes, explore links to other relevant biology sites, catch up on current information, and pursue other activities, including content updates and enhancement chapters.

Life Science Animations 3-D Videotape

The *Life Science Animations* 3-D videotape contains 42 high-quality 3-D animations. These animations bring visual movement to biological processes that are difficult to understand. These 42 animations also appear as part of the *Essential Study Partner* CD-ROM, which provides students with a wonderful reinforcement of concepts and biological processes.

Life Science Animations Videotape Series (6 tapes)

Complex processes such as active transport and osmosis come to life in this series. Students can now review more than 65 animations (in the six-tape set) of the most difficult to learn concepts.

Biology Start Up Software (Mac Only)

This 5-set computer tutorial has complete coverage of basic biological principles such as cellular respiration and cell division.

Math Prep for Biology Software

With this computer tutorial, students are given practice with their math skills through biology-specific math applications. This tutorial allows students to master their math skills for further life science study.

Customization

Chapter-by-chapter customization allows you to customize *Biology* to fit your ideal course. Select only the chapters you use, and WCB/McGraw-Hill will bind them in full color. Contact your WCB/McGraw-Hill sales representative for more information or call 1–800–228–0634.

Additional Textbook Aids

Course Solutions. To help instructors incorporate technology and additional study aids into their course, a text-specific *Course Solutions* manual is available. Organized by chapter, the *Course Solutions* offers suggestions on how ancillaries can be used in lecture and as enhancements outside of lecture.

Student Study Guide, written by Margaret Gould Burke and Ronald M. Taylor, contains chapter overviews for review and page-referenced key terms as well as student exercises in the form of fill-in-the-blank, matching, multiple-choice, and essay questions. Complete answers and explanations for the exercises are provided at the end of each chapter.

Biology Laboratory Manual, a full-color lab manual written by Darrell S. Vodopich of Baylor University and Randy Moore of the University of Louisville, contains approximately fifty laboratory exercises. The lab manual is customizable by chapter in full color and is accompanied by a *Laboratory Resource Guide.*

Transparency Set of 300 acetates contains 300 images from the text. The text contains an entirely new art program so this set of transparencies will be completely new.

Instructor's Manual and Test Item File, written by Linda Van Thiel of Wayne State University, contains chapter synopsis, chapter objectives, key terms, chapter outline, instructional strategy, and a list of related visual resources. The manual also provides lists of biological supply companies, and media resources as well as answers to the review questions in the text. The *test item file*, prepared by L. Rao Ayyagari of Lindenwood College, is available in softcover or on disk *(Microtest)* in Mac and Windows platforms. The Test Item File contains an average of forty questions per chapter in the form of fill-in-the-blank, multiple-choice, and matching.

Additional Supplements

How Scientists Think
by George Johnson

A paperbound text describing twenty-one experiments that have shaped our understanding of genetics and molecular biology. It fosters critical thinking and reinforces the scientific method.

The AIDS Booklet
by Frank D. Cox

This booklet describes how AIDS and related diseases are commonly spread so that readers can protect themselves and their friends against this debilitating and deadly disease. This booklet is updated quarterly to give readers the most current information.

Basic Chemistry for Biology, second edition,
by Carolyn Chapman of Suffolk County Community College

A self-paced book that leads students through basic concepts of inorganic and organic chemistry.

How to Study Science, 2nd Edition
by Fred Drewes, Suffolk County Community College

This excellent workbook offers students helpful suggestions for meeting the considerable challenges of a college science course. It offers tips on how to take notes, how to get the most out of laboratories, and how to overcome science anxiety. The book's unique design helps students develop critical thinking skills while facilitating careful notetaking.

Critical Thinking Case Study Workbook
by Robert Allen

This ancillary includes 34 critical thinking case studies that are designed to immerse students in the "process of science" and challenge them to solve problems in the same way biologists do. The case studies are divided into three levels of difficulty (introductory, intermediate, and advanced) to afford instructors greater choice and flexibility. An answer key accompanies this workbook.

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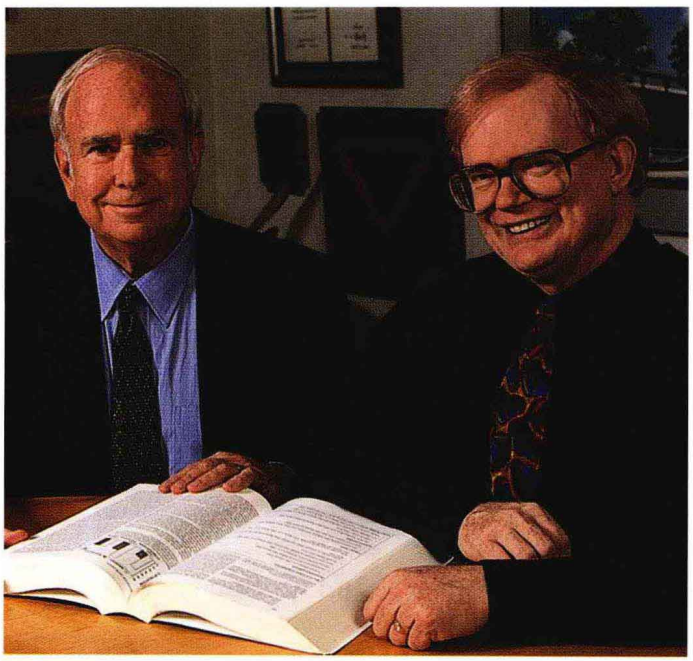
About the Authors



Peter Raven (left) and George Johnson

Dr. Peter H. Raven is director of the Missouri Botanical Garden and Englemann Professor of Botany at Washington University. Dr. Raven oversees the Garden's internationally recognized research program in tropical botany, one of the most active in the world in the study and conservation of imperiled habitats. A distinguished scientist, Dr. Raven is a member of the National Academy of Science and the National Research Council, and is a MacArthur and a Guggenheim fellow. He has received numerous honors and awards for his botanical research and work in tropical conservation.

In addition to coauthoring this text with Dr. George Johnson, Dr. Raven has authored fifteen other books and more than 450 articles.

Dr. George B. Johnson is professor of biology at Washington University in St. Louis, where he has taught undergraduates for 26 years. He regularly teaches general biology courses for majors and non-majors and has recently taken on two large biology courses, one focused on the biology underlying key current issues, the other on the biology of dinosaurs. Also professor of genetics at Washington University's school of medicine, Dr. Johnson is a student of population genetics and evolution, renowned for his pioneering studies of genetic variability. He has authored more than fifty scientific publications and seven texts, including *The Living World* (a very successful non-majors biology text) and two widely-used high school biology textbooks. Dr. Johnson has also pioneered the development of interactive CD-ROMs for biology teaching.

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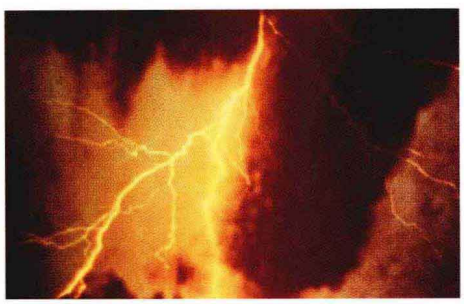
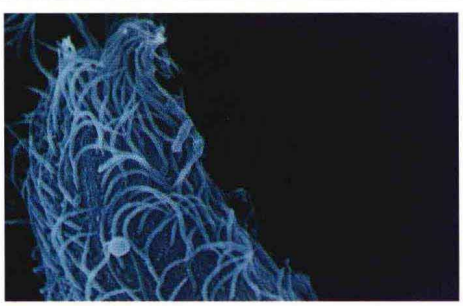
Section A General Principles

Chemical Biology



Part I The Origin of Living Things 1

Cell Biology



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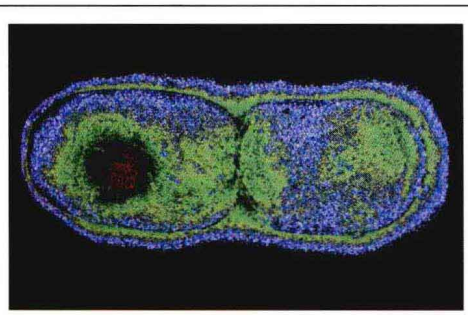

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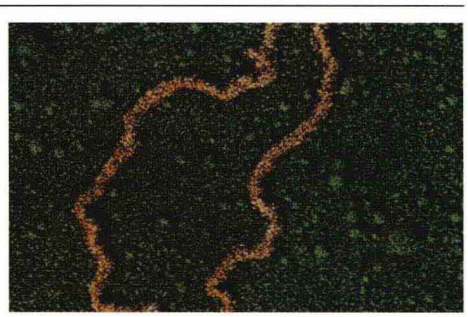

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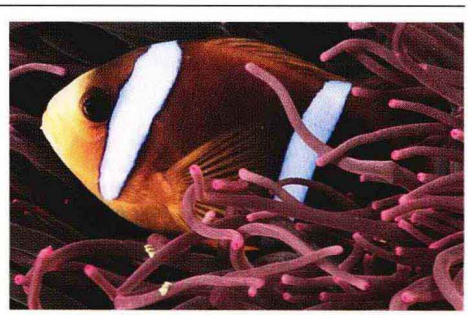

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Chemical Biology

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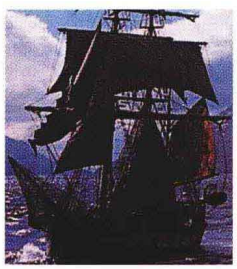
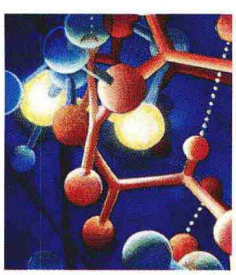


1 ***The Science of Biology*** ***1***

Science is the process of testing ideas against observation. Darwin developed his ideas about evolution by testing them against a wealth of observation. In this text science will provide the framework for your exploration of life.

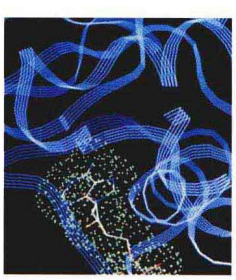
1.1 Biology is the science of life.
1.2 Scientists form generalizations from observations.
1.3 Darwin's theory of evolution illustrates how science works.
1.4 This book is organized to help you learn biology.



2 ***The Nature of Molecules*** ***19***

Organisms are chemical machines, and to understand them we must first learn a little chemistry. We first explore how atoms are linked together into molecules. The character of the water molecule in large measure determines what organisms are like.

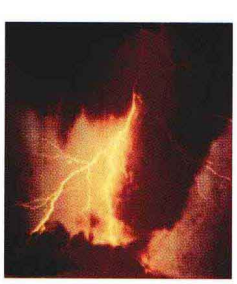
2.1 Atoms are nature's building material.
2.2 The atoms of living things are among the smallest.
2.3 Chemical bonds hold molecules together.
2.4 Water is the cradle of life.



3 ***The Chemical Building Blocks of Life*** ***37***

The four kinds of large macromolecules that are the building blocks of organisms are each built up of long chains of carbon atoms. In each, the macromolecule is assembled as a long chain of subunits, like pearls in a necklace or cars of a railway train.

3.1 Molecules are the building blocks of life.
3.2 Carbohydrates contain many CH bonds.
3.3 Lipids are not soluble in water.
3.4 Proteins perform the chemistry of the cell.
3.5 Nucleic acids store the genetic information.



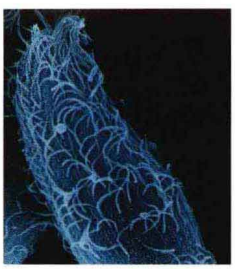
4 ***The Origin and Early History of Life*** ***61***

Little is known about how life originated on earth. If it originated spontaneously, as most biologists surmise, then it must have evolved very quickly, as microfossils of bacteria are found in rocks formed soon after the earth's surface cooled.

4.1 All living things share key characteristics.
4.2 There are many ideas about the origin of life.
4.3 The first cells had little internal structure.
4.4 The first eukaryotic cells were larger and more complex than bacteria.
4.5 Biologists classify organisms into six kingdoms.

Cell Biology

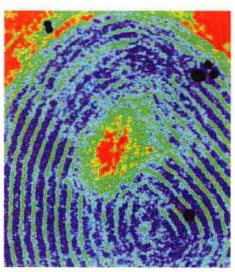
Part II *Biology of the Cell*



5 ***Cell Structure 79***

Bacterial cells have little internal organization, while the cells of eukaryotes are subdivided by internal membranes into numerous compartments with different functions. Compartmentalization is the hallmark of the eukaryotic cell.

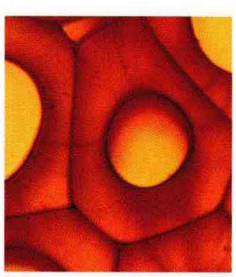
5.1 All organisms are composed of cells.
5.2 Eukaryotic cells are far more complex than bacterial cells.
5.3 Take a tour of a eukaryotic cell.
5.4 Symbiosis played a key role in the origin of eukaryotes.



6 ***Membranes 105***

Every cell is encased within a thin membrane that separates it from its environment. The membrane is a mosaic of proteins floating on a sheet of lipid that provide channels into the cell for both molecules and information.

6.1 Biological membranes are fluid layers of lipid.
6.2 Proteins embedded within the plasma membrane determine its character.
6.3 Passive transport across membranes moves down the concentration gradient.
6.4 Bulk transport utilizes endocytosis.
6.5 Active transport across membranes is powered by energy from ATP.



7 ***Cell-Cell Interactions 127***

Cells receive molecular signals with protein receptors on or within the plasma membrane. The information passes into the cell interior as a cascade of interactions that greatly amplify the strength of the original signal.

7.1 Cells signal one another with chemicals.
7.2 Proteins in the cell and on its surface receive signals from other cells.
7.3 Follow the journey of information into the cell.
7.4 Cell surface proteins mediate cell-cell interactions.

Part III *Energetics*

8 ***Energy and Metabolism*** **145**

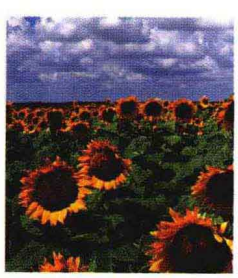
Organisms use proteins called enzymes to facilitate chemical reactions. When the products of a reaction contain more energy than the starting materials, the extra amount is supplied by ATP, the energy currency of the cell.

8.1 The laws of thermodynamics describe how energy changes.
8.2 Enzymes are biological catalysts.
8.3 ATP is the energy currency of life.
8.4 Metabolism is the chemical life of a cell.

9 ***How Cells Harvest Energy*** **161**

Cells harvest chemical energy from the CH chemical bonds of food molecules. Some of this energy is captured by rearranging chemical bonds, but most of it is harvested by oxidation, in reactions where the electrons of CH bonds are used to reduce atmospheric oxygen to water.

9.1 Cells harvest the energy in chemical bonds.
9.2 Cellular respiration oxidizes food molecules.
9.3 Catabolism of proteins and fats can yield considerable energy.
9.4 Cells can metabolize food without oxygen.



10 ***Photosynthesis*** **183**

Photosynthesis is the reverse of respiration, the energy of sunlight being harnessed to reduce carbon dioxide with electrons obtained from water, leaving oxygen gas as the by-product. All organic molecules are the direct or indirect products of photosynthetic carbon fixation.

10.1 Photosynthesis takes place in chloroplasts.
10.2 Learning about photosynthesis: An experimental journey.
10.3 Pigments capture energy from sunlight.
10.4 Cells use the energy and reducing power captured by the light reactions to make organic molecules.

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