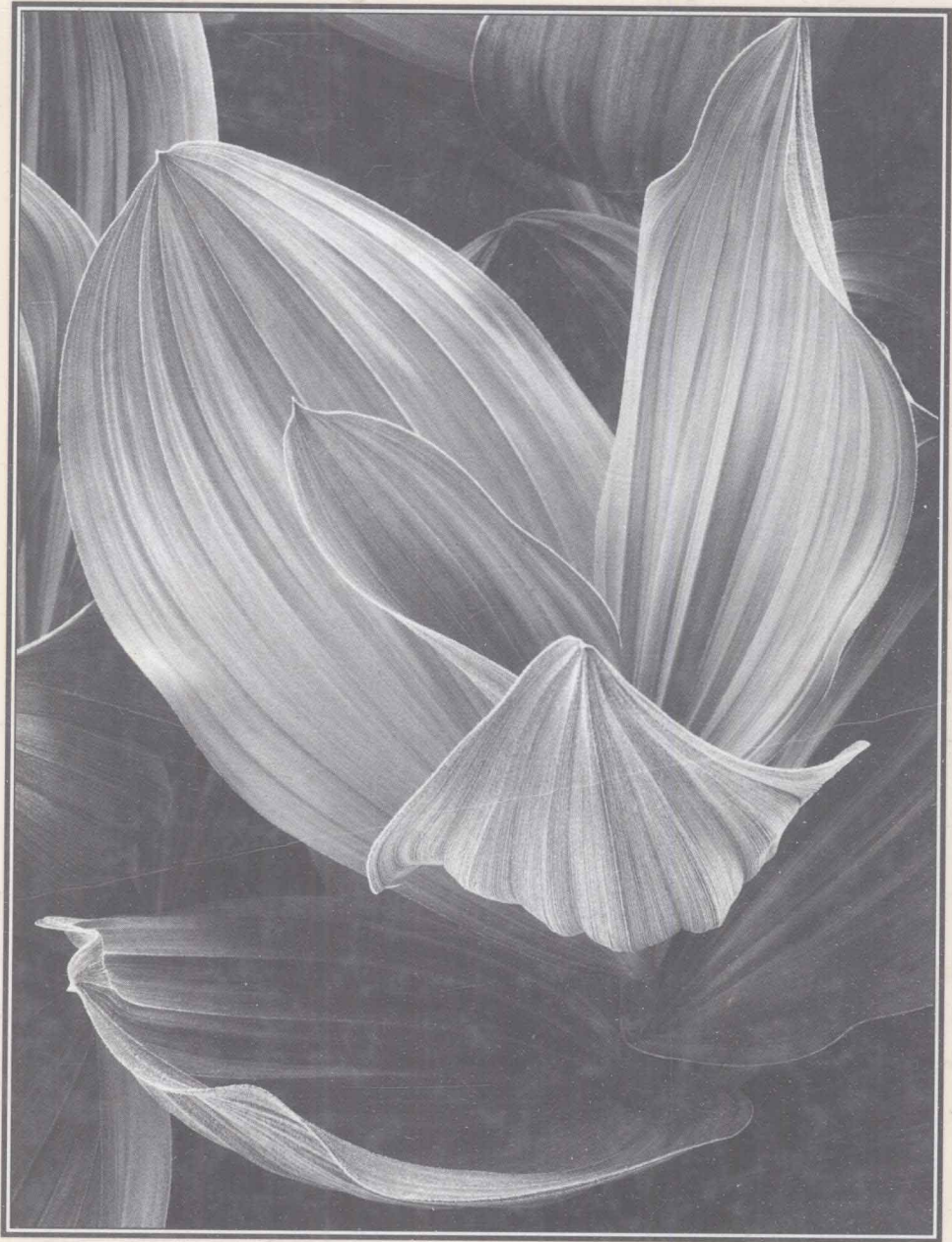


BIOLOGY

Fourth Edition



CAMPBELL

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To Rochelle and Allison, with love

ABOUT THE AUTHOR

BIOLOGY is the product of 27 years of teaching experience and many years of intensive writing and revision by Dr. Neil A. Campbell. This textbook is a natural outgrowth of Dr. Campbell's broad interest in his science. He earned his M.A. in Zoology from UCLA, where he studied the control of protein synthesis during animal development, and went on to the University of California, Riverside, where he earned a Ph.D. in plant biology. Dr. Campbell's research efforts on salt transport in plants and the cellular basis of leaf movements have resulted in publications in *Science*, *The Proceedings of the National Academy of Sciences*, and *Plant Physiology*, among other journals.

In addition to his accomplishments as a research scientist, Dr. Campbell has earned a reputation as an outstanding classroom teacher with a strong commitment to improving undergraduate education. After 10 years of teaching general biology and cell biology at San Bernardino Valley College, he took an academic leave and accepted a faculty position at Cornell University, where he reorganized a two-semester general biology course. After three successful years at Cornell, Dr. Campbell returned to California to reassume his teaching position at San Bernardino Valley College, where in 1986 he received the college's first Outstanding Professor Award for excellence in classroom instruction. He frequently returned to Cornell to teach the summer general biology course to advanced-placement high school students and Cornell undergraduates on a six-week schedule. In 1988, Dr. Campbell accepted an invitation to teach a one-semester general biology course at Pomona College.

During his many years of teaching general biology—most frequently as the sole lecturer—Dr. Campbell's teaching sensibilities have been honed in both large lecture and small classroom environments and with a diverse group of students. His textbooks have helped introduce biology to another million students. Dr. Campbell is currently a Visiting Scholar in the Department of Plant Sciences at the University of California, Riverside.

PREFACE

This fourth edition of *BIOLOGY* is true to the earlier versions' dual objectives: to explain the key concepts of biology clearly and accurately within a context of unifying themes, and to help students develop positive and realistic impressions of science as a human activity. These two teaching values evolved in the classroom, and I am pleased that the book's conceptual approach and its emphasis on science as a process have appealed to the educators and students who have made *BIOLOGY* the most widely used textbook in its field. With that acceptance, however, comes the responsibility to serve the biology community even better. Thus, in 1993, as I began to plan this new edition, I visited dozens of campuses to listen to what students and their professors had to say about their biology courses and textbooks. The most common criticism of biology texts, including this one, was that the most important concepts in each chapter did not pop out enough from the background of supporting details. Those conversations with faculty and students inspired the fourth edition's most visible and pervasive improvement.

■ The major improvement in this new edition of *BIOLOGY* is a much sharper focus on key concepts

Classroom experience convinces me that when students seem overwhelmed by the amount of biological information, it is usually because they are having difficulty structuring what they learn into a hierarchical scheme in which the main ideas rise above the supporting details, examples, and terminology. For instance, one key concept in the study of photosynthesis can be phrased like this: "The light reactions of photosynthesis transform light energy to chemical energy." But a beginning student trying to understand photosynthesis may have difficulty distilling this concept from a sea of details such as the names of electron carriers. And a student who is frustrated with what seems like a formless flood of information too often resorts to rote memorization as a substitute for conceptual comprehension. In trying to help students construct a framework of concepts, many colleagues share my experience that *oversimplifying* photosynthesis or any other topic is counterproductive; without sufficient depth, key concepts themselves collapse into meaningless factual statements to be memorized instead of organizing principles to be investigated.

My mentors are biology teachers who keep the spotlight on a topic's starring concepts, even as they introduce a supporting cast of carefully chosen details, useful terms, reinforcing examples, and validating evidence. That is the teaching philosophy that has always been at the heart of *BIOLOGY*, and my vision for this edition was to do an even better job of keeping each chapter's key concepts in the limelight. Just as every classroom presentation has its main take-home lessons, so does every chapter in this new edition of *BIOLOGY*.

There are many excellent general biology textbooks, and I am familiar with those that accent key concepts by listing them at the beginning of a chapter or highlighting them as sidebars within a chapter. But that is not what I had in mind for this edition of *BIOLOGY*. The mission was to completely rebuild each chapter around a manageable number of key concepts, usually about ten, which serve as the titles and focal points of the chapter's major sections. That meant: first, deciding which concepts are most important to teach and then phrasing those concepts as clear, concise, accurate sentences; second, arranging those key concepts so that they build in a logical sequence and interlock into a cohesive chapter; and third, rethinking the text and figures for each section so that their function is to explain and reinforce the key concept stated at the beginning of that section.

With this sharper focus on concepts, it then made sense to use the key concept statements to help students both preview and review the chapter. Thus, on the first page of each chapter, you will find a list of key concepts as a preview of the chapter's main ideas. The second time a student sees one of those conceptual statements, it will be in the body of the chapter as the banner for a section that blends text and illustrations to teach that concept. These main ideas appear for a third time at the end of the chapter, their encore in the Review of Key Concepts section. A blue square (■) marks the key concepts in all three locations, making it easier for students to relate the sections of a chapter to the overall conceptual framework.

After students study a chapter, they should be able to take one more pass through the list of key concepts and explain them in their own words. Understanding biology through its key concepts will stick with students even as the knowledge explosion refines our view of life. *BIOLOGY* should continue to serve students as a general reference after they succeed in their introductory course and continue their education.

■ The spotlight on key concepts complements *BIOLOGY*'s other hallmarks

By reconstructing each chapter of *BIOLOGY* to enable students to keep the key concepts in clear view, I have built on the pedagogical foundation of the first three editions.

Unifying Themes. A thematic approach continues to distinguish *BIOLOGY* from an “encyclopedia of life science.” Chapter 1 introduces twelve themes that resurface throughout the text to help students synthesize connections in their study of life. The themes complement the key concepts in giving form to the vastness of biology: the key concepts apply at the chapter level as that subject’s most important ideas; the themes cut across all fifty chapters as unifying features of life. For example, “The light reactions of photosynthesis transform light energy to chemical energy” is a key concept in the subject area of photosynthesis. But “Organisms are open systems that interact continuously with their environments” is a theme that unifies diverse biological concepts, including the idea that plants and other photosynthetic organisms are open systems that depend on transfusions of solar energy to make sugar. In the fourth edition of *BIOLOGY*, the focus on key concepts gives form to each chapter; the application of unifying themes gives form to the whole book.

Evolution as the Core Theme of *BIOLOGY*. If the function of *BIOLOGY*'s themes is to help students integrate their study of life, then evolution is the theme of all themes—the thread that ties together the other unifying features of biology. For example, evolution accounts for the unity and diversity of life (one of *BIOLOGY*'s themes) and lends meaning to the correlation of biological structure and function (another theme). As the overarching theme of *BIOLOGY*, evolution is built into every chapter.

Science as a Process. Chapter 1 includes a thorough introduction to the power and limitations of science as one of the book's themes, but *BIOLOGY*'s commitment to showcasing science as a human activity does not end there. Case studies, each announced by the subtitle “*science as a process*” following the concept statement it supports, enrich many chapters throughout the book by balancing “what we know” with “how we know” and “what we don't yet know.”

BIOLOGY also features many Methods Boxes, which demystify science by explaining laboratory and field methods in the context of experiments. For example, a new Methods Box in Chapter 49 (“Ecosystems”) describes how paleoecologists are studying fossil pollen to reconstruct how past climate changes affected biological communities and to make predictions about the future consequences of global warming. And eight new interviews with influential biologists, which introduce the eight units of the book, personalize science and portray it as a social activity of creative men and women, rather than an impersonal collection of facts.

Science, Technology, and Society. Biology and its applications have a profound impact on culture—on our perspective of nature, on our environmental awareness, and on our health and quality of life. It is important for students to appreciate that ethics has a place in science, even in basic research, and that technology brings with it the need to examine values and make choices. This interrelatedness of science, technology, and society is one of the themes of *BIOLOGY*. For example, environmental problems, such as the destruction of tropical rain forests, are presented as complex issues with cultural, political, and economic considerations as well as biological ones. At the end of each chapter, Science, Technology, and Society questions encourage students to incorporate the biological concepts they have learned into their broader view of the world.

A Marriage of Text and Illustrations. Biology is a visual science, and many students are visual learners. As a teacher trying to help students learn biological concepts, I have always authored the illustration program of *BIOLOGY* side-by-side with the text. Beginning with the first draft of each edition, the artists, photo researchers, editors, and I begin working together to embed the illustrations and their self-contained legends into the story line of each chapter.

With this commitment to a marriage of words and pictures, *BIOLOGY* has pioneered many breakthroughs that enhance the pedagogy of textbooks. For example, many chapters of *BIOLOGY* use a sequence of orientation diagrams as road signs to help students keep track of where they are going as they navigate through a biological process such as photosynthesis. In figures that illustrate stepwise processes, circled numbers in the text or figure legends match the numbered steps in the diagrams in order to walk students through the process. Another important navigation aid is the consistent use of color coding and icons to help students connect concepts as they move from chapter to chapter. For example, proteins are always color-coded purple, and ATP always appears in illustrations as a yellow sunburst. In this new edition, text and illustrations have continued to co-evolve, and most of the figures have been refined to improve their teaching effectiveness.

An “Overview–Closer Look” Teaching Style. *BIOLOGY* begins the development of many complex topics such as cellular respiration (Chapter 9) and protein synthesis (Chapter 16) with a panoramic view—an *overview*—of what the overall process accomplishes. Text and figures then invite the student inside the process for a *closer look* at how it works. The orientation diagrams, miniature versions of the overview illustration with appropriate parts highlighted, help students keep the larger process in sight even as they dissect it for a closer look. The “overview–closer look” teaching strategy is another example of how the hallmarks of *BIOLOGY* complement this new edition's sharper focus on key concepts to help students find their way through the multidisciplinary landscape of biology.

■ I have thoroughly updated the content of each chapter while preserving *BIOLOGY*'s versatile organization

BIOLOGY makes no pretense that there is one “correct” sequence for the major topics in a general biology course: the individuality of biology professors is one of the strengths of science education. Therefore, I built *BIOLOGY* to be versatile enough to support instructors' diverse courses, whether they choose to start with molecules or ecosystems, or somewhere in between. The eight units of the book are self-contained, and most of the chapters can be assigned in a different sequence without substantial loss of continuity. For example, professors who integrate plant and animal physiology can merge chapters from Units Six and Seven to fit their courses. And instructors who begin their courses with ecology can assign Unit Eight (“Ecology”) right after students have read Chapter 1, which introduces the themes that give each unit of chapters a general context.

Although specific updates and pedagogical improvements in this new edition of *BIOLOGY* are too numerous to list here, a brief survey of the eight units is a useful roadmap to the book's content.

Unit One: The Chemistry of Life. Many students struggle in general biology courses because they are uncomfortable with basic chemistry. Chapters 2–4 help those students by developing, in carefully paced steps, the concepts of chemistry that are essential for success in biology. I designed the chapters so that students of diverse backgrounds can use them for self-study, reducing the amount of valuable class time instructors need to spend on chemical review before they can get on to biology. However, Chapter 5 (“The Structure and Function of Macromolecules”) and Chapter 6 (“An Introduction to Metabolism”) provide important orientation even for those students with solid chemistry backgrounds. The role of chaperones in the building of proteins (Chapter 5) is one specific example of what is new in this edition.

Unit Two: The Cell. Chapters 7–11 build the study of cells around the theme of the correlation between structure and function. Throughout the unit, for example, I have accented the role of membranes in ordering cell physiology. Among the changes in this edition are greater emphasis on the structure and functions of the extracellular matrix of animal cells in Chapter 7 and a new section in Chapter 8 introducing signal-transduction pathways, a topic that is reinforced in later chapters on plant and animal physiology.

Unit Three: The Gene. Chapters 12–19 trace the history of genetics, from Mendel to DNA technology, with “science as a process” as a theme. *BIOLOGY*'s extensive coverage of human genetics is not artificially collected into a single chapter; it appears throughout the unit, integrated with general concepts that are applied to human genetics. New sections on emerging viruses and prions in Chapter 17 are examples of how *BIOLOGY* is keeping pace with current research.

Unit Four: Mechanisms of Evolution. As the core theme of *BIOLOGY*, evolution figures prominently in every unit, but Chapters 20–23 are where students will learn *how* life evolves and how biologists study evolution and test evolutionary hypotheses. Chapter 20 (“Descent with Modification: A Darwinian View of Life”) sets the stage for the unit by grounding evolutionary biology in the process of science. Students will then find many examples throughout the unit of research and debate about mechanisms of evolution. New examples of natural selection in action and a comparison of different definitions of species are among the improvements in this edition. Chapter 23 bridges this unit to the survey of biological diversity in Unit Five by highlighting how modern methods of systematics, including applications of molecular biology, are helping biologists trace the history of life.

Unit Five: The Evolutionary History of Biological Diversity. Chapters 24–30 consider the diversity of life in the context of key evolutionary junctures, such as the origin of prokaryotes, the evolution of the eukaryotic cell, the genesis of multicellular life, and the adaptive radiation of plants, fungi, and animals. The evolutionary theme of this unit contrasts with a “parade of phyla” approach. Recent discoveries of important fossils, improvements in molecular systematics, and the growing consensus for cladistic classification are transforming our view of biological history and the diversity of life. Thus, this is the most extensively revised unit in the fourth edition of *BIOLOGY*. A few examples of what is new are phylogenetic classification of bacteria, a reevaluation of protistan taxonomy, new hypotheses on the origin of plants, evolutionary relationships of fungi to other kingdoms, and the ongoing debates about human origins. The rationale for alternatives to the classical five-kingdom system of classification is thoroughly evaluated, but the unit is organized so that it also supports courses that favor the five-kingdom scheme.

Unit Six: Plants: Form and Function. Chapters 31–35 introduce students to plants in the evolutionary context of adaptation to terrestrial environments. The correlation between structure and function is also a prominent theme throughout the unit. The chapters emphasize how plant cell biologists and molecular biologists are reshaping our understanding of the morphology, physiology, and development of plants. An example of how the unit has been updated is a new section in Chapter 35 (“Control Systems in Plants”) on the responses of plants to environmental stress.

Unit Seven: Animals: Form and Function. The interaction between organisms and their environment is the focus of Chapters 36–45, which take a comparative approach in exploring the diverse adaptations that have evolved in different animal groups. Humans fit into this comparative format as an important mammalian example. The connection of bioenergetics to other animal functions is much more prevalent in this new edition, beginning with an introduction that relates bioenergetics to animal form and physiology in Chapter 36 (“An Introduction to Animal Structure and Function”). Chapter 39 (“The Body's Defenses”) has been

updated to reflect progress in immunology. And Chapter 43 (“Animal Development”) now features invertebrate models for the study of pattern formation, especially the developmental genetics of *Drosophila*.

Unit Eight: Ecology. Chapters 46–50 feature stronger connections to evolution, including an updated section on the evolution of life histories. The unit also reflects the urgent need for basic ecological research in an era when the exploding human population and its technology are treading blindly and carelessly throughout the biosphere. After careful consideration, I decided not to collect environmental issues into a separate chapter on human ecology. Given the relevance of general ecological concepts to our current environmental crises, I opted for thorough examination of environmental issues throughout the ecology unit so that students could evaluate those complex problems in the context of the basic concepts that apply. For example, an improved section in Chapter 48 (“Community Ecology”) links what students have learned about community structure to strategies for setting up biodiversity preserves. The last chapter (“Behavior”) is based on the evolutionary perspective of behavioral ecology, an orientation that fits the chapter into the ecology unit. Chapter 50 also serves as a capstone for the entire book, relating behavior and ecology to the other fields of biology, to the other natural sciences, and to the student’s general education.

■ Learning tools at the end of each chapter help students review and apply *BIOLOGY*’s key concepts

In the spirit of this edition’s major improvement, the earlier editions’ Study Outline has been replaced with a **Review of Key Concepts**. Each entry in the review restates a concept and provides an abridged explanation of it. Along with the concept are page numbers to direct students if they need to return to where that concept is developed in more depth. In most cases, each entry in the review also refers students to a particular illustration (or illustrations) in the chapter that provides the most useful visual summary of the concept.

A **Self-Quiz** at the end of each chapter helps students test their comprehension of key concepts, but many of these questions also require students to apply concepts or solve problems. Students will find the answers to the Self-Quiz questions in Appendix One. **Challenge Questions** encourage students to verbalize their interpretations of concepts, to extrapolate from what they have learned to new situations, to think critically about complex debates in biology, to apply quantitative skills in the context of biological problems, and to generate testable hypotheses of their own. The **Science, Technology, and Society** questions ask students to think about biology’s place in culture and about the consequences of applied biology. A short **Further Reading** list completes the tools at the end of each chapter.

Students will also find learning tools at the back of the book, including an extensive **Glossary** of biological terms and an improved **Index**.

■ Carefully developed supplements add value to the *BIOLOGY* package

Student Study Guide by Martha Taylor, Cornell University.

Investigating Biology, Second Edition by Judith Morgan, Emory University, and Eloise Carter, Oxford College of Emory University. A laboratory manual, with accompanying **Annotated Instructor’s Edition and Preparation Guide**.

Instructor’s Guide by Nina Caris and Harold Underwood, both of Texas A&M University.

Test Bank edited by Daniel Wivagg, Baylor University, with contributors Richard Duhkopf, Baylor University; Richard Storey, Colorado College; Gary Fabris, Red Deer College; Rebecca Pyles, East Tennessee State University; and Kurt Redborg, Coe College. This test bank is available on Microtest, a microcomputer test-generation program. The test bank is available to qualified college and university adopters.

Overhead Transparencies A set of 300 color acetates of illustrations and micrographs from *BIOLOGY*, Fourth Edition, is available to qualified college and university adopters.

35-mm Slides The same 300 illustrations available as acetates are available in 35-mm slides to qualified college and university adopters.

Transparency Masters A set of 300 black-and-white transparency masters from *BIOLOGY*, Fourth Edition, is available to qualified college and university adopters.

BioShow II: The Videodisc BioShow II is a videodisc of illustrations from the text, original animations, and motion sequences. Side one accompanies *BIOLOGY*. Art conversion from *BIOLOGY* to still figures, stepped figures, and animations was developed and executed by Tom Dallman, Ph.D. BioShow II is available to qualified adopters.

The Art CD-ROM for *BIOLOGY*, Fourth Edition A new CD-ROM containing text illustrations for projection during lecture is available to qualified adopters.

Fish Farm: Simulation Software by Robert J. Kosinski, Clemson University, with accompanying **Student Workbook** and **Instructor’s Guide**.

* * *

The real test of any textbook is how well it helps instructors teach and students learn. I welcome comments from students and professors who use *BIOLOGY*. Please address your suggestions for improving the next edition directly to me:

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ACKNOWLEDGMENTS

Like science itself, building a science textbook is a social process. Though *BIOLOGY* is in my voice, its text and illustrations are a synthesis of what I continue to learn from students, teachers, research scientists, artists, and editors. My name alone goes on *BIOLOGY*'s cover, but what you find between the covers is the result of many committed people working together toward the shared goal of improving biology education.

The biology instructors and research specialists acknowledged in the reviewer list on p. xi suggested many ways to improve *BIOLOGY*'s scientific accuracy and pedagogy. Many other professors and their students offered suggestions by writing directly to me. Those correspondents include: Peter Atsatt (University of California, Irvine), Karl Aufderheide (Texas A&M University), Howard Berg (Memphis State University), Robert Cleland (University of Washington), Morris Cline (The Ohio State University), Marshall Darley (University of Georgia), Barbara Demming-Adams (University of Colorado), Robert Eaton (University of Colorado), Steven Eiger (Montana State University), Richard Ellis (Bucknell University), John W. Evans (Memorial University, Newfoundland), Joseph Frankel (University of Iowa), Roger Gordon (Memorial University, Newfoundland), Lane Graham (University of Manitoba), Gary Grimes (Hofstra University), Jack Hailman (University of Wisconsin), Jill Hendrickson (Carleton College), Harvey Hinsz (International School of Kenya), Douglas Hunter (Oakland University), Grahame Kelly (Queensland University of Technology), Arlene Larsen (University of Colorado, Denver), Rodger Lloyd (Florida Community College, Jacksonville), Karen Mainer (El Rancho High School), Len Millis (Douglas College, British Columbia), William Moore (Wayne State University), Joseph Pelliccia (Bates College), Carl Pike (Franklin and Marshall College), Bob Ross (Linn-Benton Community College), Walter Sakai (Santa Monica City College), Ethyl Stanley (Millikin University), Lloyd Stark (University of Nevada, Las Vegas), Cyril Thong (Simon Fraser University), Gordon Ultsch (The University of Alabama), F Vella (University of Saskatchewan), Kerry Walsh (University

of Central Queensland), and Reid Wiseman (College of Charleston). Although I am responsible for any errors that remain, they are all the fewer because of the dedication of the reviewers and correspondents.

Several biologists participated in this edition by helping to revise text or by submitting early drafts of new material. These contributors are: Antonie Blackler (Cornell University), who helped plan the revision of the animal development chapter (Chapter 43); David Bourgaize (Colby College), who helped revise the chapters on the eukaryotic genome and biotechnology (Chapters 18 and 19); Lawrence Mitchell (University of Montana), the major contributor for the animal physiology unit (Unit Seven); Mary Jane Niles (University of San Francisco), who collaborated on the immunology chapter (Chapter 39); Karen Oberhauser (University of Minnesota), who made major improvements in the ecology chapters (Chapters 46–49); and Eric Strauss (University of Massachusetts, Boston), who helped with the behavior chapter (Chapter 50). Barbara Beitch and Dan Wivagg contributed several new questions for the ends of chapters. The contributors helped me make this new edition more correct, current, and clear, and I thank them for sharing their scientific expertise and teaching experience.

Numerous U.C.-Riverside colleagues continue to help shape *BIOLOGY* by discussing their research fields and exchanging ideas about biology education. In particular, I would like to thank Katharine Atkinson, Richard Cardullo, Mark Chappell, Darleen DeMason, Norman Ellstrand, Leah Haimo, Robert Heath, Anthony Huang, Bradley Hyman, Tracy Kahn, Elizabeth Lord, Carol Lovatt, Leonard Nunney, John Oross, Kathryn Platt, Mary Price, David Reznick, Rodolfo Ruibal, Clay Sassaman, Vaughan Shoemaker, William Thomson, Linda Walling, Nickolas Waser, and John Moore (whose "Science as a Way of Knowing" essays have had such an important influence on the evolution of *BIOLOGY*). I am also grateful to Pius Horner, who was my mentor during the many years we taught general biology together at San Bernardino Valley College.

One of my incentives for revising *BIOLOGY* is the opportunity to conduct

new interviews to open the eight units of the text. For the fourth edition, it was my pleasure to interview Eloy Rodriguez, Shinya Inoué, David Satcher, John Maynard Smith, Edward O. Wilson, Adrienne Clarke, Patricia Churchland, and Margaret Davis. I thank them for helping *BIOLOGY* to communicate the human face of science.

Many publishing professionals welcomed the challenge to help reinvent *BIOLOGY* so that it has a much sharper focus on key concepts. A new design, ambitious revision of the art and photo program, and an editorial eye toward the greater emphasis on key concepts are three examples of what our goals for this edition meant for the publishing team. Bruce Kortebein of Design Office experimented with us until we had the right design to make the conceptual framework of each chapter visible to students. Bruce was also one of the layout artists, along with Peter Martin, Curtis Boyer, and Chad Colburn. Yvo Riezebos designed a beautiful cover that is at once fresh and true to the elegant simplicity that distinguished the covers of earlier editions. Donna Kalal supervised production of the very complex art revision, and Don Kesner, art and design manager, played a crucial role in coordinating with Precision Graphics to develop computer art of the highest quality. Photo editor Cecilia Mills, with the help of photo researcher Laurel Anderson of Photosynthesis, were patient partners in searching for just the right photos to reinforce key concepts. Joanne Fraser and Betsy Dileria, as consulting developmental editors, made many helpful suggestions for improving chapters. Betsy was also the copyeditor, and I thank her for her perfectionism and consistency. Editorial assistant Tabinda Khan and assistant editor Hilair Chism were essential members of the editorial team. Hilair also edited most of the interviews. Kim Johnson worked with the authors of the supplements to provide students and professors with the best package of support materials ever to accompany *BIOLOGY*. Arlene Cowan and Curt Cowan worked hundreds of hours at the keyboard to produce clean "galley" from my first- and second-draft manuscripts. Roy Zitting and John Hammett were vigilant proofreaders for the fourth edition, and Charlotte Shane created an index that works much better than

earlier versions. Composition and film manager Lillian Hom and manufacturing supervisor Merry Free Osborn worked wonders to transform piles of folders to a bound book. And I am grateful for the dedication and flexibility of Laura Kenney, who coordinated the editorial and production efforts and served as our final production editor. I also thank Rani Cochran and Donna Linden, production editors. The entire publishing group worked together to craft a book that teaches biological concepts even better than earlier editions.

I am also fortunate to have the support of the Benjamin/Cummings marketing department, which keeps *BIOLOGY* in touch with the students and professors it serves. Erika Nelson, Nathalie Mainland, and biology marketing manager Larry Swanson got inside the fourth edition to understand its improvements and then launched the book with an informative promotion.

The field staff that represents *BIOLOGY* on campus is my living link to the students and professors who use the text. The field representatives tell me what you like and don't like about the book, and they provide prompt service to biology departments. The field reps are good allies in science education, and I thank them for their professionalism in communicating the merits of our

book without denigrating other publishers and their competing texts.

BIOLOGY originated from a 1979 meeting with Jim Behnke in my Cornell office. Jim was my editor for the first edition, and it took us eight years to craft the new kind of biology text we envisioned. Robin Heyden took over as sponsoring editor of the second edition and inspired many improvements in the book. Edith Brady, editor for the third edition, joined in an ambitious revision that made the book more successful than ever. I am also grateful to former editorial director Barbara Piercecchi and executive editor Johanna Schmid. And I am indebted to Benjamin/Cummings president Sally Elliott for her sustaining confidence in *BIOLOGY* and its author.

Don O'Neal was sponsoring editor for this fourth edition. I thank Don for supporting my drive to rebuild each chapter of *BIOLOGY* around a framework of key concepts. When it would have been safe for us all to be complacent with the book's success and do a cosmetic revision, Don shared the commitment to take the book to a new level of teaching effectiveness.

Although the *BIOLOGY* team changes somewhat from edition to edition, three key veterans have been especially important in

the book's long-term success. They are Carla Simmons, Anne Emerson, and Susan Weisberg. Carla Simmons, the finest illustrator in biology publishing, has helped craft the art for all four editions. Carla played an especially large role in this new edition, serving as developmental artist and bringing her sense of clarity and aesthetics to the entire art program. Anne Emerson, executive marketing manager, has been my *BIOLOGY* colleague through three editions. Anne's creativity, common sense, fairness, and commitment to science education set standards for everyone in college publishing. Susan Weisberg, senior developmental editor, was my main partner for this very demanding revision of *BIOLOGY*. Susan also worked with me on the development of the first edition of the book. She understands what I am trying to accomplish, and she helps me do it better. Susan's solid publishing values show on every page of our book, and I thank her so much for the years of teamwork and friendship.

Most of all, I thank my family and friends for their encouragement and for enduring my obsession with making *BIOLOGY* a better learning tool for students.

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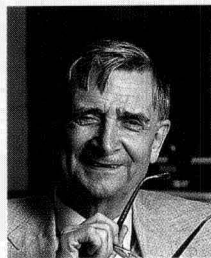
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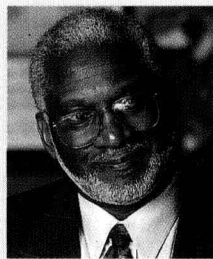
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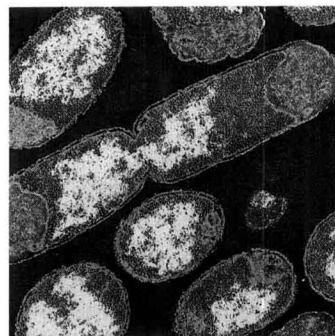
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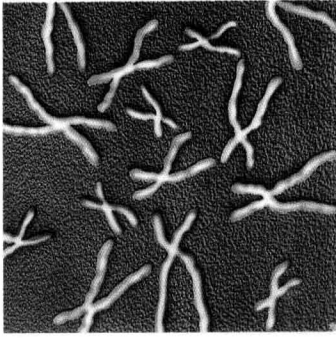
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