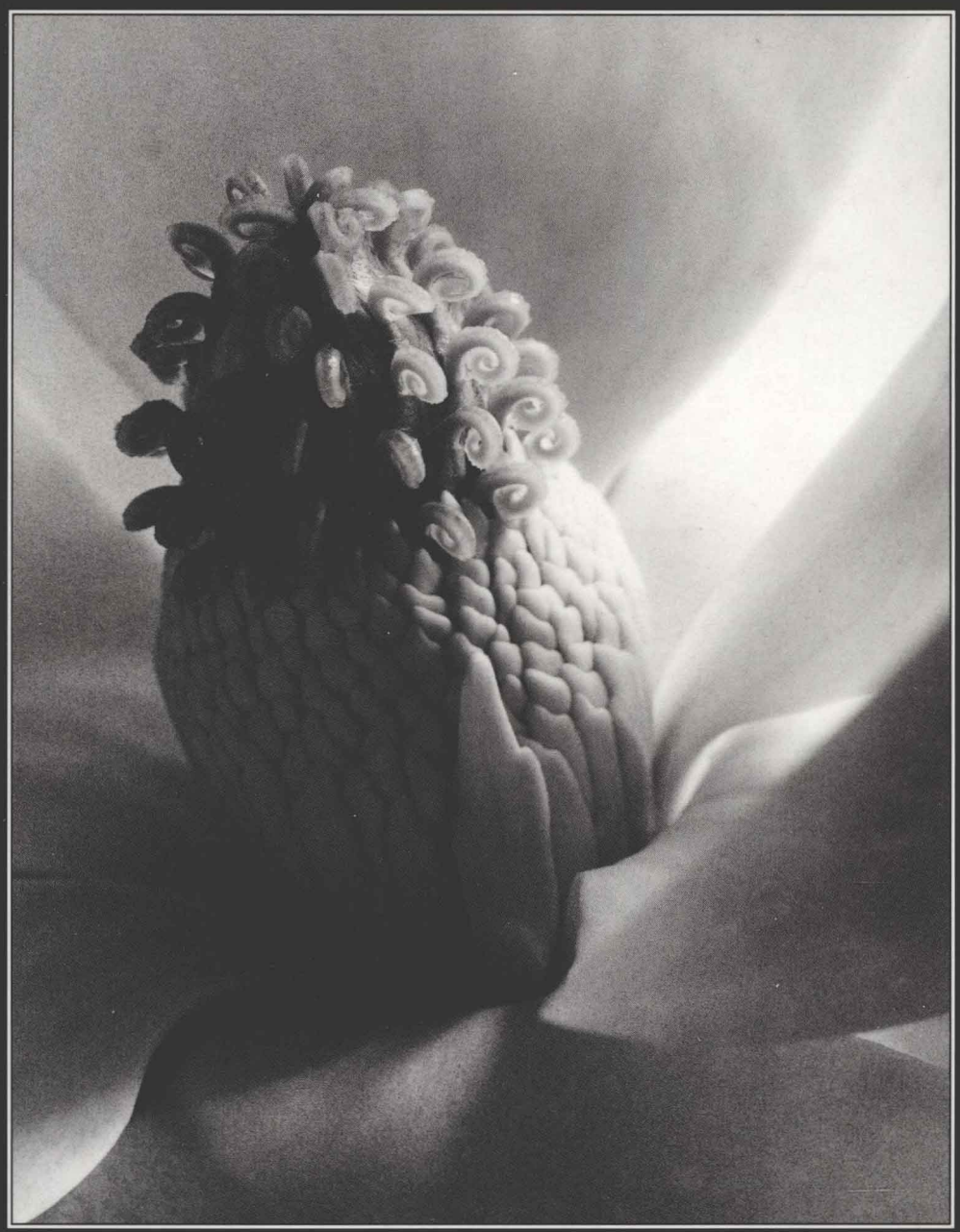
BIOLOGY

Fifth Edition



CAMPBELL
REECE MITCHELL

BIOLOGY

FIFTH EDITION

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University of California, Riverside

Jane B. Reece
Palo Alto, California

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University of Montana

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To Rochelle and Allison, with love
N.A.C.

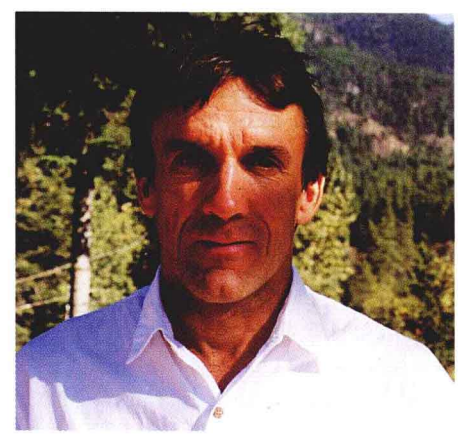
To the memory of my parents and to Daniel, with love
J.B.R.

To Charlton, Paul, Rycho, and Wesley, with love and gratitude
L.G.M.

ABOUT THE AUTHORS

Neil A. Campbell combines the investigative nature of a research scientist with the heart of an experienced and caring teacher. He earned his M.A. in zoology from UCLA and his Ph.D. in plant biology from the University of California, Riverside. Dr. Campbell has published numerous research articles on how certain desert and coastal plants thrive in salty soil and how the sensitive plant (*Mimosa*) and other legumes move their leaves. His 30 years of teaching in diverse environments include general biology courses at Cornell University, Pomona College, and San Bernardino Valley College, where he received the college's first Outstanding Professor Award in 1986. Dr. Campbell is currently a visiting scholar in the Department of Botany and Plant Sciences at the University of California, Riverside. In addition to his authorship of this book, he coauthors *Biology: Concepts and Connections* with Drs. Mitchell and Reece.

Jane B. Reece has worked in biology publishing since 1978, when she joined the editorial staff of Benjamin/Cummings. Her education includes an A.B. from Harvard University, an M.S. from Rutgers University, and a Ph.D. in bacteriology from the University of California, Berkeley. At UC Berkeley and later as a postdoctoral fellow in genetics at Stanford University, her research focused on genetic recombination in bacteria. She has taught biology at Middlesex County College (New Jersey) and Queensborough Community College (New York). During her years at Benjamin/Cummings, Dr. Reece played major roles in a number of successful textbooks, including *Microbiology: An Introduction*, by G.J. Tortora, B.R. Funke, and C.L. Case; *Molecular Biology of the Gene*, Fourth Edition, by J.D. Watson et al.; and earlier editions of this book. She is a coauthor of *The World of the Cell*, Third Edition, with W.M. Becker and M.F. Poenie, and of *Biology: Concepts and Connections.*



Lawrence G. Mitchell has 21 years of experience teaching a broad range of life science courses at both undergraduate and graduate levels. He holds a B.S. in zoology from Pennsylvania State University and a Ph.D. in zoology and microbiology from the University of Montana. Following postdoctoral research with the National Institute of Allergy and Infectious Diseases, Dr. Mitchell joined the biology faculty at Iowa State University in 1971. He received the Outstanding Teacher Award at Iowa State in 1982. In addition to numerous research publications in aquatic parasitology, Dr. Mitchell has coauthored the textbooks *Zoology* and *Biology: Concepts and Connections.* He has also developed television courses in general biology and has written, produced, and narrated programs on wildlife biology for public television. Dr. Mitchell is currently an affiliate professor in the Division of Biological Sciences at the University of Montana. Since 1989, he has devoted most of his time to writing and environmental activism.

PREFACE

by Neil A. Campbell

Students of biology are in the right place at the right time. Biology has emerged as the central science, a junction of all the natural sciences and the busiest intersection between the natural sciences and the humanities and social sciences. Biology is daily news. Advances in biotechnology, health science, agriculture, and environmental monitoring are just a few examples of how biology weaves into the fabric of society as never before. Biology is as inspirational as it is important. We are moving ever closer to understanding how a single cell develops into a plant or animal, how the human mind works, how myriad interactions among organisms structure biological communities, and how the enormous diversity of life on Earth evolved from the first microbes. For biology students and their instructors, these are the best of times.

These are also the most challenging times to learn and teach biology. The same information explosion that makes modern biology so exhilarating also threatens to suffocate students under an avalanche of facts and terminology. Most students in an introductory course do not yet own a framework of biological concepts into which they can fit the many new things they learn. More than ever, a biology textbook must help students synthesize a coherent view of life that will serve them throughout their introductory course and during their continuing education. *BIOLOGY* has always reflected my belief that education is all about making connections.

This fifth edition of *BIOLOGY* builds upon the earlier versions' dual goals: to help students construct a conceptual appreciation of life within the context of integrating themes and to inspire students to develop more positive and realistic impressions of science as a human activity. Those teaching values evolved in the classroom, and it is gratifying that the book's conceptual approach and emphasis on science as a process have had such widespread appeal for biology courses all over the world. It is a privilege to help instructors share biology with so many students, but the book's success also brings a responsibility to serve the biology community even better. Thus, in 1996, as I began planning 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. Those conversations with faculty and students helped shape this fifth edition of *BIOLOGY*, by far the most ambitious revision in the history of the book.

My New Coauthors

In planning this new edition, I was humbled by the task ahead and had to admit that it was finally time to seek the help of coauthors. Biology is a much bigger subject than it was when the first edition of the text was published in 1987, but in adapting to the growth of biology, I did not want the book to become bigger or encyclopedic. Adding content is not very hard, but deciding what to leave out is much tougher. Authoritative renewal across the whole book would require expert reevaluation of the current state of each field of biology and judicious decisions about which ideas are most important to develop in depth in an introductory textbook. Given the breathtaking progress of biology on its many fronts, I was concerned that if I continued as sole author, the text could no longer deliver the educational integrity and scientific accuracy that the biology community expects from the book.

Once I decided to recruit help, it was easy to choose coauthors: Jane Reece and Larry Mitchell. They are my longtime collaborators on our nonmajors textbook, *Biology: Concepts and Connections*, and they have contributed in various ways to earlier editions of *BIOLOGY*. Dr. Reece's knowledge of genetics and molecular biology and Dr. Mitchell's expertise in zoology and ecology complement my own research background in cell biology and botany. More importantly, Jane and Larry share my commitment to "getting it right" and to having a positive impact on biology education.

My new coauthors brought fresh ideas and reenergized me and the whole *BIOLOGY* team. Among Jane's many contributions are two new chapters: Cell Communication (Chapter 11) and The Genetic Basis of Development (Chapter 21). Larry's extensive work on this edition includes the book's new capstone chapter, Conservation Biology (Chapter 55).

Even with the help of my coauthors, I worked as hard as ever on this edition of *BIOLOGY*. In addition to writing chapters, I edited the entire book to ensure consistent voice and level. Because of my confidence in Jane and Larry as partners in the book, I also finally had more time to help plan the supplements, especially the new CD-ROM and web site. All that is new in this fifth edition of *BIOLOGY* and its supplements is firmly stamped with the hallmarks that have distinguished earlier editions.

BIOLOGY's Hallmark Features

Unifying Themes and Key Concepts. A thematic approach continues to distinguish *BIOLOGY* from an encyclopedia of life science. Chapter 1 introduces 11 themes that resurface throughout the text to help students make connections in their study of life. The core theme, the theme of all themes, is evolution, the thread that ties all of biology together.

On the scale of individual chapters, an emphasis on key concepts keeps students focused on each topic's most important ideas. For example, Chapter 9, Cellular Respiration, teaches about 10 key concepts, including "Feedback mechanisms control cellular respiration." Each chapter's key concepts appear in three places: in an overview of key concepts on the first page of the chapter; within the body of the chapter as the headings of the main subsections under broader topic headings; and in the review of key concepts at the end of the chapter. In placing such emphasis on a manageable number of big ideas in each chapter, we do not equate "conceptual" with "superficial." Oversimplifying a complex topic is a disservice to students, for without the support of sufficient detail, key concepts collapse into meaningless factual statements and lose their value as organizing principles. We avoid trying to cover everything, but if a concept is essential to include, we believe it should be developed in enough depth to leave a lasting impression on students.

BIOLOGY's key concepts and unifying themes work together to help students develop a coherent view of life. Notice, for example, that "Feedback mechanisms control cellular respiration" is a concept specific to the topic of a particular chapter. However, one of the book's overarching themes, the theme of regulation, helps students fit the concept of controlling respiration into a broader context that applies to many other biological processes. The key concepts give form to each chapter; the integrating themes connect the concepts and give form to the whole book.

Science as a Process. As one of the book's unifying themes, the nature of science is introduced at some length in Chapter 1, but *BIOLOGY*'s commitment to featuring science as a human activity does not end there. Case studies announced by the subtitle "Science as a Process" enrich many chapters throughout the book by balancing "what we know" with "how we know" and "what we do not yet know." *BIOLOGY* also features many Methods Boxes, which demystify science by walking students through laboratory and field methods in the context of experiments. For example, a new Methods Box in Chapter 21, "Using Mutation to Study the Genetic Basis of *Drosophila* Development," explains the rationale behind experiments that have revolutionized developmental biology. Another example is a new Methods Box in Chapter 55 that illustrates the use of computerized mapping techniques in conservation biology. Eight new interviews with influential scientists, which introduce the eight units of the book, help personalize science and portray it as a social activity of creative men and women. Many of the Challenge Questions at the ends of chapters also engage students in the process of science.

Another one of *BIOLOGY*'s themes, the relationship of science and technology to society, helps students connect biology to their other college courses and to their daily lives. It is important for students to realize that ethics has a place in science, even in basic research, and that the benefits of technology also bring the need to examine values and make choices. At the end of each chapter, Science, Technology, and Society questions encourage students to fit 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 of our students are visual learners. We take as much care in creating new ways to illustrate the story of life as we do in writing the narrative. I have always authored the illustration program for *BIOLOGY* side by side with the text, and Drs. Reece and Mitchell take the same approach. Beginning with the first draft of this edition, we collaborated with the designer, artists, photo researchers, and developmental editors to embed the illustrations and their legends into the flow of each chapter. Compared to the more common publishing model of deferring work on the illustration program until the text manuscript is completed, our approach creates logistical challenges. There is a benefit, however: a union of words and pictures that makes each chapter an integrated lesson.

With this commitment to integrating text and graphics, earlier editions of *BIOLOGY* pioneered many innovations in how science textbooks are illustrated. For example, many chapters in *BIOLOGY* use a sequence of orientation diagrams as road signs to help students keep track of where they are in biological processes such as photosynthesis (Chapter 10) and gene expression (Chapter 17). In figures that walk students through stepwise processes, circled numbers in the illustration are keyed to circled numbers in the figure legend or text. We think this approach works better than cluttering the illustration itself with too much text. Throughout the book, color coding and icons help students connect concepts from chapter to chapter. For example, proteins are generally purple, and ATP always appears as a yellow sunburst. These and other features of *BIOLOGY*'s illustration tradition have had a noticeable impact on many other excellent textbooks, but we have continued to refine our model to raise the standard even higher. In addition to the many new diagrams that support the narrative in this fifth edition, we have found subtle ways to improve the teaching effectiveness of a great number of the other figures in the book.

An "Overview-Closer Look" Teaching Style. *BIOLOGY* begins the development of many complex topics, such as cellular respiration (Chapter 9) and gene expression (Chapter 17), with a panoramic view—an overview—of what the whole 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 as "you are here" aids, keep the overall process in sight even as its steps unfold. This teaching approach complements *BIOLOGY*'s other hallmarks in helping students navigate through their biology course.

BIOLOGY's Versatile Organization

BIOLOGY makes no pretense that there is one "correct" sequence of topics for a general biology course. No two syllabi match, and the individual approaches of biology instructors are one of the strengths of biology education. Therefore, we have built *BIOLOGY* to be versatile enough to serve diverse courses, whether the instructor chooses to start with molecules or ecosystems or somewhere in between. The eight units of the book are largely self-contained, and most of the chapters can be assigned in a different sequence without substantial loss of continuity. For example, instructors who integrate plant and animal physiology into a systems approach can merge chapters from Units Six and Seven to fit their courses. As another example, instructors who begin their course with ecology and continue with a "top-down" approach can assign Unit Eight right after Chapter 1. It is the themes introduced in Chapter 1 that make the book so versatile in organization by providing students with a biological context no matter what the topic order of the syllabus.

An Overview of *BIOLOGY* and a Few Examples of What's New in the Fifth Edition

Unit One: The Chemistry of Life. Many students struggle in general biology courses because they are uncomfortable with basic chemistry. Chapters 2–4 help such students by developing just the chemical concepts that are essential to success in a beginning biology course. This edition features improved explanations of atomic and molecular electron orbitals and their influence on molecular shape and function. We designed the chapters of Unit One so that students of diverse educational backgrounds can use them for self-study, reducing the amount of valuable class time instructors need for reviewing chemistry before they move on to biology. However, Chapter 5 (The Structure and Function of Macromolecules) and Chapter 6 (An Introduction to Metabolism) provide important orientation even for students with solid chemistry backgrounds.

Unit Two: The Cell. Chapters 7–12 build the study of cells upon the theme of correlation between structure and function. For example, the role of membranes in ordering cell functions is emphasized throughout the unit. In the fifth edition, this unit includes a completely new chapter, called Cell Communication (Chapter 11). This chapter synthesizes our current understanding of the functions and mechanisms of cell communication and signal transduction, giving students a conceptual foundation that applies to many processes at the cellular and organismal levels.

Unit Three: Genetics. Chapters 13–21 trace the history of genetics, from Mendel to DNA technology, with the process of science as a major theme. In this edition, the chapters on molecular genetics (Chapters 16–20) have undergone a major revision, entailing both updating and organizational improvements. For instance, the explanations of transcription and translation in Chapter 17 (From Gene to Protein) have been reorganized into two distinct sections that should help students keep these two important stages of gene expression clear in their minds. The material in Chapter 19, The Organization and Control of Eukaryotic Genomes, has been extensively revised and expanded; it includes updated coverage of chromatin structure, repetitive DNA, transcriptional regulation, and cancer. Chapter 20, DNA Technology, features updated discussion of the Human Genome Project and introduces students to some exciting new techniques for studying gene function. As in previous editions, *BIOLOGY*'s extensive coverage of human genetics is integrated throughout the unit. Concluding the unit is a new chapter on one of the most important areas in biology, The Genetic Basis of Development (Chapter 21). This chapter builds on molecular, cellular, and genetic principles to introduce concepts of development that apply to both animals and plants. *Drosophila*, the nematode *C. elegans*, and the plant *Arabidopsis* provide the main case studies here. (More extensive coverage of vertebrate development and plant development appears in later units.)

Unit Four: Mechanisms of Evolution. As the core theme of *BIOLOGY*, evolution figures prominently in all parts of the book, but Chapters 22–25 focus specifically on how life evolves and how biologists study evolution and test evolutionary hypotheses. Chapter 22, 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. For instance, a new section in Chapter 24 summarizes the ongoing debate about how to define a species. An expanded discussion of systematics in Chapter 25 emphasizes current efforts to meld classification and evolutionary history. New and updated sections highlight molecular and cladistic methods and their use in formulating phylogenetic hypotheses.

Unit Five: The Evolutionary History of Biological Diversity. Chapters 26–34 view 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; the colonization of land; and the adaptive radiation of plants, fungi, and animals. This evolutionary theme contrasts with a "parade of phyla" approach. The scientific view of biological history and diversity is being transformed by discoveries of new fossils, increased application of molecular biology in systematics, and a growing consensus for cladistic classification. These trends demanded extensive revision of this unit. Chapter 26 sets the stage by comparing several classification schemes, including the traditional five-kingdom system, an eight-kingdom system, and a superkingdom, three-domain system. Chapters 27 and 28 reflect the view that the enormous diversity among prokaryotes and protists deserves recognition at the highest levels of classification. Unit Five centers on current thinking and ongoing debates about kingdoms and superkingdoms while retaining its applicability to courses with labs based on the five-kingdom system. Extensive emphasis on biodiversity is making a comeback in many courses, and we expanded our coverage of the evolution and diversity of plants (now two chapters instead of one) and animals (now three chapters instead of two.)

Unit Six: Plant Form and Function. Chapters 35–39 showcase plants in the evolutionary context of adaptation to terrestrial environments. Much of the new material emphasizes how plant cell biologists and molecular biologists are reshaping our understanding of plant morphology, physiology, and development. Just one example is the progress in our understanding of disease resistance in plants, now a major section in Chapter 39 (Control Systems in Plants). Throughout the unit in this edition, there is also more emphasis on symbiotic relationships between plants and bacteria and fungi.

Unit Seven: Animal Form and Function. The interaction between organisms and their environment is the focus of Chapters 40–49, which take a comparative approach to exploring adaptations that have evolved in diverse animal groups. The themes of regulation and bioenergetics are accented throughout, and many figures have been reconstructed to bring out these themes. Some highlights include new information on fat metabolism in Chapter 41, current findings about coreceptors and protease inhibitors relevant to HIV in Chapter 43, more about the role of cell adhesion in animal development in Chapter 47, an updated account of human brain development in Chapter 48, and an expanded section on locomotion in Chapter 49.

Unit Eight: Ecology. Chapters 50–55 emphasize the connections between ecology and evolution. The unit also reflects the urgent need for basic ecological research in an era when the growing human population and its technology are threatening the biosphere. Highlighting this issue, and serving as a capstone for the unit and the entire book, is a new chapter on conservation biology (Chapter 55). Firmly grounded in modern ecological science, this chapter examines the significance of biodiversity and discusses conservation strategies at the species, population, community, ecosystem, and landscape levels.

Learning Aids at the Ends of Chapters

At the end of each chapter is a **Review of Key Concepts**, which restates each concept with a short explanation. With each concept are page numbers and figure numbers telling students where to return if they are having trouble understanding that concept. A **Self-Quiz** helps students assess their comprehension of key concepts, and many of these questions also require students to apply concepts or solve problems. **Challenge Questions** give students opportunities to verbalize their interpretations of key concepts, to extrapolate from what they have learned to new situations, to think and write critically about controversies, to apply quantitative skill to biological problems, and to generate testable hypotheses of their own. The **Science, Technology, and Society** questions encourage students to think about biology's place in our culture and to confront the potential consequences of applied biology. A short, annotated **Further Reading** list directs students to articles and books that explore some of the chapter's topics in more depth. New to this edition is a list of **Web Links**, Internet resources selected and annotated by Dr. Iain Miller of the University of Cincinnati.

A Complete Teaching and Learning Package

This full range of supplements is highlighted by breakthrough media tools that have been developed specifically for use with *BIOLOGY*, Fifth Edition. They have been crafted with the same careful attention to scientific accuracy and teaching effectiveness found in the text. In each case, the value to instructor and student is based on integration with the text.

New! **Interactive Study Partner CD-ROM** by Richard Liebaert of Linn-Benton Community College. Packaged with the textbook at no additional charge, the Study Partner includes 120 interactive exercises, animations, and lab simulations. Icons  appear throughout the textbook to guide students to the applicable activity on the CD-ROM. Also featured are a glossary and 20 quiz questions per chapter, with feedback for all answers and page references to the relevant explanations in the textbook. The CD-ROM is also the student's gateway to the special edition of *The Biology Place*, the web site that now complements this textbook.

***New!* The Special Edition of *The Biology Place* for *BIOLOGY*, Fifth Edition.** For the past three years, I have been working with several other educators and Peregrine Publishers to develop *The Biology Place*, a web-based learning environment for general biology students. A subscription to the customized version of *The Biology Place*, specifically keyed to the fifth edition of *BIOLOGY*, is now available to all students (see www.biology.com/campbell for more details). *The Biology Place* includes BioCoach (interactive tutorials with self-assessment), investigative learning activities, LabBench (lab simulations), TestFlight (customizable practice exams), Biology News (summaries of newsworthy research breakthroughs), chapter-specific web links, and access to a web version of the Interactive Study Partner. An instructor's entrance to the special edition of *The Biology Place* provides access to fifth edition art, resources, and a new on-line Course Management System.

***New!* Course Management On-Line.** The Addison Wesley Longman Course Management System allows the instructor to offer on-line quizzing and to create a course-specific web site for posting a syllabus and/or lecture schedule. The instructor can also use the system to conduct discussion groups and administer the course.

***New!* Instructor's Presentation CD-ROM.** Over 100 animations and QuickTime movies and the complete art program from *BIOLOGY* are included. A presentation program enables instructors to design a slide show of images, import illustrations and photos from other sources, transfer figures into other software programs, and edit the figures for content.

***New!* More Transparency Acetates.** For the first time, all of the drawings in the text are available, more than 600 figures in full color.

***New!* Instructor's Guide to Media** by Iain Miller, University of Cincinnati. This useful guide to media supplements provides guidance on how best to utilize the electronic tools available with the text and how to integrate them into your course. It contains information on web sites, course management software, presentation software, the special edition of *The Biology Place*, and the Interactive Study Partner.

Instructor's Guide by Mark Sheridan, North Dakota State University. Tailored to match the content in *BIOLOGY*, Fifth Edition, the guide offers teaching assistance that is especially helpful for first-time instructors.

Student Study Guide by Martha Taylor, Cornell University. This printed learning aid provides a concept map of each chapter, chapter summaries, a variety of interactive questions, and chapter tests.

***Investigating Biology*, Third Edition,** by Judith Giles Morgan, Emory University, and M. Eloise Brown Carter, Oxford College of Emory University. This investigative laboratory manual asks students to pose their own hypotheses, design their own experiments, and then analyze their data. Also available: ***Investigating Biology*, Third Edition, Annotated Instructor's Edition** and **Preparation Guide**.

35-mm Slides. This package contains approximately 300 slides keyed to the text.

Printed Test Bank and **Computerized Testing Software for Macintosh and Windows**, edited by Dan Wivagg, Baylor University. Featuring more questions than ever, a new program allows the professor to view and edit electronic questions, transfer them to tests, and print them in a variety of formats.

■ ■ ■

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

Neil Campbell
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ACKNOWLEDGMENTS

Every edition of *BIOLOGY* has been an immense journey for many people, and the authors of this fifth edition wish to extend heartfelt thanks to the numerous instructors, researchers, students, editors, and artists who have contributed to this and previous editions. It is a privilege to be part of a global community dedicated to excellence in science education.

Special thanks go to several biologists who contributed in major ways to the revision of fourth edition chapters or helped with the creation of new chapters for the fifth edition. Chapter 21, The Genetic Basis of Development, greatly benefited from the advice of Ann Reynolds (University of Washington), Jeff Hardin (University of Wisconsin), and Nancy Hopkins (MIT) and from early drafts of new material that Ann and Jeff created. Jeff Hardin also helped reshape and refine Chapter 47, Animal Development, and was the main contributor of updated material for that chapter. Mary Jane Niles (University of San Francisco) did a superlative reorganization and updating of Chapter 43, The Body's Defenses. Steven Lebsack (Linn-Benton Community College) provided a number of new review questions for the ends of chapters. We thank these contributors for helping us make our fifth edition more accurate, up to date, coherent, and pedagogically effective. It was a pleasure to work with them.

Further helping us improve *BIOLOGY*'s scientific accuracy and pedagogy, 50 scholars and teachers, cited on page x, provided detailed reviews of one or more chapters for this edition. Numerous other professors and their students offered suggestions by writing directly to Neil Campbell. Those correspondents include: Anne Ashford (University of New South Wales), Peter Atsatt (University of California, Irvine), Anton Baudoin (Virginia Polytechnic Institute), Bruce Chorba (Mercer County Community College), Raymond Damian (University of Georgia), Marshall Darley (University of Georgia), Marianne Dauwalder (University of Texas), Earl Fleck (Whitman College), Joseph Frankel (University of Iowa), Warren Gallin (University of Alberta), Larry Giesman (Northern Kentucky University), Bruce Grant (Widener University), Albert Hendricks (Virginia Polytechnic Institute), Becky Houck (University of Portland), Roger Lloyd (Florida Community College of Jacksonville), Ernst Mayr (Harvard University), Matthias Ochs (Georg-August-Universitat Gottingen), Barry Palevitz (University of Georgia), Tom Rambo (Northern Kentucky University), Thomas Reimchen (University of Victoria, Canada), Cyril Thong (Simon Fraser University), Gordon Ultsch (University of Alabama), Itzick Vatnick (Widener University), and Cherie Wetzel (City College of San Francisco).

Of course, the authors alone bear the responsibility for any errors that remain in the text, but the dedication of our contributors, reviewers, and correspondents makes us especially confident in the accuracy of this edition.

Many colleagues have also helped shape this fifth edition by discussing their research fields and ideas about biology education. Neil Campbell thanks numerous UC Riverside colleagues, including Katharine Atkinson, Elizabeth Bray, Richard Cardullo, Mark Chappell, Timothy Close, Darleen DeMason, Norman Ellstrand, Robert Heath, Anthony Huang, Tracy Kahn, Elizabeth Lord, Carol Lovatt, Robert Neuman, Eugene Nothnagel, John Oross, Kathryn Platt, Mary Price, David Reznick, Rodolfo Ruibal, Clay Sassaman, Irwin Sherman, 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*). Neil also is grateful to Pius Horner, who taught him by example during their many years of team-teaching at San Bernardino Valley College. Among the scientists elsewhere who shared their expertise and ideas with us are Wayne Becker (University of Wisconsin), Deric Bownds (University of Wisconsin), Nicholas Davies (Cambridge University), Daniel Gagnon (Université du Quebec), David Glenn-Lewin (Wichita State University), Peter Grant (Princeton University), Ira Herskowitz (UC San Francisco), Nancy Hopkins (MIT), Richard Hutto (University of Montana), Robert Lambrecht (U.S. Forest Service), Christopher Murphy (James Madison University), Andrée Nault (Biodôme de Montréal), David Patterson (University of Sydney), Mitchell Sogin (Marine Biological Laboratory), and Kirwin Werner (Salish Kootenai College).

Interviews with prominent scientists have been a hallmark of *BIOLOGY* since its inception, and conducting these interviews was one of the great pleasures of revising the text. To open the eight units of this fifth edition and help put human faces on our science, we are proud to include interviews with Mario Molina, Bruce Alberts, Mary-Claire King, Richard Dawkins, Elisabeth Vrba, Gloria Coruzzi, Terence Dawson, and Michael Dombeck.

BIOLOGY, Fifth Edition, results from an unusually strong synergism between a team of scientists and a team of publishing professionals. A fresh design, ambitious revision of the art and photo program, and the nesting of key concepts into a pedagogical hierarchy are three examples of goals for this edition that created challenges for the publishing team. Heading Addison Wesley Longman's Biology Group, publisher Jim Green brought his high publishing standards and flair for team-building to our endeavor; we are grateful for his leadership. Linda Davis, general manager of Benjamin/Cummings Publishing, has shared the book team's commitment to excellence and provided strong support over the long haul. Our former editor Lisa Moller worked closely with the authors and book team in the planning and early draft stages. The authors are extremely grateful to Laura Kenney, production managing editor, who has been a key member of the book team since those early stages. Senior production editor Angela Mann brought her professional expertise and can-do attitude to the book's production; moreover, she brought calm and good cheer to the often-turbulent later stages of the production process. Two senior developmental editors, the incomparable Pat Burner and Shelley Parlante, worked closely with the authors through all phases of manuscript and art preparation; we are deeply grateful for their countless contributions to the book and for their professionalism, obsessive dedication, and exceptional patience. Our copyeditor and fellow biologist Alan Titche brought a rare mix of content knowledge and editing skills to late stages of the manuscript.

Art and design are key elements of *BIOLOGY*'s teaching effectiveness. Don Kesner, art and design manager of the AWL Biology Group, and book designer Mark Ong worked closely and patiently with us until we had the right design to make each chapter a better teaching tool. Senior art supervisor Donna Kalal shepherded all of our art through production. We are grateful to the artists who worked on the new and revised figures for this edition, including Mary Ann Tenorio, Karl Miyajima, Carla Simmons, and the artists of Precision Graphics. On the four previous editions Carla was a major

shaper of the art program, which continues to serve students well. Photo researchers Kathleen Cameron and Roberta Spieckerman searched for just the right photos to reinforce key concepts. Yvo Riezebos designed a handsome cover that reflects the freshness of this new edition yet remains true to the elegant simplicity that distinguished the covers of earlier editions.

We are all indebted to our supreme leader for the project, executive editor Erin Mulligan. Erin brought her leadership ability, publishing expertise, native intelligence, and down-to-earth sense of humor to the *BIOLOGY* team in 1997. She immediately began mustering the forces that gave rise to the fifth edition's outstanding supplements package. Erin's fierce dedication to this project and to excellence in educational publishing has touched us all.

Working closely with Erin and with authors of the supplements, associate editor Thor Ekstrom and associate producer Claire Cameron coordinated the print and electronic supplements, respectively. Key players on the supplements included senior developmental editor Pat Burner, senior production editor Larry Olsen, project editor Kathy Yankton, and publishing assistant Maureen Kennedy. Important contributions to the electronic components of the package were made by Russell Chun (with his threefold expertise in art, computer animation, and biology), designer Peilin Nee, several freelancers, and our incomparable media lab manager, Guy Mills. We also thank Laura Maier, executive editor at Peregrine Publishers, and Claire Cameron for their collaborative leadership in developing the special edition of *The Biology Place* as a web site coordinated with our book. Guy Mills, Lee Stayton, Rachel Collett, Betsy Burr, and Todd Rodgers also played key roles in customizing *The Biology Place* for *BIOLOGY*, Fifth Edition. As a result of the efforts of all these people, students and professors have available a marvelous assemblage of support materials for their biology courses.

Dorothy Zinky is hands-down the most efficient and unflappable administrative assistant the authors have ever had the pleasure of depending upon. Publishing assistants Kelly Millon, Claire Cameron (before her promotion), Natalia Cortes and Maureen Kennedy provided essential support to the authors and the book team. Hilair Chism helped us by editing the transcripts of some of the interviews. Anita Wagner and Carol Lombardi were careful proofreaders for the fifth edition, and Charlotte Shane created a very useful index. Prepress manager Lillian Hom and prepress supervisor Vivian McDougal worked wonders to bring about the culmination of all our efforts—a bound book. The entire publishing group worked together to craft a book that teaches biological concepts even better than earlier editions.

Both before and after the publication of the book, we are fortunate to have the support of AWL's marketing professionals. We gratefully acknowledge the contributions of market development manager David Horwitz and members of Stacy Treco's marketing team, especially biology marketing manager Gay Meixel. We also thank Lillian Carr and Bob Leone for creating effective promotional materials.

The field staff that represents *BIOLOGY* on campus is our living link to the students and professors who use the text. The field representatives tell us 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 we thank them for their professionalism in communicating the merits of our book without denigrating other publishers and their competing texts.

Finally, we wish to thank our families and friends for their encouragement and for enduring our obsession with *BIOLOGY*. In particular, we are grateful for the support of Rochelle and Allison Campbell (N.A.C.); Deborah Gale, Dan Gillen, Robin Heyden, Sharmon Hilfinger, Jeff Reece, Susan Weisberg, and Hugues d'Audiffret (J.B.R.); and Wesley, Paul, and Paula Mitchell (L.G.M.).

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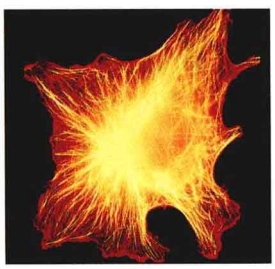

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