

# BIOLOGY

*Sixth Edition*



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# BIOLOGY

SIXTH EDITION

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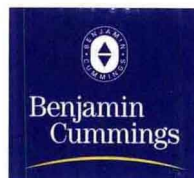
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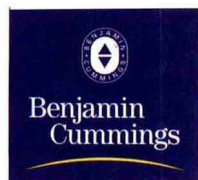
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Credits continue following the appendices.

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To Rochelle and Allison, with love

N.A.C.

To Paul and Daniel, with love

J.B.R.

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## 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, where he received the Distinguished Alumnus Award in 2001. 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* and *Essential Biology* with Jane Reece. Each year, over 500,000 students worldwide use Campbell/Reece biology textbooks.



**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. in Biology from Harvard University, an M.S. in Microbiology 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 taught biology at Middlesex County College (New Jersey) and Queensborough Community College (New York). As an editor at Benjamin Cummings, Dr. Reece played major roles in a number of successful textbooks, including *Molecular Biology of the Gene*, Fourth Edition, by J. D. Watson et al. In addition to being a coauthor with Neil Campbell on *BIOLOGY*, *Biology: Concepts and Connections* and *Essential Biology*, she coauthored *The World of the Cell*, Third Edition, with W. M. Becker and M. F. Poenie.

# PREFACE

**S**tudents come to biology during its golden age. The exhilarating progress in our understanding of life at all levels, from molecules and cells to ecosystems and the biosphere, is bound to inspire the inquisitive minds of undergraduates. And life becomes more fascinating even as it becomes less mysterious, for headway on one question leads to a dozen others that will captivate curiosity for decades to come. Today's students will also find biology at the center of current culture, more visible and more important than ever. Biology news has moved to the front page.

Reflecting the changing landscape of the subject it surveys, this Sixth Edition of *BIOLOGY* is our most sweeping revision ever. But throughout the revision process, we have kept in mind the two core goals of all earlier editions: 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 process of inquiry. These two teaching values evolved in the classroom, and we are obviously gratified that the book's dual emphases on concept-building and the process of science have appealed to the educators and students who have made *BIOLOGY* the most widely used college science textbook. But with this privilege of sharing biology with so many students comes the responsibility to continue improving the book to serve the biology community even better. Thus, throughout the entire planning and revision process, we visited dozens of campuses to listen to what students and their professors had to say about their biology courses and textbooks. These conversations with faculty and students led to the many improvements you'll find in this Sixth Edition.

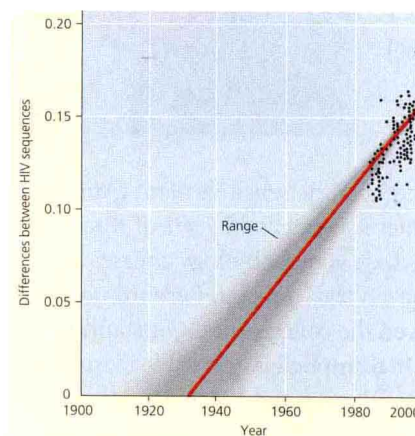
## An Even Greater Emphasis on the Process of Science

THE  
PROCESS  
OF SCIENCE

"How we know" and "what we do not yet know" are as important for students to appreciate as "what we know." The process of science has always been one of *BIOLOGY*'s unifying themes, but we have increased its presence in the Sixth Edition. First, we revised the introduction to science in Chapter 1 to set up the 215 examples of scientific inquiry embedded throughout the book. These case studies are announced by green tabs labeled "The Process of Science." An example is the case study of the greater prairie chicken and the extinction

vortex in Chapter 55 (Conservation Biology). Also new to this edition, a Process of Science question at the end of each chapter encourages student inquiry. On the CD-ROM and website that accompany *BIOLOGY*, students will find Case Studies in the Process of Science that give them additional practice with science skills, such as forming and testing hypotheses, collecting and analyzing data, and critically evaluating the evidence bearing on current debates in biology. And eight new interviews with influential researchers, which introduce the eight units of the book, humanize science and portray it as a social activity of creative men and women.

## An Evolution Theme More Pervasive Than Ever



Dating the origin of HIV-1 M with a molecular clock.

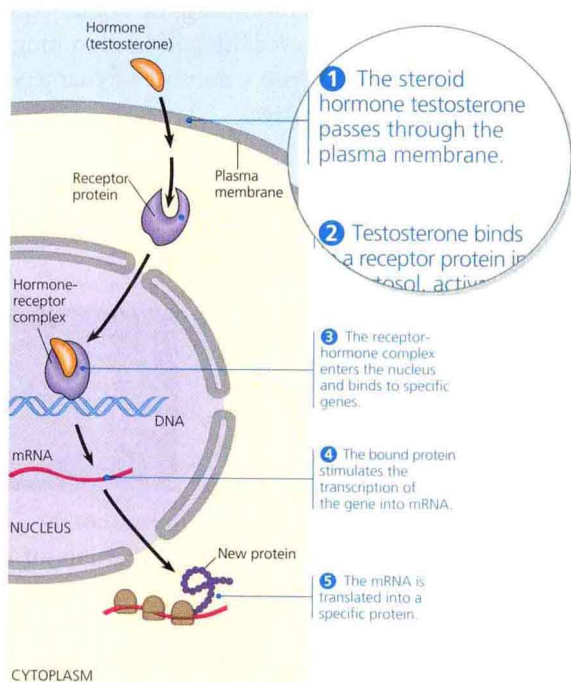
The use of ten unifying themes, introduced in Chapter 1 and serving as touchstones for students throughout the book, continues to distinguish *BIOLOGY* from a topical, encyclopedic approach. And as the one central theme that unifies all of biology by accounting for both the unity and diversity of life, evolution is woven into the fabric of every

chapter of our book. The power of this integrating theme becomes even more essential as the discovery explosion in biology threatens to suffocate students under an avalanche of what would otherwise seem to be unrelated information. Thus, we have made the evolution theme more pervasive than ever in this new edition of *BIOLOGY*. For example, a new section in Chapter 25 (Phylogeny and Systematics) explains how researchers used a molecular clock to date the origin of HIV. A new Evolution Connection question at the end of each chapter will help students fit what they have learned in the chapter into a broader biological context.



## New Guided Tour Diagrams and Other Major Improvements of *BIOLOGY*'s Graphics

Biology is a visual science, and many of our students are visual learners. As authors, we take as much care in creating new ways to illustrate biology as we do in writing the narrative. With each edition, we have found ways to improve the teaching effectiveness of the book's diagrams, and many students have taken the time to let us know how much the illustrations help them construct their understanding of key concepts. Still, in planning the Sixth Edition, we thought it was time for our most ambitious revision of the art program ever. To illustrate new examples and reinforce the most difficult concepts, we have increased the total number of illustrations by more than 150. In addition, new Guided Tour Diagrams merge art and text to walk students through complex biological structures and processes. You can see an example below.

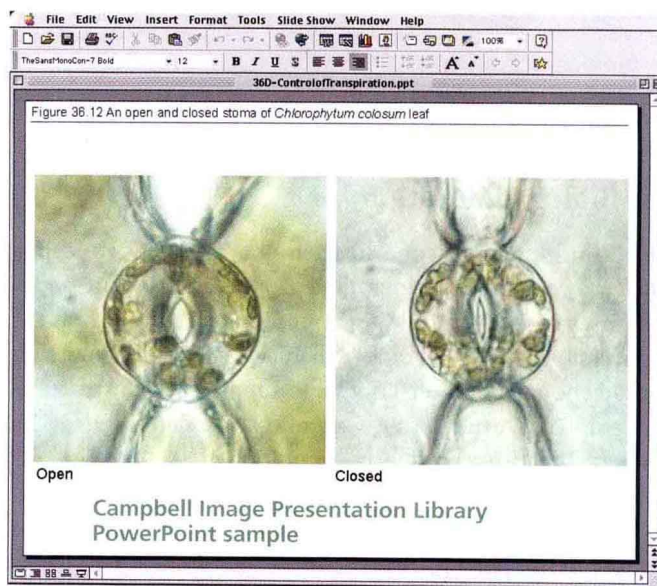


## Enriched Chapter Reviews

We have learned from students how much they value chapter reviews, especially the practice questions. Therefore, we have countered the trend of reducing the learning tools available to students at the ends of chapters. In fact, the chapter reviews in this Sixth Edition of *BIOLOGY* are more robust than ever. In addition to the chapter summary and multiple-choice questions of earlier editions, the chapter reviews now include short-answer questions, as requested by many students and instructors. And three categories of essay questions—Evolution Connection; The Process of Science; and Science, Technology, and Society—give students an opportunity to analyze and write about biology and its applications.

## The New Media Package That Instructors and Students Have Asked For

Just one example of *BIOLOGY*'s expanded media package is the new Campbell Image Presentation Library for instructors, a chapter-by-chapter digital archive that includes over 1600 photos (the text's photo program plus hundreds of additional selections), all of the book's art in a variety of formats, tables, over 100 animations, and over 80 video clips. The diagrams, photos, and tables are also provided as PowerPoint slides.



For the student, the CD-ROM and website that support the book emphasize active learning, including 55 Case Studies in the Process of Science, 230 Activities, interactive Chapter Reviews, word roots, key terms, pre-tests, activities quizzes, chapter quizzes, essay questions, web links, news links, news articles, further readings, art from the book, over 80 videos, the Campbell Biology Interviews from all editions, and a glossary with audio pronunciations.

The screenshot shows the Campbell Biology website interface. The main content area displays a lab report titled "47: Animal Development" and "What Determines Cell Differentiation in the Sea Urchin?". It includes diagrams of sea urchin spicules, a table for recording spicule types, and a text box for analyzing data.

		Host	
		Species A	Species B
Donor	Species A	NP: 100% A	NP: 100% A
	Species B	SF: 0% A	SF: 0% A

Text box content: "You are performing a control experiment here, as you did in the previous set of experiments. After the PMCs have been transplanted, click on the button to observe what type of spicules will be formed by the pluteus stage. Record the type of spicule in the data table at the bottom left of the screen in the appropriate column of the table. Click 'Reset Experiment' to continue doing additional experiments. When you have done all 4 transplantation experiments, answer Question 4 in the Lab Report and go to the next step."



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## Concepts and Themes That Work Together

*BIOLOGY*'s key concepts and unifying themes work together to help students develop a coherent view of life. For example, “Feedback mechanisms control cellular respiration” is a concept specific to the topic of Chapter 9. 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.

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## The Breadth and Depth to Support a Diversity of Courses and to Serve Students Throughout Their Biology Education

Even by limiting our scope to each chapter’s key concepts, *BIOLOGY* spans more biological territory than most introductory courses could or should attempt to explore. But given the great diversity of general biology syllabi, we have opted for a survey broad enough and deep enough to support each instructor’s special emphases. Students also seem to appreciate *BIOLOGY*'s balance of breadth and depth—more than 70% of students who have used *BIOLOGY* have kept it after completing their introductory course, apparently to have a more basic context to complement their upper division studies. In fact, we receive numerous letters and emails from upper division and graduate students, including medical students, expressing their appreciation for the long-term value of *BIOLOGY* as a general resource for their continuing education.

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## A Versatile Organization

Just as we recognize that few courses will cover all 55 chapters of the textbook, *BIOLOGY* also makes no pretense that there is one “correct” sequence of topics for a general biology course. Though a biology textbook’s table of contents must be linear, biology itself is more like a web of related ideas without a single starting point or a prescribed path. Diverse courses can navigate this network of concepts starting with molecules and cells, or with evolution and the diversity of organisms, or with the big-picture ideas of ecology. We have built *BIOLOGY* to be versatile enough to serve these different syllabi. The eight units of the book are largely self-contained, and most of the chapters within each unit can be assigned in a different sequence without substantial loss of coherence. For example, instructors who integrate plant and animal physiology into a systems approach can merge chapters from Unit Six (Plant Form and Function) and Unit Seven (Animal Form and Function) to fit their courses. As another example, instructors who begin their course with ecology and continue with this “top-down” approach can

assign Unit Eight (Ecology) right after Chapter 1 (Ten Themes in the Study of Life). It is the themes introduced in Chapter 1 that make the book so versatile in organization by providing students with a strong overall context no matter what the topic order of the course syllabus.

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## The Added Expertise of Leading Scientists

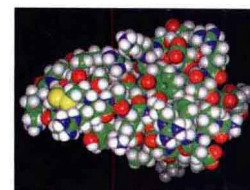
Given the rapid progress across biology’s many fields, our challenge for this new edition was to *update* without simply *adding-on*. What, we asked, are the most important breakthroughs in each field that should be included in the Sixth Edition? And, even harder to decide, what can be left out? In adapting to the growth of biology, we did not want the book to move away from its thematic, conceptual tradition to become encyclopedic. The goal was to identify the most important questions in each field of biology and make the research advances on those questions accessible to students without compromising the book’s reputation for scientific accuracy. We achieved this goal by recruiting a team of stellar specialists to help revise a number of chapters. These scientists are listed on the title page.

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## An Overview of *BIOLOGY* and a Few Examples of What’s New in the Sixth Edition

### Unit One: The Chemistry of Life

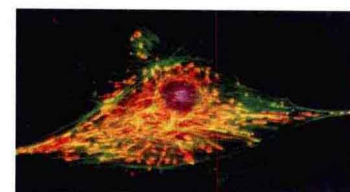
Many students struggle in general biology courses because they are uncomfortable with basic chemistry. Chapters 2–4 help such students by developing just the chemical concepts



that are essential to success in a beginning course. 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. 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. Just one example of the many improvements in Unit One is an updated discussion of chaperonins in Chapter 5.

### Unit Two: The Cell

Chapters 7–12 build the study of cells upon the theme of correlation between structure and function. For example, we emphasize the role of mem-



branes in ordering cell functions throughout the unit. In Chapter 7 (A Tour of the Cell), the improvements in this edition include completely new overview figures of animal and plant cells. Chapter 8 now includes the facilitated diffusion of water



across plasma membranes by aquaporins. We have improved Chapter 11 (Cell Communication) in response to suggestions from instructors and students. This chapter synthesizes our current understanding of the basic mechanisms of chemical signaling at the cellular level, giving students a conceptual foundation for a variety of topics that arise in later chapters. For this edition, we have enhanced the treatment of intracellular (steroid) receptors, while maintaining coverage of this topic in Chapter 45 (Chemical Signals in Animals).



**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. We integrate extensive coverage of human genetics throughout the unit. We have thoroughly updated all of the molecular biology chapters—Chapters 16–21—to reflect recent advances in this fast-moving area. Recent progress in genomics has affected Chapter 20 (DNA Technology and Genomics) most extensively; new figures include a diagram outlining the two main strategies used in genome sequencing. This unit has been further strengthened by the redesign of many existing figures (for instance, the series of diagrams explaining DNA replication). Concluding Unit Three is Chapter 21 (The Genetic Basis of Development). This chapter, updated with the guidance of Jeff Hardin (University of Wisconsin, Madison), builds on molecular, cellular, and genetic principles to introduce the basic concepts of development that apply to both animals and plants. *Drosophila*, *C. elegans*, and *Arabidopsis* provide the main case studies here. (More extensive presentations of vertebrate development and plant development appear in later units.)

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**Unit Four: Mechanisms of Evolution** As the central theme of *BIOLOGY*, evolution unifies the entire book. Chapters 22–25 focus specifically on *how* life evolves and how biologists study evolution and test evolutionary hypotheses.

Oxford University biologist Mark Ridley helped us support current concepts throughout the unit with many fresh case studies from the research literature. Here are just a few examples of the improvements: Chapter 22 (Descent with Modification: A Darwinian View of Life) now includes HIV as a case study of natural selection in action; Chapter 23 (The Evolution of Populations) has a new section on the evolutionary biology of sex; in Chapter 24 (The Origin of Species), we have examined the different definitions of species in greater depth in this edition, and we have thoroughly revised the section on “evo-devo,” the relationship of evolution to development; and Chapter 25 (Phylogeny and Systematics) uses new examples to walk students through the steps of cladistic analysis, including the construction of cladograms based on DNA-sequence data.

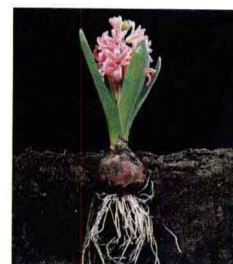
## Unit Five: The Evolutionary History of Biological Diversity

Renewed interest in the fossil record is complementing molecular systematics and cladistic analysis in arousing reevaluation of the history and classification of life. We have tried to capture the excitement of this scientific revolution. Unit Five’s introductory chapter (Chapter 26) now features a chronology of major events in the history of life as an overview of the whole unit. In Chapter 27, the survey of prokaryotic diversity is based on the major clades of archaea and bacteria. Chapter 28 (The Origins of Eukaryotic Diversity) includes the hypothesis that all three domains of life had their origins in communities of gene-swapping prokaryotes. The chapter also relates the diversity of algae to the evolutionary history of plastids. In the chapters on plant diversity (29 and 30), Linda Graham of the University of Wisconsin, Madison, helped us explain the evolution of plants from charophycean algae and reorganized our survey of plant phyla to fit recent progress in plant systematics. In Chapter 31 on the fungi, the diagrams of life cycles have been thoroughly revised to emphasize the key reproductive adaptations of each phylum. The chapters on animal diversity (Chapters 32–34), like all others in the unit, present phylogenetic hypotheses and taxonomy as works in progress, subject to revision in light of new evidence. Throughout our extensive revision of Unit Five, our goal was to help students make sense of the current taxonomic turmoil while still providing a lucid survey of life’s diversity. We would like students to understand why such issues as the relationship of annelids to arthropods remain unsettled, but we have not let our discussion of such debates obscure the biology of annelids, arthropods, and other major groups of organisms.




## Unit Six: Plant Form and Function

Plant biology is in the midst of a renaissance. The announcement in 2000 of the complete DNA sequence for the genome of *Arabidopsis*, the laboratory “white mouse” of modern plant research, commenced what promises to be an even livelier era in the study of plants. Peter Minorsky, science writer for the journal *Plant Physiology*, helped us reshape the plant unit to emphasize how research at the molecular and cellular levels is increasing our understanding of plant morphology, physiology, and development. We have updated the sections on the cellular basis of plant development and moved them to Chapter 35 to integrate development with our discussions of plant structure and growth. For example, Chapter 35 (Plant Structure and Growth) now features a research case study on the development of root hairs. The role of signal-transduction pathways is now an organizing concept throughout Chapter 39 (Plant Responses to Internal and External Signals).








**Unit Seven: Animal Form and Function**  
Chapters 40–49 explore adaptations that have evolved in diverse animal groups. Mark Chappell, University of California, Riverside, helped us give the themes of bioenergetics and regulation a stronger presence throughout the

unit. For example, the introductory chapter (Chapter 40) now features a new section on the energy budgets of diverse animals. Mary Jane Niles, University of San Francisco, helped us update the immunology chapter (Chapter 43), with special attention to the immune systems of invertebrates, the vertebrate MHC, autoimmune diseases, and AIDS. Chapter 47 (Animal Development) is now both clearer and current, thanks to input from Jeff Hardin (University of Wisconsin, Madison) and Lisa Urry (Mills College). With the help of Deric Bownds, University of Wisconsin, Madison, we thoroughly updated the neuroscience in Chapters 48 and 49. For example, Chapter 48 features recent breakthroughs in our understanding of how the brain works. There are also new sections on how axons find their way during development and on the discovery and medical significance of stem cells in the brain.



**Unit Eight: Ecology** Chapters 50–55 emphasize the connections between ecology and evolution. The unit also makes the case for basic ecological research in an age when human activities are threatening the biosphere. We targeted the ecology chapters for especially extensive revision in this edition, and so we asked Charles Krebs, University of British Columbia, to contribute his expertise to the project. One of our main goals was to in-

crease the emphasis on research case studies throughout the chapters, including analysis of many field experiments. The result amounts to a new ecology unit for *BIOLOGY*. Here are just a few examples of the improvements: Chapter 52 provides case studies of experiments ecologists perform to determine the factors that limit population growth; Chapter 53 contrasts the rivet model with the redundancy model in a discussion of community structure, and also features research on the bottom-up and top-down modes in the control of community structure; Chapter 54 on ecosystems includes a survey of experiments that test which nutrients limit productivity in various aquatic ecosystems; and Chapter 55 on conservation biology contrasts the small-population approach with the declining-population approach as strategies in slowing losses of biodiversity.

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The real test for 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 directly to one of the authors:

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or

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## Acknowledgments

This Sixth Edition of *BIOLOGY* reflects the talents and hard work of many people, and the authors wish to express their deepest thanks to the numerous instructors, researchers, students, publishing professionals, and artists who have contributed to this and previous editions.

We are particularly grateful to the biologists who are listed as Contributors and Advisors on the title page. These nine experts guided our revision of material in several critical areas of biology. Distinguished ecologist Charles Krebs was an important advisor on the revision of the ecology unit, and contributed new material to Chapters 50 and 52–55. Evolutionary biologist Mark Ridley did the same for Chapters 22–26, 34, and 51 (and also wrote a number of challenging Evolution Connection questions). Plant biologists Linda Graham and Peter Minorsky lent their considerable expertise and good judgment to Chapters 29–30 and Chapters 35–39, respectively. Animal physiologist Mark Chappell provided important new insights and material for the revisions of Chapters 40–42 and 44, as did neuroscientist Deric Bownds for Chapters 48–49. Once again for this edition, immunologist Mary Jane Niles was the mastermind behind the revision of Chapter 43, and developmental biologist Jeff Hardin was our main guide for the updating of Chapters 21 and 47. Discussions with science historian Gar Allen inspired our efforts to give the process of science enhanced prominence in this edition. We also wish to acknowledge the contributions of Larry Mitchell to previous editions of this book.

Thanks also to the instructors who contributed new questions for the chapter reviews. In addition to Mark Ridley, these include James Costa (Western Carolina University), William Fixsen (Harvard University), Martha Taylor (Cornell University), and Lisa Urry (Mills College). It's not easy to write good questions, and we appreciate the time and effort these dedicated educators put into their creation of excellent ones.

Further helping us improve *BIOLOGY*'s scientific accuracy and pedagogy, 47 biologists, cited on page xi, provided detailed reviews of one or more chapters for this edition. Among these reviewers, we would like to single out Lisa Urry (Mills College) for contributions beyond the call of duty; her detailed suggestions for the genetics and development chapters were immensely helpful. Numerous other professors and students offered suggestions by writing directly to the authors. Those correspondents include: Scott Poethig (University of Pennsylvania), Michael Marcotrigiano (University of Massachusetts), Cyril Thong (Simon Fraser University), D. Reid Wiseman (College of Charleston), Paul Broady (University of Canterbury, NZ), Allan Markezich (Black Hawk College), Barbara Demming-Adams (University of Colorado), Jon Havenhand (Flinders University), Joseph Frankel (University of Iowa), Jim Grier (North Dakota State University), Lee Sola (Glendale Community College), Barbara Beitch (Hamden Hall Country Day School), Susan Riechert (University of Tennessee, Knoxville), Christa

Schwintzer (University of Maine), Tony Hulbert (University of Wollongong), Tim Nelson (Seattle Pacific University), Sandra Baldauf (University of York), Philip Bishop (Otago University), Alison Cree (Otago University), Raymond White (City College of San Francisco), and Grahame Kelley (Queensland University of Technology).

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 scientists have also helped shape this Sixth Edition by discussing their research fields and ideas about biology education. Neil Campbell thanks many UC Riverside colleagues, including Ring Carde, Richard Cardullo, Mark Chappell, Darleen DeMason, Norman Ellstrand, Alan Fix, Kimberly Hammond, Anthony Huang, Bradley Hyman, Tracy Kahn, Elizabeth Lord, Carol Lovatt, Eugene Nothnagel, John Oross, Timothy Paine, David Reznick, Rodolfo Ruibal, Clay Sassaman, Mark Springer, Nelson Thompson, William Thomson, John Trumble, and John Moore (whose "Science as a Way of Knowing" essays have had such an important influence on the evolution of *BIOLOGY*). Jane Reece thanks Mark Guyer of the National Human Genome Research Institute for continuing to serve as an invaluable resource for Chapter 20.

The value of *BIOLOGY* as a teaching tool is greatly enhanced by the supplementary materials that have been created for instructors and students. We wish to thank Ed Zalisko and David Reid of Blackburn College and Eric Simon of Fordham University for their work on the Instructor's Guide and Steve Norton (East Carolina University) for the PowerPoint Lectures. Special thanks are due to Bill Barstow (University of Georgia) and his team of contributors (Michael Dini, Eugene Fenster, Conrad Firling, Kurt Redborg, Marshall Sundberg, Catherine Wilcoxson Ueckert, and Robert Yost) for their extensive revision of the Test Bank. Martha Taylor has once again written a superb student Study Guide. And we are grateful to the many people—biology instructors, editors, artists, production experts, and narrators—who are listed in the credits for the very impressive electronic media that accompany the book.

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 Sixth Edition, we are proud to include interviews with Thomas Eisner, George Langford, Nancy Hopkins, Peter and Rosemary Grant, Paul Sereno, Joanne Chory, Flossie Wong-Staal, and David Schindler.

*BIOLOGY*, Sixth Edition, results from an unusually strong synergism between a team of scientists and a team of publishing professionals. A new design, the sweeping revision of the art as well as the text, and a rich media package combined to create unprecedented challenges for the publishing team.

The members of the core book team at Benjamin Cummings brought extraordinary talents and extraordinary hard work to



this project. Developmental Manager Pat Burner, our colleague of many years, again worked closely with the text and art from manuscript stage through production and directed and helped create the elaborate media program that accompanies the book. For this Sixth Edition, however, Pat also amazingly found time to research and write up-to-date sections on nerve cell development and neural stem cells for Chapter 48! So, in addition to our thanks for Pat's exceptional editorial talents and dedication, we are now delighted to express our gratitude for her biological scholarship.

Pat's partner in directing the media program, Senior Producer Russell Chun, brought to the project not only his formidable skills in biological illustration and computer animation but an innate pedagogical sense that enhanced everything he touched. Also serving as art director for the book, Russell was the originator of the Guided Tour concept used for many of the more complex illustrations in this edition, and an important technical expert on the extended media package.

The other senior members of the core book team brought complementary talents to the project. Senior Project Manager Ginnie Simione Jutson miraculously managed to keep the whole team, including the authors, on track; somehow she managed to be both tough and encouraging. She was also the project leader on the complex new Campbell Image Presentation Library. Project Editor Evelyn Dahlgren made numerous contributions during manuscript development and production; this book has benefited greatly from her sharp-eyed and patient attention to text, art, and layout. In addition, Evelyn managed the supplements package and was a key member of the Image Presentation Library team. Senior Production Editor Jamie Sue Brooks was responsible for the complex design and production process and brought a wonderful design sensibility to the project.

We are also grateful to production professionals Diane Southworth, Steven Anderson, and Ariel Sosna, and to Manufacturing Supervisor Vivian McDougal for their expertise and hard work. For their tireless efforts in producing the student media package, we would like to thank the in-house media production team: Lauren Fogel, Andrew Corbett, Jim Hufford, Marlene Dabis, Michael Walsh, Roman Tobe, and Phaedra Schroeder. Little would have gotten done, of course, without the support of our bright and talented publishing assistants, including Aaron Gass (who went on to work as Assistant Editor coordinating the student media), Nina Lewallen, David De Rouen, and Krystina Sibley, all of whom performed numerous tasks relating to both the text and media package.

And now we come to our incomparable editor, Senior Editor Beth Wilbur. Joining the company just as this complex project was getting under way, Beth has faced a series of daunting challenges. But with every new challenge, she has risen to the task with creative solutions and fresh enthusiasm, and she has earned our heartfelt thanks for pulling it all together. We are proud to have Beth represent our book in the

academic community, and we are proud to have her as our colleague and friend.

In addition to the in-house editorial and production staff, a number of talented freelancers made valuable contributions to this book. We are grateful for the help of developmental editors Robin Fox, Moira Lerner, and Richard Morel; copyeditors Janet Greenblatt (who also helped develop the Ecology unit), Jan McDearmon, and Eleanor Renner Brown; text designer Detta Penna; cover designer Roy Neuhaus; layout artists Carolyn Deacy, Andrew Ogus, Leigh McLellan, and Jennifer Dunn; proofreaders Martha Ghent, Anita Wagner, Yonie Overton, Joseph Curran, Joan Saunders, Sue Rudolph, Maria Paras, Anna Trabucco, and Arlene Larson (our biologist proofreader); indexer Charlotte Shane, SAIS; and production editor Sharon Page Ritchie. Stephanie Kuhns and Kathi Townes at TechArts keyboarded and proofread final manuscript. Also, we thank Shelley Parlante for her work on the early stages of development and for taking time off from her current high-tech job to help check dummy. We are grateful for the production expertise and extra commitment of Larry Lazopoulos, Kim Johnson, Suzanne Olivier, and especially for the devotion of John Burner, who worked on review of dummy and other late-production tasks.

The illustrations in *BIOLOGY* are key elements of its teaching effectiveness. Russell Chun personally developed much of the art. His partner in that endeavor was our longtime colleague Carla Simmons, a gifted freelance biological artist. This book has benefited from Carla's artistic and pedagogical talents since its first edition. We were again fortunate to have the indomitable Senior Art Editor Donna Kalal on the team; she shepherded all of our art through production with scrupulous attention to thousands of details and unswerving commitment to quality. We wish to thank all the artists who worked on the new and revised figures for this edition, including Russell, Carla, Caitlin Duckwall, and the artists of Precision Graphics. Photo researchers Stephen Forsling and Travis Amos searched for just the right photos to reinforce key concepts. Travis also carried out the herculean task of collecting a large number of excellent photos for the Campbell Image Presentation Library, and was an important advisor, contributor, and colleague on the development of that important new supplement. Robin Heyden worked with Travis on the Image Library, as did Graham Kent (Smith College), who also contributed to the photo program for the text.

We would also like to thank the hard-working employees of GTS Graphics, especially Sherrill Redd, and Von Hoffman Press.

Linda Davis, President of Benjamin Cummings Publishing, has shared our commitment to excellence and provided strong support for two editions now, and new Editorial Director Frank Ruggirello has added his own unique brand of support and enthusiasm in the final stages of preparation of this edition. We thank our former editor Erin Mulligan for her contributions to the early stages of the project.



Both before and after publication, we are fortunate to have the support of the Benjamin Cummings marketing professionals. We gratefully acknowledge the contributions of Marketing Manager Josh Frost and Marketing VP Stacy Treco and her team. We also thank Lillian Carr for designing an elegant brochure and Jessica McFadden for the e-brochure.

The Benjamin Cummings field staff, which 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 features of our book.

Finally, we wish to thank our families and friends for their encouragement and for enduring our obsession with *BIOLOGY*.

Neil Campbell  
Jane Reece

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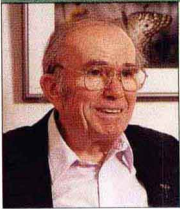
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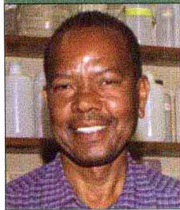
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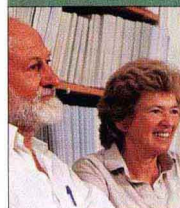
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# THE INTERVIEWS

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