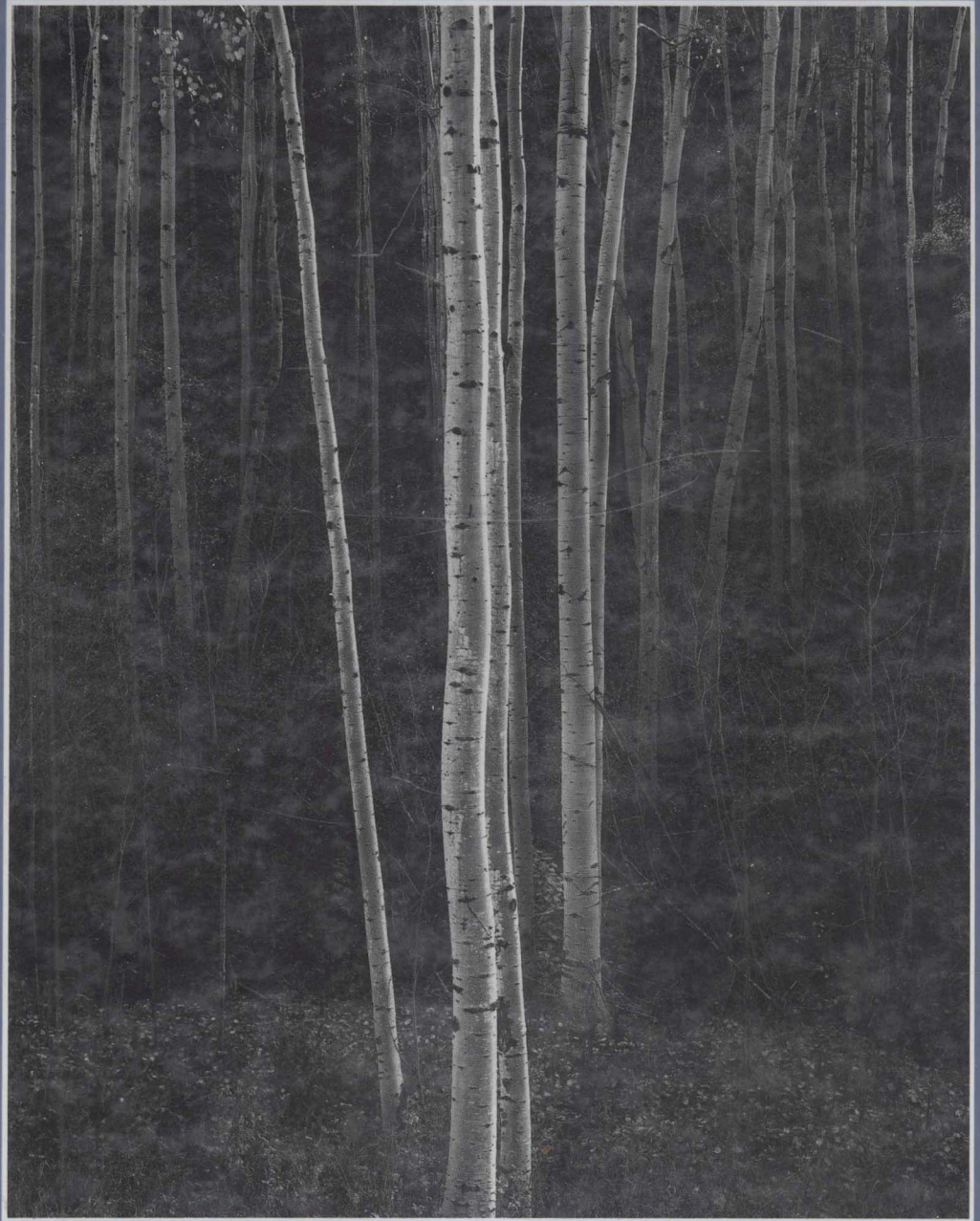


BIOLOGY

THIRD EDITION



CAMPBELL

BIOLOGY

T H I R D E D I T I O N

NEIL A. CAMPBELL

University of California, Riverside

The Benjamin/Cummings Publishing Company, Inc.

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Figure acknowledgments begin on page C-1.

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Library of Congress Cataloging-in-Publication Data

Campbell, Neil A., 1946–
Biology/Neil A. Campbell.—3rd ed.
p. cm.—(Benjamin/Cummings series in the life sciences)
Includes bibliographical references and index.
ISBN 0-8053-1880-1
1. Biology. I. Title. II. Series
QH308.2.C34 1993
574—dc20

2 3 4 5 6 7 8 9 10—DO—97 96 95 94 93



The Benjamin/Cummings Publishing Company, Inc.
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Redwood City, California 94065

*To Rochelle and Allison,
with love*

About the Author

BIOLOGY is the product of 24 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 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 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 has instructed over 13,000 students. His teaching sensibilities have been honed in both large lecture and small classroom environments and with a diverse group of students. He is currently a Visiting Scholar in the Department of Botany and Plant Sciences at the University of California, Riverside.

PREFACE



This third edition of *BIOLOGY* builds on the teaching values that characterized the first two versions. Those teaching values defined the book's two objectives: to explain biological concepts clearly and accurately within a context of unifying themes, and to help students develop more positive and realistic impressions of science as a human activity. Those dual objectives have now shaped the third edition's improvements.

FIVE MAJOR IMPROVEMENTS IN THE THIRD EDITION

1. Evolution, the core theme of *BIOLOGY*, is even more pervasive in this edition. A thematic approach distinguishes this book from an "encyclopedia of biology." The first chapter introduces several themes that resurface throughout the text to help students synthesize connections in their study of life. The overarching theme is evolution, which accounts for the unity and diversity of life and integrates the book's other themes. This edition brings the evolutionary view of life into even sharper focus. For example, several new sections in the first three units will help students link cellular and molecular biology to the core theme of evolution.

2. This edition of *BIOLOGY* features even greater emphasis on the process of science. The power and limitations of science are now presented more thoroughly in Chapter 1, and the hypothetico-deductive method is then applied in several case studies that appear throughout the text. The Methods Boxes, many of them new in this edition, help demystify science by explaining laboratory and field methods in the context of experiments. Eight new interviews with influential biologists (see pp. xiv–xv) personalize science, portraying it as a social activity of creative men and women rather than an impersonal collection of facts.

3. "Science, Technology, and Society" has been added as one of *BIOLOGY*'s themes. Biology and its applications have a profound impact on culture—on our view of the natural world, on our environmental awareness, and on our health and quality of life. It is important for students to understand that ethics has a place in science, even in basic research, and that technology brings with it the need to examine values and to

make choices. The third edition of *BIOLOGY* highlights the interrelatedness of science, technology, and society. In particular, complex environmental issues are more prominent in this edition. A new category of Science, Technology, and Society questions at the end of each chapter encourages students to incorporate biology into their world view.

4. Extensive revision of *BIOLOGY*'s illustrations helps the third edition teach difficult concepts even more effectively. Most figures have been redesigned, always with an eye toward stronger pedagogy. One important navigational aid is the consistent use of color-coding and icons throughout the book. Proteins, for example, are color-coded purple, and ATP always appears in illustrations as a yellow sunburst. This edition also improves upon the text-figure coordination that distinguished earlier editions. The artists, photo researchers, editors, and I worked together, beginning with the first draft, to embed the figures into the story line of each chapter. In fact, students will find that examining the figures and their self-contained legends is one way to preview or review the content of a chapter.

5. The "Overview–Closer Look–Postview" teaching style has been strengthened in this edition. One reason *BIOLOGY* has so many pages is that it commits much space to methodical presentations of complex topics—carefully paced presentations that add layers of detail judiciously so that the main concepts are reinforced, not obscured. This third edition makes it even easier for students to fit what they are learning into a framework of general concepts. Complicated processes, such as cellular respiration (Chapter 9) and protein synthesis (Chapter 16), are first presented in panoramic view ("overview"), providing the student with a sense of what the whole process accomplishes. Text and figures then dissect the process for "a closer look" at how it works. Orientation diagrams, miniature versions of the overview illustration with appropriate parts highlighted, keep this stepwise development connected to the central concepts. In many chapters, the closer look is followed by a postview, often a comprehensive diagram that helps students reconstruct the overall process from its components. This teaching approach and the other features of *BIOLOGY* continue to evolve from classroom experience with students who share my resolve to survive the information explosion by sorting out each topic's main points.

CONTENT AND ORGANIZATION

BIOLOGY makes no pretense that there is one “correct” way to order the major topics in an introductory biology course. Over the years, I have rearranged my own syllabus in various ways, finding that many different sequences are workable. This book is flexible enough for instructors to adapt its content to a variety of syllabi. The eight units are self-contained, allowing for rearrangement, and most of the chapters within each unit can be assigned in a different sequence without substantial loss of continuity. For example, instructors who integrate plant and animal physiology can merge chapters from Units Six and Seven to fit their courses.

A brief survey of the book’s organization will identify the content of each unit. Specific changes in each chapter are too numerous to list here.

Unit One: The Chemistry of Life My colleagues and I have found that many students struggle in their introductory biology courses because of inadequate backgrounds in basic chemistry. Chapters 2–4 are designed to help those students by developing, in carefully paced steps, the concepts of chemistry that are essential for success in biology. This approach makes self-study possible, reducing the need for instructors to spend valuable classroom time on basic chemistry. However, Chapter 5 (“The Structure and Function of Macromolecules”) and Chapter 6 (“An Introduction to Metabolism”) provide important orientation even to students with solid chemistry backgrounds. This edition builds stronger connections between chemistry and biology, with many new examples of how organisms work at the molecular level. Several new sections relate the chemistry of life to evolution.

Unit Two: The Cell Chapters 7–11 emphasize the correlation of structure and function as a theme for studying cells. For example, the importance of membranes in ordering metabolism is stressed throughout the unit. Substantial refinement of text and illustrations has strengthened the Overview–Closer Look–Postview pedagogy of these chapters. Among the other improvements is a more thorough discussion of how cell division is controlled in Chapter 11.

Unit Three: The Gene Chapters 12–19 take a historical approach to genetics, tracing its development from Gregor Mendel to DNA technology. *BIOLOGY*’s extensive coverage of human genetics in Unit Three emerges topically in each chapter, in close proximity to whatever general concept is being applied. The unit has been extensively revised to improve teaching effectiveness and to reflect the exciting progress in molecular genetics. For example, Chapter 19 (“DNA Technology”) features many new commercial applications and new techniques, such as antisense-RNA. New sections

in Unit Three examine the evolutionary significance of genetics.

Unit Four: Mechanisms of Evolution Evolution is the one theme that surfaces in every part of *BIOLOGY*, but Chapters 20–23 focus on *how* life evolves and how biologists study evolution. Chapter 20 (“Descent with Modification: A Darwinian View of Life”) now traces evolutionary theory as a case study in the scientific process. Chapter 20 also features new examples of natural selection in action. Chapter 22 has been updated to compare diverse views of how new species originate. Evolutionary biology is alive with controversy about the tempo and mechanisms of evolution, and students deserve to see that not all issues are settled.

Unit Five: The Evolutionary History of Biological Diversity Chapters 24–30 consider the diversity of life within 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 radiations of plants, fungi, and animals. The evolutionary theme of this unit contrasts sharply with a “parade of the kingdoms” approach to biodiversity. Among the improvements in the third edition are more extensive coverage of the ecological significance of bacteria and fungi. Chapter 27 includes a new section, “The Value of Plant Diversity,” an example of this edition’s greater emphasis on Science, Technology, and Society issues.

Unit Six: Plants: Form and Function Chapters 31–35 introduce students to the structure and physiology of plants within the evolutionary context of adaptation to terrestrial environments. A comprehensive revision places new emphasis on molecular and cellular approaches to plant biology. For example, Chapter 34 (“Plant Reproduction and Development”) includes new sections on pattern formation, clonal analysis of the shoot apex, and the genetic basis of flower development. Chapter 35 (“Control Systems in Plants”) now covers the cellular mechanisms of hormone action and examines signal transduction pathways in plant cells.

Unit Seven: Animals: Form and Function The organism–environment interface is the focus of Chapters 36–45, which take a comparative approach in exploring the diverse adaptations that have evolved in the animal kingdom. Humans fit into this comparative format as an important mammalian example. However, invertebrate and nonmammalian adaptations are even more visible in this edition than in the second edition. Some chapters were reorganized to improve their teaching effectiveness. For example, Chapter 39 now covers the complex topic of immunology more clearly, with the help of many new diagrams. This entire unit was also updated. Chapter 43, for example, explains recent progress in the study of animal development.

Unit Eight: Ecology Chapters 46–50 now represent a more cohesive unit on ecology, with a stronger evolutionary orientation and more connections to the book's other integrating themes. The new version of Chapter 46 is a more effective introduction to Earth's diverse environments, with increased emphasis on marine environments. In keeping with the third edition's new Science, Technology, and Society theme, all ecology chapters now cover environmental issues in greater depth. The chapters also present the different viewpoints in several of ecology's current debates, with the objective of encouraging students to evaluate arguments and evidence critically. Chapter 50 ("Behavior") was expanded and rewritten to stress behavioral ecology, which fits behavior into evolutionary context. This chapter also serves as a capstone for the entire book, relating ecology to other fields of biology, to the other natural sciences, and to the student's general education.

IN-TEXT LEARNING AIDS

Learning aids at the end of each chapter reinforce the chapter's main concepts, vocabulary, and applications. A **Study Outline** is keyed by page number to the major sections of the chapter. A **Self-Quiz** helps students measure their comprehension, but many of these questions also require students to apply knowledge or solve problems. The answers to the Self-Quiz questions are found 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. Short **Further Reading** lists complete the learning aids at the end of each chapter. Students will also find a **Glossary** of key terms at the end of the book. As references, Appendix Two presents a Classification of Life and Appendix Three the Metric System. To assist in still another way, Appendix Four introduces students to the learning tool known as **concept mapping**.

SUPPLEMENTS

Student Study Guide by Martha Taylor, Cornell University.

Investigating Biology: A Laboratory Manual for BIOLOGY by Judith Morgan, Emory University, and Eloise Carter, Oxford College of Emory University,

with accompanying Annotated Instructor's Edition and Preparation Guide.

BIOLOGY ClassNotes by Nina Caris and Harold Underwood, both of Texas A&M University.

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

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

Test Bank edited by William E. Barstow, University of Georgia, with consultants Martha Taylor, Cornell University, Margaret Waterman, Harvard Medical School, Daniel Wivagg, Baylor University, and Betty Ann Wonderley, Richardson Independent School District. This test bank is available on Microtest, a microcomputer test-generation program. (The test bank is available to qualified college and university adopters.)

Laboratory Collection edited by Judith Goodenough, University of Massachusetts.

Overhead Transparencies A set of 300 color acetates of illustrations and micrographs from *BIOLOGY*, Third 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 All of the text art from *BIOLOGY*, Third Edition, is available in black-and-white masters to qualified college and university adopters.

BioSHOW: The Videodisc A videodisc of text art, original animations, and motion sequences to accompany *BIOLOGY*, Third Edition, is available to qualified college and university adopters.

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

Many people have asked me how one person can write an entire general biology textbook. The answer, of course, is that one person *can't*, at least not without a lot of help. Though *BIOLOGY* is in my voice, each chapter is a synthesis of what I have learned from students, teachers, research scientists, contributors, artists, and editors. Their collective influence accounts for the improvements in this third edition.

Almost 75 biology instructors and research specialists reviewed chapters and helped me strengthen the scientific accuracy and teaching effectiveness of the third edition. Many other professors and their students took the time to volunteer their helpful suggestions by writing directly to me. Several scientists became even more involved by actually revising text or submitting early drafts of new material. These contributors are Gary Brusca (Humboldt State University), who helped revise the two chapters on animal diversity (Chapters 29 and 30); Berdell Funke (North Dakota State University), who collaborated on the immunology chapter (Chapter 39); Paul Hertz (Barnard College), who made major improvements in the ecology chapters (Chapters 46–49); Richard Liebaert (Linn Benton College, Oregon), who wrote many of the questions at the ends of chapters; Gary Matthews (State University of New York, Stonybrook), who contributed his expertise to the chapters on nerves, senses, and movement (Chapters 44 and 45); Jane Reece (Benjamin/Cummings) and Lawrence Mitchell (Iowa State University), who both did excellent work on the DNA technology chapter (Chapter 19); Fred Rhoades (Western Washington University), who worked extensively on three chapters in Unit Five (Chapters 25, 26, and 28); Stephen I. Rothstein (University of California, Santa Barbara), who improved the behavior chapter (Chapter 50) in many ways; and Fred Wilt (University of California, Berkeley), who guided revision of the chapters on gene expression in eukaryotes (Chapter 18) and animal development (Chapter 43). Although I am responsible for any errors that remain, they are all the fewer because of the dedication of the reviewers, correspondents, and contributors. They worked hard to help me make this edition more correct, current, and clear, and I thank them for their participation and their commitment to science education.

Numerous UC Riverside colleagues helped shape this revision by sharing insights about their research fields and exchanging ideas about biology education. In particular, I would like to thank Katherine Atkinson, Darleen DeMason, Leah Haimo, Robert Heath, Anthony Huang, Bradley Hyman, Robert Leonard, Elizabeth Lord, Carol Lovatt, John Oross, Kathryn Platt, David Reznick, Rodolfo Ruibal, Clay Sassaman, Irwin Sherman, Vaughan Shoemaker, William Thomson, Giles Waines, Marlene Zuk, and John Moore (whose "Science as a Way of Knowing" essays have influenced the evolution of this book). I am also grateful to Pius Horner, my longtime San Bernardino Valley College colleague, who was such an important mentor during my development as a classroom teacher.

One of the pleasures of revising *BIOLOGY* was the opportunity to conduct the new interviews that open the text's eight units. The interviewees for the third edition are Candace Pert, Michael Bishop and Harold Varmus, David Suzuki, Ernst Mayr, Stephen Jay Gould, Virginia Walbot, Karel Liem, and Ariel Lugo. I thank them for helping *BIOLOGY* communicate the fun of science to students.

The illustration program is such an integral part of *BIOLOGY* that the artists could be considered coauthors. More than two-thirds of the figures in the third edition are new or extensively revised. Carla Simmons and Pamela Drury-Wattenmaker were the principal artists. Carla also served as art consultant, and she is the one artist who has been a major creative force in all three editions of *BIOLOGY*. Nea Bisek, Barbara Cousins, and Sandra McMahon were the other artists who graced this edition with their work. I thank the entire art team for creating illustrations that will enhance *BIOLOGY*'s reputation for art that is as pedagogically innovative as it is visually attractive.

Photo editor Cecilia Mills and photo researcher Darcy Lanham found the many new beautiful, instructive photographs that enrich this third edition. I thank them for their perseverance in locating just the right photos to reinforce key concepts.

Suzanne Olivier, the main developmental editor for this edition, deserves special recognition as my partner throughout the revision process. She worked tirelessly in helping me make every chapter teach more effec-

tively. In particular, Suzanne engineered the ambitious revision of the book's art program, and her stamp is visible on every page. I thank Suzanne for the enormous role she played in improving *BIOLOGY*.

Many other publishing professionals helped me make this edition more useful to students. Pat Burner and Robin Fox did excellent work as developmental editors on several chapters. I also thank Susan Weisberg for editing most of the interviews. Copyeditor Betsy Dileria was outstanding in improving the clarity and consistency of the text. Proofreaders Brian Jones and Margot Otway were thorough in bringing errors and other problems to my attention. Kathy Pitcoff constructed the much-improved index. Lisa Donohoe and Valerie Kuletz put together the new supplements package. I am also grateful to editorial assistants Sissy Lemon, Christine Ruotolo, Kimberly Viano, and Thomas Viano for their help in making *BIOLOGY* a better book.

Pat Waldo, Gary Head, and Michele Mangelli of Publishing Principals, Inc., coordinated the production of this third edition, transforming manuscript, art, and photographs into a book. Pat is the human funnel through which all of the book's pieces flowed together. I am grateful for her experience, patience, flexibility, and extraordinary effort in what must be one of publishing's most complex jobs. Gary is *BIOLOGY*'s award-winning designer, the person responsible for keeping the book true to our goal of functional beauty. I also thank Gary for another great cover. Michele Mangelli worked with Gary and Pat on page layout, and I am very pleased with the results. I would also like to thank Brad Burch, Nancy Colman, Amy Head, Joshua King, and Carri Mangelli for their production assistance.

Benjamin/Cummings' own production department collaborated with Publishing Principals in designing this third edition and was also responsible for assuring quality in the manufacturing of the book you hold. In particular, I want to thank the production department's art and design manager Michele Carter, manufacturing supervisor Casimira KostECKI, and managing editor Gwen Larson.

The Benjamin/Cummings marketing department keeps *BIOLOGY* in touch with the students and professors it serves. I thank Deborah Phillips-Froese, Karryll Nason, Bob Ting, Rosemarie Forrest, and executive marketing manager Anne Emerson for announcing the third edition with an informative and dignified promotion.

The field staff that represents *BIOLOGY* on campuses is my 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. I thank them for their professionalism in communicating the strengths of our book without slurring other publishers and their competing books.

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 textbook we envisioned. Robin Heyden took over as sponsoring editor of the second edition and guided a revision that elevated *BIOLOGY* to the very top of the charts. I thank Jim and Robin for their continuing interest in the book's mission. I am also grateful to Benjamin/Cummings president Sally Elliott and vice president and editorial director Barbara Piercecchi for their sustaining faith in *BIOL-OGY* and its author.

Edith Beard Brady, the third edition's sponsoring editor, brought a fresh perspective to the book and inspired me to improve it in many ways. I admire her sincerity, publishing ethics, and genuine interest in the quality of science education. Most of all, I respect Edith for her courage; she is willing to take some risks and try new things. During this adventure of rethinking *BIOLOGY*, Edith has become a trusted friend and valued colleague. I thank her for sharing the goal of continuously improving our book.

Most of all, I thank my family and friends for their encouragement and for continuing to tolerate my obsession with making *BIOLOGY* a better textbook.

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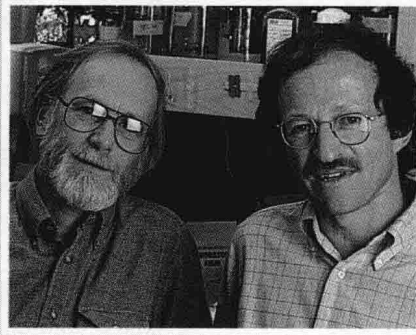


THE CHEMISTRY OF LIFE 20

Candace Pert

Scientific Director, Peptide Design

UNIT TWO

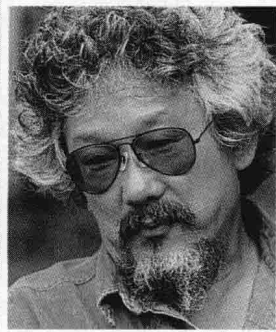


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**Michael Bishop and
Harold Varmus**

University of California, San Francisco

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David Suzuki

University of British Columbia

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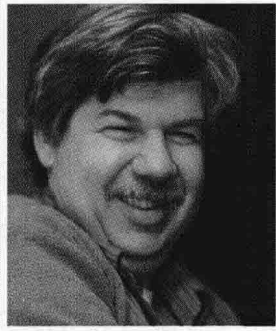


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UNIT FIVE



THE EVOLUTIONARY HISTORY
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Stephen Jay Gould

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Virginia Walbot

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UNIT SEVEN

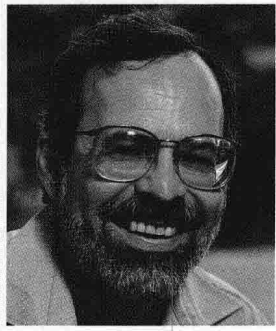


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UNIT EIGHT



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