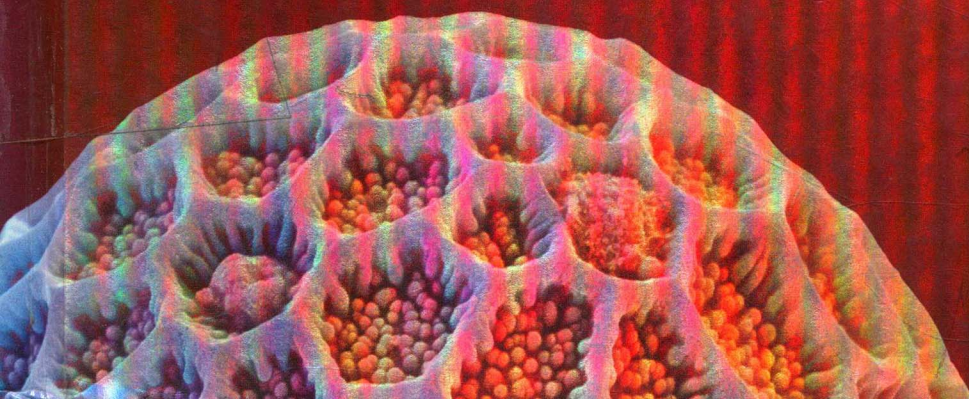


EIGHTH EDITION

BIOLOGY

Raven
Johnson
Losos
Mason
Singer



Biology

Eighth Edition

Jonathan B. Losos

Harvard University

Kenneth A. Mason

Purdue University

Susan R. Singer

Carleton College

based on the work of

Peter H. Raven

Director, Missouri Botanical Gardens;

Engelmann Professor of Botany

Washington University

George B. Johnson

Professor Emeritus of Biology

Washington University



Higher Education

Boston Burr Ridge, IL Dubuque, IA New York San Francisco St. Louis
Bangkok Bogotá Caracas Kuala Lumpur Lisbon London Madrid Mexico City
Milan Montreal New Delhi Santiago Seoul Singapore Sydney Taipei Toronto




BIOLOGY, EIGHTH EDITION

Published by McGraw-Hill, a business unit of The McGraw-Hill Companies, Inc., 1221 Avenue of the Americas, New York, NY 10020.

Copyright © 2008 by The McGraw-Hill Companies, Inc. All rights reserved. No part of this publication may be reproduced or distributed in any form or by any means, or stored in a database or retrieval system, without the prior written consent of The McGraw-Hill Companies, Inc., including, but not limited to, in any network or other electronic storage or transmission, or broadcast for distance learning.

Some ancillaries, including electronic and print components, may not be available to customers outside the United States.

 This book is printed on recycled, acid-free paper containing 10% postconsumer waste.

1 2 3 4 5 6 7 8 9 0 DOW/DOW 0 9 8 7 6

ISBN 978-0-07-296581-0

MHID 0-07-296581-9

Publisher: *Janice Roerig-Blong*

Executive Editor: *Patrick E. Reidy*

Senior Developmental Editor: *Anne L. Winch*

Director of Marketing: *Chad E. Grall*

Lead Project Manager: *Peggy J. Selle*

Senior Production Supervisor: *Kara Kudronowicz*

Senior Media Project Manager: *Jodi K. Banowitz*

Senior Media Producer: *Eric A. Weber*

Senior Coordinator of Freelance Design: *Michelle D. Whitaker*

Cover/Interior Designer: *Christopher Reese*

Senior Photo Research Coordinator: *Lori Hancock*

Photo Research: *Pronk & Associates*

Supplement Producer: *Melissa M. Leick*

Art Development/Art Studio: *Electronic Publishing Services Inc., NYC*

Compositor: *Electronic Publishing Services Inc., NYC*

Typeface: *10/12 Janson*

Printer: *R. R. Donnelley Willard, OH*

(USE) Cover Image: DNA: ©Doug Struthers/Getty Images; Female Mountain Gorilla: ©Daniel J. Cox/Getty Images; Dragonfly: ©Siede Preis/Getty Images; Maple Leaf: C Squared Studios/Getty Images; Knotweed Pollen: ©David Scharf/Getty Images

The credits section for this book begins on page C-1 and is considered an extension of the copyright page.

Library of Congress Cataloging-in-Publication Data

Biology / Peter H. Raven ... [et al.]. -- 8th ed.

p. cm.

Includes index.

ISBN 978-0-07-296581-0 --- ISBN 0-07-296581-9 (alk. paper)

1. Biology--Textbooks. I. Raven, Peter H.

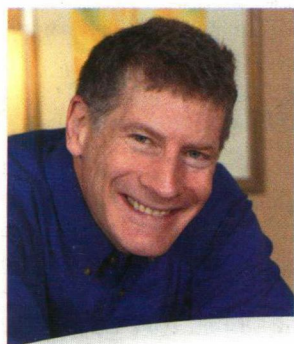
QH308.2.R38 2008

570--dc22

2006032857

www.mhhe.com

about the authors...



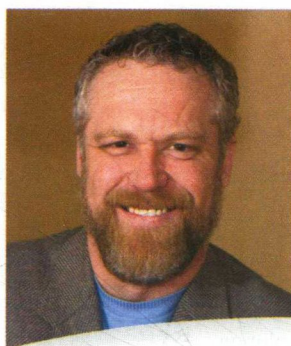
Jonathan Losos is a Monique and Philip Lehner Professor for the Study of Latin America in the Department of Organismic and Evolutionary Biology and Curator of Herpetology at the Museum of Comparative Zoology at Harvard University. Losos's research has

focused on studying patterns of adaptive radiation and evolutionary diversification in lizards. The recipient of several awards, including the prestigious Theodosius Dobzhansky and David Starr Jordan Prizes for outstanding young evolutionary biologists, Losos has published more than 100 scientific articles.



Susan Singer is the Laurence McKinley Gould Professor of the Natural Sciences in the department of biology at Carleton College in Northfield, Minnesota, where she has taught introductory biology, plant biology, genetics, plant development, and developmental genetics for 20 years. Her research

interests are focused on the development and evolution of flowering plants. Singer has authored numerous scientific publications on plant development, contributed chapters to developmental biology texts, and is actively involved with the education efforts of several professional societies. She received the American Society of Plant Biology's Excellence in Teaching Award, serves on the National Academies Board on Science Education, and chaired the National Research Council study committee that produced *America's Lab Report*.



Kenneth Mason is a Continuing Lecturer at Purdue University where he is responsible for the largest introductory biology course on campus. He is currently collaborating with faculty in the College of Engineering on an innovative new course supported by the National Science Foundation

that combines biology, chemistry, and physics. Prior to Purdue, he was an Assistant Professor at the University of Kansas, where he did research on the genetics of pigmentation in amphibians, publishing both original work and reviews on the topic. While at KU he taught a variety of courses and wrote a lab manual used in the genetics laboratory course.

preface

Everywhere you look in this edition you will see a new Raven & Johnson's *Biology*. From the new author team, to the new design and art program and the completely revised content, *Biology* has undergone a transformation. This "new" text maintains the clear, accessible, and engaging writing style of past editions and the pervasive emphasis on evolution and scientific inquiry that have made this a leading textbook for students majoring in biology. Now we have coupled this approach to a modern integration of the exciting new research in molecular biology and genomics to offer our readers the most significant and important revision of our text since the first edition.

Our New Author Team

Perhaps the greatest change to this edition is the change in authoring responsibilities. Two of us, Jonathan Losos (Harvard University) and Susan Singer (Carleton College), became new co-authors in the seventh edition, and now we've taken on full authoring responsibilities for the eighth edition as we welcome Kenneth Mason of Purdue University to our team. Ken served as a key contributor in the genetics unit for the seventh edition. The quality of the work he provided, his expertise in genetics, and his experience in teaching majors in biology at the university level made him a natural choice to join our new author team.

We're excited about the opportunity to take what was already a high-quality textbook and move it forward in a significant way for a new generation of students. All of us have extensive experience teaching undergraduate biology and we've used this knowledge as a guide in producing a text that is up-to-date, beautifully illustrated, and pedagogically sound for the student. We've also worked to make it even easier to use and more closely integrated with its media support materials to provide instructors with an excellent complement to their teaching.

Our New Visual Program

Even a casual look through the pages of the eighth edition will show the care that went into developing the art and photo program and the related page design. A brand new visual program is rare in a revision, and our team found the opportunity to reevaluate the effectiveness of the artwork and photos to be an exciting challenge. Our goal has been to provide a clear, consistent, accurate art program that is easy-to-follow and beautifully three-dimensional.

To prepare for the revision, a variety of specialists reviewed the seventh edition art and photo program to assess its instructional effectiveness and presentational value. We

worked closely with the artists and medical illustrators to produce sketches that effectively convey the chapter's most important concepts or that provide students with a particularly thought-provoking or dynamic example. A separate panel of reviewers then evaluated each newly rendered figure for pedagogical value and accuracy.

Our text-paging team then worked in conjunction with the artists to create innovative page spreads where the visuals and textual content function together in a well-coordinated and closely integrated manner. For complex processes, figures use numbered text boxes to lead the student step-by-step through the figure. For others, where the whole is more important than the pieces, the figure is not interrupted by text but explained thoroughly in the legend. Multilevel figures take students from a macro to micro view using "blow-out" arrows. Where figures can be put "inline" within the text this has been done to intimately connect the art with the text narrative and to allow the artwork to visually enliven the page.

Our Modern Content and Approach

One goal that unites our author team is the attempt to bring students an exciting and up-to-date view of modern biology. The extensive nature of this revision has produced exceptionally current content throughout. Likewise, rather than pasting paragraphs of new material into selected chapters, we have carefully worked together to reconsider our text's outline and coverage to provide a more consistent approach to concepts so that the reader is not buried in detail in one chapter and left wondering how something works in another.

Two new chapters in the evolution unit perfectly illustrate the importance of this goal. Chapter 24: *Genome Evolution* describes comparative genomics and explains how exciting new discoveries resulting from the genome sequencing of so many different species is revolutionizing our understanding of evolution. Chapter 25: *Evolution of Development* follows with a discussion of how changes in genes can produce changes in development patterns, which result in new characteristics and sometimes in speciation.

We've expanded our coverage of patterns of inheritance into chapter 12 on heredity and Mendelian principles and chapter 13 on chromosomal theory of inheritance. We've created a new chapter 23: *Systematics and the Phylogenetic Revolution* and we now provide chapter 26: *The Tree of Life* to offer a broad overview as a way of introduction to the unit.

Another individual example of the current content is the coverage of the newly discovered fossil that is transitional between fish and amphibians, *Tiktaalik*, which was announced in mid-2006 (see figure 35.14b). Similarly, our discussion of the

state of the environment is based on up-to-the-moment data on population trends, global temperatures, and CO₂ levels.

The physiology unit has been reorganized and includes a new introductory chapter 43: *The Animal Body and Principles of Regulation*. This is designed to introduce the tissues and organ systems covered in later chapters and provide an understanding of control systems and their associated feedback mechanisms.

Our Consistent Themes

It is important to have consistent themes that organize and unify a text. We met extensively to discuss our approaches to teaching biology and to design the most effective text possible. A number of themes are used throughout the book to unify the broad-ranging material that makes up modern biology. This begins with the primary goal of this textbook to provide a comprehensive understanding of evolutionary theory and the scientific basis for this view. We use an experimental framework combining both historical and contemporary research examples to help students appreciate the progressive and integrated nature of science.

Biology Is Based Upon an Understanding of Evolution

When Peter Raven and George Johnson began work on *Biology* in 1982 they set out to write a text that presented biology the way they taught in their classrooms: as the product of evolution. Much as all biology “only makes sense in the light of evolution,” this text is enhanced by a consistent evolutionary theme that is woven throughout the text, and we have enhanced this theme in the eighth edition.

The enhanced evolutionary thread can be found in obvious examples such as the two new chapters on molecular evolution, but can also be found throughout the text. As each section considers the current state of knowledge, the “what” of biological phenomenon, they also consider how each system may have arisen by evolution, the “where it came from” of biological phenomenon.

Our approach allows evolution to be dealt with in the context in which it is relevant. The material throughout this book is considered not only in terms of present structure and function, but how that structure and function may have arisen via evolution by natural selection.

Biology Uses the Methods of Scientific Inquiry

Another unifying theme within the text is that knowledge arises from experimental work that moves us progressively forward. The use of historical and experimental approaches throughout allow the student to not only see where the field is now, but more importantly, how we arrived here. The incredible expansion of knowledge in biology has created challenges for authors to decide what content to keep, and to what level an introductory text should strive. We have tried to keep as much historical context as possible and to provide this within an experimental framework consistently throughout the text.

Rather than interrupting the text with an experimental box, we describe experiments in the context of the concepts being provided. This keeps experimental approaches relevant to the story being told. Data are provided throughout the text

and figures to illustrate how we have arrived at our present view of the various topics that make up the different sections of the book. Students are also provided with “Inquiry Questions” to stimulate thought about the material throughout the book. The questions often involve data that are presented in figures, but are not limited to this approach, also leading the student to question the material in the text as well.

Biology Is an Integrative Science

The explosion of molecular information has reverberated throughout all areas of biological study. Scientists are increasingly able to describe complicated processes in terms of the interaction of specific molecules, and this knowledge of life at the molecular level has illuminated relationships that were previously unknown. Using this cutting-edge information, we have made great strides to more strongly connect the different areas of biology in this edition.

One example of this integration concerns the structure and function of biological molecules, an emphasis of modern biology. This revision brings that focus to the entire book using this as a theme to weave together the different aspects of content material with a modern perspective. Given the enormous amount of information that has accumulated in recent years, this provides a necessary thread that integrates these new perspectives into the fabric of the traditional biology text.

Likewise, all current biology texts have added a genomics chapter, and our text was one of the first to do this. This chapter has been updated, but, more importantly, the results from the analysis of genomes and the proteomes that they encode have been added throughout the book wherever this information is relevant. This allows a more modern perspective throughout the book rather than limiting it to a few chapters. Examples, for instance, can be found in the diversity chapters, where classification of some organisms were updated based on new findings revealed by molecular techniques.

This systems approach to biology also shows up at the level of chapter organization. We introduce genomes in the genetics section in the context of learning about DNA and genomics. We then come back to this topic with an entire chapter at the end of the evolution unit where we look at the evolution of genomes, followed by a chapter on the evolution of development, which leads into our unit on the diversity of organisms.

Similarly, we introduce the topic of development with a chapter in the genetics section, return to it in the evolution unit, and have dedicated chapters in both the plant and animal units. This layering of concepts is important as we believe that students best understand evolution, development, physiology, and ecology when they can reflect on the connections between the microscopic and macroscopic levels of organization.

Our Enhanced Readability and Learning System

Biology has always been considered a user-friendly text, but the sheer volume of information in a major's biology text demands that authors do everything possible to make the content clear

and well-organized to aid the student. In this eighth edition we have taken steps to help our readers through careful scrutiny of the narrative and thorough redesign of our pedagogical learning system.

Telling the Story of Biology

We had the benefit of an excellent developmental copyeditor who worked with us on each revised chapter prior to turning the manuscript over to production. The copyeditor focused on improving the use of headings to organize the content, improving the clarity of the writing, making the writing consistent between chapters, consistently identifying and defining the key terms, and eliminating redundant material within and among chapters. This process removed the clutter that can accumulate over several editions and ensured that each chapter reads smoothly from start to finish.

Providing a Learning System

Part of what makes *Biology* such an easy book to learn from is its consistent pedagogical framework, and we have strengthened this learning system in the eighth edition. Each chapter opens with an outline consisting of the numbered headings and the supporting headings. Throughout the chapter the interior design works with the content to remind the students of where they are in the chapter.

Each concept within a chapter is clearly demarcated at beginning and end. The declarative main headings and sentence-style supporting headings provide an excellent overview of each concept to be covered. Short interim summaries following each main concept within the narrative remind students of the most critical information they need to take away from that reading.

Extensive figure legends in conjunction with the new visual program provide a “visual outline” of all major ideas in

every chapter. Great care was taken during the paging process to ensure that with few exceptions figures are displayed on the same pages where the narrative detail supporting those figures is provided.

We’ve also created an extensive set of summary tables throughout the text to make study and review as easy and efficient as possible. Content reviews at the end of the chapter recapitulate important content within the same conceptual framework provided in the opening outline. We’ve also developed new Challenge Questions to promote active learning and higher level critical thinking.

Our Commitment to You

We are united in our excitement about this opportunity to take a textbook that was already accurate and innovative and move it forward in a meaningful way. We believe our research and teaching experience provides us with the tools to couple the most significant modern research findings and scientific approach to an engaging pedagogical presentation.

In working with reviewers, contributors, focus group participants, students, and our colleagues around the globe, we have been impressed with the level of energy, thoughtfulness, and dedication faculty and students bring to the study of biology. It is a privilege to serve you through the pages of this textbook and its media support program.

Please let us know how we can serve you better by writing us at ravenbiology@mcgraw-hill.com. Best wishes to you in your own classroom. We look forward to hearing from you.

Jonathan Losos

Ken Mason

Susan Singer

ACKNOWLEDGMENTS

A revision of this scope relies on the talents and efforts of many people working behind the scenes and we have benefited greatly from their assistance.

Jody Larson was our developmental copyeditor who labored many hours and provided countless suggestions for improving the organization and clarity of the text. Her contributions had a tremendous impact on the quality of the final product.

We were fortunate to have Electronic Publishing Services on our side for the overhaul of the *Biology* art program. Kim Moss, Jen Christiansen, Martin Huber, Eliza Jewett, Patty O'Connell, and the rest of the team did a fantastic job in developing art and photo concepts and page spreads based on our manuscript and the ideas exchanged in our development meetings. Our close collaboration resulted in a text that is pedagogically effective as well as more beautiful than any biology text on the market. This was a giant undertaking and the staff at EPS handled it all with professionalism, skill, and good humor.

We were fortunate in our McGraw-Hill book team led by Patrick Reidy, executive editor, Anne Winch, senior developmental editor, Chad Grall, marketing director for life sciences, Peggy Selle, lead project manager, Michelle Whitaker, senior freelance design coordinator, Linda Davoli, production copyeditor, and many more people behind the scenes.

During this revision we have had the support of spouses and children, who have seen less of us than they might have liked because of the pressures of getting this revision completed. They have adapted to the many hours this book draws us away from them, and, even more than us, look forward to its completion.

As with every edition, acknowledgments would not be complete without thanking the generations of students who have used the many editions of this text. They have taught us as least as much as we have taught them, and their questions and suggestions continue to improve the text and supplementary materials.

Finally, we need to thank our reviewers and contributors. Instructors from across the country are continually invited to share their knowledge and experience with us through reviews and focus groups. The feedback we received shaped this edition, resulting in new chapters, reorganization of the table of contents, and expanded coverage in key areas. Several faculty members were asked to provide preliminary drafts of chapters to ensure that the content was as up to date and accurate as possible, and still others were asked to provide chapter outlines and assessment questions. All of these people took time out of their already busy lives to help us build a better edition of *Biology* for the next generation of introductory biology students, and they have our heartfelt thanks.

Preliminary Draft Revision Contributors

Brian Bagatto
University of Akron

Nancy Maroushek Boury
Iowa State University

Julia Emerson
Amherst College

T. H. Frazzetta
University of Illinois, Urbana-Champaign

Douglas Gaffin
University of Oklahoma

Gonzalo Giribet
Harvard University

Richard Hill
Michigan State University

Duncan S. MacKenzie
Texas A&M University

Elizabeth A. Weiss
University of Texas, Austin

End-of-Chapter Pedagogy and Inquiry Contributors

Arthur Buikema
Virginia Polytechnic Institute

Merri Lynn Casem
California State University-Fullerton

Mark Lyford
University of Wyoming

Peter Niewiarowski
University of Akron

Thomas Pitzer
Florida International University

Laurel Roberts
University of Pittsburgh

Michael Windelspecht
Appalachian State University

Reviewers and Accuracy Checkers

Barbara J. Abraham
Hampton University

Richard Adler
University of Michigan, Dearborn

Sylvester Allred
Northern Arizona University

Steven M. Aquilani
Delaware County Community College

Jonathan W. Armbruster
Auburn University

Gregory A. Armstrong
The Ohio State University

Jorge E. Arriagada
St. Cloud State University

David K. Asch
Youngstown State University

Brian Bagatto
University of Akron

Garen Baghdasarian
Santa Monica College

Anita Davelos Baines
The University of Texas, Pan American

Ronald A. Balsamo Jr.
Villanova University

Michael Bartlett
Portland State University

Vernon W. Bauer
Francis Marion University

James E. Baxter
Oblone College

George W. Benz
Middle Tennessee State University

Gerald K. Bergtrom
University of Wisconsin, Milwaukee

Arlene G. Billock
University of Louisiana, Lafayette

Catherine S. Black
Idaho State University

Michael W. Black
California Polytechnic State University

Robert O. Blanchard
University of New Hampshire

- Andrew R. Blaustein
Oregon State University
- Mary A. Bober
Santa Monica College
- Nancy Maroushek Boury
Iowa State University
- M. Deane Bowers
University of Colorado
- Scott A. Bowling
Auburn University
- Benita A. Brink
Adams State College
- Anne Bullerjahn
Owens Community College
- Ray D. Burkett
Southwest Tennessee Community College
- Helaine Burstein
Ohio University
- Scott Burt
Truman State University
- Carol T. Burton
Bellevue Community College
- Jennifer Carr Burtwistle
Northeast Community College
- Jorge Busciglio
University of California, Irvine
- Pat Calie
Eastern Kentucky University
- Christy A. Carello
The Metropolitan State College of Denver
- Michael Carey
University of Scranton
- Jeff Carmichael
University of North Dakota
- Michael J. Carlisle
Trinity Valley Community College
- John H. Caruso
University of New Orleans
- Thomas T. Chen
University of Connecticut
- Cynthia Church
The Metropolitan State College of Denver
- Linda T. Collins
University of Tennessee, Chattanooga
- Scott T. Cooper
University of Wisconsin, La Crosse
- Joe R. Cowles
Virginia Tech
- Nigel M. Crawford
University of California, San Diego
- James Crowder
Brookdale Community College
- Karen A. Curto
University of Pittsburgh
- Bela Dadhich
Delaware County Community College
- Lydia B. Daniels
University of Pittsburgh
- Terry Davin
Penn Valley Community College
- Joseph S. Davis
University of Florida
- Neta Dean
Stony Brook University
- Kevin W. Dees
Wharton County Junior College
- D. Michael Denbow
Virginia Tech
- Donald Deters
Bowling Green State University
- Hudson DeYoe
University of Texas, Pan American
- Randy DiDomenico
University of Colorado
- Nd Dikeocha
College of the Mainland
- Robert S. Dill
Bergen Community College
- Diane M. Dixon
Southeastern Oklahoma State University
- Kevin Dixon
University of Illinois
- John S. Doctor
Duquesne University
- Ernest F. DuBrul
University of Toledo
- Charles Duggins Jr.
University of South Carolina
- Richard P. Elinson
Duquesne University
- Johnny El-Rady
University of South Florida
- Frederick B. Essig
University of South Florida
- David H. Evans
University of Florida
- Guy E. Farish
Adams State College
- Daphne G. Fautin
University of Kansas
- Bruce E. Felgenhauer
University of Louisiana, Lafayette
- Carolyn J. Ferguson
Kansas State University
- Teresa G. Fischer
Indian River Community College
- Irwin Forseth
University of Maryland
- Gail Fraizer
Kent State University
- Barbara A. Frase
Bradley University
- Sylvia Fromherz
University of Northern Colorado
- Phillip E. Funk
DePaul University
- Caitlin R. Gabor
Texas State University, San Marcos
- Purti P. Gadkari
Wharton County Junior College
- John R. Geiser
Western Michigan University
- Frank S. Gilliam
Marshall University
- Miriam S. Golbert
College of the Canyons
- Scott A. Gordon
University of Southern Indiana
- John S. Graham
Bowling Green State University
- David A. Gray
California State University, Northridge
- William F. Hanna
Massasoit Community College
- Kyle E. Harms
Louisiana State University
- Kerry D. Heafner
University of Louisiana, Monroe
- Susan E. Hengeveld
Indiana University
- Charles Henry
University of Connecticut, Storrs
- Peter Heywood
Brown University
- Juliana G. Hinton
McNeese State University
- Margaret L. Horton
University of North Carolina, Greensboro
- James Horwitz
Palm Beach Community College
- Laura A. Houston
Montgomery College
- Feng Sheng Hu
University of Illinois
- Allen N. Hunt
Elizabethtown Community and Technical College
- David C. Jarrell
University of Mary Washington
- Jennifer L. Jeffery
Wharton County Junior College
- William Jeffery
University of Maryland, College Park
- Lee Johnson
The Ohio State University
- Craig T. Jordan
The University of Texas, San Antonio
- Ronald L. Jones
Eastern Kentucky University
- Robyn Jordan
University of Louisiana, Monroe
- Walter S. Judd
University of Florida
- David Julian
University of Florida
- Daniel Kainer
Montgomery College
- Ronald C. Kaltreider
York College of Pennsylvania
- Thomas C. Kane
University of Cincinnati
- Donald A. Kangas
Truman State University
- William J. Katembe
Delta State University
- Steven J. Kaye
Red Rocks Community College
- Stephen R. Kelso
University of Illinois, Chicago
- Nancy S. Kirkpatrick
Lake Superior State University

- John Z. Kiss
Miami University
- John C. Krenetsky
The Metropolitan State College of Denver
- Karin E. Krieger
University of Wisconsin, Green Bay
- David T. Kurjiaka
University of Arizona
- Arlene T. Larson
University of Colorado, Denver
- Peter Lavrentyev
University of Akron
- Laura G. Leff
Kent State University
- Michael R. Lentz
University of North Florida
- Harvey Liftin
Broward Community College
- Yue J. Lin
St. John's University
- Amy Litt
New York Botanical Garden
- Christopher R. Little
The University of Texas, Pan American
- James Long
Boise State University
- James O. Luken
Coastal Carolina University
- Dennis J. Lye
Northern Kentucky University
- P. T. Magee
University of Minnesota, Minneapolis
- Richard Malkin
University of California, Berkeley
- Mark D. Mamrack
Wright State University
- Kathleen A. Marrs
Indiana University Purdue University, Indianapolis
- Diane L. Marshall
University of New Mexico
- Paul B. Martin
St. Philip's College
- Peter J. Martinat
Xavier University, Los Angeles
- Joel Maruniak
University of Missouri
- Patricia Matthews
Grand Valley State University
- Robin G. Maxwell
The University of North Carolina, Greensboro
- Brenda S. McAdory
Tennessee State University
- Nael A. McCarty
Georgia Institute of Technology
- Brock R. McMillan
Minnesota State University, Mankato
- Kay McMurry
The University of Texas, Austin
- Elizabeth McPartlan
De Anza College
- Brad Mehrtens
University of Illinois, Urbana-Champaign
- Michael Meighan
University of California, Berkeley
- Douglas Meikle
Miami University
- Allen F. Mensinger
University of Minnesota, Duluth
- Wayne B. Merkley
Drake University
- Catherine E. Merovich
West Virginia University
- Frank J. Messina
Utah State University
- Brian T. Miller
Middle Tennessee State University
- Sarah L. Milton
Florida Atlantic University
- Subhash Minocha
University of New Hampshire
- Hector C. Miranda Jr.
Texas Southern University
- Patricia Mire
University of Louisiana, Lafayette
- Robert W. Morris
Widener University
- Satyanarayana Swamy Mruthinti
State University of West Georgia
- Richard L. Myers
Southwest Missouri State University
- Monica Marquez Nelson
Joliet Junior College
- Jacalyn S. Newman
University of Pittsburgh
- Harry Nickla
Creighton University
- Richard A. Niesenbaum
Muhlenberg College
- Kris M. Norenberg
Xavier University, Louisiana
- Deborah A. O'Dell
University of Mary Washington
- Sharman D. O'Neill
University of California, Davis
- Cynthia P. Paul
University of Michigan, Dearborn
- John S. Peters
College of Charleston
- Jay Phelan
University of California, Los Angeles
- Gregory W. Phillips
Blinn College
- Thomas R. Pitzer
Florida International University
- Gregory J. Podgorski
Utah State University
- Alan Prather
Michigan State University
- Mitch Price
The Pennsylvania State University
- Carl Quertermus
State University of West Georgia
- Shana Rapoport
California State University, Northridge
- Kim Raun
Wharton County Junior College
- Robert S. Rawding
Gannon University
- Jill D. Reid
Virginia Commonwealth University
- Linda R. Richardson
Blinn College
- Robin K. Richardson
Winona State University
- Carolyn Roberson
Roane State Community College
- Kenneth R. Robinson
Purdue University
- Kenneth H. Roux
Florida State University
- Charles L. Rutherford
Virginia Tech University
- Margaret Saha
College of William and Mary
- Thomas Sasek
University of Louisiana, Monroe
- Bruce M. Saul
Augusta State University
- Deemah N. Schirf
The University of Texas, San Antonio
- Christopher J. Schneider
Boston University
- Timothy E. Shannon
Francis Marion University
- Rebecca Sheller
Southwestern University
- Mark A. Sheridan
North Dakota State University
- Richard Showman
University of South Carolina
- Michèle Shuster
New Mexico State University
- William Simcik
Tomball College, a North Harris Community College
- Rebecca B. Simmons
University of North Dakota
- Phillip Snider Jr.
Gadsden State Community College
- Thomas E. Snowden
Florida Memorial College
- Dianne Snyder
Augusta State University
- Farah Sogo
Orange Coast College
- Nancy G. Solomon
Miami University
- Kathryn H. Sorensen
American River College
- Kevin N. Sorensen
Snow College
- Bruce Stallsmith
University of Alabama, Huntsville
- Patricia Steinke
San Jacinto College
- Jacqueline J. Stevens
Jackson State University
- John W. Stiller
East Carolina University

Antony Stretton
University of Wisconsin, Madison

Brett W. Strong
Palm Beach Community College

Gregory W. Stunz
Texas A&M University, Corpus Christi

Cynthia A. Surmacz
Bloomsburg University

Yves S. H. Tan
Cabrillo College

Sharon Thoma
University of Wisconsin, Madison

Anne M. S. Tokazewski
Burlington County College

Marty Tracey
Florida International University

Terry M. Trier
Grand Valley State University

Marsha R. Turell
Houston Community College

Linda Tyson
Santa Fe Community College

Rani Vajravelu
University of Central Florida

Jim Van Brunt
Rogue Community College

Judith B. Varelas
University of Northern Colorado

Neal J. Voelz
St. Cloud State University

Janice Voltzow
University of Scranton

Jyoti R. Wagle
Houston Community College System, Central

Charles Walcott
Cornell University

Randall Walikonis
University of Connecticut

Eileen Walsh
Westchester Community College

Steven A. Wasserman
University of California, San Diego

R. Douglas Watson
University of Alabama, Birmingham

Cindy Martinez Wedig
University of Texas, Pan American

Richard Weinstein
Southern New Hampshire University

Elizabeth A. Weiss
University of Texas, Austin

William R. Wellnitz
Augusta State University

Jonathan F. Wendel
Iowa State University

Sue Simon Westendorf
Ohio University

Vernon Lee Wiersema
Houston Community College, Southwest

Judy Williams
Southeastern Oklahoma State University

Lawrence R. Williams
University of Houston

Robert Winning
Eastern Michigan University

C. B. Wolfe
The University of North Carolina, Charlotte

Clarence C. Wolfe
Northern Virginia Community College

Eric Vivien Wong
University of Louisville

Gene K. Wong
Quinnipiac University

Denise Woodward
The Pennsylvania State University

Richard P. Wunderlin
University of South Florida

Douglas A. Wymer
The University of West Alabama

Lan Xu
South Dakota State University

H. Randall Yoder
Lamar University

Kathryn G. Zeiler
Red Rocks Community College

Scott D. Zimmerman
Missouri State University

Henry G. Zot
University of West Georgia

International Reviewers

Mari L. Acevedo
University of Puerto Rico, Arecibo

Heather Addy
University of Calgary

Heather E. Allison
University of Liverpool

David Backhouse
University of New England

Andrew Bendall
University of Guelph

Tony Bradshaw
Oxford Brookes University

D. Bruce Campbell
Okanagan College

Clara E. Carrasco
University of Puerto Rico, Ponce

Ian Cock
Griffith University

Margaret Cooley
University of New South Wales

R. S. Currah
University of Alberta

Logan Donaldson
York University

Theo Elzenga
University of Groningen

Neil Haave
University of Alberta, Augustana

Louise M. Hafner
QUT

Clare Hasenkampf
University of Toronto, Scarborough

Annika F. M. Haywood
Memorial University of Newfoundland

Rong-Nan Huang
National Central University

William Huddleston
University of Calgary

Wendy J. Keenleyside
University of Guelph

Chris Kennedy
Simon Fraser University

Alex Law
Nanyang Technical University, Singapore

Richard C. Leegood
University of Sheffield

R. W. Longair
University of Calgary

Thomas H. MacRae
Dalhousie University

Rolf W. Matthews
Simon Fraser University

R. Ian Menz
Flinders University

Todd C. Nickle
Mount Royal College

Kirsten Poling
University of Windsor

Jim Provan
Queen's University Belfast

Roberto Quinlan
York University

Elsa I. Colón Reyes
University of Puerto Rico, Aguadilla Campus

Richard Roy
McGill University

Liliane Schoofs
Katholieke Universiteit Leuven

Joan Sharp
Simon Fraser University

Julie Smit
University of Windsor

Nguan Soon Tan
Nanyang Technological University

Fleur Tiver
University of South Australia

Llinil Torres-Ojeda
University of Puerto Rico, Aguadilla Campus

Han A. B. Wösten
University of Utrecht

H. H. Yeoh
National University of Singapore

Art Review Panel

David K. Asch
Youngstown State University

Karl J. Aufderheide
Texas A&M University

Brian Bagatto
University of Akron

Andrew R. Blaustein
Oregon State University

Mark Browning
Purdue University

Jeff Carmichael
University of North Dakota

Wes Colgan III
Pikes Peak Community College

Karen A. Curto
University of Pittsburgh

Donald Deters
Bowling Green State University

Ernest F. DuBrul
University of Toledo

Ralph P. Eckerlin
Northern Virginia Community College

Frederick B. Essig
University of South Florida

Sharon Eversman
Montana State University, Bozeman

Barbara A. Frase
Bradley University

John R. Geiser
Western Michigan University

John Graham
Bowling Green State University

Susan E. Hengeveld
Indiana University

David Julian
University of Florida

Pamela J. Lanford
University of Maryland, College Park

James B. Ludden
College of DuPage

Patricia Mire
University of Louisiana, Lafayette

Janice Moore
Colorado State University

Jacalyn S. Newman
University of Pittsburgh

Robert Newman
University of North Dakota

Nicole S. Obert
University of Illinois, Urbana-Champaign

David G. Oppenheimer
University of Florida

Ellen Ott-Reeves
Blinn College, Bryan

Laurel Bridges Roberts
University of Pittsburgh

Deemah N. Schirf
The University of Texas, San Antonio

Mark A. Sheridan
North Dakota State University

Richard Showman
University of South Carolina

Phillip Snider Jr.
Gadsden State Community College

Nancy G. Solomon
Miami University

David Tam
University of North Texas

Marty Tracey
Florida International University

Michael J. Wade
Indiana University

Jyoti R. Wagle
Houston Community College System, Central

Andy Wang
The University of Iowa

Cindy Martinez Wedig
University of Texas, Pan American

C. B. Wolfe
The University of North Carolina, Charlotte

Biology Symposium Attendees

Every year McGraw-Hill conducts several General Biology Symposia, which are attended by instructors from across the country. These events are an opportunity for editors from McGraw-Hill to gather information about the needs and challenges of instructors teaching the major's biology course. It also offers a forum for the attendees to exchange ideas and experiences with colleagues they might not have otherwise met. The feedback we have received has been invaluable, and has contributed to the development of *Biology* and its supplements.

2006

Michael Bell
Richland College

Scott Bowling
Auburn University

Peter Busher
Boston University

Allison Cleveland
University of South Florida, Tampa

Sehoya Cotner
University of Minnesota

Kathryn Dickson
California State College, Fullerton

Cathy Donald-Whitney
Collin County Community College

Stanley Faeth
Arizona State University

Karen Gerhart
University of California, Davis

William Glider
University of Nebraska, Lincoln

Stan Guffey
The University of Tennessee

Bernard Hauser
University of Florida, Gainesville

Mark Hens
University of North Carolina, Greensboro

Jim Hickey
Miami University of Ohio, Oxford

Sherry Krayesky
University of Louisiana, Lafayette

Brenda Leaday
University of Toledo

Michael Meighan
University of California, Berkeley

Comer Patterson
Texas A&M University

Debra Pires
University of California, Los Angeles

Robert Simons
University of California, Los Angeles

Steven D. Skopik
University of Delaware

Ashok Upadhyaya
University of South Florida, Tampa

Anthony Uzwiak
Rutgers University

Dave Williams
Valencia Community College, East Campus

Jay Zimmerman
St. John's University

2005

Donald Buckley
Quinnipiac University

Arthur Buikema
Virginia Polytechnic Institute

Anne Bullerjahn
Owens Community College

Garry Davies
University of Alaska-Anchorage

Marilyn Hart
Minnesota State University

Daniel Flisser
Camden County College

Elizabeth Godrick
Boston University

Miriam Golbert
College of the Canyons

Sherry Harrel
Eastern Kentucky University

William Hoese
California State University, Fullerton

Margaret Horton
University of North Carolina, Greensboro

Carol Hurney
James Madison University

James Luken
Coastal Carolina University

Mark Lyford
University of Wyoming

Gail McKenzie
Jefferson State Junior College

Melissa Michael
University of Illinois, Urbana-Champaign

Subhash C. Minocha
University of New Hampshire

Leonore Neary
Joliet Junior College

K. Sata Sathasivan
University of Texas, Austin

David Senseman
University of Texas, San Antonio

Sukanya Subramanian
Collin County Community College

Randall Terry
Lamar University

Sharon Thoma
University of Wisconsin, Madison

William Tyler
Indian River Community College

2004

Jonathan Akin
Northwestern State University of Louisiana

David Asch
Youngstown State University

Diane Bassham
Iowa State University

Donald Buckley
Quinnipiac University

Ruth Buskirk
University of Texas, Austin

Charles Creutz
University of Toledo

Lydia Daniels
University of Pittsburgh

Laura DiCaprio
Ohio University

Michael Dini
Texas Tech University

John Doctor
Duquesne University

Ernest DuBrul
University of Toledo

John Elam
Florida State University

Samuel Hammer
Boston University

Marilyn Hart
Minnesota State University

Marc Hirrel
University of Central Arkansas

Carol Johnson
Texas A&M University

Dan Krane
Wright State University

Karin Krieger
University of Wisconsin, Green Bay

Josephine Kurdziel
University of Michigan

Martha Lundell
University of Texas, San Antonio

Roberta Maxwell
University of North Carolina, Greensboro

John Merrill
Michigan State University

Melissa Michael
University of Illinois, Urbana-Champaign

Peter Niewarowski
University of Akron

Ronald Patterson
Michigan State University

Peggy Pollak
Northern Arizona University

Uwe Pott
University of Wisconsin, Green Bay

Mitch Price
Pennsylvania State University

Steven Runge
University of Central Arkansas

Thomas Shafer
*University of North Carolina
Wilmington*

Richard Showman
University of South Carolina

Michèle Shuster
New Mexico State University

Dessie Underwood
California State University, Long Beach

Mike Wade
Indiana University

Elizabeth Willott
University of Arizona

Carl Wolfe
University of North Carolina, Charlotte

Majors Biology Media Focus Group

Russell Borski
North Carolina State University

Mark Decker
University of Minnesota

John Merrill
Michigan State University

Melissa Michael
University of Illinois, Urbana-Champaign

Randall Phillis
University of Massachusetts, Amherst

Mitch Price
Pennsylvania State University

Vivid and Instructional New Art Program for Visual Learners

The *Biology* author team collaborated with a team of medical and scientific illustrators to create the new visual program for the eighth edition. Focusing on consistency, accuracy, and pedagogical value, the team created an

art program that is intimately connected with the text narrative. The resulting realistic, 3-D illustrations will stimulate student interest and help instructors teach difficult concepts.

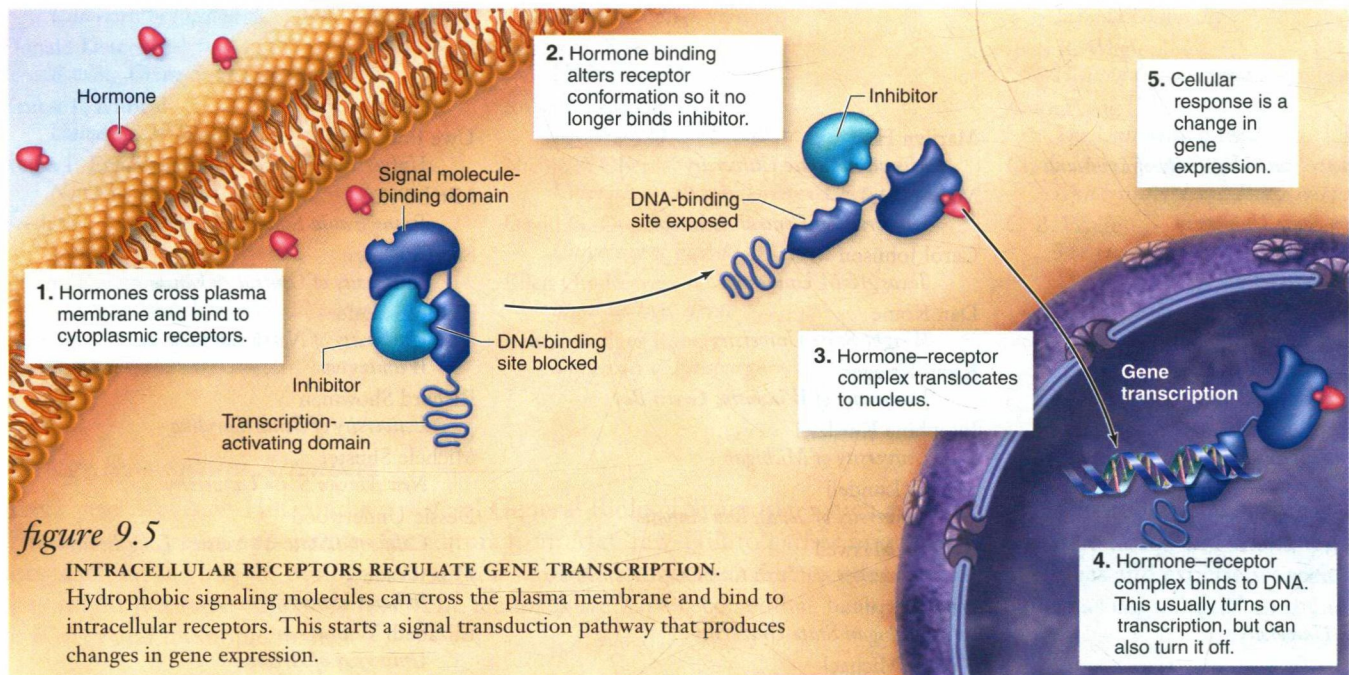


figure 9.5

INTRACELLULAR RECEPTORS REGULATE GENE TRANSCRIPTION.

Hydrophobic signaling molecules can cross the plasma membrane and bind to intracellular receptors. This starts a signal transduction pathway that produces changes in gene expression.

For complex processes, figures use numbered text boxes to lead the student step-by-step through the figure.

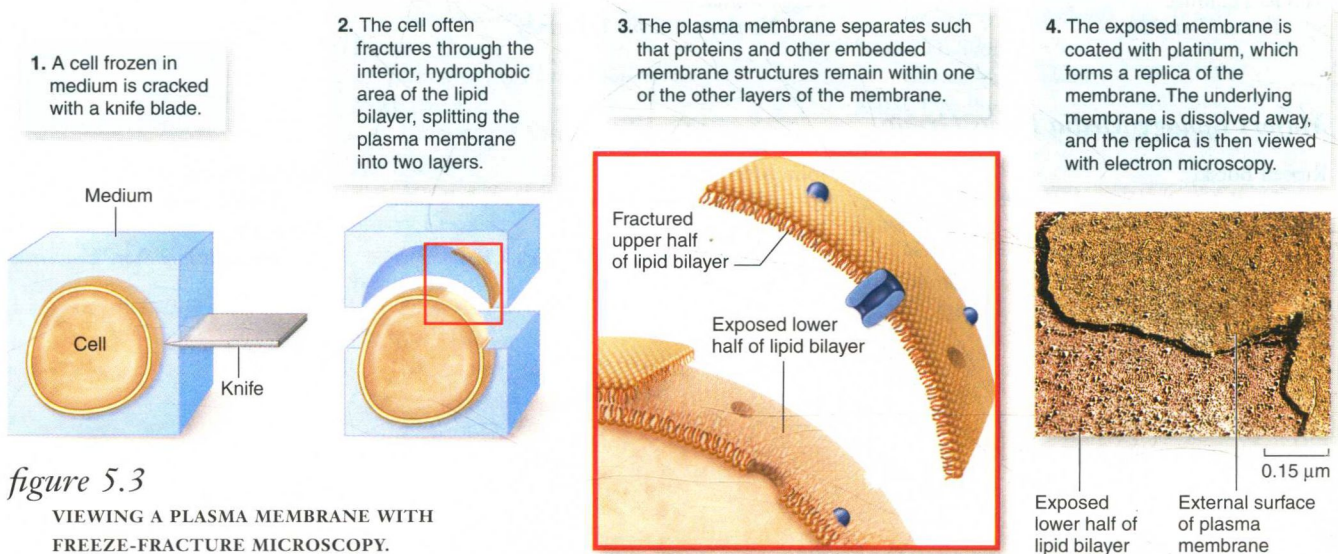
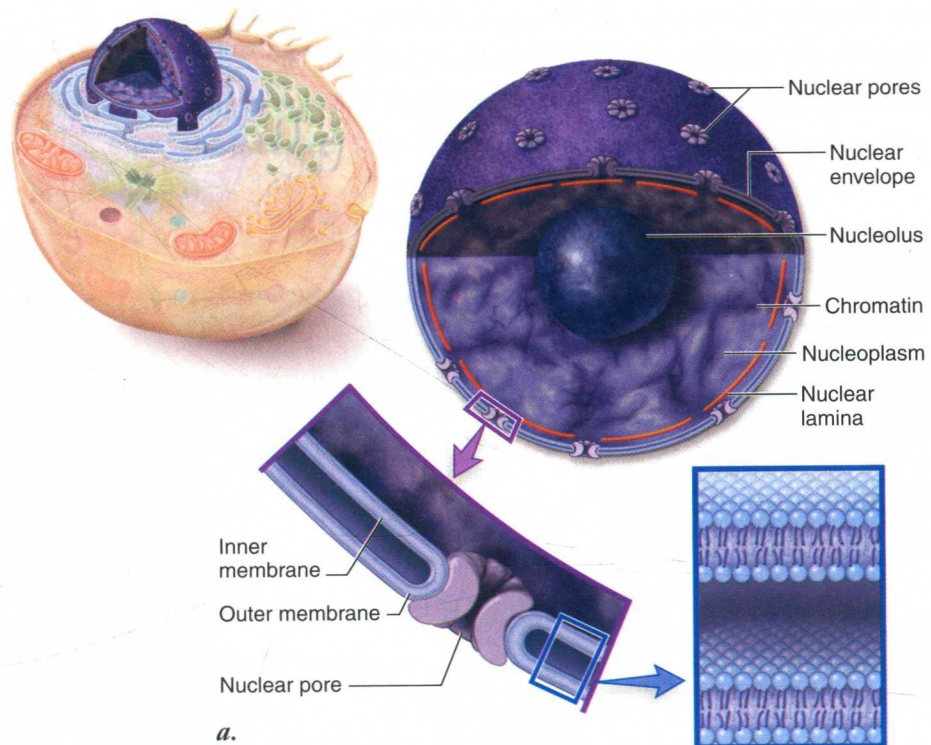


figure 5.3

VIEWING A PLASMA MEMBRANE WITH FREEZE-FRACTURE MICROSCOPY.

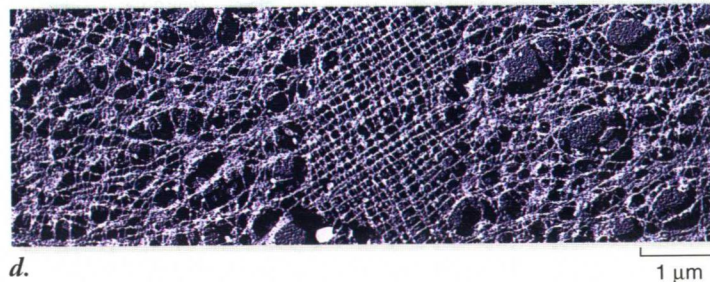
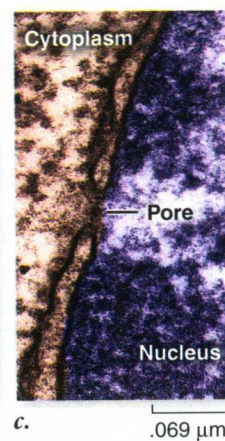
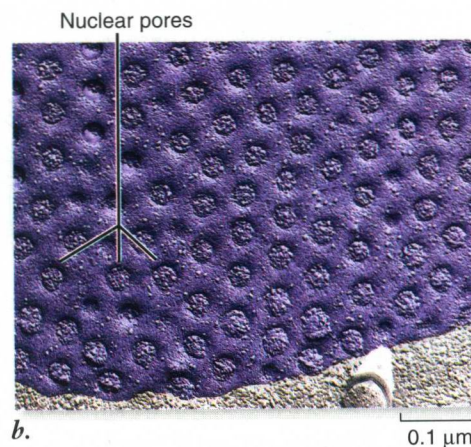
Multilevel figures

take students from a macro to micro view using “blow-out” arrows to help students put concepts into context.



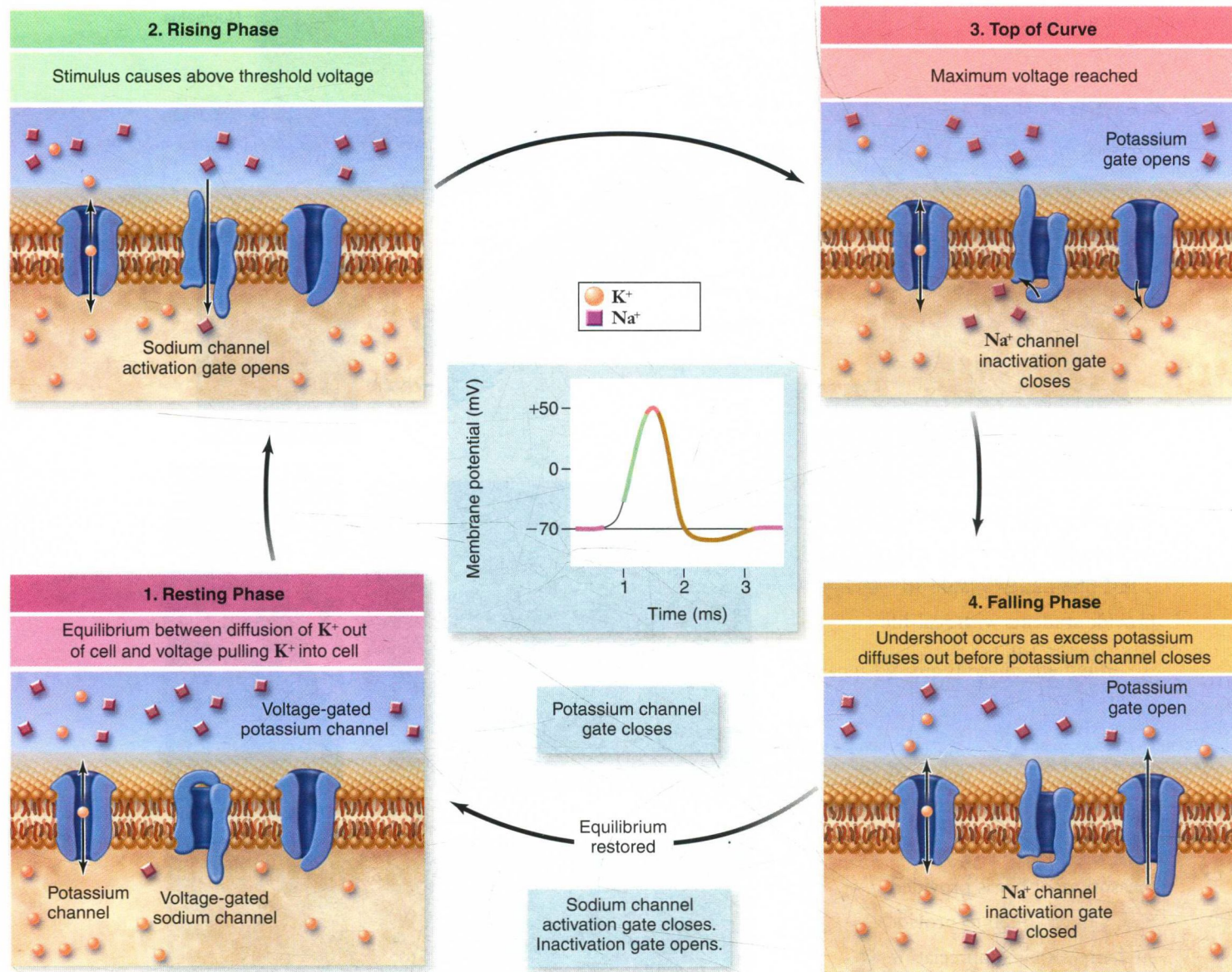
Illustrations are paired with high-quality LM, SEM, and TEM photomicrographs to provide students with real-life examples of cellular structures.

Whenever possible, a measurement bar is provided with a micrograph to provide students with an appreciation of the scale of biological structures.




Consistent color coding

means that students immediately recognize the biological structures used throughout the book. Their study time is spent learning concepts rather than orienting themselves to figure conventions. In some figures, color coding is also used to give the student visual cues to how information is related.



Consistent Pedagogical Aids to Promote Learning

Each chapter in the eighth edition is structured using the same set of pedagogical devices, which enables the student to develop a consistent learning strategy. These tools work together to provide a clear content hierarchy, break content into smaller, more accessible chunks, repeat important concepts, and provide students with opportunities for higher level thought.



chapter **24**

Genome Evolution

introduction

GENOMES CONTAIN THE RAW MATERIAL for evolution, and many clues to evolution are hidden in the ever-changing nature of genomes. As more genomes have been sequenced, the new and exciting field of comparative genomics has emerged and has yielded some surprising results and many, many questions. Comparing whole genomes, not just individual genes, enhances our ability to understand the workings of evolution, to improve crops and to identify the genetic basis of disease so that we may develop more effective treatments with minimal side effects. The focus of this chapter is on how comparative genomics is enhancing our understanding of genome evolution and how this new knowledge can be applied to improve our lives.

concept outline

24.1 Comparative Genomics

- Evolutionary differences accumulate over long periods
- Genomes evolve at different rates
- Plant, fungal, and animal genomes have unique and shared genes

24.2 Evolution of Whole Genomes

- Ancient and newly created polyploids guide studies of genome evolution
- Plant polyploidy is ubiquitous, with multiple common origins
- Polyploidy induces elimination of duplicated genes
- Polyploidy can alter gene expression
- Transposons jump around following polyploidization

24.3 Evolution Within Genomes

- Individual chromosomes may be duplicated
- DNA segments may be duplicated
- Genomes may become rearranged

24.4 Gene Function and Expression Patterns

- Gene inactivation results in pseudogenes
- Horizontal gene transfer complicates matters

24.5 Nonprotein-Coding DNA and Regulatory Function

- Chimpanzee and human gene transcription patterns differ
- Speech is uniquely human: An example of complex expression

24.6 Genome Size and Gene Number

- Noncoding DNA inflates genome size
- Plants have widely varying genome size

24.7 Genome Analysis and Disease Prevention and Treatment

- Distantly related genomes offer clues for causes of disease
- Closely related organisms enhance medical research
- Pathogen-host genome differences reveal drug targets

24.8 Crop Improvement Through Genome Analysis

- Model plant genomes provide links to genetics of crop plants
- Beneficial bacterial genes can be located and utilized

Chapter openers

include an outline comprised of the chapter headings, which provides a consistent framework for the student. Declarative, numbered main headings and sentence-style supporting headings result in a cogent overview of the content to be covered.