

GLOBAL  
EDITION



# Campbell Essential Biology with Physiology

SIXTH EDITION

Simon • Dickey • Reece



# Brief Contents

1 Learning About Life 36

## Unit 1 Cells 55

2 Essential Chemistry for Biology 56

3 The Molecules of Life 70

4 A Tour of the Cell 88

5 The Working Cell 108

6 Cellular Respiration: Obtaining Energy from Food 124

7 Photosynthesis: Using Light to Make Food 140

## Unit 2 Genetics 153

8 Cellular Reproduction: Cells from Cells 154

9 Patterns of Inheritance 178

10 The Structure and Function of DNA 204

11 How Genes Are Controlled 230

12 DNA Technology 250

## Unit 3 Evolution and Diversity 275

13 How Populations Evolve 276

14 How Biological Diversity Evolves 302

15 The Evolution of Microbial Life 326

16 The Evolution of Plants and Fungi 348

17 The Evolution of Animals 370

## Unit 4 Ecology 405

18 An Introduction to Ecology and the Biosphere 406

19 Population Ecology 436

20 Communities and Ecosystems 458

## Unit 5 Animal Structure and Function 487

21 Unifying Concepts of Animal Structure and Function 488

22 Nutrition and Digestion 508

23 Circulation and Respiration 528

24 The Body's Defenses 550

25 Hormones 568

26 Reproduction and Development 584

27 Nervous, Sensory, and Locomotor Systems 608

## Unit 6 Plant Structure and Function 637

28 The Life of a Flowering Plant 638

29 The Working Plant 658

CAMPBELL

essential <sup>6e</sup>  
biology

with  
physiology

GLOBAL EDITION

Eric J. Simon • Jean L. Dickey • Jane B. Reece

New England College

Clemson, South Carolina

Berkeley, California

with contributions from

Rebecca S. Burton

Alverno College



Courseware Portfolio Management, Director: *Beth Wilbur*  
Courseware Portfolio Management, Specialist:  
*Alison Rodal*  
Courseware Director, Content Development:  
*Ginnie Simone Jutson*  
Courseware Sr. Analyst: *John Burner*  
Developmental Editor: *Susan Teahan*  
Associate Editor, Global Edition: *Sulagna Dasgupta*  
Courseware Editorial Assistant: *Alison Candlin*  
Managing Producer: *Mike Early*  
Content Producer: *Lori Newman*  
Senior Content Developer: *Sarah Jensen*  
Rich Media Content Producers: *Tod Regan, Ziki Dekel*  
Media Production Manager, Global Edition:  
*Vikram Kumar*  
Full-Service Vendor: *Integra Software Services, Inc.*

Copyeditor: *Joanna Dinsmore*  
Compositor: *Integra Software Services, Inc.*  
Design Manager: *Mark Ong*  
Cover Designer, Global Edition: *Lumina Datamatics Ltd.*  
Interior Design: *TT Eye*  
Illustrators: *Lachina*  
Rights & Permissions Project Manager: *Ben Ferrini*  
Rights & Permissions Management: *Cenveo*  
Photo Researcher: *Kristin Piljay*  
Manufacturing Buyer: *Stacey Weinberger*  
Senior Manufacturing Controller, Global Edition:  
*Kay Holman*  
Product Marketing Manager: *Christa Pelaez*  
Field Marketing Manager: *Kelly Galli*  
Cover Photo Credit: *John Swannick/Shutterstock*

Acknowledgements of third party content appear on page A-5, which constitutes an extension of this copyright page.

*Pearson Education Limited*  
KAO Two  
KAO Park  
Harlow  
CM17 9SR  
United Kingdom

and Associated Companies throughout the world

Visit us on the World Wide Web at: [www.pearsonglobaleditions.com](http://www.pearsonglobaleditions.com)

© Pearson Education Limited 2020

The rights of Eric J. Simon, Jean L. Dickey, and Jane B. Reece to be identified as the authors of this work have been asserted by them in accordance with the Copyright, Designs and Patents Act 1988.

*Authorized adaptation from the United States edition, entitled Campbell Essential Biology with Physiology, Sixth Edition, ISBN 978-0-134-71175-1 by Eric J. Simon, Jean L. Dickey, and Jane B. Reece, published by Pearson Education © 2019.*

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without either the prior written permission of the publisher or a license permitting restricted copying in the United Kingdom issued by the Copyright Licensing Agency Ltd, Saffron House, 6–10 Kirby Street, London EC1N 8TS.

PEARSON, ALWAYS LEARNING, Mastering™ Biology, and BioFlix® are exclusive trademarks in the U.S. and/or other countries owned by Pearson Education, Inc. or its affiliates.

Unless otherwise indicated herein, any third-party trademarks that may appear in this work are the property of their respective owners and any references to third-party trademarks, logos or other trade dress are for demonstrative or descriptive purposes only. Such references are not intended to imply any sponsorship, endorsement, authorization, or promotion of Pearson's products by the owners of such marks, or any relationship between the owner and Pearson Education, Inc. or its affiliates, authors, licensees or distributors.

This eBook is a standalone product and may or may not include all assets that were part of the print version. It also does not provide access to other Pearson digital products like MyLab and Mastering. The publisher reserves the right to remove any material in this eBook at any time.

#### **British Library Cataloguing-in-Publication Data**

A catalogue record for this book is available from the British Library

**ISBN 10:** 1-292-30728-5

**ISBN 13:** 978-1-292-30728-2

**eBook ISBN 13:** 978-1-292-30729-9

Typeset by Integra Software Services Private Limited  
Printed and bound by Vivar in Malaysia

# About the Authors



## ERIC J. SIMON

is a professor in the Department of Biology and Health Science at New England College (Henniker, New Hampshire). He teaches introductory biology to science majors and nonscience majors, as well as upper-level courses in tropical marine biology and careers in science. Dr. Simon received a B.A. in biology and computer science, an M.A. in biology from Wesleyan University, and a Ph.D. in biochemistry

from Harvard University. His research focuses on innovative ways to use technology to increase active learning in the science classroom, particularly for nonscience majors. Dr. Simon is also the author of the introductory biology textbook *Biology: The Core*, 2nd Edition, and a coauthor of *Campbell Biology: Concepts & Connections*, 9th Edition.

*To my lifelong friends BZ, SR, and SR, who have taught me the value of loyalty and trust during decades of unwavering friendship*



## JEAN L. DICKEY

is Professor Emerita of Biological Sciences at Clemson University (Clemson, South Carolina). After receiving her B.S. in biology from Kent State University, she went on to earn a Ph.D. in ecology and evolution from Purdue University. In 1984, Dr. Dickey joined the faculty at Clemson, where she devoted her career to teaching biology to nonscience majors in a variety of courses. In addition to creating content-based instructional

materials, she developed many activities to engage lecture and laboratory students in discussion, critical thinking, and writing, and implemented an investigative laboratory curriculum in general biology. Dr. Dickey is the author of *Laboratory Investigations for Biology*, 2nd Edition, and is a coauthor of *Campbell Biology: Concepts & Connections*, 9th Edition.

*To my mother, who taught me to love learning, and to my daughters, Katherine and Jessie, the twin delights of my life*



## JANE B. REECE

was Neil Campbell's longtime collaborator and a founding author of *Campbell Essential Biology* and *Campbell Essential Biology with Physiology*. Her education includes an A.B. in biology from Harvard University (where she was initially a philosophy major), 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. Dr. Reece taught biology at Middlesex County College (New Jersey) and Queensborough Community College (New York). Dr. Reece's publishing career began in 1978 when she joined the editorial staff of Benjamin Cummings, and since then, she played a major role in a number of successful textbooks. She was the lead author of *Campbell Biology* Editions 8–10 and a founding author of *Campbell Biology: Concepts & Connections*.

*To my wonderful coauthors, who have made working on our books a pleasure*



## NEIL A. CAMPBELL

(1946–2004) combined the inquiring nature of a research scientist with the soul of a caring teacher. Over his 30 years of teaching introductory biology to both science majors and nonscience majors, many thousands of students had the opportunity to learn from him and be stimulated by his enthusiasm for the study of life. He is greatly missed by his many friends in the biology community. His coauthors remain inspired by his

visionary dedication to education and are committed to searching for ever-better ways to engage students in the wonders of biology.

# Preface

Biology education has been transformed in the last decade. The non-majors introductory biology course was (in most cases) originally conceived as a slightly less deep and broad version of the general biology course. But a growing recognition of the importance of this course—one that is often the most widely enrolled within the department, and one that serves as the sole source of science education for many students—has prompted a reevaluation of priorities and a reformulation of pedagogy. Many instructors have narrowed the focus of the course from a detailed compendium of facts to an exploration of broader themes within the discipline—themes such as the central role of evolution and an understanding of the process of science. For many educators, the goals have shifted from communicating a great number of bits of information toward providing a deep understanding of fewer, but broader, principles. Luckily for anyone teaching or learning biology, opportunities to marvel at the natural world and the life within it abound. Furthermore, nearly everyone realizes that the subject of biology has a significant impact on his or her own life through its connections to medicine, biotechnology, agriculture, environmental issues, forensics, and many other areas. Our primary goal in writing *Campbell Essential Biology with Physiology* is to help teachers motivate and educate the next generation of citizens by communicating the broad themes that course through our innate curiosity about life.

## Goals of the Book

Although our world is rich with “teachable moments” and learning opportunities, an explosion of knowledge threatens to bury a curious person under an avalanche of information. “So much biology, so little time” is the universal lament of biology educators. Neil Campbell conceived of *Campbell Essential Biology with Physiology* as a tool to help teachers and students focus on the most important areas of biology. To that end, the book is organized into six core areas: cells, genes, evolution, ecology, animal physiology, and plant physiology. Dr. Campbell’s vision, which we carry on and extend in this edition, has enabled us to keep *Campbell Essential Biology with Physiology* manageable in size and thoughtful in the development of the concepts that are most fundamental to understanding life. We’ve aligned this new edition with today’s “less is more” approach in biology education for non-science majors—where the emphasis is on fewer topics but broader themes—while never allowing the important content to be diluted.

We formulated our approach after countless conversations with teachers and students in which we noticed some important trends in how biology is taught. In particular, many instructors identify three goals: (1) to engage students by relating biology content to their lives and the greater society; (2) to help students understand the process of science by teaching critical thinking skills that can be used in everyday life; and (3) to demonstrate how biology’s broader themes—such as evolution and the relationship of structure to function—serve to unify the entire subject. To help achieve these

goals, every chapter of this book includes several important features. First, a chapter-opening essay called Biology and Society highlights a connection between the chapter’s core content and students’ lives. Second, an essay called The Process of Science (in the body of the chapter) describes how the scientific process has illuminated the topic at hand, using a classic or modern experiment as an example. Third, a chapter-closing Evolution Connection essay relates the chapter to biology’s unifying theme of evolution. Fourth, the broad themes that unify all subjects within biology are explicitly called out (in blue) multiple times within each chapter. Finally, to maintain a cohesive narrative throughout each chapter, the content is tied together with a unifying chapter thread, a relevant high-interest topic that is touched on several times in the chapter and woven throughout the three feature essays. Thus, this unifying chapter thread ties together the pedagogical goals of the course, using a topic that is compelling and relevant to students.

## New to This Edition

This latest edition of *Campbell Essential Biology with Physiology* goes even further than previous editions to help students relate the material to their lives, understand the process of science, and appreciate how broad themes unify all aspects of biology. To this end, we’ve added significant new features and content to this edition:

- **A new approach to teaching the process of science.** Conveying the process of science to non-science-major undergraduate students is one of the most important goals of this course. Traditionally, we taught the scientific method as a predefined series of steps to be followed in an exact order (observation, hypothesis, experiment, and so forth). Many instructors have shifted away from such a specific flow chart to a more nuanced approach that involves multiple pathways, frequent restarts, and other features that more accurately reflect how science is actually undertaken. Accordingly, we have revised the way that the process of science is discussed within our text, both in Chapter 1 (where the process is discussed in detail) and in The Process of Science essay in every chapter of the textbook. Rather than using specific terms in a specific order to describe the process, we now divide it into three broad interrelated areas: background, method, and results. We believe that this new approach better conveys how science actually proceeds and demystifies the topic for non-scientists. Chapter 1 also contains important information that promotes critical thinking, such as discussion of control groups, pseudoscience, and recognizing reliable sources of information. We believe that providing students with such critical-thinking tools is one of the most important outcomes of the non-science-major introductory course.
- **Major themes in biology incorporated throughout the book.** In 2009, the American Association for the Advancement of Science published a document that served as a call to action in undergraduate biology education.

The principles of this document, which is titled “Vision and Change,” are becoming widely accepted throughout the biology education community. “Vision and Change” presents five core concepts that serve as the foundation of undergraduate biology. In this edition of *Campbell Essential Biology with Physiology*, we repeatedly and explicitly link book content to themes multiple times in each chapter, calling out such instances with boldfaced blue text. For example, in Chapter 4 (A Tour of the Cell), the interrelationships of cellular structures are used to illustrate the theme of interactions within biological systems. The plasma membrane is presented as an example of the relationship between structure and function. The cellular structures in the pathway from DNA to protein are used to illustrate the importance of information flow. The chloroplasts and mitochondria serve as an example of the transformations of energy and matter. The DNA within these structures is also used to illustrate biology’s overarching theme of evolution. Students will find three to five examples of themes called out in each chapter, which will help them see the connections between these major themes and the course content.

To reinforce these connections, this edition of *Campbell Essential Biology with Physiology* includes new end-of-chapter questions and Mastering Biology activities that promote critical thinking relating to these themes. Additionally, PowerPoint® lecture slides have been updated to incorporate chapter examples and offer guidance to faculty on how to include in these themes within classroom lectures.

- **Updated connections to students’ lives.** In every edition of *Campbell Essential Biology with Physiology*, we seek to improve and extend the ways that we connect the course content to students’ lives. Accordingly, every chapter begins with an improved feature called Why It Matters showing the relevance of the chapter content from the very start. Additionally, with every edition, we introduce some new unifying chapter threads intended to improve student relevance. For example, this edition includes new threads that discuss evolution in a human-dominated world (Chapter 14) and the importance of biodiversity to human affairs (Chapter 20). As always, we include some updated Biology and Society chapter-opening essays (such as “A Solar Revolution” in Chapter 7), The Process of Science sections (such as a recent experiment investigating the efficacy of radiation therapy to treat prostate cancer, in Chapter 2), and Evolution Connection chapter-closing essays (such as an updated discussion of biodiversity hot spots in Chapter 20). As we always do, this edition includes many content updates that connect to students’ lives, such as information on

cutting-edge cancer therapies (Chapter 8) and recent examples of DNA profiling (Chapter 12).

- **Developing data literacy through infographics.** Many nonscience-major students express anxiety when faced with numerical data, yet the ability to interpret data can help with many important decisions we all face. Increasingly, the general public encounters information in the form of infographics, visual images used to represent data. Consistent with our goal of preparing students to approach important issues critically, this edition includes a series of new infographics, or Visualizing the Data figures. Examples include the elemental composition of the human body (Chapter 2), a comparison of calories burned through exercise versus calories consumed in common foods (Chapter 5), and ecological footprints (Chapter 19). In addition to the printed form, these infographics are available as assignable tutorial questions within Mastering Biology.
- **Helping students to understand key figures.** For this new edition, a key figure in each chapter is supplemented by a short video explaining the concept to the student. These Figure Walkthrough videos will be assignable in Mastering Biology. The animations are written and narrated by authors Eric Simon and Jean Dickey, as well as teacher and contributor Rebecca Burton.

Attitudes about science and scientists are often shaped by a single, required science class—*this* class. We hope to nurture an appreciation of nature into a genuine love of biology. In this spirit, we hope that this textbook and its supplements will encourage all readers to make biological perspectives a part of their personal worldviews. Please let us know how we are doing and how we can improve the next edition of *Campbell Essential Biology with Physiology*.

**ERIC SIMON**  
Department of Biology and  
Health Science  
New England College  
Henniker, NH 03242  
SimonBiology@gmail.com

**JEAN DICKEY**  
Clemson, SC  
dickeyj@clemson.edu

**JANE B. REECE**  
Berkeley, California



**The following Visual Walkthrough  
highlights key features of  
*Campbell Essential Biology with Physiology 6e.***

# Develop and practice science literacy skills

Learn how to view your world using scientific reasoning with *Campbell Essential Biology with Physiology*. See how concepts from class and an understanding of how science works can apply to your everyday life. Engage with the concepts and practice science literacy skills with Mastering Biology and Pearson eText.

**NEW!** New and updated **Process of Science essays** present scientific discovery as a flexible and non-linear process.

Each essay summarizes the **background, method, and results** from a scientific study.

**New Thinking Like a Scientist questions** appear at the end of each Process of Science essay and involve applying a scientific reasoning skill.

## Examples of new Process of Science topics include:

- Chapter 4: How Was the First 21st-Century Antibiotic Discovered? p. 95
- Chapter 9: What Is the Genetic Basis of Short Legs in Dogs? p.190
- Chapter 11: Can Avatars Improve Cancer Treatment? p.244
- Chapter 16: What Killed the Pines? p.364
- Chapter 20: Does Biodiversity Protect Human Health? p.480



9 PATTERNS OF INHERITANCE

## THE PROCESS OF SCIENCE Dog Breeding

### What Is the Genetic Basis of Short Legs in Dogs?

#### BACKGROUND

It's obvious that dogs come in a wide variety of physical types. In fact, domesticated dogs display the greatest range of phenotypes of any mammal. One of the most striking features that distinguishes some breeds is chondrodysplasia, a condition that affects the growth of bones in the leg. The resulting shortened, curved bones are a defining characteristic of a few dog breeds (Figure 9.16a). Through test crosses, breeders have long known that the short-legged trait is dominant, but nothing was known about the cause of the phenotype.

#### METHOD

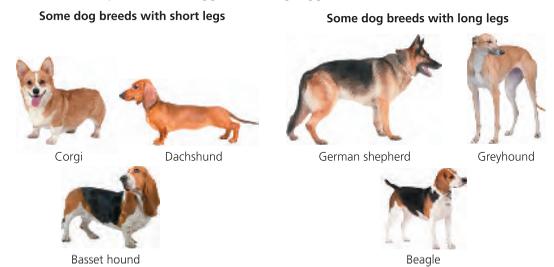
A group of researchers set out to discover the genetic basis of the short-legged phenotype. They used an automated gene chip (see Figure 11.10) to examine the DNA of 95 dogs from 7 short-legged breeds (the experimental group) and 702 dogs from 64 breeds with long legs (the control group). They compared the results to identify any differences between the two groups at thousands of sites across the dog genome (Figure 9.16b).

#### RESULTS

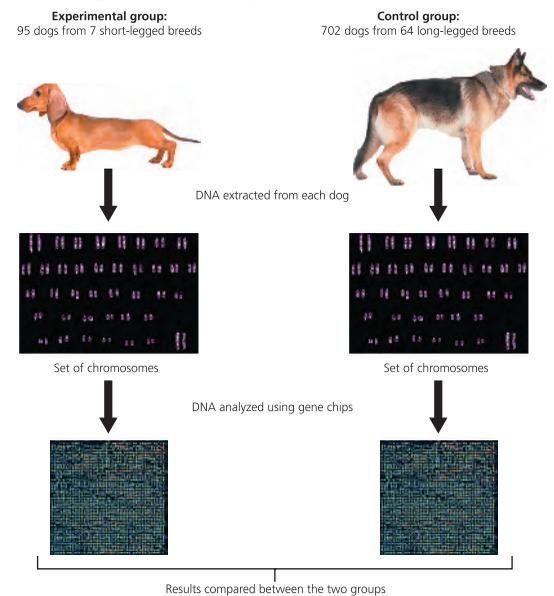
One location on chromosome 18 stood out for being strongly associated with short legs. Closer examination of the region surrounding that location revealed a gene that codes for a protein called fibroblast growth factor 4. The protein produced by this gene is known to be associated with the growth of legs during embryonic development. The researchers identified a specific change in the chromosome that corresponded to short legs. Interestingly, they were able to link the effect of this gene in dogs to a related protein associated with the growth of legs during embryonic development. The researchers identified a specific change in the chromosome that corresponded to short legs. This experiment shows how animal models may provide insight into genetic conditions in humans.

▼ Figure 9.16 The genetic basis of chondrodysplasia in dogs.

#### (a) Some examples of short-legged and long-legged breeds



#### (b) Comparing DNA from different dog breeds



#### Thinking Like a Scientist

Why might it be easier to find the genetic basis for a physical condition in dogs than to do so in humans? For the answer, see Appendix D.

190

**NEW!** A new organization and new content in Chapter 1 focus on science literacy skills to introduce the process of science right from the start.

# Explore biology with . . .

## 7 Photosynthesis: Using Light to Make Food

### CHAPTER CONTENTS

The Basics of Photosynthesis 142

The Light Reactions: Converting Solar Energy to Chemical Energy 144

The Calvin Cycle: Making Sugar from Carbon Dioxide 149

### Why Photosynthesis Matters

Do you like to eat? We humans can trace every morsel of our food back to plants. By capturing the energy of sunlight and using it to create organic materials, plants performing photosynthesis feed the world.

NEARLY ALL LIFE ON EARTH—INCLUDING YOU—CAN TRACE ITS SOURCE OF ENERGY BACK TO THE SUN.



COVER UP! PROTECTING YOURSELF FROM SHORT WAVELENGTHS OF LIGHT CAN BE LIFESAVING.

WANT TO DO SOMETHING SIMPLE TO COMBAT GLOBAL CLIMATE CHANGE? PLANT A TREE—YOU'LL BE GLAD YOU DID!



140

**Why It Matters Photo Collages** have been updated to give real-world examples to convey why abstract concepts like cellular respiration or photosynthesis matter.

# ... the most relevant, real-world examples

**New and Updated Chapter Threads** weave a compelling topic throughout each chapter, highlighted in the Biology and Society, The Process of Science, and Evolution Connection essays.

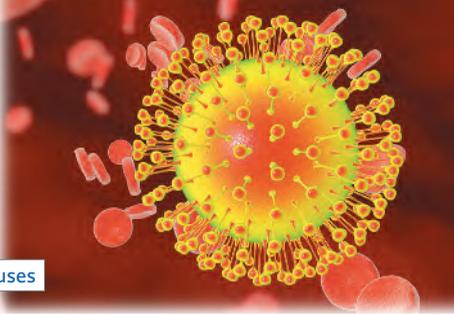
**CHAPTER THREAD**  
**Deadly Viruses**

**BIOLOGY AND SOCIETY** The Global Threat of Zika Virus 205

**THE PROCESS OF SCIENCE** Can DNA and RNA Vaccines Protect Against Viruses? 224

**EVOLUTION CONNECTION** Emerging Viruses 226

**BIOLOGY AND SOCIETY** **Deadly Viruses**



**The Global Threat of Zika Virus**

In 2015, an alarming number of babies were born in Brazil with severe damage to their central nervous systems and sensory organs. The affected babies had neurological problems (such as underdeveloped brains and seizures), slow growth, difficulty feeding, and joint and muscle problems. After a frantic search, health officials discovered a link between these abnormalities and exposure to a little-known pathogen: the Zika virus. By 2016, when the United Nations World Health Organization (WHO) issued a worldwide health emergency, Zika virus and Zika-related health problems in newborns began appearing in warm, humid regions of the United States and many other countries.

The Zika virus was first discovered to infect humans in 1952 and had been identified in African monkeys a few years earlier. Zika virus can be transmitted to humans by one species of mosquito. It can also be spread between sexual partners. But Zika virus is not dangerous to most healthy adults. In fact, some people feel just fine after being infected, while others have mild symptoms like aches or a fever. However, Zika virus can be spread from mother to fetus. Unfortunately, developing babies are particularly vulnerable to the virus's effects.

Health agencies have few weapons against Zika virus. There is no vaccine, and medicines can only treat symptoms. Nighttime mosquito netting and staying indoors after dusk can offer protection against many mosquito-borne diseases, but the mosquitoes that carry Zika virus bite both night and day. Public awareness campaigns aimed at avoiding mosquito bites and eliminating mosquito breeding grounds (such as stagnant water) have been implemented in Zika-prone areas. In November of 2016, WHO declared that the Zika global health emergency was over, not because Zika is gone, but because it is expected to be a long-term problem, the "new normal" rather than an emergency.

The Zika virus, like all viruses, consists of a relatively simple structure of nucleic acid (RNA in this case) and protein. Viruses operate by hijacking our own cells and turning them into virus factories. Combating any virus therefore requires a detailed understanding of life at the molecular level. In this chapter, we will explore the structure of life's most important molecule—DNA—to learn how it replicates, mutates, and controls the cell by directing the synthesis of RNA and protein.

**A computer illustration of the Zika virus. Spikes made of protein enable the virus to recognize a host cell.**

## NEW!

### New Chapter Threads include:

- Chapter 1: Swimming with the Turtles
- Chapter 2: Helpful Radiation
- Chapter 7: Solar Energy
- Chapter 13: Evolution in Action
- Chapter 14: Evolution in the Human-Dominated World
- Chapter 20: Importance of Biodiversity

### EVOLUTION CONNECTION **Deadly Viruses**

#### Emerging Viruses

Viruses that suddenly come to the attention of medical scientists are called **emerging viruses** (Figure 10.33). We've already explored Zika virus (first recognized in Brazil in 2015) and West Nile virus (which first appeared in North America in 1999). Although each virus had persisted at low levels for many years, each became a much greater threat quite suddenly.

How do viruses give rise to new diseases? First, they can evolve into more dangerous forms. Although viruses are not

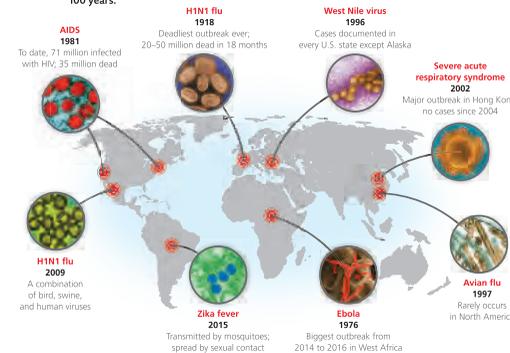
alive, they are subject to natural selection, which is accelerated by high mutation rates. Unlike DNA, RNA has no mechanisms to repair copying errors, so RNA viruses can mutate rapidly. Some mutations enable viruses to infect people who had developed resistance to the ancestral strain. This is why we need yearly flu vaccines. Mutations create new influenza virus strains to which people have no immunity.

Second, viral diseases can spread from one host species to another. Scientists estimate that about three-quarters of new

human diseases originated in other animals. When humans hunt, live, or raise livestock in new habitats, the risk increases. HIV (which causes AIDS) may have started as a slightly different virus in chimpanzees. Human hunters were probably infected when they butchered infected animals. As the virus mutated in the human hosts, strains that out-competed other varieties for human host cells became increasingly common.

Third, viral diseases from a small, isolated population can spread, leading to an epidemic. AIDS went unnamed and virtually ignored for decades. Several factors, including international travel, intravenous drug use, sexual activity, and delayed effective action allowed it to become a global scourge. Nobel Prize winner Joshua Lederberg warned: "We live in evolutionary competition with microbes. There is no guarantee that we will be the survivors." If we are to be victorious in the fight against emerging viruses, we must understand molecular biology and evolutionary processes.

**Figure 10.33**  
A sample of major emerging virus outbreaks of the past 100 years.



226

## Biology and Society essays

relating biology to everyday life are either new or updated. Some new topics:

- Chapter 7: A Solar Revolution p. 141
- Chapter 10: The Global Threat of Zika Virus p. 205
- Chapter 14: Humanity's Footprint p. 303
- Chapter 17: Evolving Adaptability p. 371

## Evolution Connection essays

demonstrate the importance of evolution as a theme throughout biology, by appearing in every chapter.

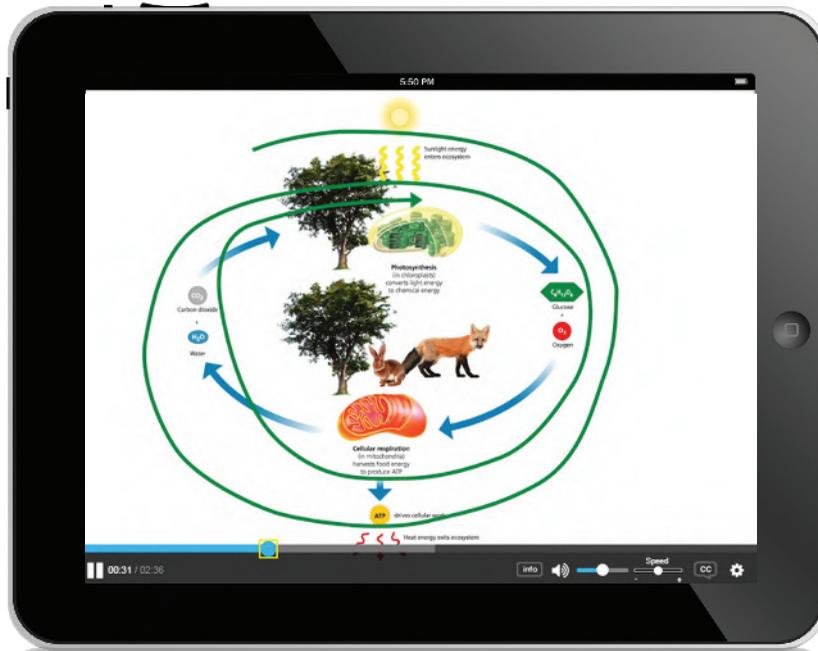
Some new topics:

- Chapter 1 Turtles in the Tree of Life p. 52
- Chapter 10 Emerging Viruses p. 226
- Chapter 20 Saving the Hot Spots p. 483
- Chapter 27 A Neurotoxin Arms Race p. 633

# Complex biological processes are explained . . .

**Mastering™ Biology** is an online homework, tutorial, and assessment platform that improves results by helping students quickly master concepts.

A wide range of interactive, engaging, and assignable activities, many of them contributed by *Campbell Essential Biology with Physiology* authors, encourage active learning and help with understanding tough course concepts.



**NEW! 29 Figure Walkthrough Videos**, created and narrated by the authors, give clear, concise explanations of key figures in each chapter. The videos are accessible through QR codes in the print text, and assignable in Mastering Biology.



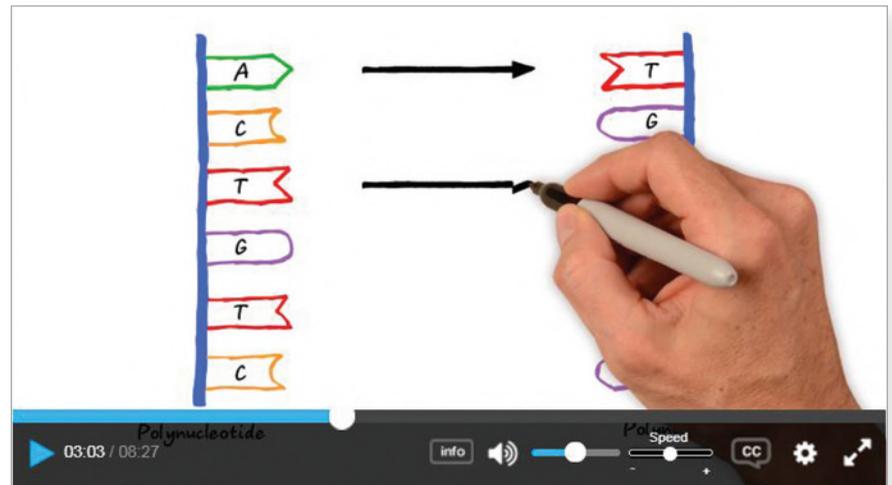
**NEW! Visualizing the Data** coaching activities bring the infographic figures in the text to life and are assignable in Mastering Biology.

# ... with engaging visuals and narrated examples in Mastering Biology

**12 Topic Overview videos**, created by the authors, introduce key concepts and vocabulary. These brief, engaging videos introduce topics that will be explored in greater depth in class.

Topics include:

- Macromolecules
  - Ecological Organization
  - Mechanisms of Evolution
  - An Introduction to Structure and Function
  - Interactions Between the Respiratory and Circulatory Systems
  - DNA Structure and Function
- ... And more!



**Part A**

Can you match the terms to their definitions?

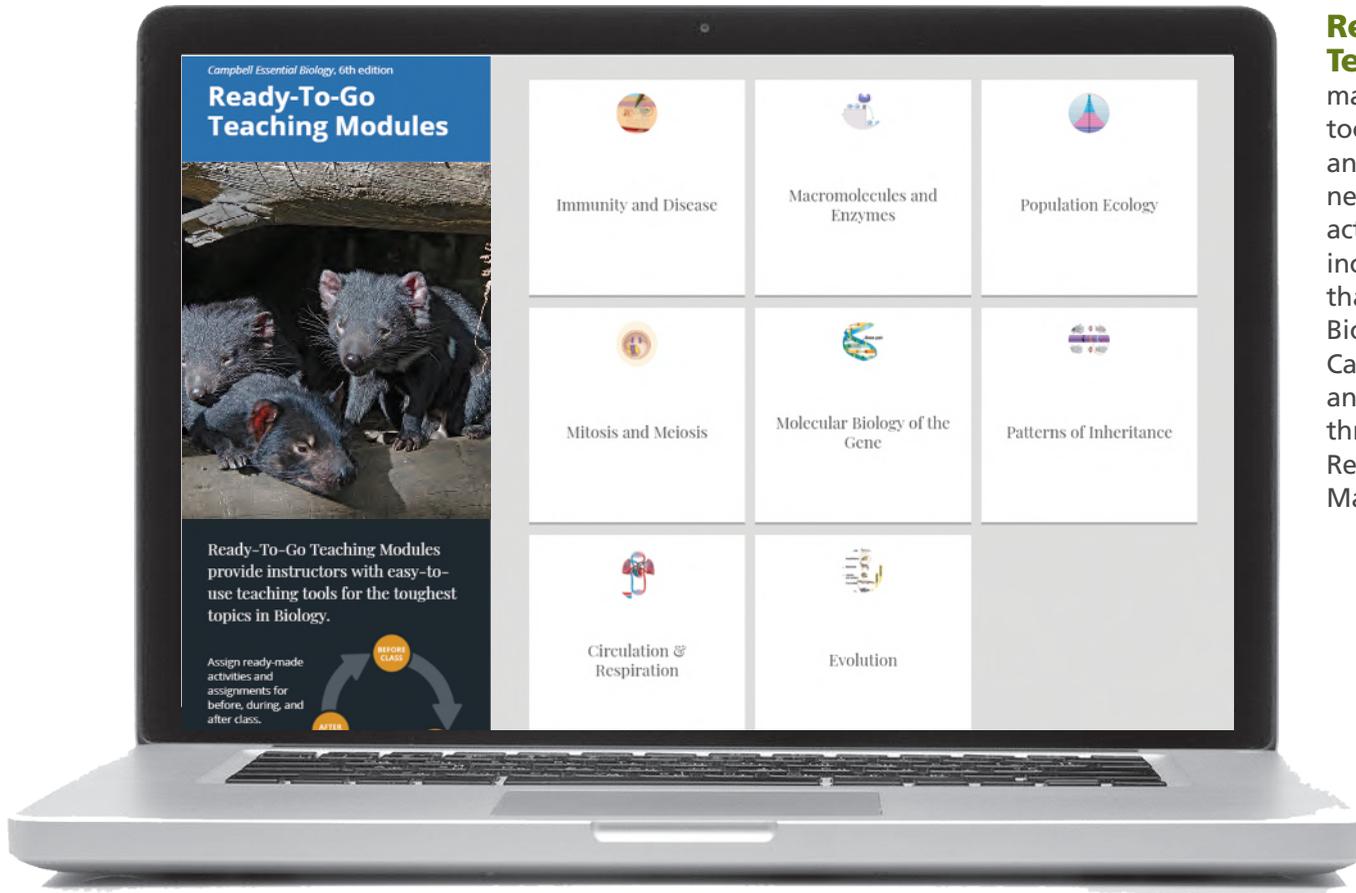
Drag the terms on the left to the appropriate blanks on the right to complete the sentences.

Reset Help

RNA	<input type="text"/> serves as the molecular basis for life.
replication	DNA copies itself via the process of <input type="text"/> .
base	RNA is produced from DNA via the process of <input type="text"/> .
translation	Proteins are produced from RNA via the process of <input type="text"/> .
DNA	There are five examples of a <input type="text"/> : A, G, C, T, and U.
transcription	One way that <input type="text"/> is different from DNA is that it contains Us instead of Ts.

**BioInteractive Short Films from HHMI, Video Tutors, BioFlix® 3D animations, and MP3 Audio Tutors** support key concept areas covered in the text and provide coaching by using personalized feedback on common wrong answers.

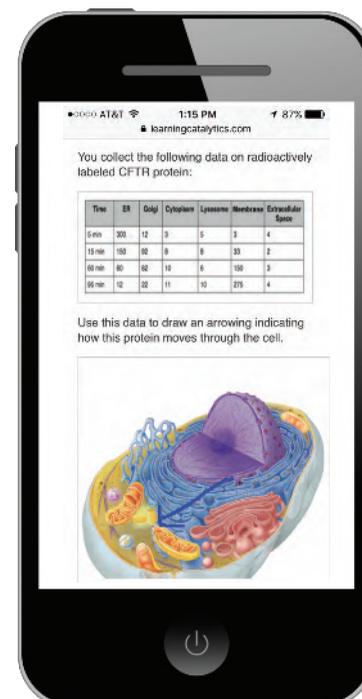
# New approaches to teaching and learning . . .



**Ready-to-Go Teaching Modules** make use of teaching tools for before, during, and after class, including new ideas for in-class activities. These modules incorporate the best that the text, Mastering Biology, and Learning Catalytics have to offer and can be accessed through the Instructor Resources area of Mastering Biology.

**Learning Catalytics™** helps generate class discussion, customize lectures, and promote peer-to-peer learning with real-time analytics. Learning Catalytics acts as a student response tool that uses students' smartphones, tablets, or laptops to engage them in more interactive tasks and thinking.

- Help your students develop critical thinking skills
- Monitor responses to find out where your students are struggling
- Rely on real-time data to adjust your teaching strategy



# ... and the resources to accomplish them

**Extensive resources** save instructors valuable time both in course preparation and during class. Instructor materials can be accessed and downloaded from the Instructor Resources area of Mastering Biology. [www.pearson.com/mastering/biology](http://www.pearson.com/mastering/biology)

**New! Identifying Major Themes end-of-chapter questions** in the text and coaching activities in Mastering Biology give instructors resources to integrate Vision and Change biological themes into their course.

**Revised Guided Reading Activities** in the Mastering Biology Study Area and Instructor Resources offer a simple resource that encourages students to get the most out of each text chapter. These worksheets accompany each chapter of the text and are downloadable from Mastering Biology.

Complete the following questions as you read the chapter content—Cellular Respiration: Aerobic Harvest of Food Energy:

- The majority of a cell's ATP is produced within which of the following organelles?
  - mitochondria
  - nucleus
  - ribosome
  - Golgi apparatus
- Students frequently have the misconception that plant cells don't perform cellular respiration. Briefly explain the basis of this misconception.
- Briefly explain why the overall equation for cellular respiration has multiple arrows. Use the following figure, which illustrates the equation for cellular respiration, to help you answer.



Identifying Major Themes—Chapter 18

**Part A**

Can you identify the major theme illustrated by each of the following examples? If necessary, you can review the themes in Chapter 1 of your book. Match the themes on the left with the examples on the right. Not all themes will be used.

Reset Help

Information flow	Solar energy from sunlight, captured by chlorophyll during the process of photosynthesis, powers most ecosystems. <b>Pathways that transform energy and matter</b>
	After a period of lower-than-average rainfall, drought-resistant individuals may be more prevalent in a plant population. <b>Evolution</b>
	Reptilian scales and the waxy coating on many leaves reduce water loss. <b>Relationship of structure to function</b>
	Other organisms may compete with an organism for its physical and chemical environment. <b>Interactions within biological systems</b>

Submit My Answers Give Up

Correct

## IDENTIFYING MAJOR THEMES

For each statement, identify which major theme is evident (the relationship of structure to function, information flow, pathways that transform energy and matter, interactions within biological systems, or evolution) and explain how the statement relates to the theme. If necessary, review the themes (see Chapter 1) and review the examples highlighted in blue in this chapter.

- The highly folded membranes of the mitochondria make these organelles well suited to carry out the huge number of chemical reactions required for cellular respiration to proceed.
- Cellular respiration and photosynthesis are linked, with each process using inputs created by the other.
- Your body uses many different intersecting chemical pathways that, all together, constitute your metabolism.

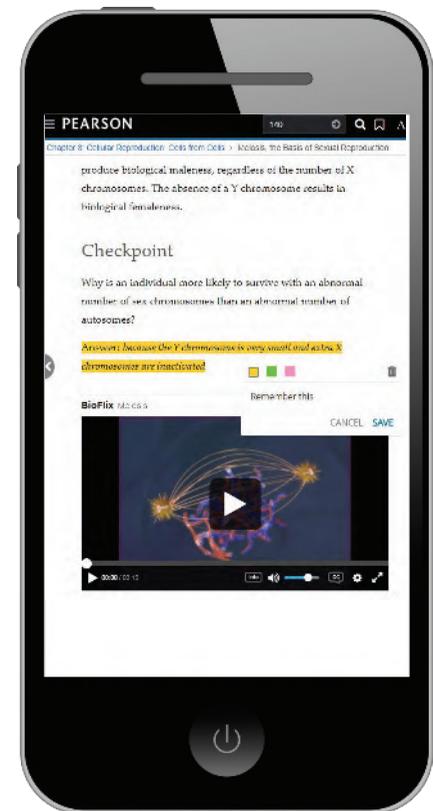
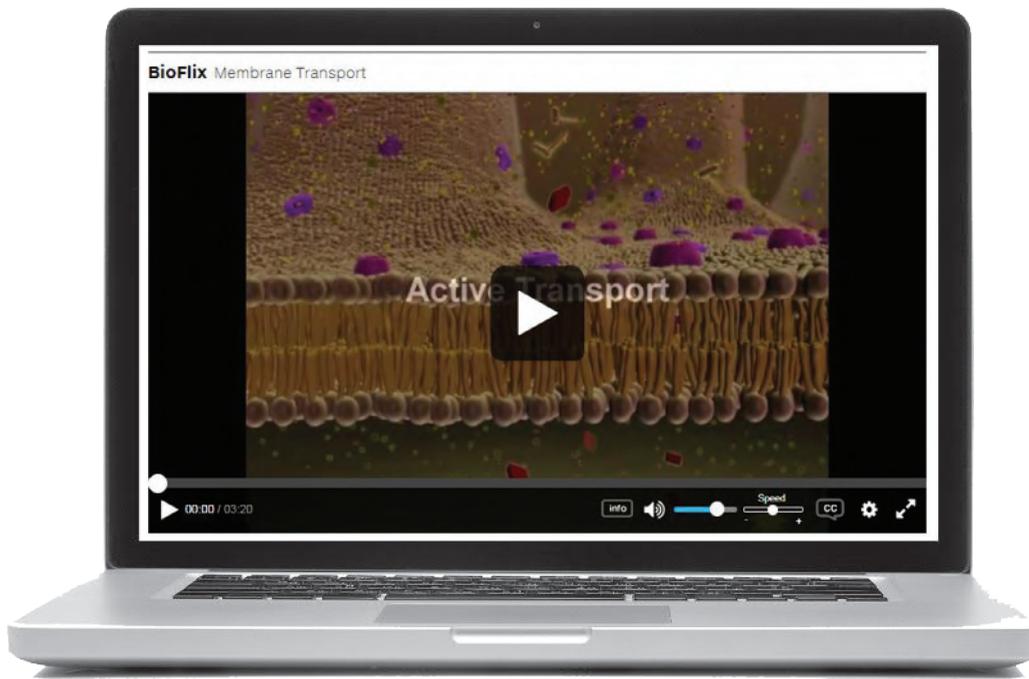
For answers to Identifying Major Themes, see Appendix D.

The **Instructor Exchange** in the Instructor Resources area of Mastering Biology provides successful, class-tested active learning techniques and analogies from biology instructors around the world, offering a springboard for quick ideas to create more compelling lectures. Contributor Kelly Hogan moderates contributions to the exchange.

# Engage with biology concepts anytime, anywhere with Pearson eText

**New** to *Campbell Essential Biology* 7th edition/*Campbell Essential Biology with Physiology* 6th edition, the Pearson eText includes videos, interactives, animations, and audio tutors that bring the text to life and help you understand key concepts. Get all the help you need in one integrated digital experience.

**NEW!** Over 100 rich media resources, many of them created by the author team, are included in the Pearson eText and accessible on smartphones, tablets, and computers. Examples of the rich media include: Figure Walkthrough videos, Topic Overview videos, MP3 Audio Tutors, Video Tutors, and BioFlix Tutorials.



**Pearson eText** Mobile App offers offline access and can be downloaded for most iOS and Android phones/tablets from the Apple App Store or Google Play.

# Acknowledgments

Throughout the process of planning and writing *Campbell Essential Biology with Physiology*, the author team has had the great fortune of collaborating with an extremely talented group of publishing professionals and educators. We are all truly humbled to be part of one of the most experienced and successful publishing teams in biology education. Although the responsibility for any shortcomings lies solely with the authors, the merits of the book and its supplements reflect the contributions of a great many dedicated colleagues.

First and foremost, we must acknowledge our huge debt to Neil Campbell, the founding author of this book and a source of ongoing inspiration for each of us. Although this edition has been carefully and thoroughly revised—to update its science, its connections to students' lives, its pedagogy, and its currency—it remains infused with Neil's original vision and his commitment to share biology with introductory students.

This edition benefited significantly from the efforts of contributor Rebecca S. Burton from Alverno College. Using her years of teaching expertise, Becky made substantial improvements to two chapters, contributed to the development of new and revised Chapter Thread essays, and helped shape the emphasis on the unifying themes throughout the text and in Mastering Biology. We thank Becky for bringing her considerable talents to bear on this edition!

This book could not have been completed without the efforts of the *Campbell Essential Biology with Physiology* team at Pearson Education. Leading the team is courseware portfolio management specialist Alison Rodal, who is tireless in her pursuit of educational excellence and who inspires all of us to constantly seek better ways to help teachers and students. Alison stands at the interface between the book development team and the educational community of professors and students. Her insights and contributions are invaluable. We also thank the Pearson Science executive team for their supportive leadership, in particular, senior vice president of portfolio management Adam Jaworski, director of portfolio management Beth Wilbur, and directors of courseware content development Barbara Yien and Ginnie Simone Jutson.

It is no exaggeration to say that the talents of the best editorial team in the industry are evident on every page of this book. The authors were continuously guided with great patience and skill by courseware senior analyst John Burner and senior developmental editor Susan Teahan. We owe this editorial team—which also includes the wonderfully capable and friendly editorial assistant Alison Candlin—a deep debt of gratitude for their talents and hard work.

Once we formulated our words and images, the production and manufacturing teams transformed them into the final book. Senior content producer Lori Newman oversaw the production process and kept everyone and everything on track. We also thank the managing content producer Mike Early for his careful oversight. Every edition of *Campbell Essential Biology with Physiology* is distinguished by continuously updated and beautiful photography. For that we thank photo researcher Kristin Piljay, who constantly dazzles us with her keen ability to locate memorable images.

For the production and composition of the book, we thank senior project editor Margaret McConnell of Integra Software Services, whose professionalism and commitment to the quality of the finished product is visible throughout. The authors owe much to copyeditor Joanna Dinsmore and proofreader Pete Shanks for their keen eyes and attention to detail. We thank design manager Mark Ong and designer tani hasegawa of TT Eye for the beautiful interior and [U.S.-edition] cover designs; and we are grateful to Rebecca Marshall and Courtney Coffman and the artists at Lachina for rendering clear and compelling illustrations. We also thank rights and permissions project manager Matt Perry at Cenveo and the manager of rights and permissions Ben Ferrini. In the final stages of production, the talents of manufacturing buyer Stacy Weinberger shone.

Most instructors view the textbook as just one piece of the learning puzzle, with the book's supplements and media completing the picture. We are lucky to have a *Campbell Essential Biology with Physiology* supplements team that is fully committed to the core goals of accuracy and readability. Content producer Lori Newman expertly coordinated the supplements, a difficult task given their number and variety. We also thank media project manager Ziki Dekel for his work on the excellent Instructor Resources and eText that accompanies the text. We owe particular gratitude to the supplements authors, especially the indefatigable and eagle-eyed Ed Zalisko of Blackburn College, who wrote the Instructor Guide and the PowerPoint® Lectures; the highly skilled and multitalented Doug Darnowski of Indiana University Southeast, who revised the Quiz Shows and Clicker Questions; and Jean DeSaix of the University of North Carolina at Chapel Hill, Justin Shaffer of the University of California, Irvine, Kristen Miller of the University of Georgia, and Suann Yang of SUNY Geneseo, our collaborative team of Test Bank authors for ensuring excellence in our assessment program. In addition, the authors thank Reading Quiz authors Amaya Garcia Costas of Montana State University and Cindy Klevickis of James Madison University; Reading Quiz accuracy reviewer Veronica Menendez; Practice Test author Chris Romero of Front Range Community College; and Practice Test accuracy reviewer Justin Walgaurnery of the University of Hawaii.

We wish to thank the talented group of publishing professionals who worked on the comprehensive media program that accompanies *Campbell Essential Biology with Physiology*. The team members dedicated to Mastering Biology are true “game changers” in the field of biology education. We thank rich media content producers Ziki Dekel and Tod Regan for coordinating our multimedia plan. Vital contributions were also made by associate Mastering media producer Kaitlin Smith and web developer Barry Offringa. We also thank Sarah Jensen, senior content developer, for her efforts to make our media products the best in the industry.

As educators and writers, we are very lucky to have a crack marketing team. Product marketing manager Christa Pelaez and field marketing manager Kelli Galli seemed to be everywhere at once as they helped us achieve

our authorial goals by keeping us constantly focused on the needs of students and instructors.

We also thank the Pearson Science sales representatives, district and regional managers, and learning technology specialists for representing *Campbell Essential Biology with Physiology* on campuses. These representatives are our lifeline to the greater educational community, telling us what you like (and don't like) about this book and the accompanying supplements and media. Their enthusiasm for helping students makes them not only ideal ambassadors but also our partners in education. We urge all educators to take full advantage of the wonderful resource offered by the Pearson sales team.

Eric Simon would like to thank his colleagues at New England College for their support and for providing a model of excellence in education, in particular, Lori Koziol, Deb Dunlop, Mark Mitch, Bryan Partridge, and Wayne Lesperance. Eric would also like to acknowledge the contributions of Jim Newcomb of New England College for lending his keen eye for accuracy and for always being

available to discuss teaching innovations; Jay Withgott for sharing his expertise; Elyse Carter Vosen for providing much-needed social context; Jamey Barone for her sage sensitivity; and Amanda Marsh for her expert eye, sharp attention to detail, tireless commitment, constant support, compassion, and seemingly endless wisdom.

At the end of these acknowledgments, you'll find a list of the many instructors who provided valuable information about their courses, reviewed chapters, and/or conducted class tests of *Campbell Essential Biology with Physiology* with their students. All of our best ideas spring from the classroom, so we thank them for their efforts and support.

Most of all, we thank our families, friends, and colleagues, who continue to tolerate our obsession with doing our best for science education. And finally, we all wish to welcome budding superstar Leo to our *Campbell Essential Biology with Physiology* family.

ERIC SIMON, JEAN DICKEY, JANE REECE

### Reviewers of this Edition

Lois Bartsch  
*Metropolitan Community College*

Allison Beck  
*Black Hawk College*

Lisa Boggs  
*Southwestern Oklahoma State University*

Steven Brumbaugh  
*Green River College*

Ryan Caesar  
*Schriener University*

Alexander Cheroske  
*Moorpark College*

Gregory Dahlem  
*Northern Kentucky University*

Richard Gardner  
*South Virginia University*

Thomas Hinckley  
*Landmark College*

Sue Hum-Musser  
*Western Illinois University*

Brian Kram  
*Prince George's Community College*

Tangela Marsh  
*Ivy Tech Community College East Central Region*

Roy Mason  
*Mt. San Jacinto College*

Mary Miller  
*Baton Rouge Community College*

Michele Nash  
*Springfield Technical Community College*

Mary Poffenroth  
*San Jose State University*

Michelle Rogers  
*Austin Peay State University*

Troy Rohn  
*Boise State University*

Sanghamitra Saha  
*University of Houston Downtown*

Mark Smith  
*Santiago Canyon College*

Anna Sorin  
*University of Memphis*

Jennifer Stueckle  
*West Virginia University*

Alice Tarun  
*Alfred State SUNY College of Technology*

Ron Tavernier  
*SUNY Canton*

Anotia Wijte  
*Irvine Valley College*

Edwin Wong  
*Western Connecticut State University*

Calvin Young  
*Fullerton College*

### Reviewers of Previous Editions

Marilyn Abbott  
*Lindenwood College*

Tammy Adair  
*Baylor University*

Shazia Ahmed  
*Texas Woman's University*

Felix O. Akojie  
*Paducah Community College*

Shireen Alemadi  
*Minnesota State University, Moorhead*

William Sylvester Allred, Jr.  
*Northern Arizona University*

Megan E. Anduri  
*California State University, Fullerton*

Estrella Z. Ang  
*University of Pittsburgh*

David Arieti  
*Oakton Community College*

C. Warren Arnold  
*Allan Hancock Community College*

Mohammad Ashraf  
*Olive-Harvey College*

Heather Ashworth  
*Utah Valley University*

Tami Asplin  
*North Dakota State*

Bert Atsma  
*Union County College*

Yael Avissar  
*Rhode Island College*

Barbara J. Backley  
*Elgin Community College*

Gail F. Baker  
*LaGuardia Community College*

Neil Baker  
*Ohio State University*

Kristel K. Bakker  
*Dakota State University*

Andrew Baldwin  
*Mesa Community College*

Linda Barham  
*Meridian Community College*

Charlotte Barker  
*Angelina College*

Verona Barr  
*Heartland Community College*

Lois Bartsch  
*Metropolitan Community College*

S. Rose Bast  
*Mount Mary College*

Erin Baumgartner  
*Western Oregon University*

Sam Beattie  
*California State University, Chico*

Allison Beck  
*Black Hawk College*

Rudi Berkelhamer  
*University of California, Irvine*

Penny Bernstein  
*Kent State University, Stark Campus*

Suchi Bhardwaj  
*Winthrop University*

Donna H. Bivans  
*East Carolina University*

Andrea Bixler  
*Clarke College*

Brian Black  
*Bay de Noc Community College*

Allan Blake  
*Seton Hall University*

Karyn Bledsoe  
*Western Oregon University*

Judy Bluemer  
*Morton College*

Sonal Blumenthal  
*University of Texas at Austin*

Lisa Boggs  
*Southwestern Oklahoma State University*

Dennis Bogyo  
*Valdosta State University*

David Boose  
*Gonzaga University*

Virginia M. Borden  
*University of Minnesota, Duluth*

James Botsford  
*New Mexico State University*

Cynthia Bottrell  
*Scott Community College*

Richard Bounds  
*Mount Olive College*

Cynthia Boyd  
*Hawkeye Community College*

Robert Boyd  
*Auburn University*

B. J. Boyer  
*Suffolk County Community College*

TJ Boyle  
*Blinn College, Bryan Campus*

Mimi Bres  
*Prince George's Community College*

Patricia Brewer  
*University of Texas at San Antonio*

Jerald S. Bricker  
*Cameron University*

Carol A. Britton  
*University of Mississippi*

George M. Brooks  
*Ohio University, Zanesville*

Janie Sue Brooks  
*Brevard College*

Steve Browder  
*Franklin College*

Evert Brown  
*Casper College*

Mary H. Brown  
*Lansing Community College*

Richard D. Brown  
*Brunswick Community College*

Steven Brumbaugh  
*Green River Community College*

Joseph C. Bundy  
*University of North Carolina at Greensboro*

Carol T. Burton  
*Bellevue Community College*

Rebecca Burton  
*Alverno College*

Warren R. Buss  
*University of Northern Colorado*

Wilbert Butler  
*Tallahassee Community College*

Ryan Caesar  
*Schreiner University*

Miguel Cervantes-Cervantes  
*Lehman College, City University of New York*

Maitreyee Chandra  
*Diablo Valley College*

Miriam Chavez  
*University of New Mexico, Valencia*

Bane Cheek  
*Polk Community College*

Alexander Cheroske  
*Moorpark College*

Thomas F. Chubb  
*Villanova University*

Reggie Cobb  
*Nash Community College*

Pamela Cole  
*Shelton State Community College*

William H. Coleman  
*University of Hartford*

Jay L. Comeaux  
*McNeese State University*

James Conkey  
*Truckee Meadows Community College*

Joe W. Conner  
*Pasadena City College*

Karen A. Conzelman  
*Glendale Community College*

Ann Coopersmith  
*Maui Community College*

Erica Corbett  
*Southeastern Oklahoma State University*

James T. Costa  
*Western Carolina University*

Pat Cox  
*University of Tennessee, Knoxville*

Laurie-Ann Crawford  
*Hawkeye Community College*

Michael Cullen  
*University of Evansville*

Gregory Dahlem  
*Northern Kentucky University*

Pradeep M. Dass  
*Appalachian State University*

Paul Decelles  
*Johnson County Community College*

Galen DeHay  
*Tri County Technical College*

Cynthia L. Delaney  
*University of South Alabama*

Terry Derting  
*Murray State University*

Jean DeSaix  
*University of North Carolina at Chapel Hill*

Elizabeth Desy  
*Southwest State University*

Edward Devine  
*Moraine Valley Community College*

Dwight Dimaculangan  
*Winthrop University*

Danielle Dodenhoff  
*California State University, Bakersfield*

Deborah Dodson  
*Vincennes Community College*

Diane Doidge  
*Grand View College*

Don Dorfman  
*Monmouth University*

Richard Driskill  
*Delaware State University*

Lianne Drysdale  
*Ozarks Technical Community College*

Terese Dudek  
*Kishwaukee College*

Shannon Dullea  
*North Dakota State College of Science*

David A. Eakin  
*Eastern Kentucky University*

Brian Earle  
*Cedar Valley College*

Ade Ejire  
*Johnston Community College*

Dennis G. Emery  
*Iowa State University*

Hilary Engebretson  
*Whatcom Community College*

Renee L. Engle-Goodner  
*Merritt College*

Virginia Erickson  
*Highline Community College*

Carl Estrella  
*Merced College*

Marirose T. Ethington  
*Genesee Community College*

Paul R. Evans  
*Brigham Young University*

Zenephia E. Evans  
*Purdue University*

Jean Everett  
*College of Charleston*

Holly Swain Ewald  
*University of Louisville*

Dianne M. Fair  
*Florida Community College at Jacksonville*

Joseph Faryniarz  
*Naugatuck Valley Community College*

Phillip Fawley  
*Westminster College*

Lynn Fireston  
*Ricks College*

Jennifer Floyd  
*Leeward Community College*

Dennis M. Forsythe  
*The Citadel*

Angela M. Foster  
*Wake Technical Community College*

Brandon Lee Foster  
*Wake Technical Community College*

Carl F. Friese  
*University of Dayton*

Suzanne S. Frucht  
*Northwest Missouri State University*

Edward G. Gabriel  
*Lycoming College*

Anne M. Galbraith  
*University of Wisconsin, La Crosse*

Kathleen Gallucci  
*Elon University*

J. Yvette Gardner  
*Clayton State University*

Richard Gardner  
*South Virginia University*

Gregory R. Garman  
*Centralia College*

Wendy Jean Garrison  
*University of Mississippi*

Gail Gasparich  
*Towson University*

Kathy Gifford  
*Butler County Community College*

Sharon L. Gilman  
*Coastal Carolina University*

Mac Given  
*Neumann College*

Patricia Glas  
*The Citadel*

Ralph C. Goff  
*Mansfield University*

Marian R. Goldsmith  
*University of Rhode Island*

Andrew Goliszek  
*North Carolina Agricultural and Technical State University*

Tamar Liberman Goulet  
*University of Mississippi*

Curt Gravis  
*Western State College of Colorado*

Larry Gray  
*Utah Valley State College*

Tom Green  
*West Valley College*

Robert S. Greene  
*Niagara University*

Ken Griffin  
*Tarrant County Junior College*

Denise Guerin  
*Santa Fe Community College*

Paul Gurn  
*Naugatuck Valley Community College*

Peggy J. Guthrie  
*University of Central Oklahoma*

Henry H. Hagedorn  
*University of Arizona*

Blanche C. Haning  
*Vance-Granville Community College*

Laszlo Hanzely  
*Northern Illinois University*

Sig Harden  
*Troy University*

Sherry Harrel  
*Eastern Kentucky University*

Reba Harrell  
*Hinds Community College*

Frankie Harris  
*Independence Community College*

Lysa Marie Hartley  
*Methodist College*

Janet Haynes  
*Long Island University*

Michael Held  
*St. Peter's College*

Consetta Helmick  
*University of Idaho*

J. L. Henriksen  
*Bellevue University*

Michael Henry  
*Contra Costa College*

Linda Hensel  
*Mercer University*

Jana Henson  
*Georgetown College*

James Hewlett  
*Finger Lakes Community College*

Richard Hilton  
*Towson University*

Thomas Hinckley  
*Landmark College*

Juliana Hinton  
*McNeese State University*

Phyllis C. Hirsch  
*East Los Angeles College*

W. Wyatt Hoback  
*University of Nebraska at Kearney*

Elizabeth Hodgson  
*York College of Pennsylvania*

Jay Hodgson  
*Armstrong Atlantic State University*

A. Scott Holaday  
*Texas Tech University*

Robert A. Holmes  
*Hutchinson Community College*

R. Dwain Horrocks  
*Brigham Young University*

Howard L. Hosick  
*Washington State University*

Carl Huether  
*University of Cincinnati*

Sue Hum-Musser  
*Western Illinois University*

Celene Jackson  
*Western Michigan University*

John Jahoda  
*Bridgewater State College*

Dianne Jennings  
*Virginia Commonwealth University*

Richard J. Jensen  
*Saint Mary's College*

Corey Johnson  
*University of North Carolina*

Scott Johnson  
*Wake Technical Community College*

Tari Johnson  
*Normandale Community College*

Tia Johnson  
*Mitchell Community College*

Gregory Jones  
*Santa Fe College, Gainesville, Florida*

John Jorstad  
*Kirkwood Community College*

Tracy L. Kahn  
*University of California, Riverside*

Robert Kalbach  
*Finger Lakes Community College*

Mary K. Kananen  
*Pennsylvania State University, Altoona*

Thomas C. Kane  
*University of Cincinnati*

Arnold J. Karpoff  
*University of Louisville*

John M. Kasmer  
*Northeastern Illinois University*

Valentine Kefeli  
*Slippery Rock University*

Dawn Keller  
*Hawkeye College*

John Kelly  
*Northeastern University*

Tom Kennedy  
*Central New Mexico Community College*

Cheryl Kerfeld  
*University of California, Los Angeles*

Henrik Kibak  
*California State University, Monterey Bay*

Kerry Kilburn  
*Old Dominion University*

Joyce Kille-Marino  
*College of Charleston*

Peter King  
*Francis Marion University*

Peter Kish  
*Oklahoma School of Science and Mathematics*

Robert Kitchin  
*University of Wyoming*

Cindy Klevickis  
*James Madison University*

Richard Koblin  
*Oakland Community College*

H. Roberta Koepfer  
*Queens College*

Michael E. Kovach  
*Baldwin-Wallace College*

Brian Kram  
*Prince George's Community College*

Jocelyn E. Krebs  
*University of Alaska, Anchorage*

Ruhul H. Kuddus  
*Utah Valley State College*

Nuran Kumbaraci  
*Stevens Institute of Technology*

Holly Kupfer  
*Central Piedmont Community College*

Gary Kwiecinski  
*The University of Scranton*

Roya Lahijani  
*Palomar College*

James V. Landrum  
*Washburn University*

Erica Lannan  
*Prairie State College*

Lynn Larsen  
*Portland Community College*

Grace Lasker  
*Lake Washington Institute of Technology*

Brenda Leaday  
*University of Toledo*

Siu-Lam Lee  
*University of Massachusetts, Lowell*

Thomas P. Lehman  
*Morgan Community College*

William Leonard  
*Central Alabama Community College*

Shawn Lester  
*Montgomery College*

Leslie Lichtenstein  
*Massasoit Community College*

Barbara Liedl  
*Central College*

Harvey Liftin  
*Broward Community College*

David Loring  
*Johnson County Community College*

Eric Lovely  
*Arkansas Tech University*

Lewis M. Lutton  
*Mercyhurst College*

Bill Mackay  
*Edinboro University*

Maria P. MacWilliams  
*Seton Hall University*

Mark Manteuffel  
*St. Louis Community College*

Lisa Maranto  
*Prince George's Community College*

Michael Howard Marcovitz  
*Midland Lutheran College*

Tangela Marsh  
*Ivy Tech Community College East Central Region*

Angela M. Mason  
*Beaufort County Community College*

Roy B. Mason  
*Mt. San Jacinto College*

John Mathwig  
*College of Lake County*

Lance D. McBrayer  
*Georgia Southern University*

Bonnie McCormick  
*University of the Incarnate Word*

Katrina McCrae  
*Abraham Baldwin Agricultural College*

Tonya McKinley  
*Concord College*

Mary Anne McMurray  
*Henderson Community College*

Diane Melroy  
*University of North Carolina Wilmington*

Maryanne Menvielle  
*California State University, Fullerton*

Ed Mercurio  
*Hartnell College*

Timothy D. Metz  
*Campbell University*

Andrew Miller  
*Thomas University*

Mary Miller  
*Baton Rouge Community College*

David Mirman  
*Mt. San Antonio College*

Kiran Misra  
*Edinboro University*

Nancy Garnett Morris  
*Volunteer State Community College*

Angela C. Morrow  
*University of Northern Colorado*

Susan Mounce  
*Eastern Illinois University*

Patricia S. Muir  
*Oregon State University*

James Newcomb  
*New England College*

Jon R. Nickles  
*University of Alaska, Anchorage*

Zia Nisani  
*Antelope Valley College*

Jane Noble-Harvey  
*University of Delaware*

Michael Nosek  
*Fitchburg State College*

Jeanette C. Oliver  
*Flathead Valley Community College*

David O'Neill  
*Community College of Baltimore County*

Sandra M. Pace  
*Rappahannock Community College*

Lois H. Peck  
*University of the Sciences, Philadelphia*

Kathleen E. Pelkki  
*Saginaw Valley State University*

Jennifer Penrod  
*Lincoln University*

Rhoda E. Perozzi  
*Virginia Commonwealth University*

John S. Peters  
*College of Charleston*

Pamela Petrequin  
*Mount Mary College*

- Paula A. Piehl  
*Potomac State College of West Virginia University*
- Bill Pietraface  
*State University of New York Oneonta*
- Gregory Podgorski  
*Utah State University*
- Mary Poffenroth  
*San Jose State University*
- Rosamond V. Potter  
*University of Chicago*
- Karen Powell  
*Western Kentucky University*
- Martha Powell  
*University of Alabama*
- Elena Pravosudova  
*Sierra College*
- Hallie Ray  
*Rappahannock Community College*
- Jill Raymond  
*Rock Valley College*
- Dorothy Read  
*University of Massachusetts, Dartmouth*
- Nathan S. Reyna  
*Howard Payne University*
- Philip Ricker  
*South Plains College*
- Todd Rimkus  
*Marymount University*
- Lynn Rivers  
*Henry Ford Community College*
- Jennifer Roberts  
*Lewis University*
- Laurel Roberts  
*University of Pittsburgh*
- Michelle Rogers  
*Austin Peay State University*
- Troy Rohn  
*Boise State University*
- April Rottman  
*Rock Valley College*
- Maxine Losoff Rusche  
*Northern Arizona University*
- Michael L. Rutledge  
*Middle Tennessee State University*
- Mike Runyan  
*Lander University*
- Travis Ryan  
*Furman University*
- Tyson Sacco  
*Cornell University*
- Sanghamitra Saha  
*University of Houston Downtown*
- Bassam M. Salameh  
*Antelope Valley College*
- Sarmad Saman  
*Quinsigamond Community College*
- Carsten Sanders  
*Kutztown University*
- Pamela Sandstrom  
*University of Nevada, Reno*
- Leba Sarkis  
*Aims Community College*
- Walter Saviuk  
*Daytona Beach Community College*
- Neil Schanker  
*College of the Siskiyous*
- Robert Schoch  
*Boston University*
- John Richard Schrock  
*Emporia State University*
- Julie Schroer  
*Bismarck State College*
- Karen Schuster  
*Florida Community College at Jacksonville*
- Brian W. Schwartz  
*Columbus State University*
- Michael Scott  
*Lincoln University*
- Eric Scully  
*Towson State University*
- Lois Sealy  
*Valencia Community College*
- Sandra S. Seidel  
*Elon University*
- Wayne Seifert  
*Brookhaven College*
- Susmita Sengupta  
*City College of San Francisco*
- Justin Shaffer  
*University of California, Irvine*
- Patty Shields  
*George Mason University*
- Cara Shillington  
*Eastern Michigan University*
- Brian Shmaefsky  
*Kingwood College*
- Rainy Inman Shorey  
*Ferris State University*
- Cahleen Shrier  
*Azusa Pacific University*
- Jed Shumsky  
*Drexel University*
- Greg Sievert  
*Emporia State University*
- Jeffrey Simmons  
*West Virginia Wesleyan College*
- Frederick D. Singer  
*Radford University*
- Anu Singh-Cundy  
*Western Washington University*
- Kerri Skinner  
*University of Nebraska at Kearney*
- Sandra Slivka  
*Miramar College*
- Jennifer Smith  
*Triton College*
- Margaret W. Smith  
*Butler University*
- Mark Smith  
*Santiago Canyon College*
- Thomas Smith  
*Armstrong Atlantic State University*
- Anna Sorin  
*University of Memphis*
- Deena K. Spielman  
*Rock Valley College*
- Minou D. Spradley  
*San Diego City College*
- Ashley Spring  
*Eastern Florida State College*
- Robert Stamatis  
*Daytona Beach Community College*
- Joyce Stamm  
*University of Evansville*
- Eric Stavney  
*Highline Community College*
- Michael Stevens  
*Utah Valley University*
- Bethany Stone  
*University of Missouri, Columbia*
- Jennifer Stueckle  
*West Virginia University*
- Mark T. Sugalski  
*New England College*
- Marshall D. Sundberg  
*Emporia State University*
- Adelaide Svoboda  
*Nazareth College*
- Alice Tarun  
*Alfred State SUNY College of Technology*
- Ron Tavernier  
*SUNY Canton*
- Sharon Thoma  
*Edgewood College*
- Kenneth Thomas  
*Hillsborough Community College*
- Sumesh Thomas  
*Baltimore City Community College*
- Betty Thompson  
*Baptist University*
- Chad Thompson  
*Westchester Community College*
- Paula Thompson  
*Florida Community College*
- Michael Anthony Thornton  
*Florida Agriculture and Mechanical University*
- Linda Tichenor  
*University of Arkansas, Fort Smith*

John Tjepkema <i>University of Maine, Orono</i>	Eileen Walsh <i>Westchester Community College</i>	Bethany Williams <i>California State University, Fullerton</i>
Bruce L. Tomlinson <i>State University of New York, Fredonia</i>	Helen Walter <i>Diablo Valley College</i>	Daniel Williams <i>Winston-Salem University</i>
Leslie R. Towill <i>Arizona State University</i>	Kristen Walton <i>Missouri Western State University</i>	Judy A. Williams <i>Southeastern Oklahoma State University</i>
Bert Tribbey <i>California State University, Fresno</i>	Jennifer Warner <i>University of North Carolina at Charlotte</i>	Dwina Willis <i>Freed Hardeman University</i>
Nathan Trueblood <i>California State University, Sacramento</i>	Arthur C. Washington <i>Florida Agriculture and Mechanical University</i>	David Wilson <i>University of Miami</i>
Robert Turner <i>Western Oregon University</i>	Kathy Watkins <i>Central Piedmont Community College</i>	Mala S. Wingerd <i>San Diego State University</i>
Michael Twaddle <i>University of Toledo</i>	Dave Webb <i>St. Clair County Community College</i>	E. William Wischusen <i>Louisiana State University</i>
Virginia Vandergon <i>California State University, Northridge</i>	Harold Webster <i>Pennsylvania State University, DuBois</i>	Darla J. Wise <i>Concord College</i>
William A. Velhagen, Jr. <i>Longwood College</i>	Ted Weinheimer <i>California State University, Bakersfield</i>	Michael Womack <i>Macon State College</i>
Melinda Verdone <i>Rock Valley College</i>	Lisa A. Werner <i>Pima Community College</i>	Edwin Wong <i>Western Connecticut State University</i>
Leonard Vincent <i>Fullerton College</i>	Joanne Westin <i>Case Western Reserve University</i>	Bonnie Wood <i>University of Maine at Presque Isle</i>
Jonathan Visick <i>North Central College</i>	Wayne Whaley <i>Utah Valley State College</i>	Holly Woodruff (Kupfer) <i>Central Piedmont Community College</i>
Michael Vitale <i>Daytona Beach Community College</i>	Joseph D. White <i>Baylor University</i>	Jo Wen Wu <i>Fullerton College</i>
Lisa Volk <i>Fayetteville Technical Community College</i>	Quinton White <i>Jacksonville University</i>	Mark L. Wygoda <i>McNeese State University</i>
Daryle Waechter-Brulla <i>University of Wisconsin, Whitewater</i>	Leslie Y. Whiteman <i>Virginia Union University</i>	Calvin Young <i>Fullerton College</i>
Stephen M. Wagener <i>Western Connecticut State University</i>	Rick Wiedenmann <i>New Mexico State University at Carlsbad</i>	Shirley Zajdel <i>Housatonic Community College</i>
Sean E. Walker <i>California State University, Fullerton</i>	Anotia Wijte <i>Irvine Valley College</i>	Samuel J. Zeakes <i>Radford University</i>
James A. Wallis <i>St. Petersburg Community College</i>	Peter J. Wilkin <i>Purdue University North Central</i>	Uko Zylstra <i>Calvin College</i>

## Acknowledgments for the Global Edition

Pearson would like to thank the following for contributing to the Global Edition:

Alan Feest <i>University of Bristol</i>	Sarah Taylor <i>Keele University</i>
Clemens Kiecker <i>King's College London</i>	Christiane Van den Branden <i>Vrije Universiteit Brussel</i>

Pearson would like to thank the following for reviewing the Global Edition:

Mohamad Faiz Foong Abdullah <i>Universiti Teknologi MARA System</i>	Alan Feest <i>University of Bristol</i>
Paul Broady <i>University of Canterbury</i>	Federico Formenti <i>King's College London</i>
Adriaan Engelbrecht <i>University of the Western Cape</i>	Quek Choon Lau <i>Ngee Ann Polytechnic</i>

# Detailed Contents

## 1 Learning About Life 36

CHAPTER THREAD

Swimming with the Turtles 37

BIOLOGY AND SOCIETY *A Passion for Life* 37

### The Scientific Study of Life 38

An Overview of the Process of Science 38

Hypotheses, Theories, and Facts 41

Controlled Experiments 42

THE PROCESS OF SCIENCE *Do Baby Turtles Swim?* 42

Evaluating Scientific Claims 43

### The Properties of Life 44

### Major Themes in Biology 45

The Relationship of Structure to Function 46

Information Flow 46

Pathways That Transform Energy and Matter 47

Interactions within Biological Systems 48

Evolution 50

EVOLUTION CONNECTION *Turtles in the Tree of Life* 52

## Unit 1 Cells 55

## 2 Essential Chemistry for Biology 56

CHAPTER THREAD

Helpful Radiation 57

BIOLOGY AND SOCIETY *Nuclear Medicine* 57

### Some Basic Chemistry 58

Matter: Elements and Compounds 58

Atoms 59

THE PROCESS OF SCIENCE *How Effective Is Radiation in Treating Prostate Cancer?* 60

Chemical Bonding and Molecules 61

Chemical Reactions 62

### Water and Life 63

Water 63

Acids, Bases, and pH 65

EVOLUTION CONNECTION *Radioactivity as an Evolutionary Clock* 67

## 3 The Molecules of Life 70

CHAPTER THREAD

Lactose Intolerance 71

BIOLOGY AND SOCIETY *Got Lactose?* 71

### Organic Compounds 72

Carbon Chemistry 72

Giant Molecules from Smaller Building Blocks 73

### Large Biological Molecules 74

Carbohydrates 74

Lipids 77

Proteins 80

Nucleic Acids 83

THE PROCESS OF SCIENCE *Does Lactose Intolerance Have a Genetic Basis?* 85

EVOLUTION CONNECTION *The Evolution of Lactose Intolerance in Humans* 85



# 4 A Tour of the Cell

CHAPTER THREAD  
Humans Versus Bacteria

**BIOLOGY AND SOCIETY** Antibiotics: Drugs That Target Bacterial Cells

## The Microscopic World of Cells

- The Two Major Categories of Cells
- An Overview of Eukaryotic Cells

## Membrane Structure

- The Plasma Membrane
- Cell Surfaces

**THE PROCESS OF SCIENCE** How Was the First 21st-Century Antibiotic Discovered?

## The Nucleus and Ribosomes: Genetic Control of the Cell

- The Nucleus
- Ribosomes
- How DNA Directs Protein Production

## The Endomembrane System: Manufacturing and Distributing Cellular Products

- The Endoplasmic Reticulum
- The Golgi Apparatus
- Lysosomes
- Vacuoles

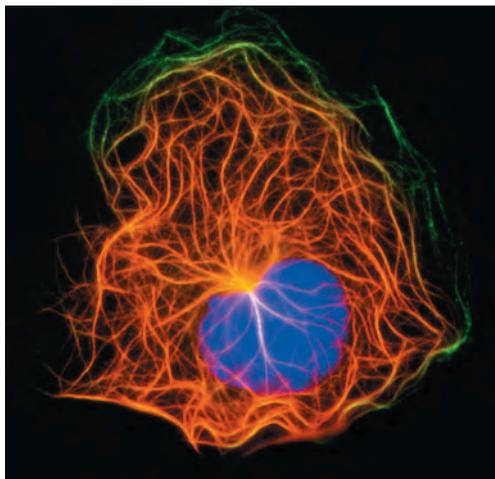
## Chloroplasts and Mitochondria: Providing Cellular Energy

- Chloroplasts
- Mitochondria

## The Cytoskeleton: Cell Shape and Movement

- Maintaining Cell Shape
- Flagella and Cilia

**EVOLUTION CONNECTION** The Evolution of Bacterial Resistance in Humans



88	<b>5 The Working Cell</b>	108
89	CHAPTER THREAD Nanotechnology	109
	<b>BIOLOGY AND SOCIETY</b> Harnessing Cellular Structures	109
89	Some Basic Energy Concepts	110
90	Conservation of Energy	110
91	Heat	111
92	Chemical Energy	111
94	Food Calories	112
94	ATP and Cellular Work	113
95	The Structure of ATP	113
	Phosphate Transfer	113
	The ATP Cycle	114
95	Enzymes	114
96	Activation Energy	114
97	<b>THE PROCESS OF SCIENCE</b> Can Enzymes Be Engineered?	115
97	Enzyme Activity	116
	Enzyme Inhibitors	116
98	Membrane Function	117
98	Passive Transport: Diffusion across Membranes	117
99	Osmosis and Water Balance	118
100	Active Transport: The Pumping of Molecules across Membranes	120
101	Exocytosis and Endocytosis: Traffic of Large Molecules	120
	<b>EVOLUTION CONNECTION</b> The Origin of Membranes	121



# 6 Cellular Respiration: Obtaining Energy from Food 124

CHAPTER THREAD  
Exercise Science 125

**BIOLOGY AND SOCIETY** *Getting the Most Out of Your Muscles* 125

**Energy Flow and Chemical Cycling in the Biosphere** 126

Producers and Consumers 126

Chemical Cycling between Photosynthesis and Cellular Respiration 126

**Cellular Respiration: Aerobic Harvest of Food Energy** 128

An Overview of Cellular Respiration 128

The Three Stages of Cellular Respiration 130

The Results of Cellular Respiration 134

**Fermentation: Anaerobic Harvest of Food Energy** 135

Fermentation in Human Muscle Cells 135

**THE PROCESS OF SCIENCE** *What Causes Muscle Burn?* 136

Fermentation in Microorganisms 136

**EVOLUTION CONNECTION** *The Importance of Oxygen* 137

# 7 Photosynthesis: Using Light to Make Food 140

CHAPTER THREAD  
Solar Energy 141

**BIOLOGY AND SOCIETY** *A Solar Revolution* 141

**The Basics of Photosynthesis** 142

Chloroplasts: Sites of Photosynthesis 142

An Overview of Photosynthesis 143

**The Light Reactions: Converting Solar Energy to Chemical Energy** 144

The Nature of Sunlight 144

**THE PROCESS OF SCIENCE** *What Colors of Light Drive Photosynthesis?* 145

Chloroplast Pigments 145

How Photosystems Harvest Light Energy 146

How the Light Reactions Generate ATP and NADPH 147

**The Calvin Cycle: Making Sugar from Carbon Dioxide** 149

**EVOLUTION CONNECTION** *Creating a Better Biofuel Factory* 149



# Unit 2 Genetics 153

## 8 Cellular Reproduction: Cells from Cells 154

CHAPTER THREAD  
Life with and without Sex

**BIOLOGY AND SOCIETY** *Virgin Birth of a Shark*

### What Cell Reproduction Accomplishes 156

#### The Cell Cycle and Mitosis 157

- Eukaryotic Chromosomes 157
- Duplicating Chromosomes 159
- The Cell Cycle 159
- Mitosis and Cytokinesis 160
- Cancer Cells: Dividing Out of Control 162

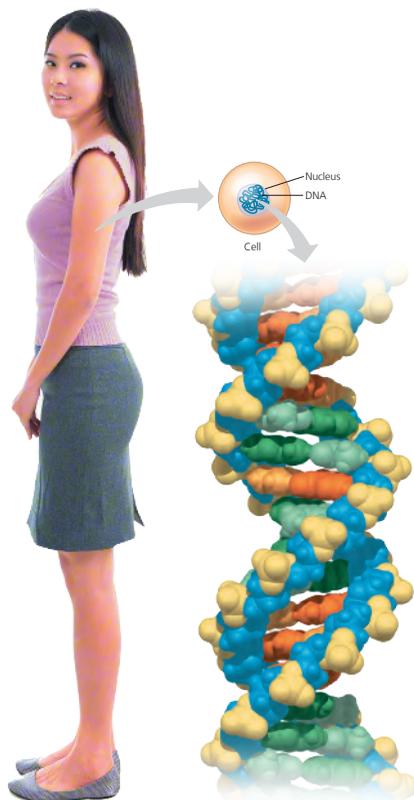
#### Meiosis, the Basis of Sexual Reproduction 164

- Homologous Chromosomes 164
- Gametes and the Life Cycle of a Sexual Organism 165
- The Process of Meiosis 166
- Review: Comparing Mitosis and Meiosis 168
- The Origins of Genetic Variation 169

**THE PROCESS OF SCIENCE** *Do All Animals Have Sex?* 171

- When Meiosis Goes Wrong 172

**EVOLUTION CONNECTION** *The Advantages of Sex* 174



## 9 Patterns of Inheritance 178

CHAPTER THREAD  
Dog Breeding 179

**BIOLOGY AND SOCIETY** *Darwin's Dogs* 179

### Genetics and Heredity 180

- In an Abbey Garden 180
- Mendel's Law of Segregation 181
- Mendel's Law of Independent Assortment 184
- Using a Testcross to Determine an Unknown Genotype 186
- The Rules of Probability 186
- Family Pedigrees 187
- Human Traits Controlled by a Single Gene 188

**THE PROCESS OF SCIENCE** *What Is the Genetic Basis of Short Legs in Dogs?* 190

### Variations on Mendel's Laws 192

- Incomplete Dominance in Plants and People 192
- ABO Blood Groups: An Example of Multiple Alleles and Codominance 193
- Pleiotropy and Sickle-Cell Disease 194
- Polygenic Inheritance 194
- Epigenetics and the Role of Environment 195

### The Chromosomal Basis of Inheritance 196

- Linked Genes 196
- Sex Determination in Humans 197
- Sex-Linked Genes 197

**EVOLUTION CONNECTION** *Barking Up the Evolutionary Tree* 199



# 10 The Structure and Function of DNA

204

CHAPTER THREAD  
Deadly Viruses 205

**BIOLOGY AND SOCIETY** The Global Threat of Zika Virus 205

- DNA: Structure and Replication** 206
- DNA and RNA Structure 206
  - Watson and Crick's Discovery of the Double Helix 207
  - DNA Replication 209

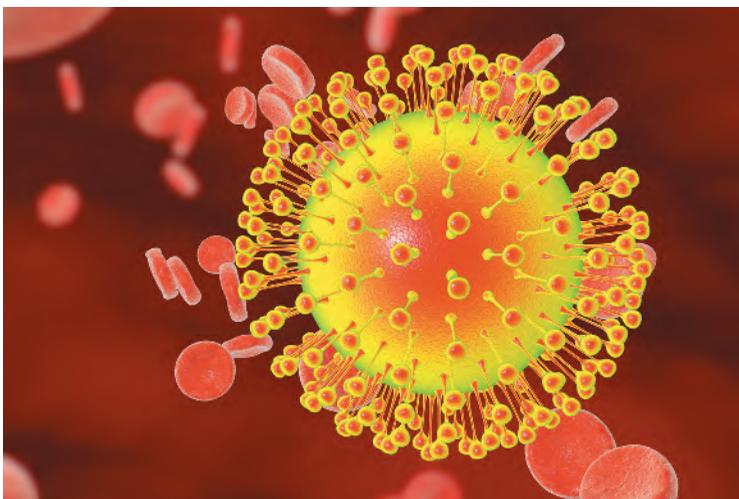
- From DNA to RNA to Protein** 210
- How an Organism's Genotype Determines Its Phenotype 210
  - From Nucleotides to Amino Acids: An Overview 211
  - The Genetic Code 212
  - Transcription: From DNA to RNA 213
  - The Processing of Eukaryotic RNA 214
  - Translation: The Players 214
  - Translation: The Process 216
  - Review: DNA → RNA → Protein 217
  - Mutations 218

- Viruses and Other Noncellular Infectious Agents** 220
- Bacteriophages 220
  - Plant Viruses 222
  - Animal Viruses 222

**THE PROCESS OF SCIENCE** Can DNA and RNA Vaccines Protect Against Viruses? 224

- HIV, the AIDS Virus 224
- Prions 226

**EVOLUTION CONNECTION** Emerging Viruses 226



# 11 How Genes Are Controlled

230

CHAPTER THREAD  
Cancer 231

**BIOLOGY AND SOCIETY** Breast Cancer and Chemotherapy 231

- How and Why Genes Are Regulated** 232
- Gene Regulation in Bacteria 232
  - Gene Regulation in Eukaryotic Cells 234
  - Cell Signaling 237
  - Homeotic Genes 238
  - Visualizing Gene Expression 238

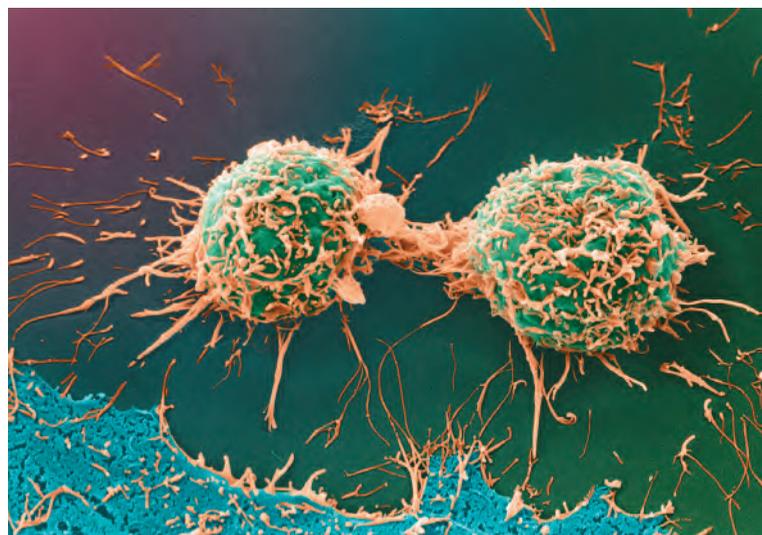
- Cloning Plants and Animals** 239
- The Genetic Potential of Cells 239
  - Reproductive Cloning of Animals 240
  - Therapeutic Cloning and Stem Cells 242

- The Genetic Basis of Cancer** 243
- Genes That Cause Cancer 243

**THE PROCESS OF SCIENCE** Can Avatars Improve Cancer Treatment? 244

- Cancer Risk and Prevention 246

**EVOLUTION CONNECTION** The Evolution of Cancer in the Body 247



# 12 DNA Technology 250

CHAPTER THREAD  
DNA Profiling 251

## BIOLOGY AND SOCIETY Using DNA to Establish Guilt and Innocence 251

<b>Genetic Engineering</b>	252
Recombinant DNA Techniques	252
Gene Editing	254
Medical Applications	255
Genetically Modified Organisms in Agriculture	256
Human Gene Therapy	258

<b>DNA Profiling and Forensic Science</b>	259
DNA Profiling Techniques	259
Investigating Murder, Paternity, and Ancient DNA	262

<b>Bioinformatics</b>	263
DNA Sequencing	263
Genomics	264
Genome-Mapping Techniques	265
The Human Genome	265

<b>THE PROCESS OF SCIENCE Did Nic Have a Deadly Gene?</b>	267
Applied Genomics	267
Systems Biology	268

<b>Safety and Ethical Issues</b>	269
The Controversy over Genetically Modified Foods	269
Ethical Questions Raised by Human DNA Technologies	270

<b>EVOLUTION CONNECTION The Y Chromosome as a Window on History</b>	271
---------------------------------------------------------------------	-----



# Unit 3 Evolution and Diversity 275

## 13 How Populations Evolve 276

CHAPTER THREAD  
Evolution in Action 277

### BIOLOGY AND SOCIETY Mosquitoes and Evolution 277

<b>The Diversity of Life</b>	278
Naming and Classifying the Diversity of Life	278
Explaining the Diversity of Life	279

<b>Charles Darwin and <i>The Origin of Species</i></b>	280
Darwin's Journey	280
Darwin's Theory	282

<b>Evidence of Evolution</b>	282
Evidence from Fossils	282
Evidence from Homologies	284
Evolutionary Trees	285

<b>Natural Selection as the Mechanism for Evolution</b>	286
Natural Selection in Action	287
Key Points about Natural Selection	288

<b>The Evolution of Populations</b>	288
Sources of Genetic Variation	288
Populations as the Units of Evolution	289
Analyzing Gene Pools	290
Population Genetics and Health Science	291
Microevolution as Change in a Gene Pool	291

<b>Mechanisms of Evolution</b>	292
Natural Selection	292
Genetic Drift	292
Gene Flow	294
Natural Selection: A Closer Look	295

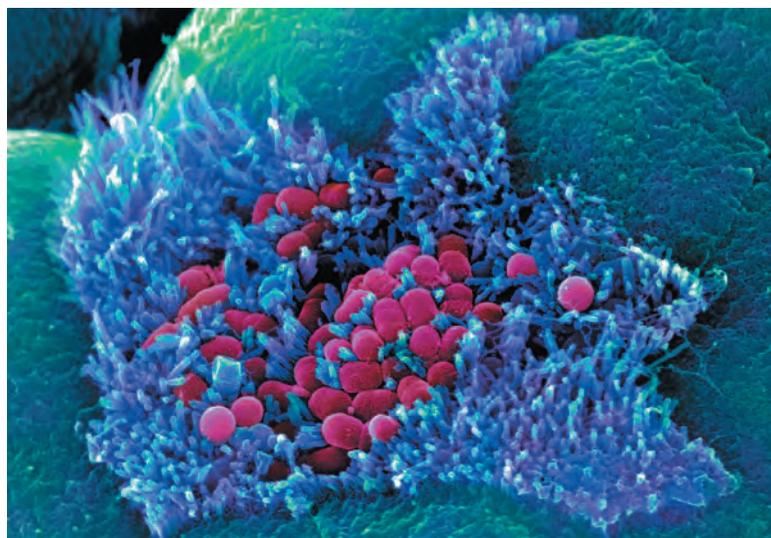
<b>THE PROCESS OF SCIENCE Did Natural Selection Shape the Beaks of Darwin's Finches?</b>	296
------------------------------------------------------------------------------------------	-----

<b>EVOLUTION CONNECTION The Rising Threat of Antibiotic Resistance</b>	299
------------------------------------------------------------------------	-----



14	<h2>How Biological Diversity Evolves</h2> <p>302</p> <p>CHAPTER THREAD Evolution in the Human-Dominated World 303</p> <p><b>BIOLOGY AND SOCIETY</b> Humanity's Footprint 303</p> <p><b>The Origin of Species</b> 304</p> <ul style="list-style-type: none"> <li>What Is a Species? 305</li> <li>Reproductive Barriers between Species 306</li> <li>Mechanisms of Speciation 308</li> </ul> <p><b>THE PROCESS OF SCIENCE</b> Do Human Activities Facilitate Speciation? 310</p> <p><b>Earth History and Macroevolution</b> 313</p> <ul style="list-style-type: none"> <li>The Fossil Record 313</li> <li>Plate Tectonics and Biogeography 315</li> <li>Mass Extinctions and Explosive Diversifications of Life 317</li> </ul> <p><b>Mechanisms of Macroevolution</b> 317</p> <ul style="list-style-type: none"> <li>Large Effects from Small Genetic Changes 317</li> <li>The Evolution of Biological Novelty 318</li> </ul> <p><b>Classifying the Diversity of Life</b> 320</p> <ul style="list-style-type: none"> <li>Classification and Phylogeny 320</li> <li>Classification: A Work in Progress 322</li> </ul> <p><b>EVOLUTION CONNECTION</b> Evolution in the Anthropocene 323</p>
----	---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

15	<h2>The Evolution of Microbial Life</h2> <p>326</p> <p>CHAPTER THREAD Human Microbiota 327</p> <p><b>BIOLOGY AND SOCIETY</b> Our Invisible Inhabitants 327</p> <p><b>Major Episodes in the History of Life</b> 328</p> <p><b>The Origin of Life</b> 330</p> <ul style="list-style-type: none"> <li>A Four-Stage Hypothesis for the Origin of Life 330</li> <li>From Chemical Evolution to Darwinian Evolution 332</li> </ul> <p><b>Prokaryotes</b> 333</p> <ul style="list-style-type: none"> <li>They're Everywhere! 333</li> <li>The Structure and Function of Prokaryotes 334</li> <li>The Ecological Impact of Prokaryotes 337</li> <li>The Two Main Branches of Prokaryotic Evolution: Bacteria and Archaea 338</li> </ul> <p><b>THE PROCESS OF SCIENCE</b> Are Intestinal Microbiota to Blame for Obesity? 340</p> <p><b>Protists</b> 341</p> <ul style="list-style-type: none"> <li>Protozoans 342</li> <li>Slime Molds 343</li> <li>Unicellular and Colonial Algae 344</li> <li>Seaweeds 344</li> </ul> <p><b>EVOLUTION CONNECTION</b> The Sweet Life of <i>Streptococcus mutans</i> 345</p>
----	----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------



# 16 The Evolution of Plants and Fungi

348

CHAPTER THREAD  
Plant-Fungus Interactions 349

**BIOLOGY AND SOCIETY** The Diamond of the Kitchen 349

**Colonizing Land** 350  
 Terrestrial Adaptations of Plants 350  
 The Origin of Plants from Green Algae 352

**Plant Diversity** 352  
 Highlights of Plant Evolution 352  
 Bryophytes 353  
 Ferns 355  
 Gymnosperms 356  
 Angiosperms 358  
 Plant Diversity as a Nonrenewable Resource 361

**Fungi** 362  
 Characteristics of Fungi 363

**THE PROCESS OF SCIENCE** What Killed the Pines? 364  
 The Ecological Impact of Fungi 365  
 Commercial Uses of Fungi 365

**EVOLUTION CONNECTION** A Pioneering Partnership 366



# 17 The Evolution of Animals

370

CHAPTER THREAD  
Human Evolution 371

**BIOLOGY AND SOCIETY** Evolving Adaptability 371

**The Origins of Animal Diversity** 372  
 What Is an Animal? 372  
 Early Animals and the Cambrian Explosion 373  
 Animal Phylogeny 374

**Major Invertebrate Phyla** 375  
 Sponges 375  
 Cnidarians 376  
 Molluscs 377  
 Flatworms 378  
 Annelids 379  
 Roundworms 380  
 Arthropods 381  
 Echinoderms 387

**Vertebrate Evolution and Diversity** 388  
 Characteristics of Chordates 388  
 Fishes 390  
 Amphibians 391  
 Reptiles 392  
 Mammals 394

**The Human Ancestry** 395  
 The Evolution of Primates 395  
 The Emergence of Humankind 397

**THE PROCESS OF SCIENCE** What Can Lice Tell Us About Ancient Humans? 400

**EVOLUTION CONNECTION** Are We Still Evolving? 401



# Unit 4 Ecology 405

## 18 An Introduction to Ecology and the Biosphere 406

CHAPTER THREAD  
Climate Change 407

**BIOLOGY AND SOCIETY** Penguins, Polar Bears, and People in Peril 407

**An Overview of Ecology** 408  
Ecology and Environmentalism 408  
A Hierarchy of Interactions 409

**Living in Earth's Diverse Environments** 410  
Abiotic Factors of the Biosphere 410  
The Evolutionary Adaptations of Organisms 412  
Adjusting to Environmental Variability 412

**Biomes** 414  
Freshwater Biomes 414  
Marine Biomes 416  
How Climate Affects Terrestrial Biome Distribution 418  
Terrestrial Biomes 419  
The Water Cycle 425  
Human Impact on Biomes 426

**Climate Change** 428  
The Greenhouse Effect and Global Warming 428  
The Accumulation of Greenhouse Gases 429  
Effects of Climate Change on Ecosystems 430

**THE PROCESS OF SCIENCE** How Does Climate Change Affect Species Distribution? 431  
Looking to Our Future 432

**EVOLUTION CONNECTION** Climate Change as an Agent of Natural Selection 433



## 19 Population Ecology 436

CHAPTER THREAD  
Biological Invasions 437

**BIOLOGY AND SOCIETY** Invasion of the Lionfish 437

**An Overview of Population Ecology** 438  
Population Density 439  
Population Age Structure 439  
Life Tables and Survivorship Curves 440  
Life History Traits as Adaptations 440

**Population Growth Models** 442  
The Exponential Population Growth Model: The Ideal of an Unlimited Environment 442  
The Logistic Population Growth Model: The Reality of a Limited Environment 443  
Regulation of Population Growth 444

**Applications of Population Ecology** 446  
Conservation of Endangered Species 446  
Sustainable Resource Management 446  
Invasive Species 447  
Biological Control of Pests 448

**THE PROCESS OF SCIENCE** Can Fences Stop Cane Toads? 449  
Integrated Pest Management 450

**Human Population Growth** 451  
The History of Human Population Growth 451  
Age Structures 452  
Our Ecological Footprint 453

**EVOLUTION CONNECTION** Humans as an Invasive Species 455

