GLOBAL EDITION

Campbell Essential Biology with Physiology

FIFTH EDITION

Eric J. Simon • Jean L. Dickey • Kelly A. Hogan • Jane B. Reece

ALWAYS LEARNING

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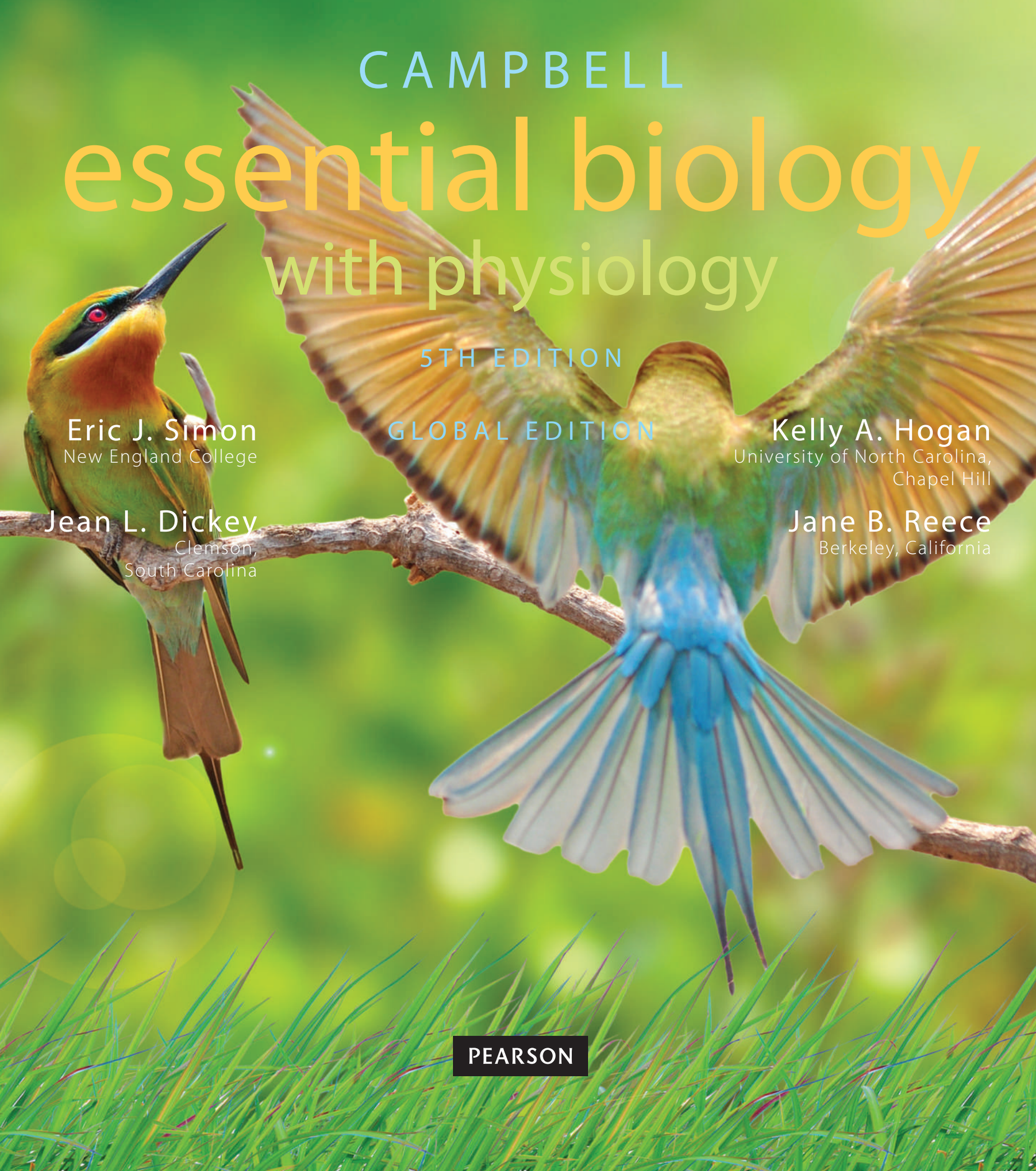
Brief Contents


CAMPBELL
essential biology
with physiology
5TH EDITION
GLOBAL EDITION
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To Muriel, my wonderful mother, who always supported my efforts with love, compassion, great empathy, and an unwavering belief in me

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*, 8th Edition.

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

KELLY A. HOGAN

is a faculty member in the Department of Biology and the Director of Instructional Innovation at the University of North Carolina at Chapel Hill, teaching introductory biology and introductory genetics to science majors. Dr. Hogan teaches hundreds of students at a time, using active-learning methods that incorporate technology such as cell phones as clickers, online homework, and peer evaluation tools. Dr. Hogan received her B.S. in biology at the College of New Jersey and her Ph.D. in pathology at the University of North Carolina, Chapel Hill. Her research interests relate to how large classes can be more inclusive through evidence-based teaching methods and technology. She provides faculty development to other instructors through peer coaching, workshops, and mentoring. Dr. Hogan is the author of *Stem Cells and Cloning,* 2nd Edition, and is lead moderator of the *Instructor Exchange*, a site within MasteringBiology® for instructors to exchange classroom materials and ideas. She is also a coauthor of *Campbell Biology: Concepts & Connections*, 8th Edition.

To the good-looking boy I met in my introductory biology course many moons ago—and to our two children, Jake and Lexi, who are everyday reminders of what matters most in life

JANE B. REECE

has worked in biology publishing since 1978, when she joined the editorial staff of Benjamin Cummings. Her education includes an A.B. in biology from Harvard University (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). During her 12 years as an editor at Benjamin Cummings, she played a major role in a number of successful textbooks. She is the lead author of *Campbell Biology*, 10th Edition, and *Campbell Biology: Concepts & Connections*, 8th Edition.

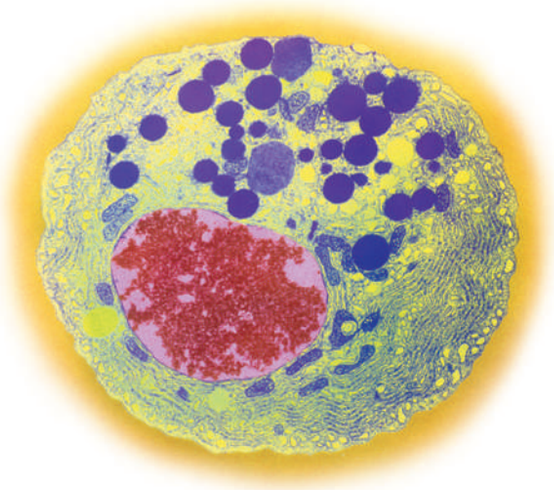
To my wonderful coauthors, who have made working on our books a pleasure

NEIL A. CAMPBELL

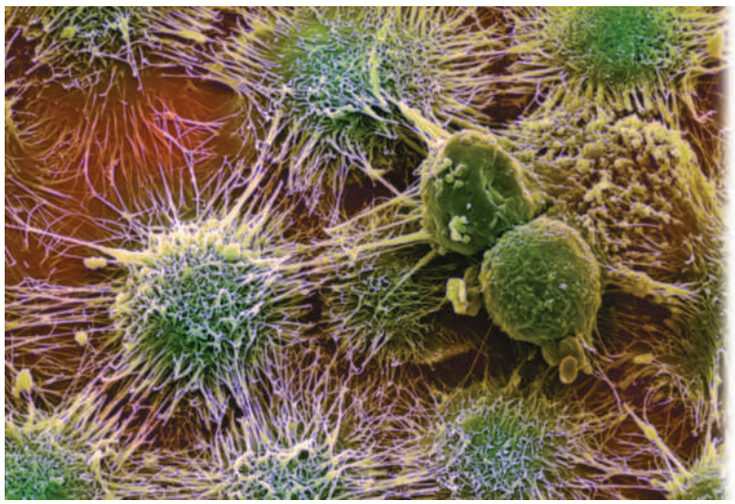
(1946–2004) combined the inquiring nature of a research scientist with the soul of a caring teacher. Over his 30 years of teaching introductory biology to both science majors and nonscience majors, many thousands of students had the opportunity to learn from him and be stimulated by his enthusiasm for the study of life. While 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.

Detailed Contents

UNIT 1 Cells

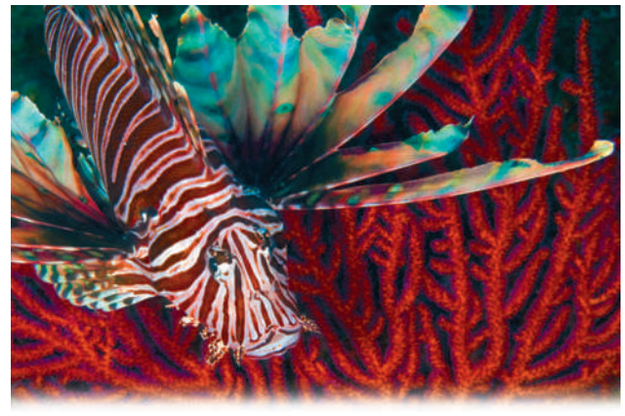


UNIT 2 Genetics

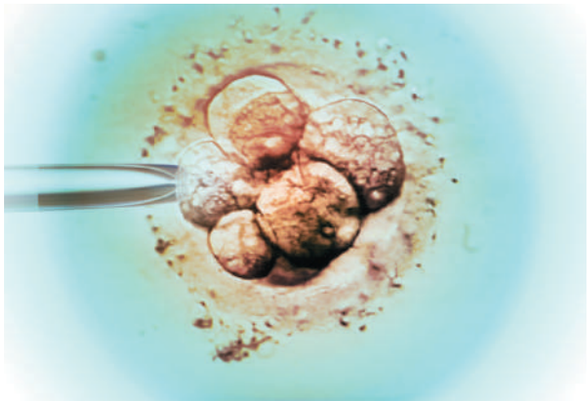


UNIT 3 Evolution and Diversity

UNIT 4 Ecology



UNIT 5 Animal Structure and Function

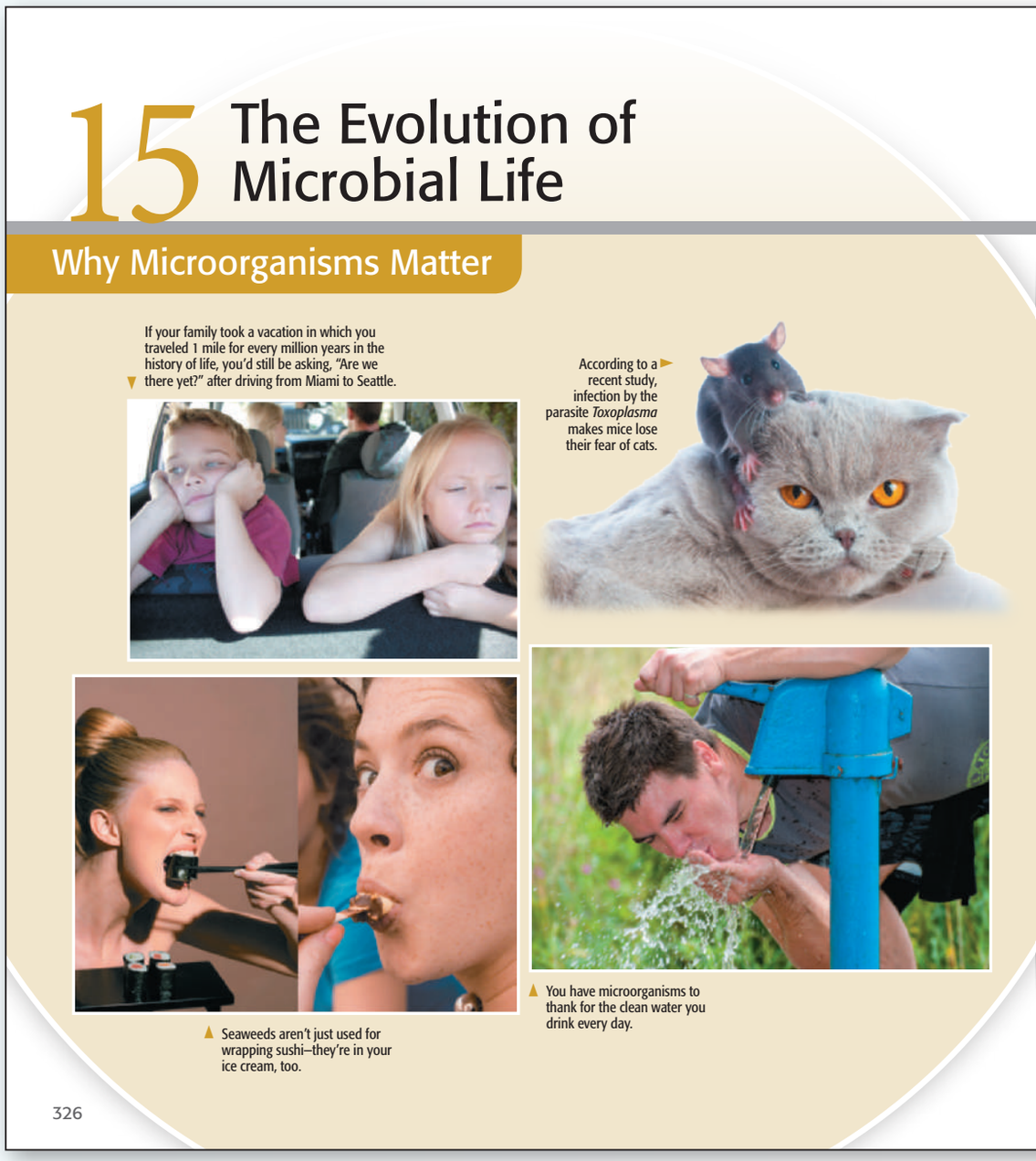


UNIT 6 Plant Structure and Function

Discover Why Biology *Matters*

Campbell Essential Biology highlights how the concepts that you learn in your biology class are relevant to your everyday life.

- **NEW! Why Biology Matters Photo Essays** use dynamic photographs and intriguing scientific observations to introduce each chapter. Each scientific tidbit is revisited in the chapter.



MasteringBiology®

NEW! Everyday Biology Videos briefly explore interesting and relevant biology topics that relate to concepts that students are learning in class. These 20 videos can be assigned in MasteringBiology with assessment questions.

- **UPDATED! Chapter Threads** weave a single compelling topic throughout the chapter. In Chapter 15, human microbiota are explored.

CHAPTER CONTENTS

CHAPTER THREAD

Human Microbiota

Human Microbiota BIOLOGY AND SOCIETY

Our Invisible Inhabitants

You probably know that your body contains trillions of individual cells, but did you know that they aren't all "you"? In fact, microorganisms residing in and on your body outnumber your own cells by 10 to 1. That means 100 trillion bacteria, archaea, and protists call your body home. Your skin, mouth, and nasal passages and your digestive and urogenital tracts are prime real estate for these microorganisms. Although each individual is so tiny that it would have to be magnified hundreds of times for you to see it, the weight of your microbial residents totals two to five pounds.

We acquire our microbial communities during the first two years of life, and they remain fairly stable thereafter. However, modern life is taking a toll on that stability. We alter the balance of these communities by taking antibiotics, purifying our water, sterilizing our food, attempting to germproof our surroundings, and scrubbing our skin and teeth. Scientists hypothesize that disrupting our microbial communities may increase our susceptibility to infectious diseases, predispose us to certain cancers, and contribute to conditions such as asthma and other allergies, irritable bowel syndrome, Crohn's disease, and autism. Researchers are even investigating whether having the wrong microbial community could make us fat. In addition, scientists are studying how our microbial communities have evolved over the course of human history. As you'll discover in the Evolution Connection section at the end of this chapter, for example, dietary changes invited decay-causing bacteria to make themselves at home on our teeth.

Colorized scanning electron micrograph of bacteria on a human tongue (14,500×).

Throughout this chapter, you will learn about the benefits and drawbacks of human-microbe interactions. You will also sample a bit of the remarkable diversity of prokaryotes and protists. This chapter is the first of three that explore the magnificent diversity of life. And so it is fitting that we begin with the prokaryotes, Earth's first life-form, and the protists, the bridge between unicellular eukaryotes and multicellular plants, fungi, and animals.

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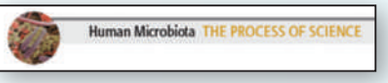
Biology and Society essays relate biology to your life and interests. This example discusses the microorganisms that live in your own body.



Process of Science explorations give you real-world examples of how the scientific method is applied. Chapter 15 explores a recent investigation into the possible role of microbiota in obesity.

Evolution Connection essays conclude each chapter by demonstrating how the theme of evolution runs throughout all of biology. The example in Chapter 15 discusses how changes in the typical human diet over generations is linked to bacteria that cause tooth decay.

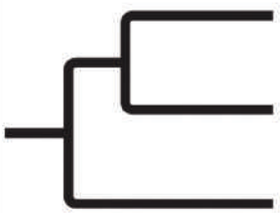
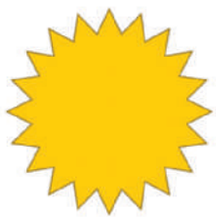
- **Additional updated Chapter Threads and essays** include radioactivity in Chapter 2, muscle performance in Chapter 6, and theft of used cooking oil for biofuel recycling in Chapter 7.

Identify "Big Picture" Themes

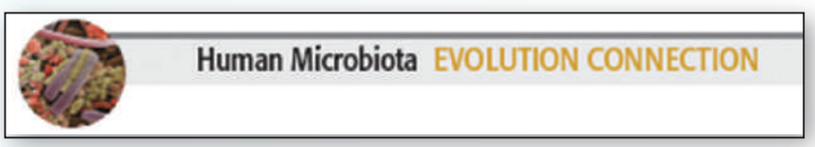
Examples of major themes in biology are highlighted throughout the text to help you see how overarching biology concepts are interconnected.

- **NEW! Important Themes in Biology** are introduced in Chapter 1 to underscore unifying principles that run throughout biology.

MAJOR THEMES IN BIOLOGY

Evolution	Structure/Function	Information Flow	Energy Transformations	Interconnections within Systems
				
Evolution by natural selection is biology's core unifying theme and can be seen at every level in the hierarchy of life.	The structure of an object, such as a molecule or a body part, provides insight into its function, and vice versa.	Within biological systems, information stored in DNA is transmitted and expressed.	All biological systems depend on obtaining, converting, and releasing energy and matter.	All biological systems, from molecules to ecosystems, depend on interactions between components.

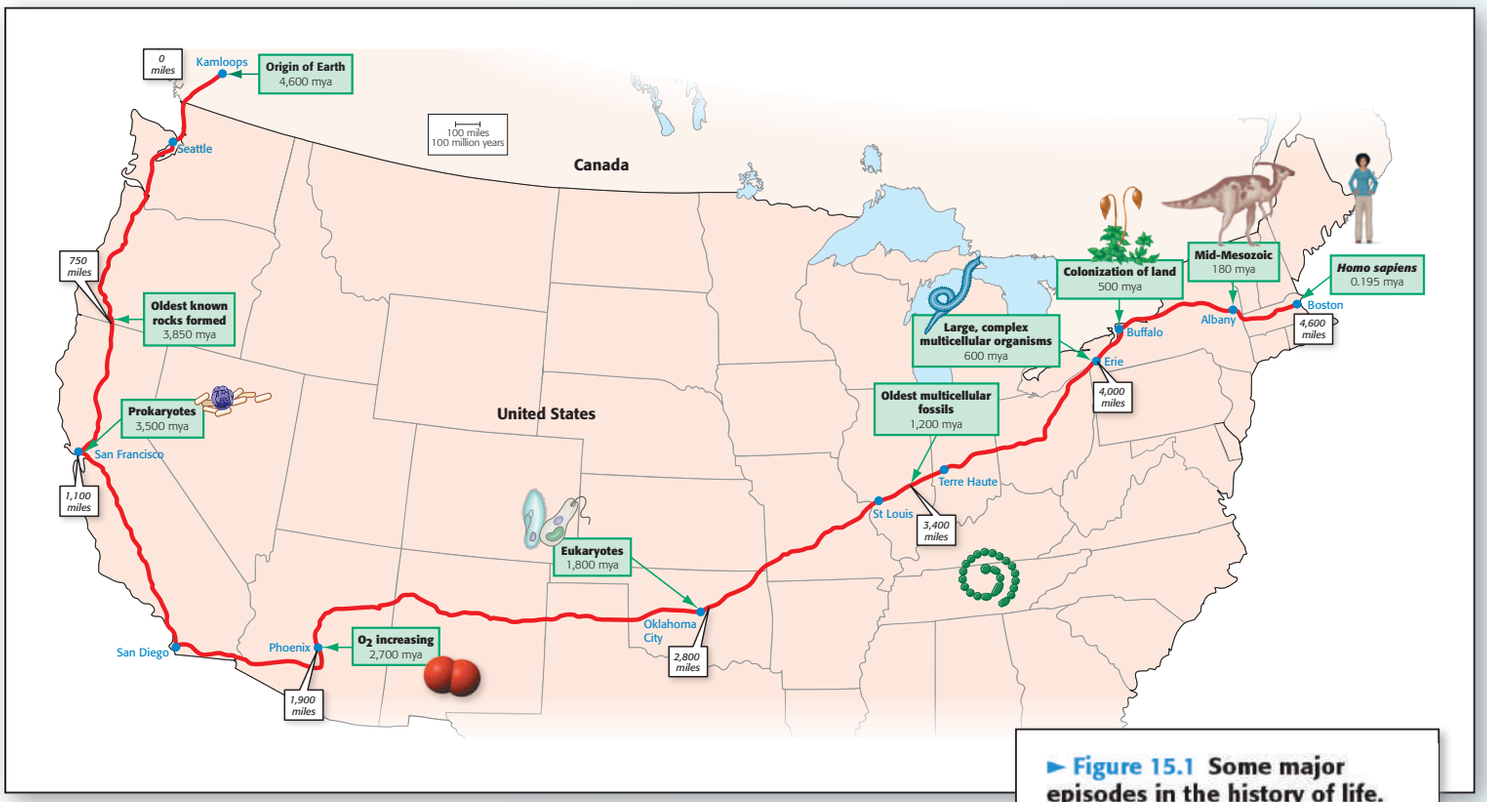
- These themes—Evolution, Structure/Function, Information Flow, Energy Transformations, and Interconnections within Systems—are **signaled with icons** throughout the text to help you notice the reoccurring examples of the major themes.



- The role of evolution throughout all of biology is further explored in depth at the end of each chapter in **Evolution Connection** discussions.

Recognize Analogies and Applications

Analogies and applications to everyday life make unfamiliar biology concepts easier to visualize and understand.



► **Figure 15.1 Some major episodes in the history of life.** On this 4,600-mile metaphorical road trip, each mile equals 1 million years in Earth's history.

If your family took a vacation in which you traveled 1 mile for every million years in the history of life, you'd still be asking, "Are we there yet?" after driving from Miami to Seattle.

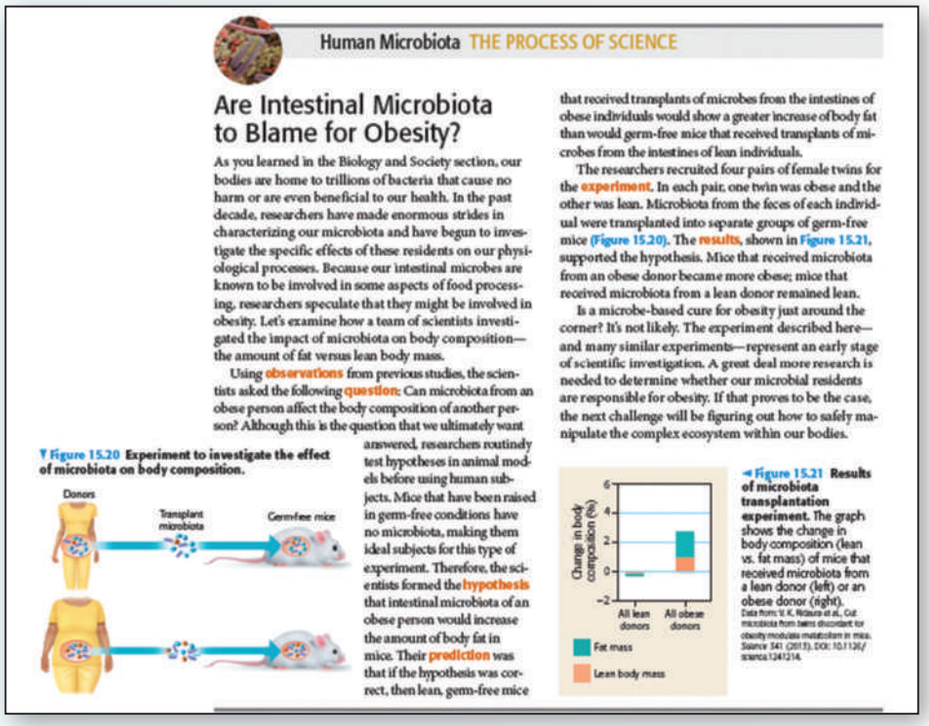
- **NEW analogies and applications** have been added throughout the prose and the illustrations, making it easier to learn and remember key concepts for the first time. Examples include:
  - comparing the significant differences between prokaryotic and eukaryotic cells to the differences between a bicycle and an SUV (Chapter 4)
  - comparing the process of DNA winding into chromosomes with the act of winding yarn into a skein (Chapter 10)
  - comparing a 4,600-mile road trip that describes the scale of biological evolution on Earth (Chapter 15)
  - comparing signal transduction to email communication (Chapter 27*)
  - comparing how dominoes relate to an action potential moving along an axon (Chapter 27*)

* Chapters 21–29 are included in the expanded version of the text that includes coverage of animal and plant anatomy and physiology.

Boost Your Scientific Literacy

A wide variety of exercises and assignments can help you move beyond memorization and think like a scientist.

● **UPDATED! Process of Science essays** appear in every chapter and walk through each step of the scientific method as it applies to a specific research question.



Human Microbiota THE PROCESS OF SCIENCE

Are Intestinal Microbiota to Blame for Obesity?

As you learned in the Biology and Society section, our bodies are home to trillions of bacteria that cause no harm or are even beneficial to our health. In the past decade, researchers have made enormous strides in characterizing our microbiota and have begun to investigate the specific effects of these residents on our physiological processes. Because our intestinal microbes are known to be involved in some aspects of food processing, researchers speculate that they might be involved in obesity. Let's examine how a team of scientists investigated the impact of microbiota on body composition—the amount of fat versus lean body mass.

Using **observations** from previous studies, the scientists asked the following **question**: Can microbiota from an obese person affect the body composition of another person? Although this is the question that we ultimately want answered, researchers routinely test hypotheses in animal models before using human subjects. Mice that have been raised in germ-free conditions have no microbiota, making them ideal subjects for this type of experiment. Therefore, the scientists formed the **hypothesis** that intestinal microbiota of an obese person would increase the amount of body fat in mice. Their **prediction** was that if the hypothesis was correct, then lean, gem-free mice that received transplants of microbes from the intestines of obese individuals would show a greater increase of body fat than would germ-free mice that received transplants of microbes from the intestines of lean individuals.

The researchers recruited four pairs of female twins for the **experiment**. In each pair, one twin was obese and the other was lean. Microbiota from the feces of each individual were transplanted into separate groups of germ-free mice (Figure 15.20). The **results**, shown in Figure 15.21, supported the hypothesis. Mice that received microbiota from an obese donor became more obese; mice that received microbiota from a lean donor remained lean.

Is a microbe-based cure for obesity just around the corner? It's not likely. The experiment described here—and many similar experiments—represent an early stage of scientific investigation. A great deal more research is needed to determine whether our microbial residents are responsible for obesity. If that proves to be the case, the next challenge will be figuring out how to safely manipulate the complex ecosystem within our bodies.

▼ Figure 15.20 **Experiment to investigate the effect of microbiota on body composition.**

◄ Figure 15.21 **Results of microbiota transplantation experiment.** The graph shows the change in body composition (lean vs. fat mass) of mice that received microbiota from a lean donor (left) or an obese donor (right).

Data from: V. K. Ridaura et al., Gut microbiota from twins discordant for obesity modulate metabolism in mice. Science 341 (2013). DOI: 10.1126/science.1241214.

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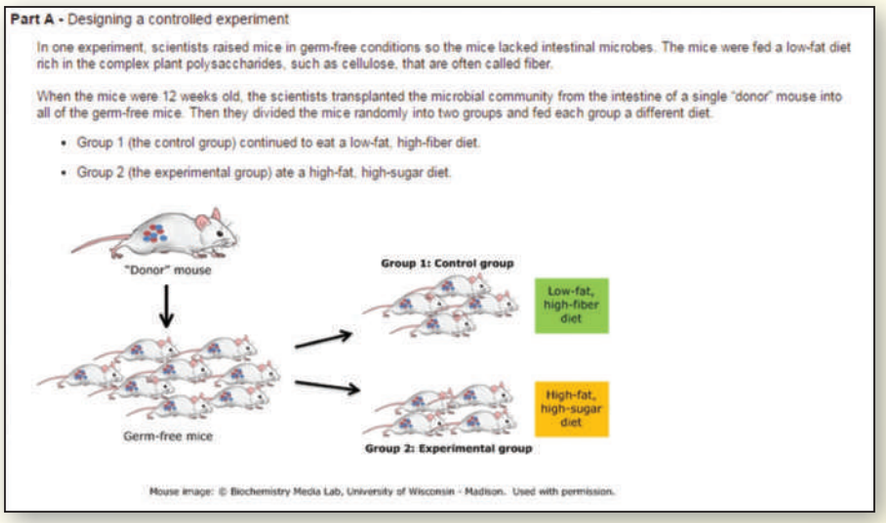


Part A - Designing a controlled experiment

In one experiment, scientists raised mice in germ-free conditions so the mice lacked intestinal microbes. The mice were fed a low-fat diet rich in the complex plant polysaccharides, such as cellulose, that are often called fiber.

When the mice were 12 weeks old, the scientists transplanted the microbial community from the intestine of a single "donor" mouse into all of the germ-free mice. Then they divided the mice randomly into two groups and fed each group a different diet.

- Group 1 (the control group) continued to eat a low-fat, high-fiber diet.
- Group 2 (the experimental group) ate a high-fat, high-sugar diet.

Mouse image: © Biochemistry Media Lab, University of Wisconsin - Madison. Used with permission.

◄ **NEW! Scientific Thinking Activities** are designed to help you develop an understanding of how scientific research is conducted.

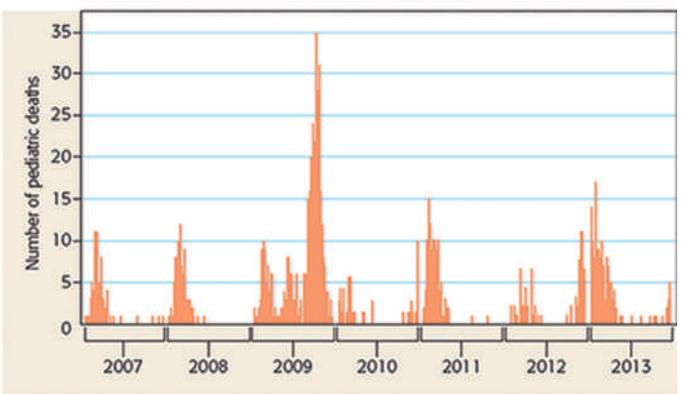
NEW! Evaluating Science in the Media Activities challenge you to recognize validity, bias, purpose, and authority in everyday sources of information.

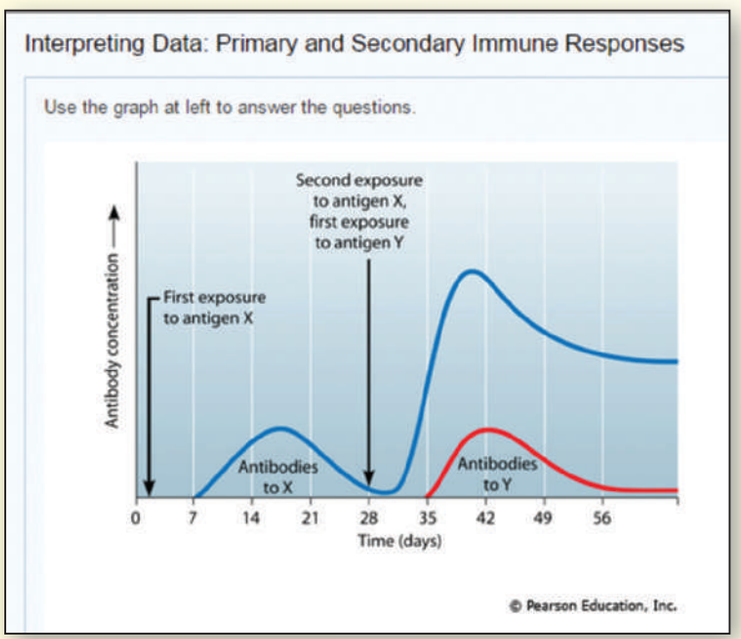
Learn to Interpret Data

Data interpretation is important for understanding biology and for making many important decisions in everyday life. Exercises in the text and online will help you develop this important skill.

- **NEW! Interpreting Data end-of-chapter questions** help you learn to use quantitative material by analyzing graphs and data. This example from Chapter 10 invites you to examine historical data of flu mortality. Other examples include:
  - Chapter 13: Learn how markings on snail shells affect predation rates in an environment
  - Chapter 15: Calculate how quickly bacteria can multiply on unrefrigerated food

14. Interpreting Data The graph below summarizes the number of children who died of all strains of flu from 2007 until 2013. Each bar represents the number of child deaths occurring in one week. Why does the graph have the shape it does, with a series of peaks and valleys? Looking over the Biology and Society section at the start of the chapter, why does the graph reach its highest points near the middle? Based on these data, when does flu season begin and end in a typical year?





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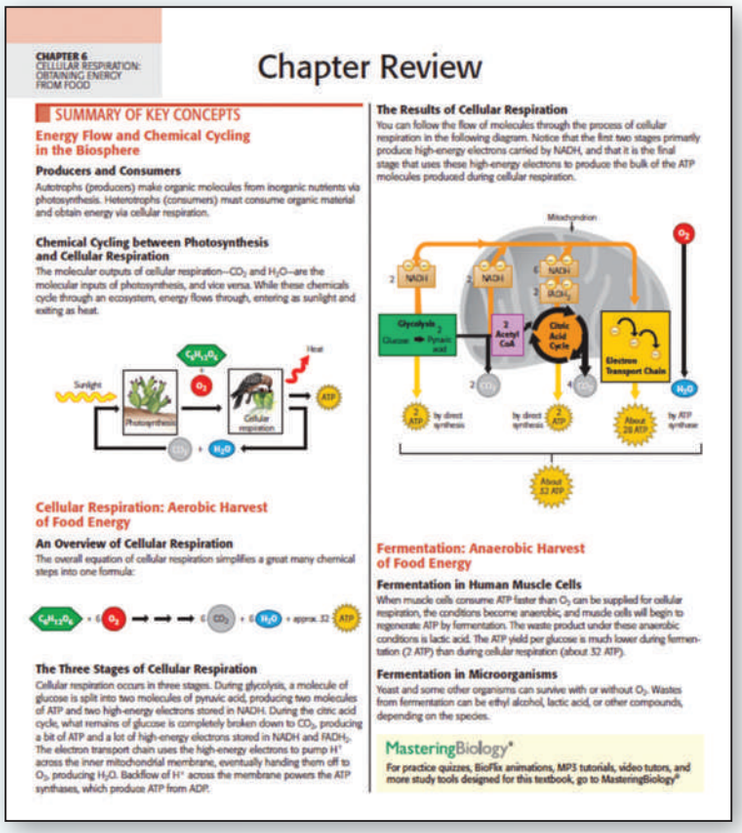
- **NEW! Interpreting Data Activities** help you build and practice data analysis skills.

Maximize Your Study Time

Campbell Essential Biology and the **MasteringBiology** homework, tutorial, and assessment program work hand-in-hand to help students succeed in introductory biology.

- **The Chapter Review** offers a built-in study guide that combines words with images to help you organize the key concepts. The unique figures in the Chapter Review synthesize information from the corresponding chapter, which helps you study more efficiently.



CHAPTER 6
CELLULAR RESPIRATION: OBTAINING ENERGY FROM FOOD

Chapter Review

SUMMARY OF KEY CONCEPTS

Energy Flow and Chemical Cycling in the Biosphere

Producers and Consumers

Autotrophs (producers) make organic molecules from inorganic nutrients via photosynthesis. Heterotrophs (consumers) must consume organic material and obtain energy via cellular respiration.

Chemical Cycling between Photosynthesis and Cellular Respiration

The molecular outputs of cellular respiration—CO_2 and H_2O—are the molecular inputs of photosynthesis, and vice versa. While these chemicals cycle through an ecosystem, energy flows through, entering as sunlight and exiting as heat.

Cellular Respiration: Aerobic Harvest of Food Energy

An Overview of Cellular Respiration

The overall equation of cellular respiration simplifies a great many chemical steps into one formula:

The Three Stages of Cellular Respiration

Cellular respiration occurs in three stages. During glycolysis, a molecule of glucose is split into two molecules of pyruvic acid, producing two molecules of ATP and two high-energy electrons stored in NADH. During the citric acid cycle, what remains of glucose is completely broken down to CO_2, producing a bit of ATP and a lot of high-energy electrons stored in NADH and $FADH_2$. The electron transport chain uses the high-energy electrons to pump H^+ across the inner mitochondrial membrane, eventually handing them off to O_2, producing H_2O. Backflow of H^+ across the membrane powers the ATP synthases, which produce ATP from ADP.

The Results of Cellular Respiration

You can follow the flow of molecules through the process of cellular respiration in the following diagram. Notice that the first two stages primarily produce high-energy electrons carried by NADH, and that it is the final stage that uses these high-energy electrons to produce the bulk of the ATP molecules produced during cellular respiration.

Fermentation: Anaerobic Harvest of Food Energy

Fermentation in Human Muscle Cells

When muscle cells consume ATP faster than O_2 can be supplied for cellular respiration, the conditions become anaerobic, and muscle cells will begin to regenerate ATP by fermentation. The waste product under these anaerobic conditions is lactic acid. The ATP yield per glucose is much lower during fermentation (2 ATP) than during cellular respiration (about 32 ATP).

Fermentation in Microorganisms

Yeast and some other organisms can survive with or without O_2. Wastes from fermentation can be ethyl alcohol, lactic acid, or other compounds, depending on the species.

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For practice quizzes, BioFlix animations, MP3 tutorials, video tutors, and more study tools designed for this textbook, go to MasteringBiology®

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MasteringBiology provides a wide range of activities and study tools to match your learning style, including BioFlix animations, MP3 audio tutorials, interactive practice quizzes, and more. Your instructor can assign activities for extra practice to monitor your progress in the course.

NEW! Essential Biology videos introduce you to key concepts and vocabulary, and are narrated by authors Eric Simon and Kelly Hogan. Topics include the **Scientific Method, Molecules of Life, DNA Replication, Mechanisms of Evolution, Ecological Principles,** and more.

Learn Before, During, and After Class

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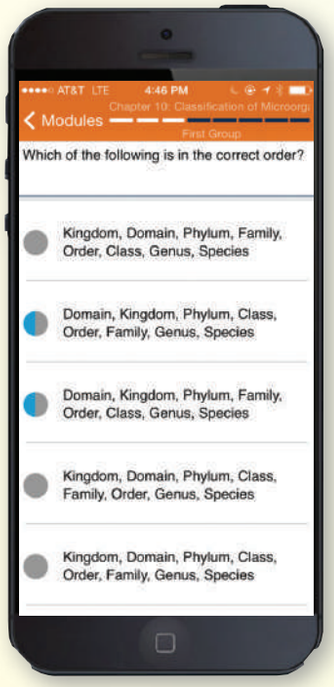
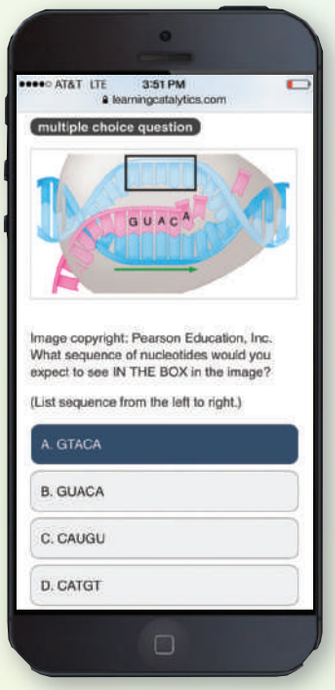


BEFORE CLASS

NEW! Dynamic Study Modules help you acquire, retain, and recall information faster and more efficiently than ever before. The convenient practice questions and detailed review explanations can be accessed on the go using a smartphone, tablet, or computer.

DURING CLASS

NEW! Learning Catalytics is a "bring your own device" assessment and classroom activity system that expands the possibilities for student engagement. Using Learning Catalytics, instructors can deliver a wide range of auto-gradable or open-ended questions that test content knowledge and build critical thinking skills using eighteen different answer types.



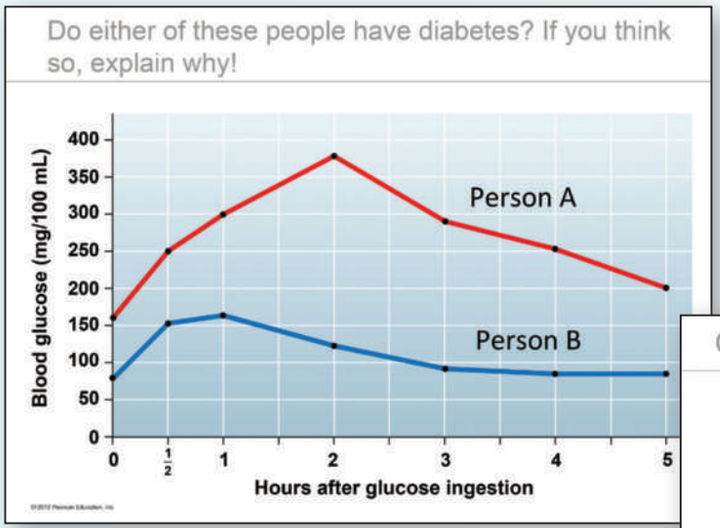
AFTER CLASS

- **Over 100 Coaching Activities** are created by the textbook author team and help you focus on learning key concepts and building your biology vocabulary.
- **NEW! Everyday Biology videos** briefly explore interesting and relevant biology topics that relate to concepts in the course.

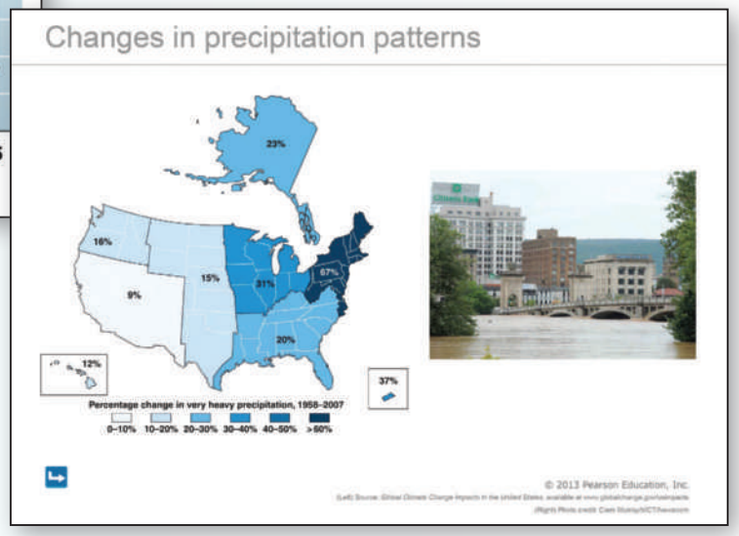
Instructors: Extensive Resources for You

Extensive resources save valuable time both in course prep and during class.

- The **Test Bank** provides a variety of test questions, many art- or scenario-based, in both TestGen® and Microsoft® Word.



EXPANDED! Current Topic PowerPoint® presentations include new topics such as DNA Profiling, Stem Cells and Cloning, Diabetes, Biodiversity, and more. Each Powerpoint Presentation includes instructor teaching tips and active learning strategies to help you easily create a high-interest, active lecture.



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Instructor media resources such as PowerPoint slides, animations, teaching tips videos, and more can be accessed and downloaded from the Instructor Resources area of MasteringBiology.

The **Instructor Exchange** provides successful, class-tested active learning techniques and analogies from biology instructors around the nation, offering a springboard for quick ideas to create more compelling lectures. Co-author Kelly Hogan moderates contributions to the exchange.

Preface

This is a wonderful time to teach and learn biology. Opportunities to marvel at the natural world and the life within it abound. It's difficult to view a news website without finding stories that touch on biology and its intersection with society. In addition, the world of pop culture is rich with books, movies, TV shows, comic strips, and video games that feature biological wonders and challenge us to think about important biological concepts and their implications. Although some people *say* that they don't like biology (or, more often, science in general), nearly everyone will admit to an inborn biophilia. After all, most of us keep pets, tend a garden, enjoy zoos and aquariums, or appreciate time spent outdoors. 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 myriad other areas. But despite the inborn affinity that nearly everyone has for biology, it can be a struggle for nonscientists to delve into the subject. Our primary goal in writing *Campbell Essential Biology with Physiology* is to help teachers motivate and educate the next generation of citizens by tapping into the inherent curiosity about life that we all share.

Goals of the Book

Although our world is rich with "teachable moments" and learning opportunities, the explosion of knowledge we have already witnessed in the 21st century 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, animals, and plants. 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 nonscience majors—where the emphasis is on fewer topics and more focused explanations—and we never allow the content we do include to be diluted. Toward that end, in this new edition we removed some of the most technical details and terminology, which we hope will help nonscience major students to focus on the key topics in biology.

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 teachers identify three goals: (1) to engage students by relating the core content to their lives and the greater society; (2) to clarify the process of science by showing how it is applied in the real world and to give students practice in applying scientific and critical thinking skills themselves; and (3) to demonstrate how evolution serves as biology's unifying theme. To help achieve these goals, every chapter of this book includes three 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 (found 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. 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 woven throughout the three chapter essays and is touched on several additional times in the chapter. Thus, this unifying chapter thread ties together the three pedagogical goals of the course using a topic that is compelling and relevant to students.

New to This Edition

We hope that this latest edition of *Campbell Essential Biology with Physiology* goes even further in helping students relate the material to their lives, understand the process of science, and appreciate how evolution is the unifying theme of biology. To this end, we've added significant new features and content to this edition:

- **Clarifying the importance of biology to students' lives.** Every student taking an introductory biology course should be made keenly aware of the myriad ways that biology affects his or her own life. To help put such issues front and center, and to "prime the learning pump" before diving into the content, we have included a new feature at the start of each chapter called Why It Matters. Every chapter begins with a series of attention-grabbing facts in conjunction with compelling photographs that illustrate the importance of that chapter's topic to students' lives. These high-interest facts appear again in the chapter narrative, typeset in a design meant to capture students' attention and placed adjacent to the science discussion that explains the fact. Examples include: Why Macromolecules Matter ("A long-distance runner who carbo-loads the night before a race is banking glycogen to be used the next day"), Why Ecology Matters ("Producing the beef for a hamburger requires eight times as much land as producing the soybeans for a soyburger") and Why Hormones Matter ("Strike a pose before a job interview and you just might decrease the hormone that triggers stress").
- **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 each of the five themes. For example, the first theme, the relationship of structure to function, is illustrated in Chapter 2 in the discussion of how the unique chemistry of water accounts for its biological properties. The second theme, information flow, is explored in Chapter 10 in the discussion on how genes control traits. The third theme, interconnections within systems, is illustrated in Chapter 18 in the discussion on the global water cycle. The fourth theme, evolution, is called out in Chapter 17 in the discussion on the phylogeny of animals. The fifth theme, energy transformations, is explored in Chapter 6 in the discussion on the flow of energy through ecosystems. Readers will find at least one major theme called out per chapter, which will help students see the connections between these major themes and the course content, and instructors will have myriad easy-to-reference examples to help underscore these five themes.

- **New unifying chapter threads.** As discussed earlier, every chapter in *Campbell Essential Biology with Physiology* has a unique unifying chapter thread—a high-interest topic that helps to demonstrate the relevance of the chapter content. The chapter thread is incorporated into the three main essays of each chapter (Biology and Society, The Process of Science, and Evolution Connection) and appears throughout the chapter text. This fifth edition features many new chapter threads and essays, each of which highlights a current topic that applies biology to students' lives and to the greater society. For example, Chapter 2 presents a new thread on radioactivity, including discussions of its use in health care and as a tool to test evolutionary hypotheses. Chapter 15 features a new thread on human microbiota, including a recent investigation into the possible role of microbiota in obesity and an exploration of how the change from a hunter-gatherer lifestyle to a diet heavy in processed starch and sugar selected for oral bacteria that cause tooth decay. Chapter 24 offers a new thread on vaccines, introducing the importance of vaccinating an entire community and the reason why a new influenza vaccine is required each year.
- **Developing data literacy.** 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. To help foster critical thinking skills, we have incorporated a new feature called Interpreting Data into the end-of-chapter assessments. These questions, one per chapter, offer students the opportunity to practice their science literacy skills. For example, in Chapter 10, students are asked to examine historical data of flu mortality; in Chapter 15, students are tasked with calculating how quickly bacteria can multiply on unrefrigerated food; and in Chapter 24, students are presented with a graph illustrating the prevalence of food allergies in children and asked to determine what conclusions can be drawn from the data. We hope that practice examining these simple yet relevant data sets will help students be more comfortable when they must confront numerical data in their own lives.
- **Updated content and figures.** As we do in every edition, we have made many significant updates to the content presented in the book. Examples of new or updated material include new discussions on epigenetics, metagenomics, and RNA interference; an examination of new genomic information on Neanderthals; updated climate change statistics; a discussion of advances in fetal genetic testing; and an updated discussion of new threats to biodiversity. We have also included nearly a dozen new examples of DNA profiling and a cutting-edge exploration of genetically modified foods. We also strive with each new edition to update our photos and illustrations. New figures include examples that show how a prion protein can cause brain damage (Figure 3.20), how a breast cancer drug inhibits cancer cells (Figure 25.15), how angioplasty can repair diseased arteries (Figure 23.15), and how real data from DNA profiling can exonerate wrongly accused individuals (Figure 12.16).
- **New analogies.** As part of our continuing effort to help students visualize and relate to biology concepts, we have included numerous new analogies in this edition. For example, in Chapter 4, we compare the significant differences between prokaryotic and eukaryotic cells to the differences between a bicycle and an SUV. In Chapter 8, we compare the process of DNA winding into chromosomes with the act of winding yarn into a skein. In Chapter 27, we analogize humans seeing an array of colors with only three types of photoreceptor cones to how a printer can print an array of colors from only three colors included in a toner cartridge. We also have included new analogies in visual format, such as how dominoes relate to an action potential moving along an axon (Figure 27.4). Additional examples, both narrative and visual, bring biological scale into focus, such as a 4,600-mile road trip that is used to help students imagine the scale of biological evolution on Earth (Figure 15.1).

- **MasteringBiology updates.** New whiteboard-style animated videos provide students with an introduction to key biological concepts so students can arrive to class better prepared to explore applications or dive into any topic more deeply. New Everyday Biology videos, produced by the BBC, promote connections between concepts and biology in everyday life, and Evaluating Science in the Media activities teach students how to be wise consumers of scientific information and coach them through critically evaluating the validity of scientific information on the Internet. New Scientific Thinking activities encourage students to develop scientific reasoning skills as they explore a current area of research and allows instructors to easily assess student mastery of these skills.
- **Teaching the Issues.** Because many instructors, including the authors, prefer to use current topics to demonstrate the relevance of biology to students' lives, we've expanded our series of Current Topic Instructor PowerPoints© with this edition. New topics include DNA Profiling, Stem Cells and Cloning, Diabetes, Biodiversity, and more. Each PowerPoint© Presentation includes instructor teaching tips and active learning strategies to easily create a high-interest, active lecture.

Attitudes about science and scientists are often shaped by a single required science class—*this* class. We hope to tap into the innate appreciation of nature we all share and nurture this affection 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*.

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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. Project Manager Libby Reiser expertly coordinated the supplements, a difficult task given their number and variety. We thank media project manager Eddie Lee for his work on the excellent Instructor Resources DVD 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 Hilary Engebretson, of Whatcom Community College, who revised the Quiz Shows and Clicker questions; and Jean DeSaix (University of North Carolina at Chapel Hill), Justin Shaffer (University of California, Irvine), Kristen Miller (University of Georgia), and Suann Yang (Presbyterian College), our collaborative team of test bank authors for ensuring excellence in our assessment program. The authors also thank Justin Shaffer (University of California, Irvine), Suzanne Wakim (Butte Community College), and Eden Effert (Eastern Illinois University) for their fine work on the issues-based presentation Campbell Current Topics PowerPoint© Presentations. In addition, the authors thank Reading Quiz authors Amaya Garcia Costas, Montana State University, and Cindy Klevickis, James Madison University; Reading Quiz accuracy reviewer Veronica Menendez; Practice Test author Chris Romero, Front Range Community College; and Practice Test accuracy reviewer Justin Walgaurnery, University of Hawaii.

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