GLOBAL EDITION

Biology

A Global Approach

TENTH EDITION

Campbell • Reece • Urry • Cain • Wasserman • Minorsky • Jackson

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BIOLOGY

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About the Authors

The Tenth Edition author team's contributions reflect their biological expertise as researchers and their teaching sensibilities gained from years of experience as instructors at diverse institutions. The team's highly collaborative style continues to be evident in the cohesiveness and consistency of the Tenth Edition.

Neil A. Campbell

Neil Campbell (1946–2004) combined the investigative nature of a research scientist with the soul of an experienced and caring teacher. He earned his M.A. in zoology from the University of California, Los Angeles, and his Ph.D. in plant biology from the University of California, Riverside, where he received the Distinguished Alumnus Award in 2001. Neil published numerous research articles on desert and coastal plants and how the sensitive plant (*Mimosa*) and other legumes move their leaves. His 30 years of teaching in diverse environments included introductory biology courses at Cornell University, Pomona College, and San Bernardino Valley College, where he received the college's first Outstanding Professor Award in 1986. Neil was a visiting scholar in the Department of Botany and Plant Sciences at the University of California, Riverside.

Jane B. Reece

Jane Reece was Neil Campbell's longtime collaborator, and she has participated in every edition of *BIOLOGY*. Earlier, Jane taught biology at Middlesex County College and Queensborough Community College. She holds an A.B. in biology from Harvard University, an M.S. in microbiology from Rutgers University, and a Ph.D. in bacteriology from the University of California, Berkeley. Jane's research as a doctoral student at UC Berkeley and postdoctoral fellow at Stanford University focused on genetic recombination in bacteria. Besides her work on *BIOLOGY*, she has been a coauthor on *Campbell Biology in Focus*, *Campbell Biology: Concepts & Connections*, *Campbell Essential Biology*, and *The World of the Cell*.

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Michael L. Cain

Michael Cain is an ecologist and evolutionary biologist who is now writing full-time. Michael earned a joint degree in biology and math at Bowdoin College, an M.Sc. from Brown University, and a Ph.D. in ecology and evolutionary biology from Cornell University. As a faculty member at New Mexico State University and Rose-Hulman Institute of Technology, he taught a wide range of courses, including introductory biology, ecology, evolution, botany, and conservation biology. Michael is the author of dozens of scientific papers on topics that include foraging behavior in insects and plants, long-distance seed dispersal, and speciation in crickets. In addition to his work on *BIOLOGY* and *Campbell Biology in Focus*, Michael is the lead author of an ecology textbook.

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Peter Minorsky is Professor of Biology at Mercy College in New York, where he teaches introductory biology, evolution, ecology, and botany. He received his A.B. in biology from Vassar College and his Ph.D. in plant physiology from Cornell University. He is also the science writer for the journal *Plant Physiology*. After a postdoctoral fellowship at the University of Wisconsin at Madison, Peter taught at Kenyon College, Union College, Western Connecticut State University, and Vassar College. His research interests concern how plants sense environmental change. Peter received the 2008 Award for Teaching Excellence at Mercy College. Peter is also a coauthor of *Campbell Biology in Focus*.

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Preface

We are honored to present *BIOLOGY: A Global Approach*, which has been adapted from *CAMPBELL BIOLOGY*, Tenth Edition, for a global audience. For the last quarter century, *BIOLOGY* has been the leading college text in the biological sciences. It has been translated into more than a dozen languages and has provided millions of students with a solid foundation in college-level biology. This success is a testament not only to Neil Campbell's original vision but also to the dedication of thousands of reviewers, who, together with editors, artists, and contributors, have shaped and inspired this work. Although this Tenth Edition represents a milestone, science and pedagogy are not static—as they evolve, so does *BIOLOGY*.

Our goals for the Tenth Edition include:

- helping students **make connections visually** across the diverse topics of biology
- giving students a strong foundation in **scientific thinking and quantitative reasoning skills**
- inspiring students with the excitement and relevance of modern biology, particularly in the realm of **genomics**

Our starting point, as always, is our commitment to crafting text and visuals that are accurate, are current, and reflect our passion for teaching and learning about biology.

New to This Edition

Here we provide an overview of the new features that we have developed for the Tenth Edition; we invite you to explore pages 10–26 for more information and examples.

- **Make Connections Figures** draw together topics from different chapters to show how they are all related in the "big picture." By reinforcing fundamental conceptual connections throughout biology, these figures help overcome students' tendencies to compartmentalize information.
- **Scientific Skills Exercises** in every chapter use real data and guide students in learning and practicing data interpretation, graphing, experimental design, and math skills. All 56 Scientific Skills Exercises have assignable, automatically graded versions in **MasteringBiology**®.

- **Interpret the Data Questions** throughout the text engage students in scientific inquiry by asking them to interpret data presented in a graph, figure, or table. The Interpret the Data Questions can be assigned and automatically graded in **MasteringBiology**.
- The impact of **genomics** across biology is explored throughout the Tenth Edition with examples that reveal how our ability to rapidly sequence DNA and proteins is transforming all areas of biology, from molecular and cell biology to phylogenetics, physiology, and ecology. Chapter 5 provides a launching point for this feature in a new Key Concept, "Genomics and proteomics have transformed biological inquiry and applications." Illustrative examples are distributed throughout later chapters.
- **Synthesize Your Knowledge Questions** at the end of each chapter ask students to synthesize the material in the chapter and demonstrate their big-picture understanding. A striking photograph with a thought-provoking question helps students see how material they learned in the chapter connects to their world and provides insight into natural phenomena.
- The Tenth Edition provides a range of new practice and assessment opportunities in **MasteringBiology.** Besides the Scientific Skills Exercises and Interpret the Data Questions, **Solve It Tutorials** in MasteringBiology engage students in a multistep investigation of a "mystery" or open question. Acting as scientists, students must analyze real data and work through a simulated investigation. In addition, **Adaptive Follow-Up Assignments** provide coaching and practice that continually adapt to each student's needs, making efficient use of study time. Students can use the **Dynamic Study Modules** to study anytime and anywhere with their smartphones, tablets, or computers.
- **Learning Catalytics**™ allows students to use their smartphones, tablets, or laptops to respond to questions in class.
- As in each new edition of *BIOLOGY*, the Tenth Edition incorporates **new content.** The key updates for the Tenth Edition are summarized on pp. 8–9, following this Preface.

Our Hallmark Features

Teachers of general biology face a daunting challenge: to help students acquire a conceptual framework for organizing an ever-expanding amount of information. The hallmark features of *BIOLOGY* provide such a framework, while promoting a deeper understanding of biology and the process of science.

To help students distinguish the "forest from the trees," each chapter is organized around a framework of three to seven carefully chosen **Key Concepts**. The text, Concept Check Questions, Summary of Key Concepts, and MasteringBiology all reinforce these main ideas and essential facts.

BIOLOGY also helps students organize and make sense of what they learn by emphasizing **evolution and other unifying themes** that pervade biology. These themes are introduced in Chapter 1 and are integrated throughout the book. Each chapter includes at least one Evolution section that explicitly focuses on evolutionary aspects of the chapter material, and each chapter ends with an Evolution Connection Question and a Write About a Theme Question.

Because text and illustrations are equally important for learning biology, **integration of text and figures** has been a hallmark of this text since the First Edition. In addition to the new Make Connections Figures, our popular Exploring Figures on selected topics epitomize this approach: Each is a learning unit of core content that brings together related illustrations and text. Another example is our Guided Tour Figures, which use descriptions in blue type to walk students through complex figures as an instructor would. Visual Organizer Figures highlight the main parts of a figure, helping students see key categories at a glance. And Summary Figures visually recap information from the chapter.

To encourage **active reading** of the text, *BIOLOGY* includes numerous opportunities for students to stop and think about what they are reading, often by putting pencil to paper to draw a sketch, annotate a figure, or graph data. Active learning questions include Make Connections Questions, What If? Questions, Figure Legend Questions, Draw It Questions, Summary Questions, and the new Synthesize Your Knowledge and Interpret the Data Questions.

Finally, *BIOLOGY* has always featured **scientific inquiry**, an essential component of any biology course. Complementing stories of scientific discovery in the text narrative and the unit-opening interviews, our standard-setting Inquiry Figures deepen the ability of students to understand how we know what we know. Scientific Inquiry Questions give students opportunities to practice scientific thinking, along with the new Scientific Skills Exercises and Interpret the Data Questions.

MasteringBiology®

MasteringBiology, the most widely used online assessment and tutorial program for biology, provides an extensive library of homework assignments that are graded automatically. In addition to the new Scientific Skills Exercises, Interpret the Data Questions, Solve It Tutorials, Adaptive Follow-Up Assignments, and Dynamic Study Modules, MasteringBiology offers BioFlix® Tutorials with 3-D Animations, Experimental Inquiry Tutorials, Interpreting Data Tutorials, BLAST Tutorials, Make Connections Tutorials, Video Tutor Sessions, Get Ready for Biology, Activities, Reading Quiz Questions, Student Misconception Questions, 4,500 Test Bank Questions, and MasteringBiology Virtual Labs. MasteringBiology also includes the *BIOLOGY* eText, Study Area, and Instructor Resources. See pages 18–21 and www.masteringbiology.com for more details.

Our Partnership with Instructors and Students

A core value underlying our work is our belief in the importance of a partnership with instructors and students. One primary way of serving instructors and students, of course, is providing a text that teaches biology well. In addition, Pearson Education offers a rich variety of instructor and student resources, in both print and electronic form (see pp. 18–23). In our continuing efforts to improve the book and its supplements, we benefit tremendously from instructor and student feedback, not only in formal reviews from hundreds of scientists, but also via e-mail and other avenues of informal communication.

The real test of any textbook is how well it helps instructors teach and students learn. We welcome comments from both students and instructors. Please address your suggestions to any of us:

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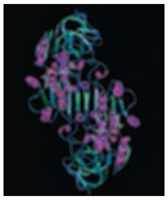
New Content

This section highlights selected new content in *BIOLOGY: A Global Approach*, Tenth Edition.

CHAPTER 1 Biology and Its Themes

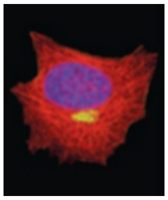
To help students focus on the big ideas of biology, we now emphasize five themes: Organization, Information, Energy and Matter, Interactions, and the core theme of Evolution. The new Figure 1.8 on gene expression equips students from the outset with an understanding of how gene sequences determine an organism's characteristics. Concept 1.3 has been reframed to more realistically reflect the scientific process, including a new figure on the complexity of the practice of science (Figure 1.23). A new case study in scientific inquiry (Figures 1.24 and 1.25) deals with evolution of coloration in mice.

UNIT 1 The Role of Chemistry in Biology



New chapter-opening photos and introductory stories engage students in learning this foundational material. Chapter 2 has a new Evolution section on radiometric dating. In Chapter 5, there is a new Key Concept section, "Genomics and proteomics have transformed biological inquiry and applications" (Concept 5.6), and a new Make Connections Figure, "Contributions of Genomics and Proteomics to Biology" (Figure 5.26).

UNIT 2 Cell Biology



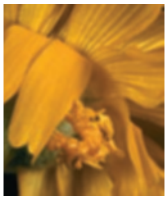
Our main goal for this unit was to make the material more accessible to students. We have streamlined coverage of the cytoskeleton in Chapter 7 and historical aspects of the membrane model in Chapter 8. We have revised the photosynthesis summary figure (Figure 11.22) to incorporate a big-picture view of photosynthesis. The new Make Connections Figure 11.23 integrates the cellular activities covered in Chapters 5–11 in the context of a single plant cell. Concept 12.3 has been streamlined, with a new Figure 12.17 that covers the M checkpoint as well as the G_1 checkpoint.

UNIT 3 The Genetic Basis of Life

In Chapters 13–17, we have incorporated changes that help students make connections between the more abstract concepts of genetics and their molecular underpinnings. For example, Chapter 13 includes a new figure (Figure 13.9) detailing the events of crossing over during prophase. Figure 14.4, showing alleles on chromosomes, has been enhanced to show the DNA sequences of both alleles, along with their biochemical and phenotypic consequences. A new figure on sickle-cell disease also connects these levels (Figure 14.17). In Chapter 17, material on coupled transcription and translation in bacteria has been united with coverage of polyribosomes.

Chapters 18–20 are extensively updated, driven by exciting new discoveries based on high-throughput sequencing. Chapter 18 includes a new figure (Figure 18.15) on the role of siRNAs in chromatin remodeling. A new Make Connections Figure (Figure 18.27) describes four subtypes of breast cancer that have recently been proposed, based on gene expression in tumor cells. In Chapter 19, techniques that are less commonly used have been pruned, and the chapter has been reorganized to emphasize the important role of sequencing. A new figure (Figure 19.4) illustrates next-generation sequencing. Chapter 20 has been updated to reflect new research, including the ENCODE project, the Cancer Genome Atlas, and the genome sequences of the gorilla and bonobo. A new figure (Figure 20.15) compares the 3-D structures of lysozyme and α-lactalbumin and their amino acid sequences, providing support for their common evolutionary origin.

UNIT 4 Evolution



One goal of this revision was to highlight connections among fundamental evolutionary concepts. Helping meet this goal, new material connects Darwin's ideas to what can be learned from phylogenetic trees, and a new figure (Figure 25.13) and text illustrate how the combined effects of speciation and extinction determine the number of species in different groups of organisms. The unit also features new material on nucleotide variability within genetic loci, including a new figure (Figure 23.4) that shows variability within coding and noncoding regions of a gene. Other changes enhance the storyline of the unit. For instance, Chapter 25 includes new text on how the rise of large eukaryotes in the Ediacaran period represented a monumental transition in the history of life—the end of a microbe-only world. Updates include revised discussions of the events and underlying causes of the Cambrian explosion and the Permian mass extinction, as well as new figures providing fossil evidence of key evolutionary events, such as the formation of plant-fungi symbioses (Figure 25.12). A new Make Connections Figure (Figure 23.17) explores the sickle-cell allele and its impact from the molecular and cellular levels to organisms to the evolutionary explanation for the allele's global distribution in the human population.

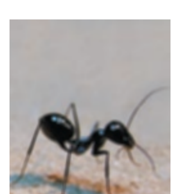
UNIT 5 The Diversity of Life

In keeping with our Tenth Edition goals, we have expanded the coverage of genomic and other molecular studies and how they inform our understanding of phylogeny. Examples include a new Inquiry Figure (Figure 34.49) on the Neanderthal genome and presentation of new evidence that mutualistic interactions between plants and fungi are ancient. In addition, many phylogenies have been revised to reflect recent miRNA and genomic data. We continue to emphasize evolutionary events that underlie the diversity of life on Earth. For example, a new section in Chapter 32 discusses the origin of multicellularity in animal ancestors. A new Make Connections Figure (Figure 33.9) explores the diverse structural solutions for maximizing surface area that have evolved across different kingdoms.

UNIT 6 Plants: Structure and Function

In developing the Tenth Edition, we have continued to provide students with a basic understanding of plant anatomy and function while highlighting dynamic areas of plant research and the many important connections between plants and other organisms. To underscore the relevance of plant biology to society, there is now expanded coverage of plant biotechnology and the development of biofuels in Chapter 38. Other updates include expanded coverage of bacterial components of the rhizosphere (Figure 37.9), plant mineral deficiency symptoms (Table 37.1), evolutionary trends in floral morphology (Chapter 38), and chemical communication between plants (Chapter 39). The discussion of plant defenses against pathogens and herbivores has been extensively revised and now includes a Make Connections Figure that examines how plants deter herbivores at numerous levels of biological organization, ranging from the molecular level to the community level (Figure 39.27).

UNIT 7 Animals: Structure and Function



In revising this unit, we strove to enhance student appreciation of the core concepts and ideas that apply across diverse organisms and varied organ systems. For example, a new Make Connections Figure (Figure 40.22) highlights challenges common to plant and animal physiology and presents both shared and divergent solutions to those challenges; this figure provides both a useful summary of plant physiology and an introduction to animal physiology. To help students recognize the central concept of homeostasis, figures have been revised across six chapters to provide a consistent organization that facilitates interpretation of individual hormone pathways as well as the comparison of pathways for different hormones. Homeostasis and endocrine regulation are highlighted by new and engaging chapter-opening photos and stories on the desert ant (Chapter 40) and on sexual dimorphism (Chapter 41), a revised presentation of the variation in target cell responses to a hormone (Figure 41.8), and a new figure integrating art and text on human endocrine glands and hormones (Figure 41.9). Many figures have been reconceived to emphasize key information, including new figures introducing the classes of essential nutrients (Figure 42.2) and showing oxygen and carbon dioxide partial pressures throughout the circulatory system (Figure 43.29). A new Make Connections Figure (Figure 44.17) demonstrates the importance of concentration gradients in animals as well as all other organisms. Throughout the unit, new state-of-the-art images and material on current and compelling topics—such as the human stomach microbiome (Figure 42.18) and the identification of the complete set of human taste receptors (Chapter 50)—will help engage students and encourage them to make connections beyond the text.

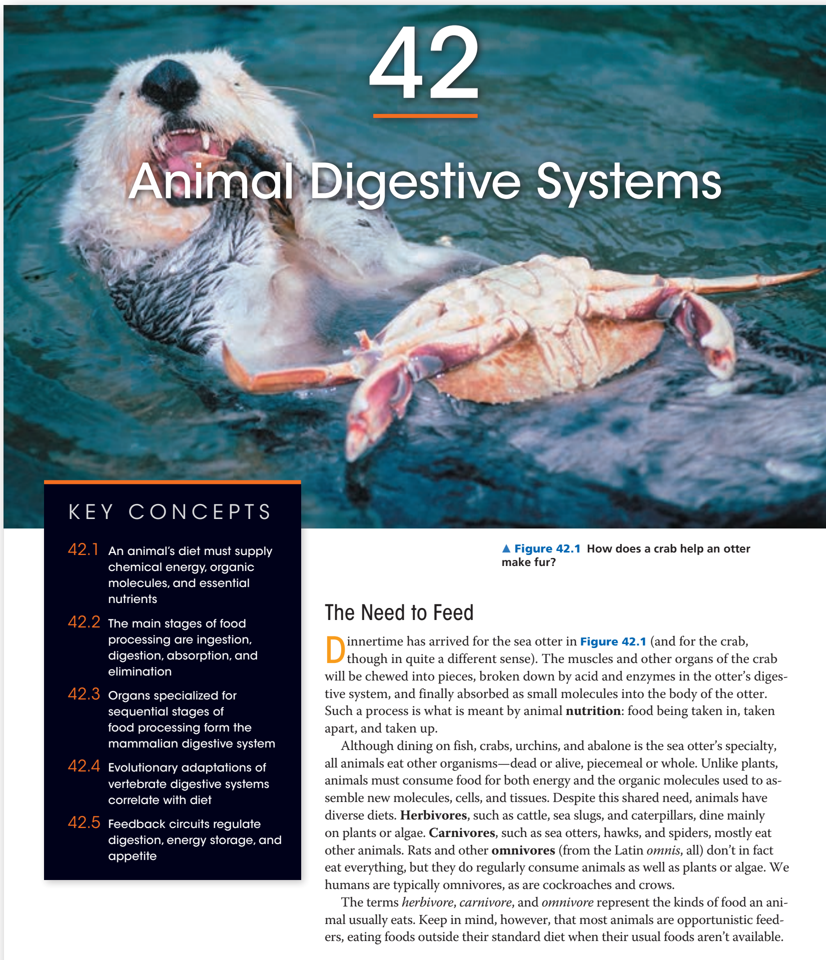
UNIT 8 The Ecology of Life

For the Tenth Edition, the ecology unit engages students with new ideas and examples. Chapter 51 highlights the discovery of the world's smallest vertebrate species. New text and a figure use the saguaro cactus to illustrate how abiotic and biotic factors limit the distribution of species (Figure 51.15). Greater emphasis is placed on the importance of disturbances, such as the effects of Hurricane Katrina on forest mortality. Chapter 53 features the loggerhead turtle in the chapter opener, Concept 53.1 (reproduction), and Concept 53.4 (evolution and life history traits). The chapter also includes new molecular coverage: how ecologists use genetic profiles to estimate the number of breeding loggerhead turtles (Figure 53.7) and how a single gene influences dispersal in the Glanville fritillary. In Chapter 54, new text and a figure highlight the mimic octopus, a recently discovered species that illustrates how predators use mimicry (Figure 54.6). A new Make Connections Figure ties together population, community, and ecosystem processes in the arctic tundra (Figure 55.13). Chapter 55 also has a new opening story on habitat transformation in the tundra. Chapter 56 highlights the emerging fields of urban ecology and conservation biology, including the technical and ethical challenges of resurrecting extinct species. It also examines the threat posed by pharmaceuticals in the environment. The book ends on a hopeful note, charging students to use biological knowledge to help solve problems and improve life on Earth.

See the Big Picture

KEY CONCEPTS

Each chapter is organized around a framework of 3 to 7 **Key Concepts** that focus on the big picture and provide a context for the supporting details.


42

Animal Digestive Systems

KEY CONCEPTS

42.1 An animal's diet must supply chemical energy, organic molecules, and essential nutrients

42.2 The main stages of food processing are ingestion, digestion, absorption, and elimination

42.3 Organs specialized for sequential stages of food processing form the mammalian digestive system

42.4 Evolutionary adaptations of vertebrate digestive systems correlate with diet

42.5 Feedback circuits regulate digestion, energy storage, and appetite

▲ **Figure 42.1** How does a crab help an otter make fur?

The Need to Feed

Dinnertime has arrived for the sea otter in **Figure 42.1** (and for the crab, though in quite a different sense). The muscles and other organs of the crab will be chewed into pieces, broken down by acid and enzymes in the otter's digestive system, and finally absorbed as small molecules into the body of the otter. Such a process is what is meant by animal **nutrition**: food being taken in, taken apart, and taken up.

Although dining on fish, crabs, urchins, and abalone is the sea otter's specialty, all animals eat other organisms—dead or alive, piecemeal or whole. Unlike plants, animals must consume food for both energy and the organic molecules used to assemble new molecules, cells, and tissues. Despite this shared need, animals have diverse diets. **Herbivores**, such as cattle, sea slugs, and caterpillars, dine mainly on plants or algae. **Carnivores**, such as sea otters, hawks, and spiders, mostly eat other animals. Rats and other **omnivores** (from the Latin *omnis*, all) don't in fact eat everything, but they do regularly consume animals as well as plants or algae. We humans are typically omnivores, as are cockroaches and crows.

The terms *herbivore*, *carnivore*, and *omnivore* represent the kinds of food an animal usually eats. Keep in mind, however, that most animals are opportunistic feeders, eating foods outside their standard diet when their usual foods aren't available.

◀ Every chapter opens with a visually dynamic **photo** accompanied by an **intriguing question** that invites students into the chapter.

▲ The **List of Key Concepts** introduces the big ideas covered in the chapter.

After reading a Key Concept section, students can check their understanding using the **Concept Check Questions**.

CONCEPT CHECK 42.1

1. All 20 amino acids are needed to make animal proteins. Why aren't they all essential to animal diets?
2. **MAKE CONNECTIONS** Considering the role of enzymes in metabolic reactions (see Concept 6.4), explain why vitamins are required in very small amounts in the diet.
3. **WHAT IF?** If a zoo animal eating ample food shows signs of malnutrition, how might a researcher determine which nutrient is lacking in its diet?

◀ Questions throughout the chapter encourage students to **read the text actively**.

Make Connections Questions ▶ ask students to relate content in the chapter to material presented earlier in the course.

What if? Questions ask students ▶ to apply what they've learned.

The **Summary of Key Concepts** refocuses students on the main points of the chapter.

42 Chapter Review

SUMMARY OF KEY CONCEPTS

- Animals have diverse diets. **Herbivores** mainly eat plants; **carnivores** mainly eat other animals; and **omnivores** eat both. In meeting their nutritional needs, animals must balance consumption, storage, and use of food.

CONCEPT 42.1

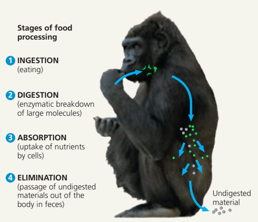
An animal's diet must supply chemical energy, organic molecules, and essential nutrients (pp. 979–983)

- Food provides animals with energy for ATP production, carbon skeletons for biosynthesis, and **essential nutrients**—nutrients that must be supplied in preassembled form. Essential nutrients include certain amino acids and fatty acids that animals cannot synthesize; **vitamins**, which are organic molecules; and **minerals**, which are inorganic substances.
- Animals can suffer from two types of malnutrition: an inadequate intake of essential nutrients and a deficiency in sources of chemical energy. Studies of disease at the population level help researchers determine human dietary requirements.

? *How can an enzyme cofactor needed for a process that is vital to all animals be an essential nutrient (vitamin) for only some?*

CONCEPT 42.2

The main stages of food processing are ingestion, digestion, absorption, and elimination (pp. 983–986)

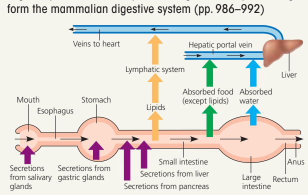


- Animals differ in the ways they obtain and ingest food. Many animals are **bulk feeders**, eating large pieces of food. Other strategies include filter feeding, suspension feeding, and fluid feeding.
- Compartmentalization is necessary to avoid self-digestion. In intracellular digestion, food particles are engulfed by endocytosis and digested within food vacuoles that have fused with lysosomes. In extracellular digestion, which is used by most animals, enzymatic hydrolysis occurs outside cells in a **gastrovascular cavity** or **alimentary canal**.

? *Propose an artificial diet that would eliminate the need for one of the first three steps in food processing.*

CONCEPT 42.3

Organs specialized for sequential stages of food processing form the mammalian digestive system (pp. 986–992)



? *What structural feature of the small intestine makes it better suited for absorption of nutrients than the stomach?*

CONCEPT 42.4

Evolutionary adaptations of vertebrate digestive systems correlate with diet (pp. 992–994)

- Vertebrate digestive systems display many evolutionary adaptations associated with diet. For example, dentition, which is the assortment of teeth, generally correlates with diet. In a form of mutualism, many herbivores, including cows, have fermentation chambers where microorganisms digest cellulose. Herbivores also usually have longer alimentary canals than carnivores, reflecting the longer time needed to digest vegetation.

? *How does human anatomy indicate that our primate ancestors were not strict vegetarians?*

CONCEPT 42.5

Feedback circuits regulate c appetite (pp. 994–998)

- **Nutrition** is regulated at mu canal triggers nervous and h secretion of digestive juices ingested material through th for energy production is reg and **glucagon**, which contro glycogen.
- Vertebrates store excess calo cells) and in fat (in adipose c tapped when an animal expe If, however, an animal consu normal metabolism, the resu the serious health problem o
- Several hormones, including by affecting the brain's satiet

? *Explain why your stomach m skip a meal.*

▲ **Summary Figures** recap key information in a visual way. **Summary of Key Concepts Questions** check students' understanding of a key idea from each concept.

TEST YOUR UNDERSTANDING

Multiple-choice Self-Quiz questions #1–6 can be found in the Study Area in MasteringBiology.

7. DRAW IT Make a flowchart of the events that occur after partially digested food leaves the stomach. Use the following terms: bicarbonate secretion, circulation, decrease in acidity, increase in acidity, secretin secretion, signal detection. Next to each term, indicate the compartment(s) involved. You may use terms more than once.
8. EVOLUTION CONNECTION
The human esophagus and trachea share a passage leading from the mouth and nasal passages, which can cause problems. After reviewing vertebrate evolution (see Chapter 34), explain how the evolutionary concept of descent with modification explains this "imperfect" anatomy.
9. SCIENTIFIC INQUIRY
In human populations of northern European origin, the disorder called hemochromatosis causes excess iron uptake from food and affects one in 200 adults. Among adults, men are ten times as likely as women to suffer from iron overload. Taking into account the existence of a menstrual cycle in humans, devise a hypothesis that explains this difference.
10. WRITE ABOUT A THEME: ORGANIZATION
Hair is largely made up of the protein keratin. In a short essay (100–150 words), explain why a shampoo containing protein is not effective in replacing the protein in damaged hair.
11. SYNTHESIZE YOUR KNOWLEDGE

Hummingbirds are well adapted to obtain sugary nectar from flowers, but they use some of the energy obtained from nectar when they forage for insects and spiders. Explain why this foraging is necessary.

For selected answers, see Appendix A.

MasteringBiology®

Students Go to **MasteringBiology** for assignments, the eText, and the Study Area with practice tests, animations, and activities.

Instructors Go to **MasteringBiology** for automatically graded tutorials and questions that you can assign to your students, plus Instructor Resources.

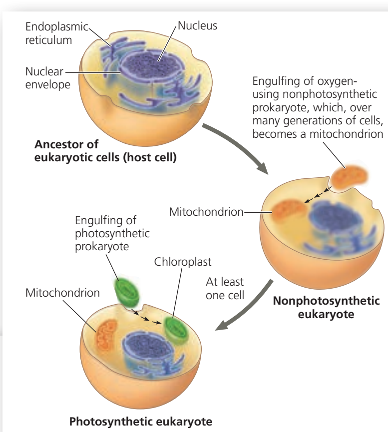
◄ **NEW! Synthesize Your Knowledge Questions** ask students to apply their understanding of the chapter content to explain an intriguing photo.

▲ To reinforce the themes, every chapter ends with an **Evolution Connection Question** and a **Write About a Theme Question**.

THEMES

To help students focus on the big ideas of biology, five **themes** are introduced in Chapter 1 and woven throughout the text:

- Evolution
- Organization
- Information
- Energy and Matter
- Interactions



Every chapter has a section explicitly relating the chapter content to **evolution**, the fundamental theme of biology. ►

The Evolutionary Origins of Mitochondria and Chloroplasts

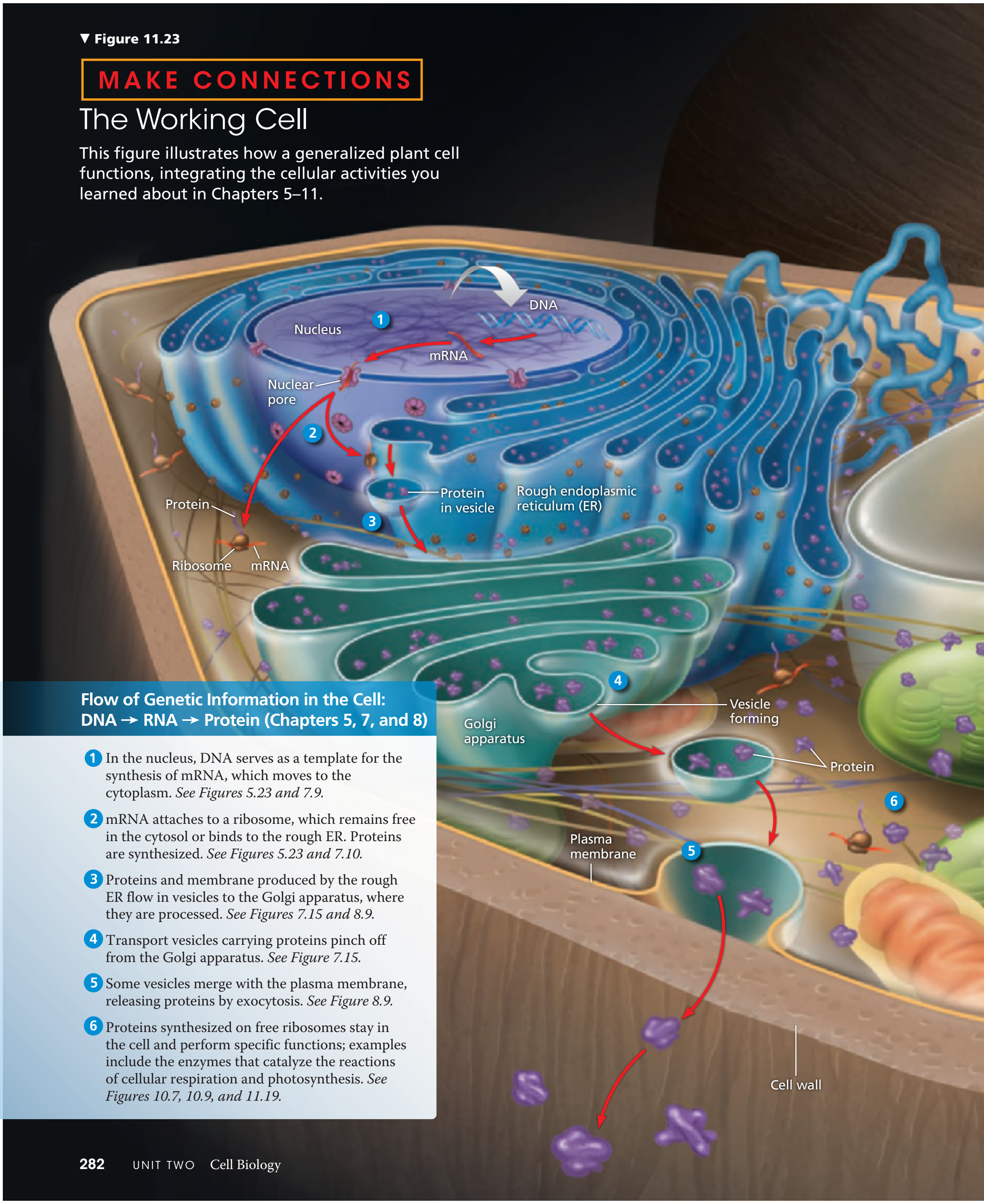
EVOLUTION Mitochondria and chloroplasts display similarities with bacteria that led to the **endosymbiont theory**, illustrated in **Figure 7.16**. This theory states that an early ancestor of eukaryotic cells engulfed an oxygen-using nonphotosynthetic prokaryotic cell. Eventually, the engulfed

Make Connections Visually

NEW! **Make Connections Figures** pull together content from different chapters, providing a visual representation of "big picture" relationships.

Make Connections Figures include:

- Figure 5.26 Contributions of Genomics and Proteomics to Biology, p. 138
- Figure 11.23 The Working Cell, shown at right and on pp. 282–283
- Figure 18.27 Genomics, Cell-Signaling, and Cancer, p. 443
- Figure 23.17 The Sickle-Cell Allele, pp. 560–561
- Figure 33.9 Maximizing Surface Area, p. 751
- Figure 39.27 Levels of Plant Defenses Against Herbivores, pp. 926–927
- Figure 40.22 Life Challenges and Solutions in Plants and Animals, pp. 954–955
- Figure 44.17 Ion Movement and Gradients, p. 1049
- Figure 55.13 The Working Ecosystem, pp. 1314–1315


▼ **Figure 11.23**

MAKE CONNECTIONS

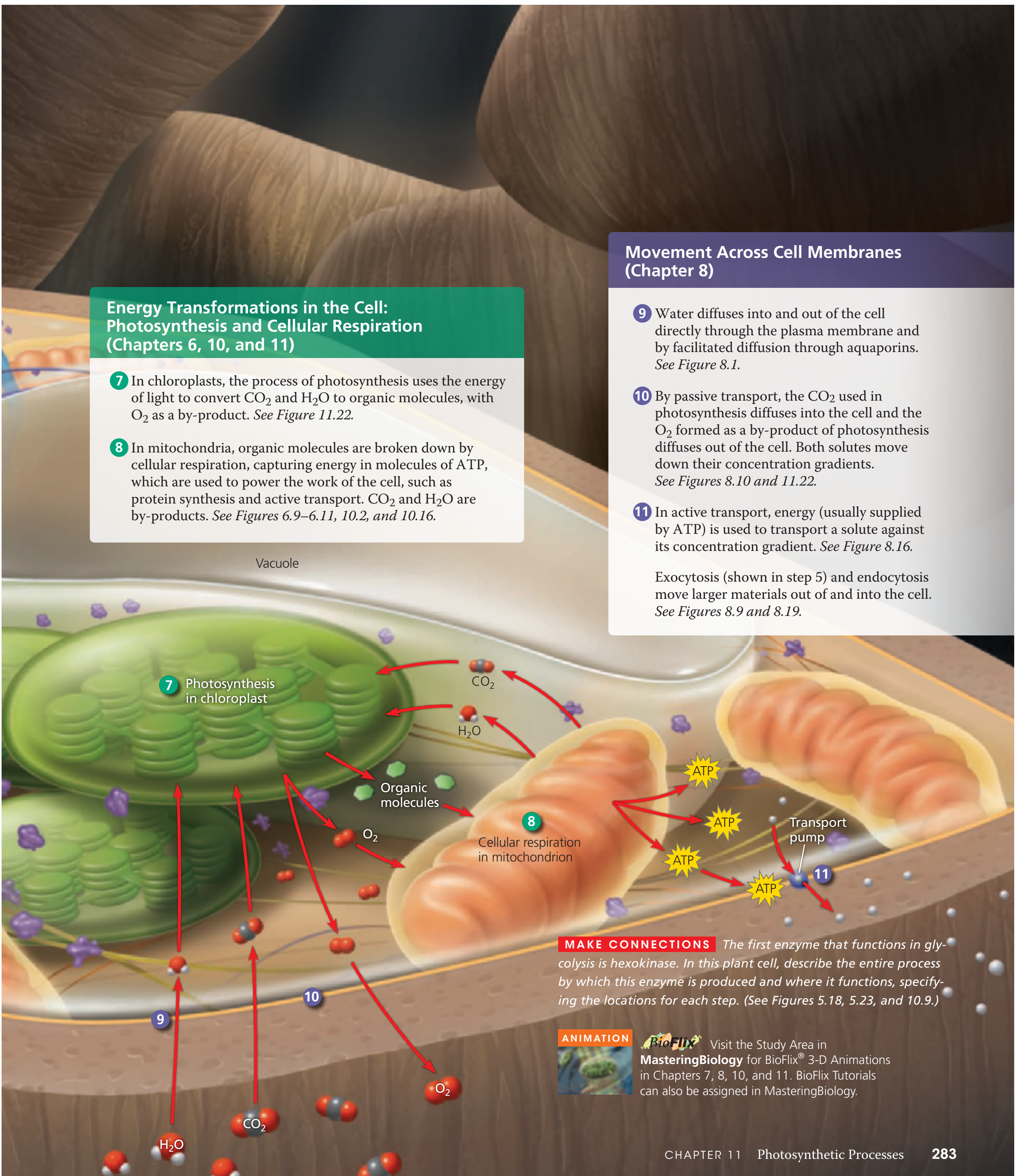
The Working Cell

This figure illustrates how a generalized plant cell functions, integrating the cellular activities you learned about in Chapters 5–11.

Flow of Genetic Information in the Cell: DNA → RNA → Protein (Chapters 5, 7, and 8)

1. In the nucleus, DNA serves as a template for the synthesis of mRNA, which moves to the cytoplasm. *See Figures 5.23 and 7.9.*
2. mRNA attaches to a ribosome, which remains free in the cytosol or binds to the rough ER. Proteins are synthesized. *See Figures 5.23 and 7.10.*
3. Proteins and membrane produced by the rough ER flow in vesicles to the Golgi apparatus, where they are processed. *See Figures 7.15 and 8.9.*
4. Transport vesicles carrying proteins pinch off from the Golgi apparatus. *See Figure 7.15.*
5. Some vesicles merge with the plasma membrane, releasing proteins by exocytosis. *See Figure 8.9.*
6. Proteins synthesized on free ribosomes stay in the cell and perform specific functions; examples include the enzymes that catalyze the reactions of cellular respiration and photosynthesis. *See Figures 10.7, 10.9, and 11.19.*

282 UNIT TWO Cell Biology



Energy Transformations in the Cell: Photosynthesis and Cellular Respiration (Chapters 6, 10, and 11)

7 In chloroplasts, the process of photosynthesis uses the energy of light to convert CO_2 and H_2O to organic molecules, with O_2 as a by-product. *See Figure 11.22.*

8 In mitochondria, organic molecules are broken down by cellular respiration, capturing energy in molecules of ATP, which are used to power the work of the cell, such as protein synthesis and active transport. CO_2 and H_2O are by-products. *See Figures 6.9–6.11, 10.2, and 10.16.*

Movement Across Cell Membranes (Chapter 8)

9 Water diffuses into and out of the cell directly through the plasma membrane and by facilitated diffusion through aquaporins. *See Figure 8.1.*

10 By passive transport, the CO_2 used in photosynthesis diffuses into the cell and the O_2 formed as a by-product of photosynthesis diffuses out of the cell. Both solutes move down their concentration gradients. *See Figures 8.10 and 11.22.*

11 In active transport, energy (usually supplied by ATP) is used to transport a solute against its concentration gradient. *See Figure 8.16.*

Exocytosis (shown in step 5) and endocytosis move larger materials out of and into the cell. *See Figures 8.9 and 8.19.*

MAKE CONNECTIONS *The first enzyme that functions in glycolysis is hexokinase. In this plant cell, describe the entire process by which this enzyme is produced and where it functions, specifying the locations for each step. (See Figures 5.18, 5.23, and 10.9.)*

ANIMATION BioFlix® Visit the Study Area in **MasteringBiology** for BioFlix® 3-D Animations in Chapters 7, 8, 10, and 11. BioFlix Tutorials can also be assigned in MasteringBiology.

CHAPTER 11 Photosynthetic Processes 283

Make Connections Questions ask students to relate content in the chapter to material presented earlier in the course. Every chapter has at least three Make Connections Questions.

Practice Scientific Skills

NEW! **Scientific Skills Exercises** in every chapter use real data to build key skills needed for biology, including data interpretation, graphing, experimental design, and math skills.

▼ **Photos** provide visual interest and context.

Each Scientific Skills Exercise ▶ is based on an **experiment related to the chapter content**.

Most Scientific Skills Exercises ▶ use **data from published research**.

Questions build in difficulty, ▶ walking students through new skills step by step and providing opportunities for higher-level critical thinking.

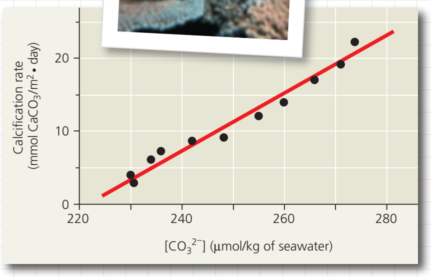
SCIENTIFIC SKILLS EXERCISE

Interpreting a Scatter Plot with a Regression Line

How Does the Carbonate Ion Concentration of Seawater Affect the Calcification Rate of a Coral Reef? Scientists predict that acidification of the ocean due to higher levels of atmospheric CO_2 will lower the concentration of dissolved carbonate ions, which living corals use to build calcium carbonate reef structures. In this exercise, you will analyze data from a controlled experiment that examined the effect of carbonate ion concentration ($[CO_3^{2-}]$) on calcium carbonate deposition, a process called calcification.

How the Experiment Was Done The Biosphere 2 aquarium in Arizona contains a large coral reef system that behaves like a natural reef. For several years, a group of researchers measured the rate of calcification by the reef organisms and examined how the calcification rate changed with differing amounts of dissolved carbonate ions in the seawater.

Data from the Experiment The black data points in the graph form a scatter plot. The red line, known as a linear regression line, is the best-fitting straight line for these points.



Interpret the Data

1. When presented with a graph of experimental data, the first step in analysis is to determine what each axis represents. (a) In words, explain what is being shown on the *x*-axis. Be sure to include the units. (b) What is being shown on the *y*-axis (including units)? (c) Which variable is the independent variable—the variable that was *manipulated* by the researchers? (d) Which variable is the dependent variable—the variable that responded to or depended on the treatment, which was *measured* by the researchers? (For additional information about graphs, see the Scientific Skills Review in Appendix F and in the Study Area in MasteringBiology.)
2. Based on the data shown in the graph, describe in words the relationship between carbonate ion concentration and calcification rate.
3. (a) If the seawater carbonate ion concentration is 270 µmol/kg, what is the approximate rate of calcification, and approximately how many days would it take 1 square meter of reef to accumulate 30 mmol of calcium carbonate ($CaCO_3$)? (b) If the seawater carbonate ion concentration is 250 µmol/kg, what is the approximate rate of calcification, and approximately how many days would it take 1 square meter of reef to accumulate 30 mmol of calcium carbonate? (c) If carbonate ion concentration decreases, how does the calcification rate change, and how does that affect the time it takes coral to grow?
4. (a) Referring to the equations in Figure 3.11, determine which step of the process is measured in this experiment. (b) Are the results of this experiment consistent with the hypothesis that increased atmospheric $[CO_2]$ will slow the growth of coral reefs? Why or why not?

MB A version of this Scientific Skills Exercise can be assigned in MasteringBiology.

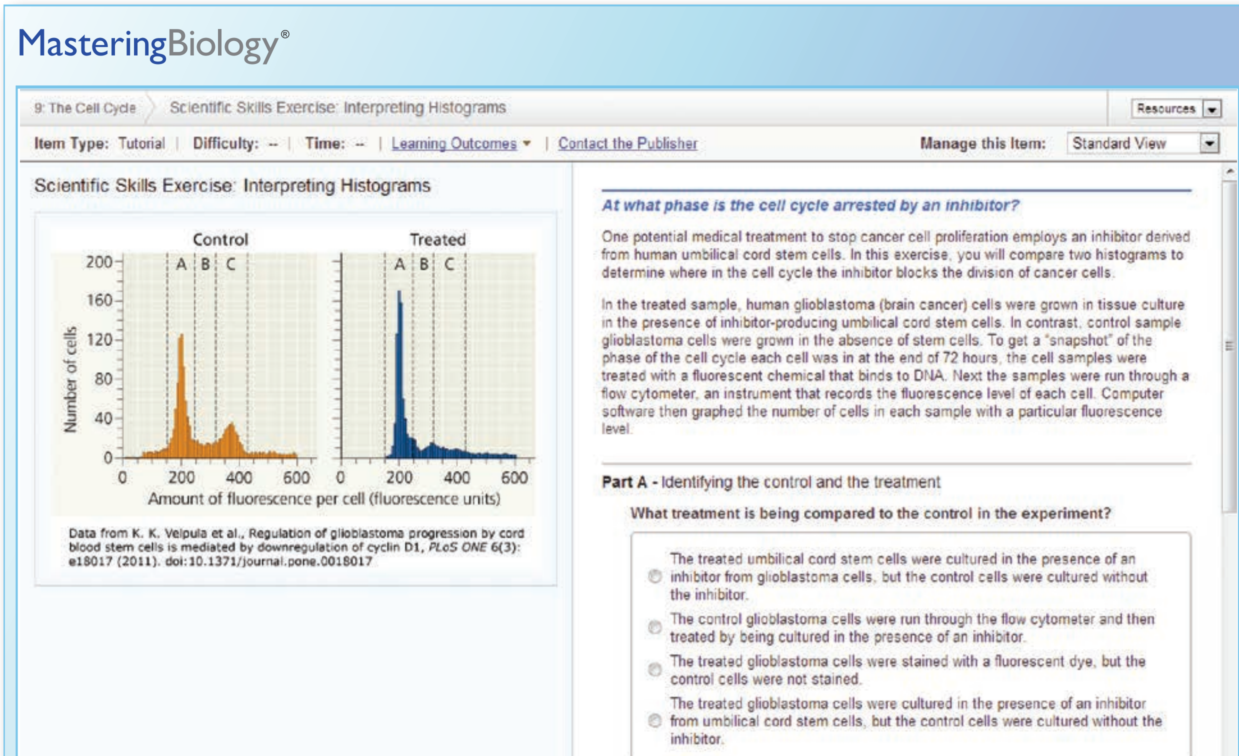
Data from C. Langdon et al., Effect of calcium carbonate saturation state on the calcification rate of an experimental coral reef, *Global Biogeochemical Cycles* 14:639–654 (2000).

▲ Each Scientific Skills Exercise **cites the published research**.

Every chapter has a Scientific Skills Exercise

1. Interpreting a Pair of Bar Graphs, p. 70
2. Calibrating a Standard Radioactive Isotope Decay Curve and Interpreting Data, p. 83
3. Interpreting a Scatter Plot with a Regression Line, p. 104
4. Working with Moles and Molar Ratios, p. 108
5. Analyzing Polypeptide Sequence Data, p. 139
6. Making a Line Graph and Calculating a Slope, p. 157
7. Using a Scale Bar to Calculate Volume and Surface Area of a Cell, p. 173
8. Interpreting a Scatter Plot with Two Sets of Data, p. 208
9. Using Experiments to Test a Model, p. 232
10. Making a Bar Graph and Evaluating a Hypothesis, p. 253
11. Making Scatter Plots with Regression Lines, p. 279
12. Interpreting Histograms, p. 302
13. Making a Line Graph and Converting Between Units of Data, p. 318
14. Making a Histogram and Analyzing a Distribution Pattern, p. 337
15. Using the Chi-Square (χ^2) Test, p. 358
16. Working with Data in a Table, p. 372
17. Interpreting a Sequence Logo, p. 405
18. Analyzing DNA Deletion Experiments, p. 426
19. Analyzing Quantitative and Spatial Gene Expression Data, p. 460
20. Reading an Amino Acid Sequence Identity Table, p. 492
21. Making and Testing Predictions, p. 519
22. Using Protein Sequence Data to Test an Evolutionary Hypothesis, p. 540
23. Using the Hardy-Weinberg Equation to Interpret Data and Make Predictions, p. 551
24. Identifying Independent and Dependent Variables, Making a Scatter Plot, and Interpreting Data, p. 571
25. Estimating Quantitative Data from a Graph and Developing Hypotheses, p. 596
26. Analyzing a Sequence-Based Phylogenetic Tree to Understand Viral Evolution, p. 624

NEW! All **56 Scientific Skills Exercises** from the text have assignable, interactive versions in **MasteringBiology®** that are automatically graded.



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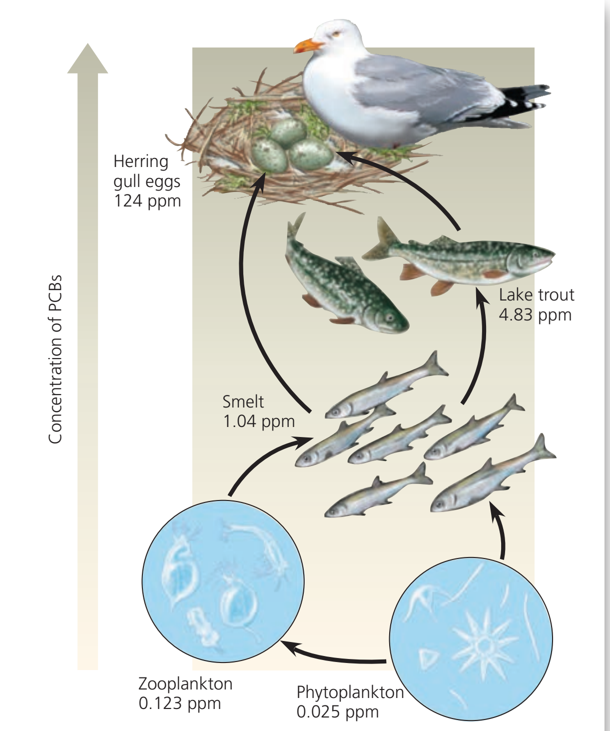
27. Making a Bar Graph and Interpreting Data, p. 646
28. Interpreting Comparisons of Genetic Sequences, p. 651
29. Making Bar Graphs and Interpreting Data, p. 685
30. Using Natural Logarithms to Interpret Data, p. 695
31. Interpreting Genomic Data and Generating Hypotheses, p. 713
32. Calculating and Interpreting Correlation Coefficients, p. 734
33. Understanding Experimental Design and Interpreting Data, p. 756
34. Determining the Equation of a Regression Line, p. 807
35. Using Bar Graphs to Interpret Data, p. 820
36. Calculating and Interpreting Temperature Coefficients, p. 848
37. Making Observations, p. 870
38. Using Positive and Negative Correlations to Interpret Data, p. 892
39. Interpreting Experimental Results from a Bar Graph, p. 922
40. Interpreting Pie Charts, p. 952
41. Designing a Controlled Experiment, p. 973
42. Interpreting Data from Experiments with Genetic Mutants, p. 998
43. Making and Interpreting Histograms, p. 1018
44. Describing and Interpreting Quantitative Data, p. 1037
45. Making Inferences and Designing an Experiment, p. 1067
46. Interpreting a Change in Slope, p. 1085
47. Comparing Two Variables on a Common *x*-Axis, p. 1125
48. Interpreting Data Values Expressed in Scientific Notation, p. 1144
49. Designing an Experiment Using Genetic Mutants, p. 1157
50. Interpreting a Graph with Log Scales, p. 1198
51. Making a Bar Graph and a Line Graph to Interpret Data, p. 1227
52. Testing a Hypothesis with a Quantitative Model, p. 1242
53. Using the Logistic Equation to Model Population Growth, p. 1266
54. Making a Bar Graph and a Scatter Plot, p. 1283
55. Interpreting Quantitative Data in a Table, p. 1312
56. Graphing Cyclic Data, p. 1345

Interpret Data

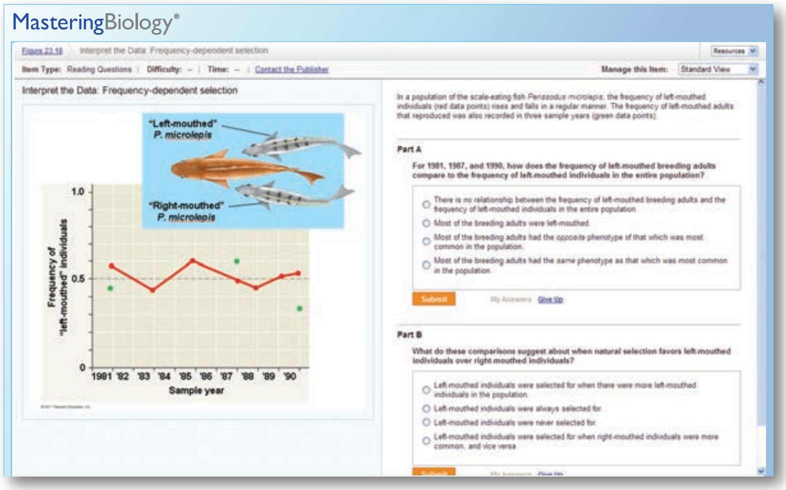
BIOLOGY, Tenth Edition, and MasteringBiology® offer a wide variety of ways for students to move beyond memorization and **think like a scientist**.



▲ **Figure 56.25 Biological magnification of PCBs in a Great Lakes food web.** (ppm = parts per million)

INTERPRET THE DATA *If a typical smelt weighs 225 g, what is the total mass of PCBs in a smelt in the Great Lakes? If an average lake trout weighs 4,500 g, what is the total mass of PCBs in a trout in the Great Lakes? Assume that a lake trout from an unpolluted source is introduced into the Great Lakes and smelt are the only source of PCBs in the trout's diet. The new trout would have the same level of PCBs as the existing trout after eating how many smelt? (Assume that the trout retains 100% of the PCBs it consumes.)*

◀ **NEW! Interpret the Data Questions** throughout the text ask students to analyze a graph, figure, or table.



▲ **NEW!** Every **Interpret the Data Question** from the text is assignable in **MasteringBiology**.

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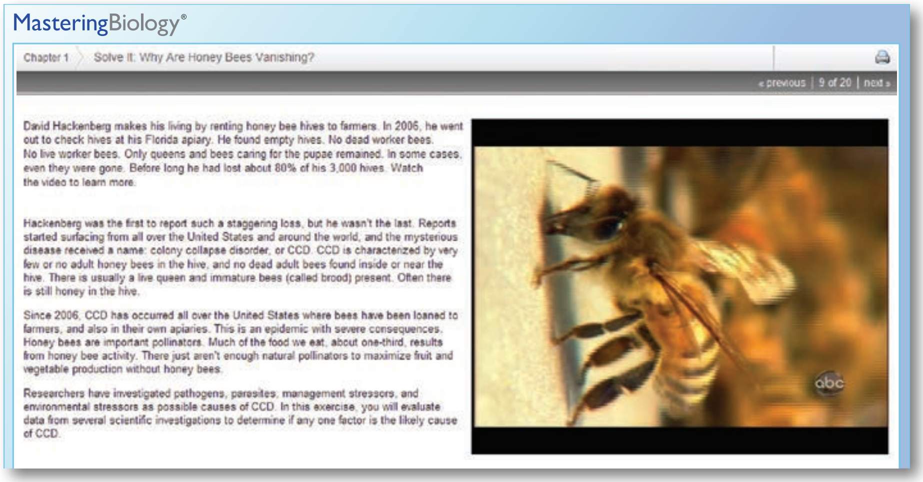


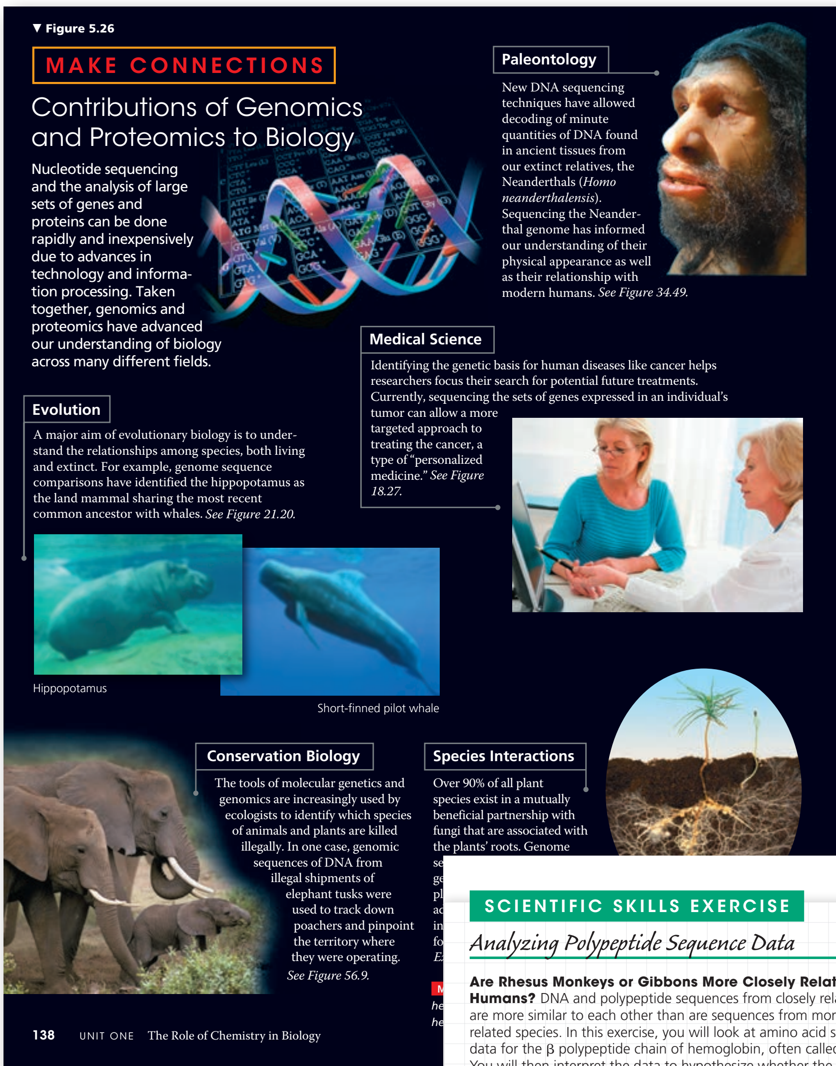
◀ **NEW! Solve It Tutorials** engage students in a multi-step investigation of a "mystery" or open question in which they must analyze real data. These are assignable in **MasteringBiology**.

Topics include:

- Is It Possible to Treat Bacterial Infections Without Traditional Antibiotics?
- Are You Getting the Fish You Paid For?
- Why Are Honey Bees Vanishing?
- Which Biofuel Has the Most Potential to Reduce our Dependence on Fossil Fuels?
- Which Insulin Mutations May Result in Disease?
- What is Causing Episodes of Muscle Weakness in a Patient?

Explore the Impact of Genomics

NEW! Throughout the Tenth Edition, new examples show students how our ability to **sequence DNA and proteins rapidly and inexpensively** is transforming every subfield of biology, from cell biology to physiology to ecology.



▼ Figure 5.26

MAKE CONNECTIONS

Contributions of Genomics and Proteomics to Biology

Nucleotide sequencing and the analysis of large sets of genes and proteins can be done rapidly and inexpensively due to advances in technology and information processing. Taken together, genomics and proteomics have advanced our understanding of biology across many different fields.

Paleontology

New DNA sequencing techniques have allowed decoding of minute quantities of DNA found in ancient tissues from our extinct relatives, the Neanderthals (*Homo neanderthalensis*). Sequencing the Neanderthal genome has informed our understanding of their physical appearance as well as their relationship with modern humans. *See Figure 34.49.*

Medical Science

Identifying the genetic basis for human diseases like cancer helps researchers focus their search for potential future treatments. Currently, sequencing the sets of genes expressed in an individual's tumor can allow a more targeted approach to treating the cancer, a type of "personalized medicine." *See Figure 18.27.*

Evolution

A major aim of evolutionary biology is to understand the relationships among species, both living and extinct. For example, genome sequence comparisons have identified the hippopotamus as the land mammal sharing the most recent common ancestor with whales. *See Figure 21.20.*

Hippopotamus

Short-finned pilot whale

Conservation Biology

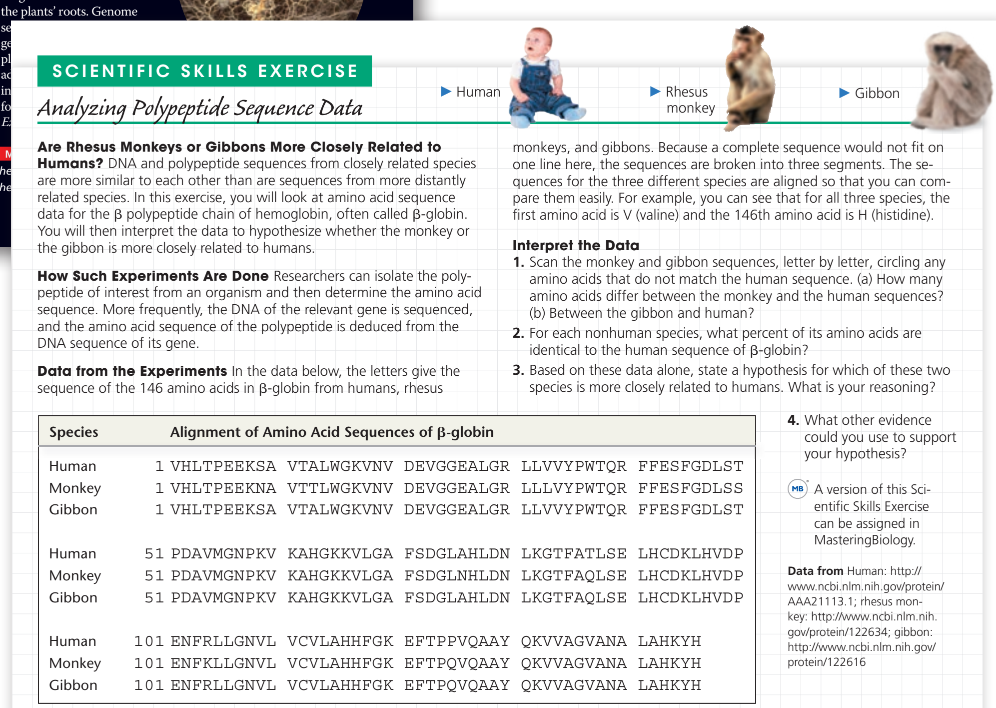
The tools of molecular genetics and genomics are increasingly used by ecologists to identify which species of animals and plants are killed illegally. In one case, genomic sequences of DNA from illegal shipments of elephant tusks were used to track down poachers and pinpoint the territory where they were operating. *See Figure 56.9.*

Species Interactions

Over 90% of all plant species exist in a mutually beneficial partnership with fungi that are associated with the plants' roots. Genome ...

138 UNIT ONE The Role of Chemistry in Biology

◀ This new **Make Connections Figure** in Chapter 5 previews some examples of how genomics and proteomics have helped shed light on diverse biological questions. These examples are explored in greater depth later in the text.



SCIENTIFIC SKILLS EXERCISE

Analyzing Polypeptide Sequence Data

Are Rhesus Monkeys or Gibbons More Closely Related to Humans? DNA and polypeptide sequences from closely related species are more similar to each other than are sequences from more distantly related species. In this exercise, you will look at amino acid sequence data for the β polypeptide chain of hemoglobin, often called β-globin. You will then interpret the data to hypothesize whether the monkey or the gibbon is more closely related to humans.

How Such Experiments Are Done Researchers can isolate the polypeptide of interest from an organism and then determine the amino acid sequence. More frequently, the DNA of the relevant gene is sequenced, and the amino acid sequence of the polypeptide is deduced from the DNA sequence of its gene.

Data from the Experiments In the data below, the letters give the sequence of the 146 amino acids in β-globin from humans, rhesus monkeys, and gibbons. Because a complete sequence would not fit on one line here, the sequences are broken into three segments. The sequences for the three different species are aligned so that you can compare them easily. For example, you can see that for all three species, the first amino acid is V (valine) and the 146th amino acid is H (histidine).

Interpret the Data

1. Scan the monkey and gibbon sequences, letter by letter, circling any amino acids that do not match the human sequence. (a) How many amino acids differ between the monkey and the human sequences? (b) Between the gibbon and human?
2. For each nonhuman species, what percent of its amino acids are identical to the human sequence of β-globin?
3. Based on these data alone, state a hypothesis for which of these two species is more closely related to humans. What is your reasoning?

Species	Alignment of Amino Acid Sequences of β-globin
Human	1 VHLTPEEKSA VTALWGKVNV DEVGGEALGR LLVVYPWTQR FFESFGDLST
Monkey	1 VHLTPEEKNA VTTLWGKVNV DEVGGEALGR LLLVYPWTQR FFESFGDLSS
Gibbon	1 VHLTPEEKSA VTALWGKVNV DEVGGEALGR LLVVYPWTQR FFESFGDLST
Human	51 PDAVMGNPKV KAHGKKVLGA FSDGLAHLDN LKGTFATLSE LHCDKLHVDP
Monkey	51 PDAVMGNPKV KAHGKKVLGA FSDGLNHLDN LKGTFAQLSE LHCDKLHVDP
Gibbon	51 PDAVMGNPKV KAHGKKVLGA FSDGLAHLDN LKGTFAQLSE LHCDKLHVDP
Human	101 ENFRLLGNVL VCVLAHHFGK EFTPPVQAAY QKVVAGVANA LAHKYH
Monkey	101 ENFKLLGNVL VCVLAHHFGK EFTPQVQAAY QKVVAGVANA LAHKYH
Gibbon	101 ENFRLLGNVL VCVLAHHFGK EFTPQVQAAY QKVVAGVANA LAHKYH

4. What other evidence could you use to support your hypothesis?

A version of this Scientific Skills Exercise can be assigned in MasteringBiology.

Data from Human: http://www.ncbi.nlm.nih.gov/protein/AAA21113.1; rhesus monkey: http://www.ncbi.nlm.nih.gov/protein/122634; gibbon: http://www.ncbi.nlm.nih.gov/protein/122616

Selected Scientific Skills Exercises involve **working with DNA or protein sequences**. ▶

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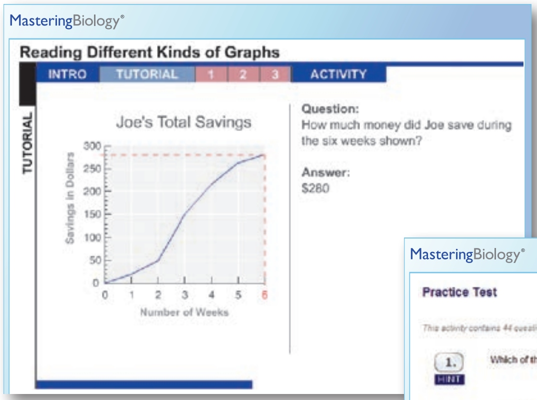
Instructors can even write notes for the class and highlight important materials using a tool that works like an electronic pen on a whiteboard.

STUDY AREA

Students can access the **Study Area** for use on their own or in a study group.



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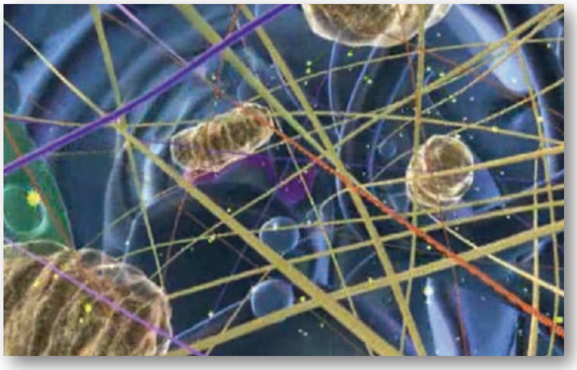

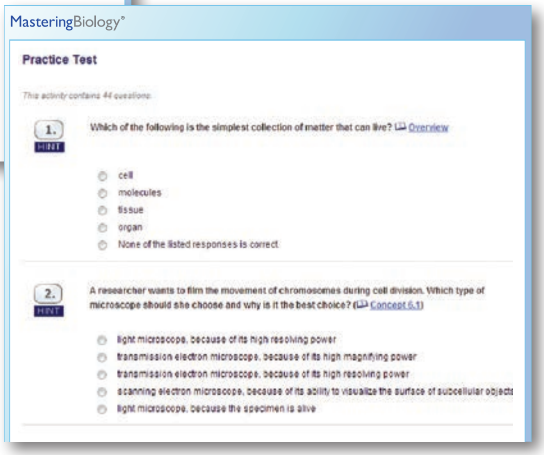

◀ **Practice Tests** help students assess their understanding of each chapter, providing feedback for right and wrong answers.

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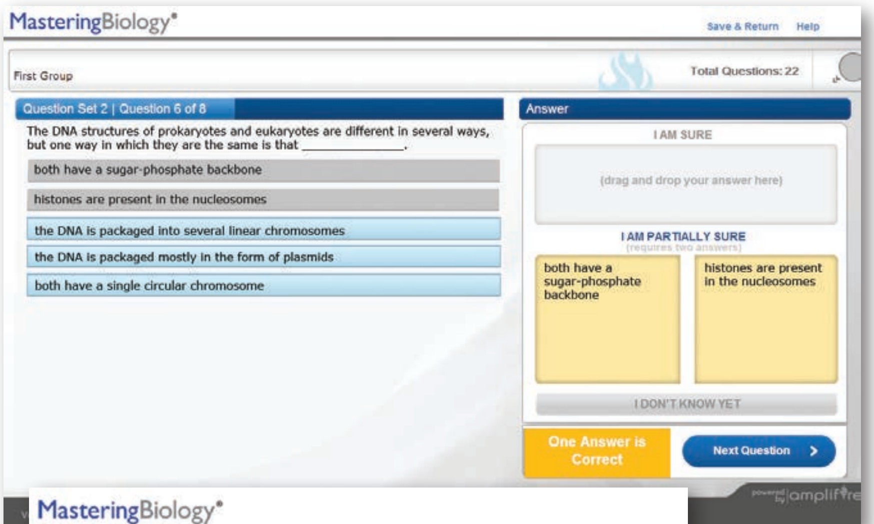
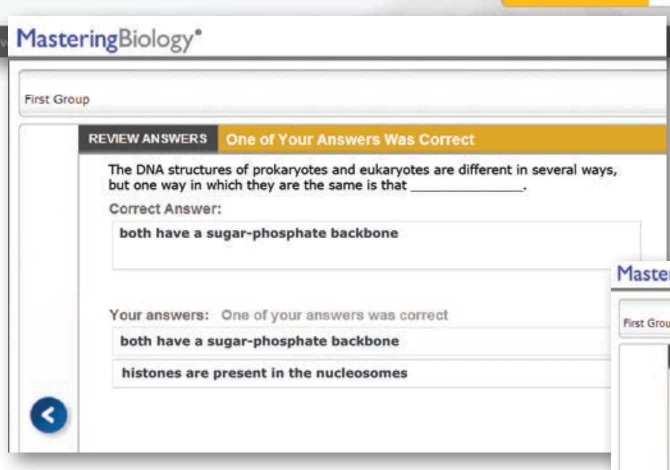
NEW! **Dynamic Study Modules**, designed to enable students to study effectively on their own, help students quickly access and learn the information they need to be more successful on quizzes and exams.



How it works:

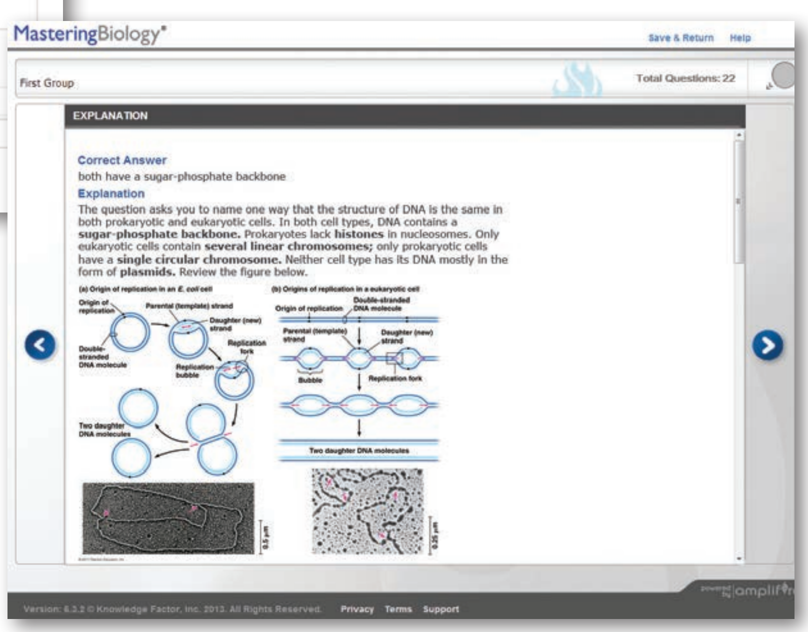
1. Students receive an initial **set of questions**.

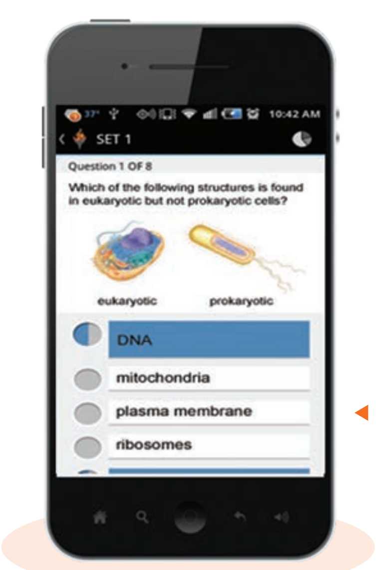
◀ A unique answer format asks students to indicate how **confident** they are about their answer.



2. After answering each set of questions, students **review their answers**.

3. Each answer has an **explanation** using material that is taken directly **from the textbook**.





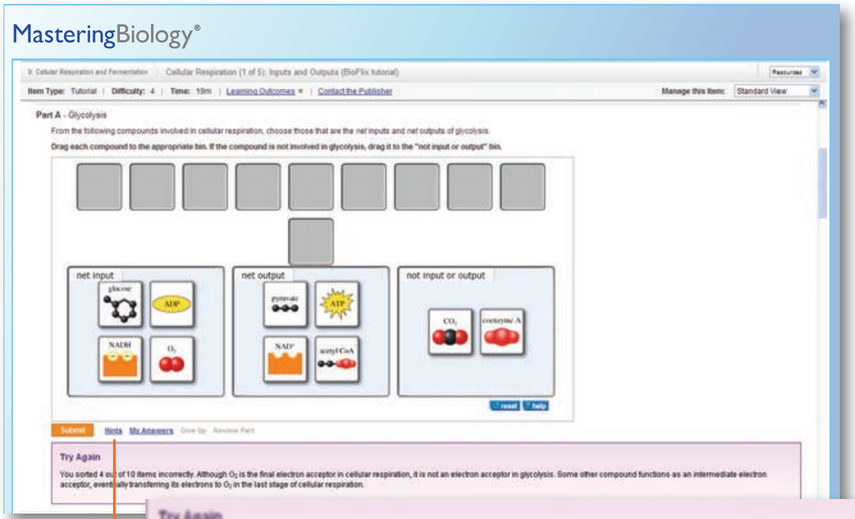
◀ These modules can be accessed on smartphones, tablets, and computers. Results can be tracked in the MasteringBiology Gradebook.

4. Once students review the explanations from the textbook, they are presented with a new set of questions. Students cycle through this **dynamic process of test-learn-retest** until they achieve mastery of the textbook material.

Learn more at www.masteringbiology.com

Learn Through Assessment

Instructors can assign **self-paced MasteringBiology® tutorials** that provide students with individualized coaching with specific hints and feedback on the toughest topics in the course.



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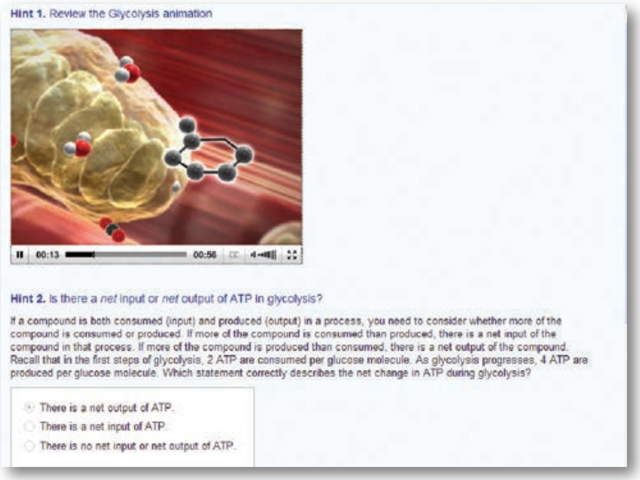
1. If a student gets stuck ...

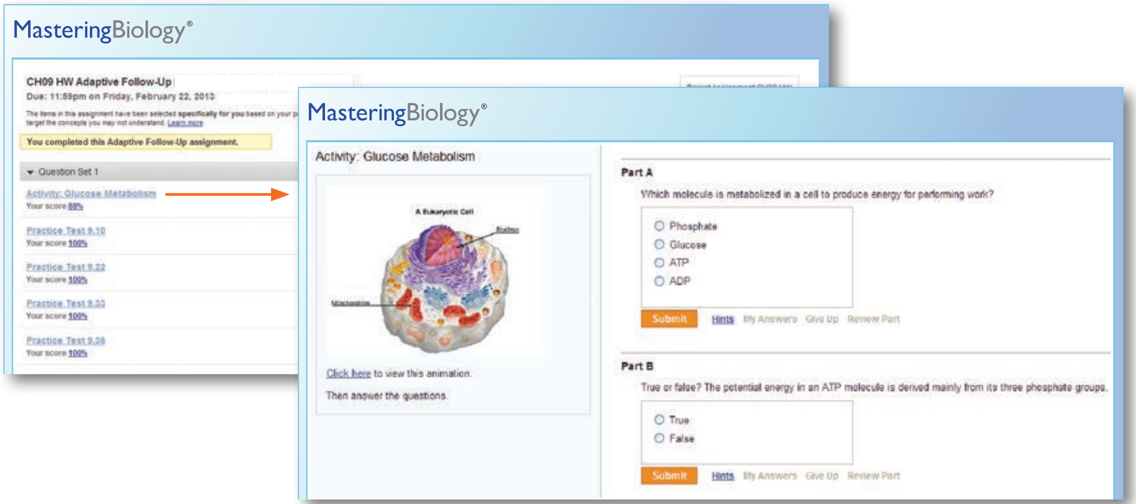
2. specific wrong-answer **feedback** appears in the purple feedback box.



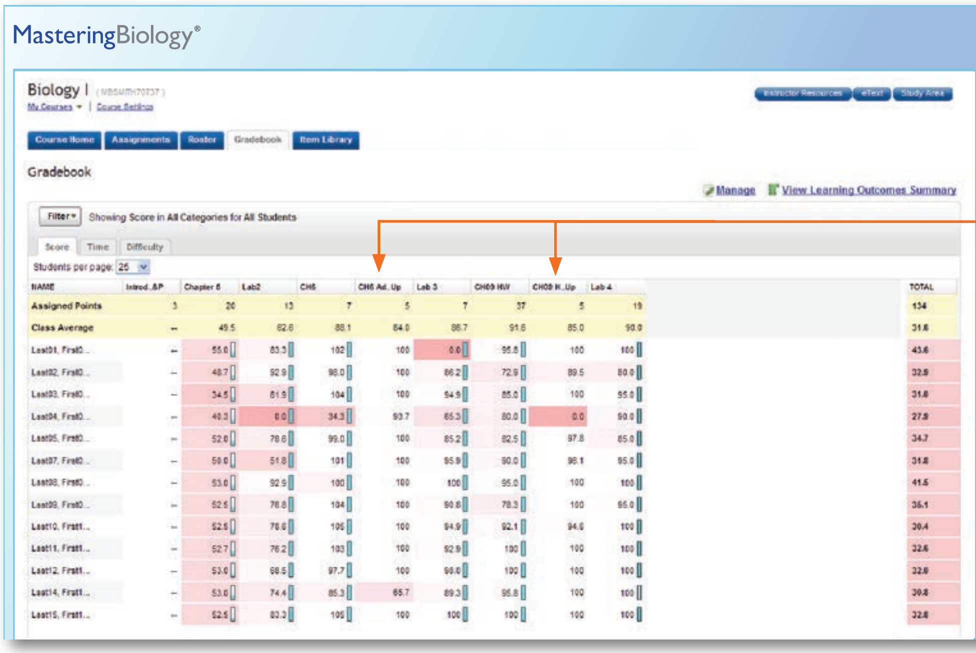
3. **Hints** coach the student to the correct response.

4. **NEW!** Optional **Adaptive Follow-Up Assignments** are based on each student's performance on the original homework assignment and provide additional coaching and practice as needed.

Question sets in the Adaptive Follow-Up Assignments **continuously adapt** to each student's needs, making efficient use of study time.

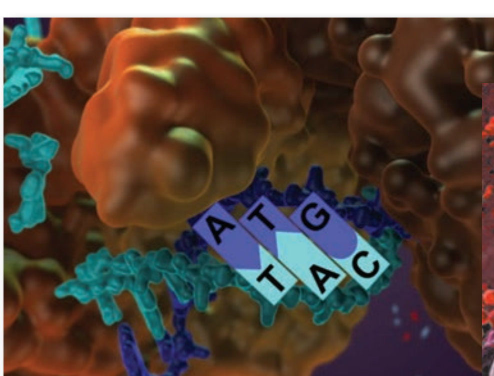


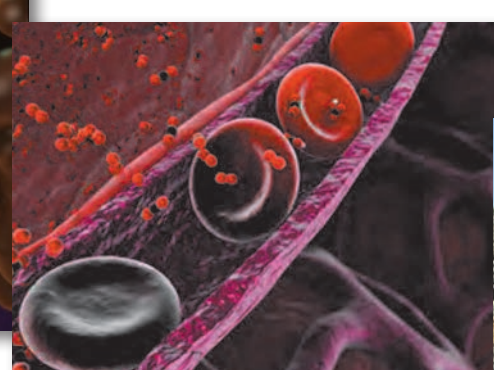
The MasteringBiology® Gradebook provides instructors with quick results and easy-to-interpret insights into student performance. Every assignment is automatically graded. Shades of red highlight vulnerable students and challenging assignments.

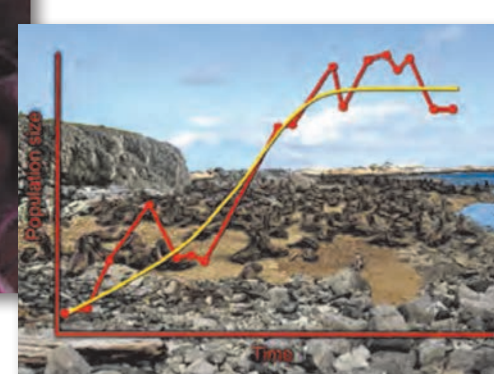


NEW! Student scores on the optional **Adaptive Follow-Up Assignments** are recorded in the gradebook and offer additional diagnostic information for instructors to monitor learning outcomes and more.

MasteringBiology offers a wide variety of tutorials that can be assigned as homework. For example, **BioFlix Tutorials** use 3-D, movie-quality **Animations** and coaching exercises to help students master tough topics outside of class. Animations can also be shown in class.







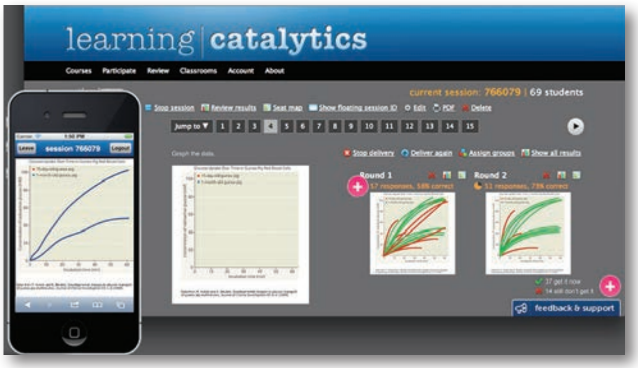
BioFlix Tutorials and 3-D Animations include:

- A Tour of the Animal Cell
- A Tour of the Plant Cell
- Membrane Transport
- Cellular Respiration
- Photosynthesis
- Mitosis
- Meiosis
- DNA Replication
- Protein Synthesis
- Mechanisms of Evolution
- Water Transport in Plants
- Homeostasis: Regulating Blood Sugar
- Gas Exchange
- How Neurons Work
- How Synapses Work
- Muscle Contraction
- Population Ecology
- The Carbon Cycle

Supplements

FOR INSTRUCTORS

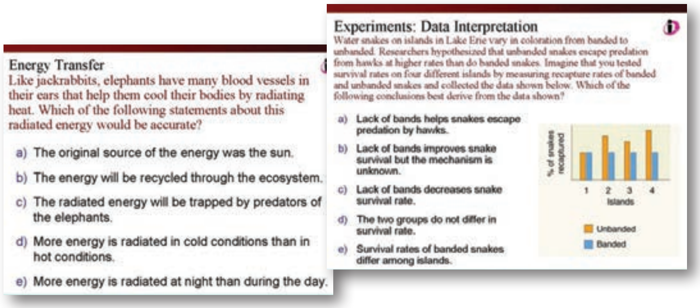
NEW! **Learning Catalytics™** allows students to use their smartphone, tablet, or laptop to respond to questions in class. Visit www.learningcatalytics.com.



Instructor Resources Area in MasteringBiology®

The instructor resources for ***BIOLOGY: A Global Approach,* Tenth Edition,** are combined into an online chapter-by-chapter resource that includes:

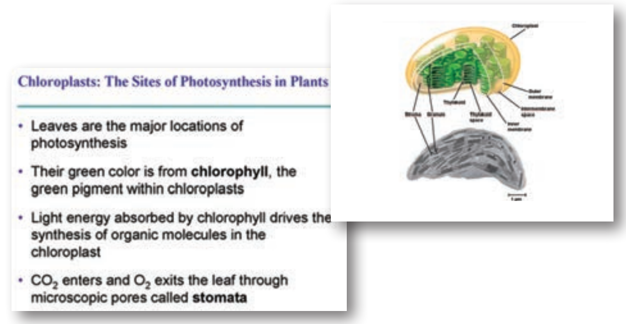
- Editable figures (art and photos) and tables from the text in PowerPoint®
- Prepared PowerPoint Lecture Presentations for each chapter, with lecture notes, editable figures, tables, and links to animations and videos
- 250+ Instructor Animations and Videos, including BioFlix® 3-D Animations and *ABC News* Videos
- JPEG Images, including labeled and unlabeled art, photos from the text, and extra photos
- Digital Transparencies
- Clicker Questions in PowerPoint
- Quick Reference Guide
- Test Bank questions in TestGen® software and Microsoft® Word
- Lecture Outlines
- Learning Objectives
- Pre-Tests, Post-Tests, and Strategies for Overcoming Common Student Misconceptions
- Instructor Guides for Supplements
- Rubric and Tips for Grading Short-Answer Essays
- Suggested Answers for Scientific Skills Exercises and Short-Answer Essay Questions
- Lab Media



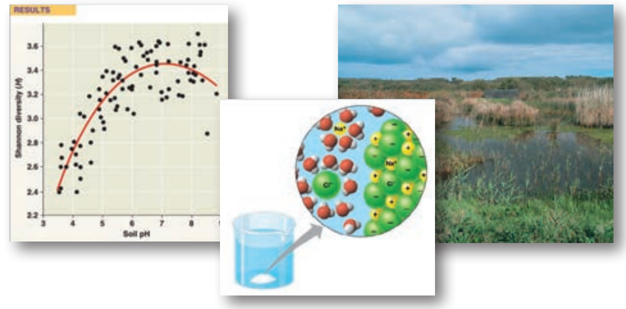
▲ **Clicker Questions** can be used to stimulate effective classroom discussions (for use with or without clickers).

Instructor Resources for Flipped Classrooms

- Lecture videos can be posted on MasteringBiology for students to view before class.
- Homework can be assigned in MasteringBiology so students come to class prepared.
- In-class resources: Learning Catalytics, Clicker Questions, Student Misconception Questions, end-of-chapter essay questions, and activities and case studies from the student supplements.



▲ **Customizable PowerPoints** provide a jumpstart for each lecture.



▲ **All of the art, graphs, and photos from the book** are provided with customizable labels. More than 1,600 photos from the text and other sources are included.

Test Bank

This invaluable resource contains more than 4,500 questions, including scenario-based questions and art, graph, and data interpretation questions. The Test Bank is available electronically in MasteringBiology and via www.pearsonglobaleditions.com/campbell.

Course Management Systems

MasteringBiology New Design offers the usual Mastering features plus:

- Blackboard integration with single sign-on
- Temporary access (grace period)
- Discussion boards
- Email
- Chat and class live (synchronous whiteboard presentation)
- Submissions (Dropbox)

FOR STUDENTS

***Study Guide,* Tenth Edition**
by Martha R. Taylor, *Ithaca, New York*
This popular study aid provides concept maps, chapter summaries, word roots, and a variety of interactive activities including multiple-choice, short-answer essay, art labeling, and graph-interpretation questions.

***Inquiry in Action: Interpreting Scientific Papers,* Third Edition**
by Ruth Buskirk, *University of Texas at Austin,*
and Christopher M. Gillen, *Kenyon College*
978-0-321-83417-1 / 0-321-83417-8
This guide helps students learn how to read and understand primary research articles. Part A presents complete articles accompanied by questions that help students analyze the article. Related Inquiry Figures are included in the supplement. Part B covers every part of a research paper, explaining the aim of the sections and how the paper works as a whole. An Instructor Guide is available for download in the Instructor Resources Area in MasteringBiology.

***Spanish Glossary,* Tenth Edition**
by Laura P. Zanello, *University of California, Riverside*
978-0-321-83498-0 / 0-321-83498-4
This resource provides definitions in Spanish for glossary terms.

Into the Jungle: Great Adventures in the Search for Evolution
by Sean B. Carroll, *University of Wisconsin, Madison*
978-0-321-55671-4 / 0-321-55671-2
These nine short tales vividly depict key discoveries in evolutionary biology and the excitement of the scientific process. Online resources available at www.aw-bc.com/carroll.

Get Ready for Biology
978-0-321-50057-1 / 0-321-50057-1
This engaging workbook helps students brush up on important math and study skills and get up to speed on biological terminology and the basics of chemistry and cell biology.

***A Short Guide to Writing About Biology,* Eighth Edition**
by Jan A. Pechenik, *Tufts University*
978-0-321-83386-0 / 0-321-83386-4
This best-selling writing guide teaches students to think as biologists and to express ideas clearly and concisely through their writing.

***An Introduction to Chemistry for Biology Students,* Ninth Edition**
by George I. Sackheim, *University of Illinois, Chicago*
978-0-8053-9571-6 / 0-8053-9571-7
This text/workbook helps students review and master all the basic facts, concepts, and terminology of chemistry that they need for their life science course.

FOR LAB

***Investigating Biology Laboratory Manual,* Eighth Edition**
by Judith Giles Morgan, *Emory University,* and M. Eloise Brown Carter, *Oxford College of Emory University*
978-0-321-83899-5 / 0-321-83899-8
Now in full color! With its distinctive investigative approach to learning, this best-selling laboratory manual is now more engaging than ever, with full-color art and photos throughout. As always, the lab manual encourages students to participate in the process of science and develop creative and critical-reasoning skills.

The Eighth Edition includes major revisions that reflect new molecular evidence and the current understanding of phylogenetic relationships for plants, invertebrates, protists, and fungi. A new lab topic, "Fungi," has been added, providing expanded coverage of the major fungi groups. The "Protists" lab topic has been revised and expanded with additional examples of all the major clades. In the new edition, population genetics is covered in one lab topic with new problems and examples that connect ecology, evolution, and genetics.

***Annotated Instructor Edition for Investigating Biology Laboratory Manual,* Eighth Edition**
by Judith Giles Morgan, *Emory University,* and M. Eloise Brown Carter, *Oxford College of Emory University*
978-0-321-83497-3 / 0-321-83497-6

***Preparation Guide for Investigating Biology Laboratory Manual,* Eighth Edition**
by Judith Giles Morgan, *Emory University,* and M. Eloise Brown Carter, *Oxford College of Emory University*
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Symbiosis: The Pearson Custom Laboratory Program for the Biological Sciences
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MasteringBiology® Virtual Labs
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This online environment promotes critical thinking skills using virtual experiments and explorations that may be difficult to perform in a wet lab environment due to time, cost, or safety concerns. Designed to supplement or substitute for existing wet labs, this product offers students unique learning experiences and critical thinking exercises in the areas of microscopy, molecular biology, genetics, ecology, and systematics.

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*The Inquiry Figure, original research paper, and a worksheet to guide you through the paper are provided in *Inquiry in Action: Interpreting Scientific Papers*, Third Edition.
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As authors of this text, we are mindful of the daunting challenge of keeping up to date in all areas of our rapidly expanding subject. We are grateful to the many scientists who helped shape this text by discussing their research fields with us, answering specific questions in their areas of expertise, and sharing their ideas about biology education. We are especially grateful to the following, listed alphabetically: Monika Abedin, John Archibald, Chris Austin, Kristian Axelsen, Jamie Bascom, Ethan Bier, Barbara Bowman, Daniel Boyce, Jean DeSaix, Amy Dobberteen, Ira Greenbaum, Ken Halanych, Robert Hebbel, Erin Irish, Duncan Irschick, Azarias Karamanlidis, Patrick Keeling, Nikos Kyrpides, Teri Liegler, Gene Likens, Tom Owens, Kevin Peterson, Michael Pollock, Amy Rappaport, Andrew Roger, Andrew Roth, Andrew Schaffner, Thomas Schneider, Alastair Simpson, Doug Soltis, Pamela Soltis, Anna Thanukos, Elisabeth Wade, Phillip Zamore, and Christine Zardecki. In addition, the biologists listed on pages 28–31 provided detailed reviews, helping us ensure the text's scientific accuracy and improve its pedagogical effectiveness. We thank Marty Taylor, author of the Study Guide, for her many contributions to the accuracy, clarity, and consistency of the text; and we thank Carolyn Wetzel, Ruth Buskirk, Joan Sharp, Jennifer Yeh, and Charlene D'Avanzo for their contributions to the Scientific Skills Exercises. We especially thank the Global Edition contributors, listed on p. 26.

Thanks also to the other professors and students, from all over the world, who contacted the authors directly with useful suggestions. We alone bear the responsibility for any errors that remain, but the dedication of our consultants, reviewers, and other correspondents makes us confident in the accuracy and effectiveness of this text.

Interviews with prominent scientists have been a hallmark of *BIOLOGY* since its inception. To open the eight units of this edition, we are proud to include interviews with Lydia Makhubu, Paul Nurse, Venki Ramakrishnan, Geerat Vermeij, Robert Hill, Luis Herrera-Estrella, Masashi Yanagisawa, and David Schindler.

The value of *BIOLOGY* as a learning tool is greatly enhanced by the supplementary materials that have been created for instructors and students. We recognize that the dedicated authors of these materials are essentially writing mini (and not so mini) books. We appreciate the hard work and creativity of all the authors listed, with their creations, on page 23. We are also grateful to Kathleen Fitzpatrick and Nicole Tunbridge (PowerPoint® Lecture Presentations); Scott Meissner, Roberta Batorsky, Tara Turley Stoulig, Lisa Flick, and Bryan Jennings (Clicker Questions); Ed Zalisko, Melissa Fierke, Rebecca Orr, and Diane Jokinen (Test Bank); Natalie Bronstein, Linda Logdberg, Matt McArdle, Ria Murphy, Chris Romero, and Andy Stull (Dynamic Study Modules); and Eileen Gregory, Rebecca Orr, and Elena Pravosudova (Adaptive Follow-up Assignments).

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