GLOBAL EDITION

Biology

A Global Approach

ELEVENTH EDITION

Campbell
Urry
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BIOLOGY

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About the Authors

Neil A. Campbell (1946–2004) earned his M.A. from the University of California, Los Angeles, and his Ph.D. from the University of California, Riverside. His research focused on desert and coastal plants. Neil's 30 years of teaching 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. For many years he was also a visiting scholar at UC Riverside. Neil was the founding author of *BIOLOGY*.

Lisa A. Urry is Professor of Biology and Chair of the Biology Department at Mills College. After earning a B.A. at Tufts University, she completed her Ph.D. at the Massachusetts Institute of Technology (MIT). Lisa has conducted research on gene expression during embryonic and larval development in sea urchins. Deeply committed to promoting opportunities in science for women and underrepresented minorities, she has taught courses ranging from introductory and developmental biology to a nonmajors course called Evolution for Future Presidents. Lisa is a coauthor of *Campbell Biology in Focus*.

Michael L. Cain is an ecologist and evolutionary biologist who is now writing full-time. Michael earned an A.B. from Bowdoin College, an M.Sc. from Brown University, and a Ph.D. from Cornell University. As a faculty member at New Mexico State University, he taught 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. He is a coauthor of *Campbell Biology in Focus* and of an ecology textbook.

Steven A. Wasserman is Professor of Biology at the University of California, San Diego (UCSD). He earned an A.B. from Harvard University and a Ph.D. from MIT. Working on the fruit fly *Drosophila*, Steve has done research on developmental biology, reproduction, and immunity. Having taught genetics, development, and physiology to undergraduate, graduate, and medical students, he now focuses on introductory biology, for which he has been honored with UCSD's Distinguished Teaching Award. He is a coauthor of *Campbell Biology in Focus*.

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

Jane B. Reece, the head of the author team for Editions 8–10 of *BIOLOGY*, was Neil Campbell's longtime collaborator. Jane taught biology at Middlesex County College and Queensborough Community College. She holds an A.B. from Harvard University, an M.S. from Rutgers University, and a Ph.D. 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*, Jane has been a coauthor on all the *Campbell* texts.

Preface

We are honored to present *BIOLOGY: A Global Approach,* which has been adapted from *Campbell BIOLOGY,* Eleventh Edition, for a global audience. For the last three decades, *BIOLOGY* has been the leading college text in the biological sciences. It has been translated into 19 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 hundreds of reviewers (listed on pages 28–32), who, together with editors, artists, and contributors, have shaped and inspired this work.

Our goals for the Eleventh Edition include:

- **increasing visual literacy** through new figures, questions, and exercises that build students' skills in understanding and creating visual representations of biological structures and processes
- asking students to **practice scientific skills** by applying scientific skills to real-world problems
- **supporting instructors** by providing teaching modules with tools and materials for introducing, teaching, and assessing important and often challenging topics
- **integrating text and media** to engage, guide, and inform students in an active process of inquiry and learning

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

New to This Edition

Here we provide an overview of the new features that we have developed for the Eleventh Edition; we invite you to explore pages 9–26 for more information and examples.

- **Visualizing Figures** and **Visual Skills Questions** give students practice in interpreting and creating visual representations in biology. Assignable questions are also available in **MasteringBiology** to give students practice with the visual skills addressed in the figures.
- **Problem-Solving Exercises** challenge students to apply scientific skills and interpret data in solving real-world problems. These exercises are designed to engage students through compelling case studies and provide practice with data analysis skills. Problem-Solving Exercises have assignable versions in **MasteringBiology**. Some also have more extensive "Solve It" investigations to further explore a given topic.
- **Ready-to-Go Teaching Modules** on key topics provide instructors with assignments to use before and after class, as well as in-class activities that use clickers or Learning Catalytics™ for assessment.
- **Integrated text and media**: Media references in the printed book direct students to the wealth of online self-study resources available to them in the **Study Area** section of **MasteringBiology**. The new online learning tools include:
  - **Get Ready for This Chapter** questions provide a quick check of student understanding of the background information needed to learn a new chapter's content, with feedback to bolster their preparation.
  - **Figure Walkthroughs** guide students through key figures with narrated explanations, figure markups, and questions that reinforce important points. Additional questions can be assigned in **MasteringBiology**.
  - More than **450 animations and videos** bring biology to life. These include resources from **HHMI BioInteractive** that engage students in topics from the discovery of the double helix to evolution.
  - QR codes and URLs within the Chapter Review provide easy access to **Vocabulary Self-Quizzes** for each chapter that can be used on smartphones, tablets, and computers.
  - **Interviews** from the First Edition through the Eleventh Edition of *BIOLOGY* are referenced in the chapter where they are most relevant. The interviews show students the human side of science by featuring diverse scientists talking about how they became interested in what they study, how they began, and what inspires them.
- The impact of **climate change** at all levels of the biological hierarchy is explored throughout the text, starting with a new figure (Figure 1.12) and discussion in Chapter 1 and concluding with a new Make Connections Figure (Figure 56.30) and expanded coverage on causes and effects of climate change in Chapter 56.
- As in each new edition of *BIOLOGY*, the Eleventh Edition incorporates **new content** and **pedagogical improvements**. These are summarized on pp. 6–8, following this Preface. Content updates reflect rapid, ongoing changes in technology and knowledge in the fields of genomics, gene editing technology (CRISPR), evolutionary biology, microbiology, and more. In addition, significant revisions to Unit 8, The Ecology of Life, improve the conceptual framework for core ecological topics (such

as population growth, species interactions, and community dynamics) and more deeply integrate evolutionary principles.

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. As such, they are well aligned with the core competencies outlined by the 2009 **Vision and Change** national conference, organized by the American Association for the Advancement of Science, where more than 500 biologists met to discuss the needs of undergraduate biology. Furthermore, the core concepts defined by Vision and Change have close parallels in the unifying themes that are introduced in Chapter 1 and integrated throughout the book. Chief among the themes of both Vision and Change and *BIOLOGY* is **evolution.** Each chapter of this text 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.

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 resources all reinforce these main ideas and essential facts.

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 Visualizing Figures, our popular Exploring Figures and Make Connections Figures epitomize this approach. Each Exploring Figure is a learning unit of core content that brings together related illustrations and text. Make Connections Figures reinforce fundamental conceptual connections throughout biology, helping students overcome tendencies to compartmentalize information. The Eleventh Edition features two new Make Connections Figures. There are also Guided Tour Figures that walk students through complex figures as an instructor would.

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 reading questions include Visual Skills Questions, Draw It Questions, Make Connections Questions, What If? Questions, Figure Legend Questions, Summary Questions, Synthesize Your Knowledge Questions, and Interpret the Data Questions. Answering these questions requires students to write or draw as well as think and thus helps develop the core competency of communicating science.

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 Problem-Solving Exercises, Scientific Skills Exercises, and Interpret the Data Questions. Together, these activities provide students practice in both applying the process of science and using quantitative reasoning, addressing additional core competencies outlined in Vision and Change.

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 Get Ready for This Chapter Questions, Figure Walkthroughs, Problem-Solving Exercises, and Visualizing Figures**, MasteringBiology offers Dynamic Study Modules, Adaptive Follow-Up Assignments, Scientific Skills Exercises, Interpret the Data Questions, Solve It Tutorials, HHMI Bio-Interactive Short Films, BioFlix® Tutorials with 3-D Animations, Experimental Inquiry Tutorials, Interpreting Data Tutorials, BLAST Tutorials, Make Connections Tutorials, Video Field Trips, 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, Instructor Resources, and Ready-to-Go Teaching Modules. See pages 9–23 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 offers a rich variety of instructor and student resources, in both print and electronic form (see pp. 9–23). 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:

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Highlights of New Content

This section highlights selected new content and pedagogical changes in *BIOLOGY*, Eleventh Edition.

CHAPTER 1 Biology and Its Themes

Chapter 1 opens with a new introduction to a case study on the evolution of coloration in mice. New text and a new photo (Figure 1.12) relate climate change to species survival.

UNIT 1 THE ROLE OF CHEMISTRY IN BIOLOGY

In Unit 1, new content engages students in learning this foundational material. The opening of Chapter 3 and new **Figure 3.7** show organisms affected by **loss of Arctic sea ice**. Chapter 5 has updates on lactose intolerance, *trans* fats, the effects of diet on blood cholesterol, protein sequences and structures, and intrinsically disordered proteins. New Visualizing Figure 5.16 helps students understand various ways proteins are depicted. A new Problem-Solving Exercise engages students by having them compare DNA sequences in a case of possible fish fraud. Chapter 6 includes a beautiful new photo of a geyser with thermophilic bacteria in Figure 6.17, bringing to life the graphs of optimal temperatures for enzyme function.

Figure 3.7 Effects of climate change on the Arctic.

UNIT 2 CELL BIOLOGY

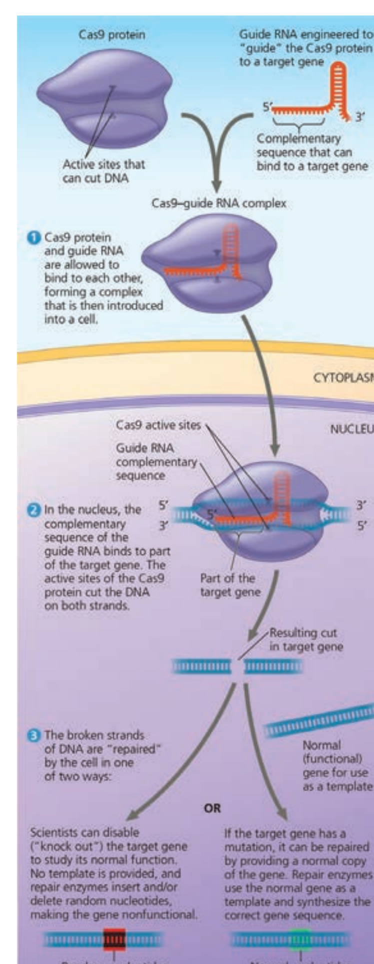
Our main goal for this unit was to make the material more accessible and inviting to students. New Visualizing Figure 7.32 shows the profusion of molecules and structures in a cell, all drawn to scale. In Chapter 8, a new figure illustrates levels of LDL receptors in people with and without familial hypercholesterolemia. Chapter 9 includes a new Problem-Solving Exercise that guides students through assessing possible new treatments for bacterial infections by blocking quorum sensing. Chapter 11 discusses current research trying to genetically modify rice (a C_3 crop) so that it is capable of carrying out C_4 photosynthesis to increase yields. In Chapter 12, the mechanism of chromosome movement in bacteria has been updated and more cell cycle control checkpoints have been added, including one proposed by researchers in 2014.

UNIT 3 THE GENETIC BASIS OF LIFE

In Chapters 13–17, we have incorporated changes that help students grasp the more abstract concepts of genetics and their chromosomal and molecular underpinnings. For example, a new Visual Skills Question with Figure 13.6 asks students to identify where in the three life cycles haploid cells undergo mitosis, and what type of cells are formed. Chapter 14 includes new information from a 2014 genomic study on the number of genes and genetic variants contributing to height. Figure 14.15b now uses "inability to taste PTC" rather than "attached earlobe." Chapters 14 and 15 are more inclusive, clarifying the meaning of the term "normal" in genetics and explaining that sex is no longer thought to be simply binary. Other updates in Chapter 15 include new research in sex determination and a technique being developed to avoid passing on mitochondrial diseases. New Visualizing Figure 16.7 shows students various ways that DNA is illustrated. Chapter 17 has a new opening photo and story about albino donkeys to pique student interest in gene expression. To help students understand the Beadle and Tatum experiment, new Figure 17.2 explains how they obtained nutritional mutants. A new Problem-Solving Exercise asks students to identify mutations in the insulin gene and predict their effect on the protein.

Chapters 18–20 are extensively updated, driven by exciting new discoveries based on DNA sequencing and gene-editing technology. Chapter 18 has updates on histone modifications, nuclear location and the persistence of transcription factories, chromatin remodeling by ncRNAs, long noncoding RNAs (lncRNAs), the role of master regulatory genes in modifying chromatin structure, and the possible role of *p53* in the low incidence of cancer in elephants. Make Connections Figure 18.27, "Genomics, Cell Signaling, and Cancer," has been expanded to include more information on cell signaling. Chapter 19 has a new photo of next-generation DNA sequencing machines (Figure 19.2) and a new illustration of the widely used technique of RNA sequencing (Figure 19.13). A new section titled Editing Genes and Genomes has been added describing the **CRISPR-Cas9 system** **(Figure 19.14)** that has been developed to edit genes in living cells. Information has also been added later in the chapter on use of the CRISPR-Cas9 system, including a study in which a genetic mutation for the disease tyrosinemia was corrected in mice. Finally, the discussion of ethical considerations has been updated to include a recent report of scientists using the CRISPR-Cas9 system to edit a gene in human embryos, along with a discussion of the ethical questions raised by such experiments, such as its usage in the gene drive approach to combat carrying of diseases

Figure 19.14 Gene editing using the CRISPR-Cas9 system.

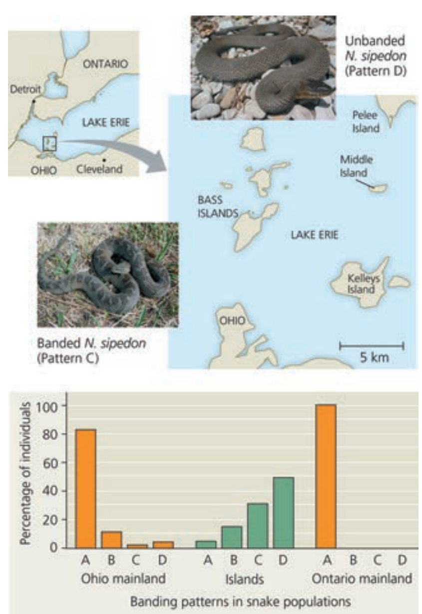


by mosquitoes. In Chapter 20, in addition to the usual updates of sequence-related data (speed of sequencing, number of species' genomes sequenced, etc.), there are several research updates, including some early results from the new Roadmap Epigenomics Project and results from a 2015 study focusing on 414 important yeast genes.

UNIT 4 EVOLUTION

A major goal for this revision was to strengthen how we help students understand and interpret visual representations of evolutionary data and concepts. Toward this end, we have added a new figure (Figure 25.8), "Visualizing the Scale of Geologic Time," and a new figure **(Figure 23.12)** on **gene flow**. Another new figure (Figure 22.5, "Visualizing Phylogenetic Relationships") introduces the visual conventions used in phylogenetic trees and helps students understand what such trees do and don't convey. Several figures have been revised to improve the presentation of data, including Figure 24.6 (on reproductive isolation in mosquitofish), Figure 24.10 (on allopolyploid speciation), and Figure 25.25 (on the origin of the insect body plan). The unit also features new material that connects evolutionary concepts and societal problems. Examples include text in Chapter 21 on the 2015 discovery of teixobactin, an antibiotic that is effective against some hard-to-treat pathogens, a new discussion in Chapter 24 on the impact of climate change on hybrid zones, and a new Problem-Solving Exercise in Chapter 24 on how hybridization may have led to the spread of insecticide resistance genes in mosquitoes that transmit malaria. The unit also includes new chapter-opening stories in Chapter 21 (on a moth whose features illustrate the concepts of unity, diversity, and adaptation) and Chapter 25 (on the discovery of whale bones in the Sahara Desert). Additional changes include new text in Concept 21.3 emphasizing how populations can evolve over short periods of time, new text and a new figure (Figure 22.22) on horizontal gene transfer from prokaryotes to eukaryotes, a new table (Table 23.1) highlighting the five conditions required for a population to be in Hardy-Weinberg equilibrium, and new material in Concept 25.1 describing how researchers recently succeeded for the first time in constructing a "protocell" in which replication of a template strand of RNA could occur.

▼ Figure 23.12 Gene flow and local adaptation in the Lake Erie water snake (*Nerodia sipedon*).



UNIT 5 THE DIVERSITY OF LIFE

Chapter 26, the first chapter of this unit, features a new section that covers bacterial defenses against bacteriophages and describes the CRISPRCas9 system (Figure 26.7); updates include the Ebola, Chikungunya, and Zika viruses (Figure 26.10) and discovery of the largest virus known to date. A discussion has been added of mosquito transmission of diseases and concerns about the effects of global climate change on disease transmission. Students are provided many opportunities to practice their visual skills, with many new Visual Skills Questions on topics ranging from interpreting phylogenetic trees to predicting which regions of a bacterial flagellum are hydrophobic. The unit also contains new content on tree thinking, emphasizing such key points as how sister groups provide a clear way to describe evolutionary relationships and how trees do not show a "direction" in evolution. Other major content changes include new text in Concepts 27.4, and 28.1 on the 2015 discovery of the Lokiarchaeota, a group of archaea that may represent the sister group of the eukaryotes, new text in Concept 27.6 describing the CRISPR-Cas9 system and a new figure (Figure 27.21) that illustrates one example of how CRISPR-Cas 9 technology has opened new avenues of research on HIV, and new material in Concept 29.3 describing how early forests contributed to global climate change (in this case, global cooling). A new Problem-Solving Exercise in Chapter 34 engages students in interpreting data from a study investigating whether frogs can acquire resistance to a fungal pathogen through controlled exposure to it. Other updates include the revision of many phylogenies to reflect recent phylogenomic data, new chapter-opening stories in Chapter 31 (on how mycorrhizae link trees of different species) and Chapter 33 (on the "blue dragon," a mollusc that preys on the highly toxic Portuguese man-of-war), new text and a new figure (Figure 34.37) on the adaptations of the kangaroo rat to its arid environment, and new material in Concept 34.7, including a new figure (Figure 34.52) describing fossil and DNA evidence indicating that humans and Neanderthals interbred, producing viable offspring. The discussion of **human evolution** also includes new text and a new figure **(Figure 34.53)** on *Homo naledi*, the most recently discovered member of the human evolutionary lineage.

▼ Figure 34.53 Fossils of hand and foot bones of *Homo naledi*.

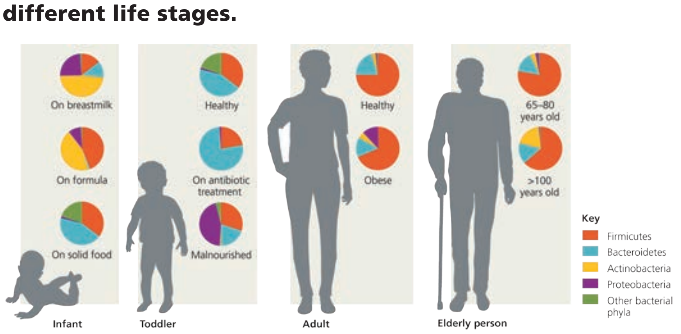
UNIT 6 PLANTS: STRUCTURE AND FUNCTION

A major aim in revising Chapter 35 was to help students better understand how primary and secondary growth are related. New Visualizing Figure 35.11 enables students to picture growth at the cellular level. Also, the terms *protoderm, procambium*, and *ground meristem* have been introduced to underscore the transition of meristematic to mature tissues. A new flowchart (Figure 35.24) summarizes growth in a woody shoot. New text and a figure (Figure 35.26) focus on genome analysis of *Arabidopsis* ecotypes, relating plant morphology to ecology and evolution. In Chapter 36, new Figure 36.8 illustrates the fine branching of leaf veins, and information on phloem-xylem water transfer has been updated. New Make Connections Figure 37.10 highlights mutualism across kingdoms and domains. Figure 37.13 and the related text include new findings on how some soil nitrogen derives from weathering of rocks. New Figure 38.3 clarifies how the terms *carpel* and *pistil* are related. The text on flower structure and the angiosperm life cycle figure identify carpels as megasporophylls and stamens as microsporophylls, correlating with the plant evolution discussion in Unit 5. In Concept 38.3, the current problem of glyphosate-resistant crops is discussed in detail. A revised Figure 39.7 helps students visualize how cells elongate. Figure 39.8 now addresses apical dominance in a Guided Tour format. Information about the role of sugars in controlling apical dominance has been added. In Concept 39.4, a new Problem-Solving Exercise highlights how global climate change affects crop productivity. Figure 39.26 on defense responses against pathogens has been simplified and improved.

UNIT 7 ANIMALS: STRUCTURE AND FUNCTION

A major goal of the Unit 7 revision was to transform how students interact with and learn from representations of anatomy and physiology. For example, gastrulation is now introduced with a Visualizing Figure (Figure 46.8) that provides a clear and carefully paced introduction to three-dimensional processes that may be difficult for students to grasp. In addition, a number of the new and revised figures help students explore spatial relationships in anatomical contexts, such as the interplay of lymphatic and cardiovascular circulation (Figure 43.15) and the relationship of the limbic system to overall brain structure (Figure 49.14). A new Problem-Solving Exercise in Chapter 41 taps into student interest in medical mysteries through a case study that explores the science behind laboratory testing and diagnosis. Content updates help students appreciate the continued evolution of our understanding of even familiar phenomena, such as the sensation of thirst (Concept 44.4) and the locomotion of kangaroos and jellies (Concept 50.6). Furthermore, new text and figures introduce students to cutting-edge technology relating to such topics as RNA-based antiviral defense in invertebrates (Figure 47.4) and rapid, comprehensive characterization of viral exposure (Figure 47.24), as well as recent discoveries regarding brown fat in adult humans (Figure 40.16), the **microbiome (Figure 42.17)**, parthenogenesis (Concept 45.1), and magnetoreception (Concept 50.1). As always, there is fine-tuning of pedagogy, as in discussions of the complementary roles of inactivation and voltage gating of ion channels during action potential formation (Concept 48.3).

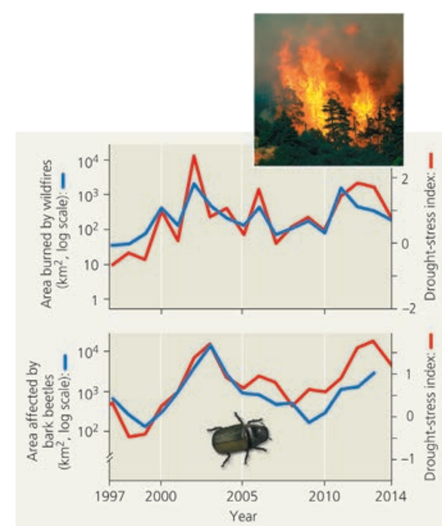
▼ Figure 42.17 Variation in human gut microbiome at different life stages.



UNIT 8 THE ECOLOGY OF LIFE

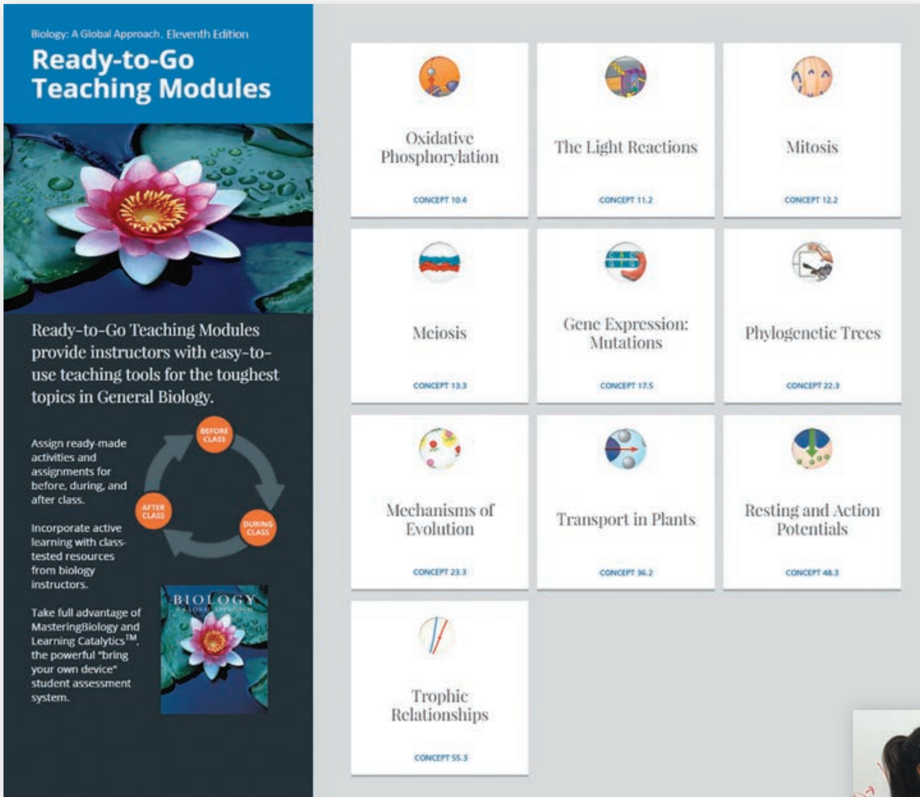
The Ecology Unit has been extensively revised for the Eleventh Edition. We have reorganized and improved the conceptual framework with which students are introduced to the following core ecological topics: life tables, per capita population growth, intrinsic rate of increase ("*r*"), exponential population growth, logistic population growth, density dependence, species interactions (in particular, parasitism, commensalism, and mutualism), and MacArthur and Wilson's island biogeography model. The revision also includes a deeper integration of evolutionary principles, including a new Key Concept (51.5) and two new figures (Figures 51.22 and 51.23) on the reciprocal effects of ecology and evolution, new material in Concept 51.4 on how the geographic distributions of species are shaped by a combination of evolutionary history and ecological factors, and five new Make Connections Questions that ask students to examine how ecological and evolutionary mechanisms interact. In keeping with our goal of expanding and strengthening our coverage of climate change, we have added a new discussion and a new figure (Figure 51.20) on how climate change has affected the distribution of a keystone species, a new section of text in Concept 55.2 on how climate change affects NPP, a new figure **(Figure 55.8)** on how **climate change** has caused an increase in wildfires and insect outbreaks, a new Problem-Solving Exercise in Chapter 55 that explores how insect outbreaks induced by climate change can cause an ecosystem to switch from a carbon sink to a carbon source, a new figure (Figure 56.29) on the greenhouse effect, new text in Concept 56.4 on biological effects of climate change, and a new Make Connections Figure (Figure 56.30) on how climate change affects all levels of biological organization. Additional updates include a new figure (Figure 53.25) on per capita ecological footprints, a new chapter-opening story in Chapter 54 on a seemingly unlikely mutualism between a shrimp and a much larger predatory fish, new text in Concept 54.1 emphasizing that each partner in a mutualism experiences both benefits and costs, new text in Concept 54.1 describing how the outcome of an ecological interaction can change over time, two new figures (Figures 54.29 and 54.30) on the island equilibrium model, a new figure (Figure 54.31) documenting two shrew species as unexpected hosts of the Lyme disease, new text in Concept 56.1 comparing extinction rates today with those typically seen in the fossil record, and a new discussion and figure (Figure 56.22) on the restoration of a degraded urban stream.

▼ Figure 55.8 Climate change, wildfires, and insect outbreaks.



Ready-to-Go Teaching Modules for Instructors

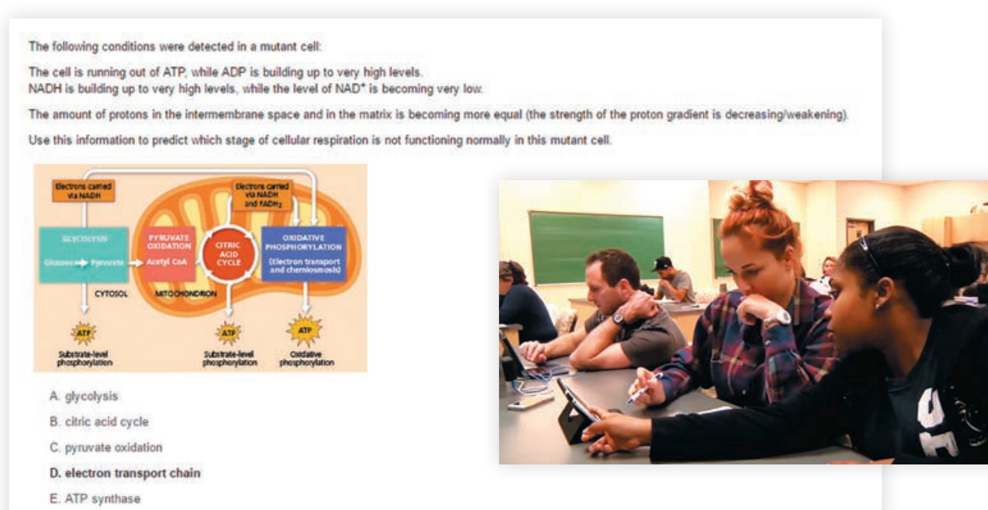
NEW! Ready-to-Go Teaching Modules help instructors efficiently make use of the best teaching tools before, during, and after class.



The **Ready-to-Go Teaching Modules** incorporate the best that the text, MasteringBiology, and Learning Catalytics have to offer, along with new ideas for in-class activities. The modules can be accessed through the Instructor Resources area of MasteringBiology.

Instructors can easily incorporate **active learning** into their courses using suggested activity ideas and questions. Videos demonstrate how the activities can be used in class.

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

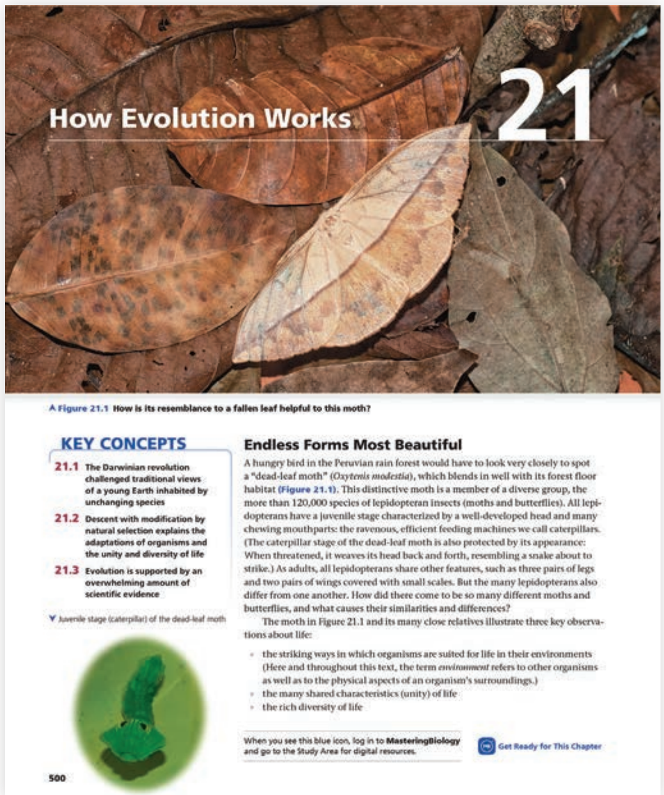


See the Big Picture

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

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.


How Evolution Works

21

▲ **Figure 21.1** How is its resemblance to a fallen leaf helpful to this moth?

KEY CONCEPTS

21.1 The Darwinian revolution challenged traditional views of a young Earth inhabited by unchanging species

21.2 Descent with modification by natural selection explains the adaptations of organisms and the unity and diversity of life

21.3 Evolution is supported by an overwhelming amount of scientific evidence

▼ Juvenile stage (caterpillar) of the dead-leaf moth

Endless Forms Most Beautiful

A hungry bird in the Peruvian rain forest would have to look very closely to spot a "dead-leaf moth" (*Oxytenis modestia*), which blends in well with its forest floor habitat (**Figure 21.1**). This distinctive moth is a member of a diverse group, the more than 120,000 species of lepidopteran insects (moths and butterflies). All lepidopterans have a juvenile stage characterized by a well-developed head and many chewing mouthparts: the ravenous, efficient feeding machines we call caterpillars. (The caterpillar stage of the dead-leaf moth is also protected by its appearance: When threatened, it weaves its head back and forth, resembling a snake about to strike.) As adults, all lepidopterans share other features, such as three pairs of legs and two pairs of wings covered with small scales. But the many lepidopterans also differ from one another. How did there come to be so many different moths and butterflies, and what causes their similarities and differences?

The moth in Figure 21.1 and its many close relatives illustrate three key observations about life:

- the striking ways in which organisms are suited for life in their environments (Here and throughout this text, the term *environment* refers to other organisms as well as to the physical aspects of an organism's surroundings.)
- the many shared characteristics (unity) of life
- the rich diversity of life

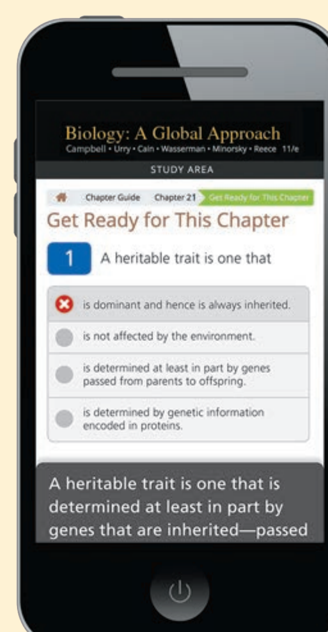
When you see this blue icon, log in to **MasteringBiology** and go to the Study Area for digital resources.

Get Ready for This Chapter

500

Get Ready for This Chapter

NEW! Get Ready for This Chapter questions provide a quick check of students' knowledge of basic information needed to learn the new content of a chapter, with feedback.



These questions are available as MasteringBiology assignments and as self-study quizzes in the Study Area.

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

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

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

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

CONCEPT CHECK 21.2

1. How does the concept of descent with modification explain both the unity and diversity of life?
2. **WHAT IF?** ➤ If you discovered a fossil of an extinct mammal that lived high in the Andes, would you predict that it would more closely resemble present-day mammals from South American jungles or present-day mammals that live high in Asian mountains? Explain.
3. **MAKE CONNECTIONS** ➤ Review the relationship between genotype and phenotype (see Figures 14.5 and 14.6). Suppose that in a particular pea population, flowers with the white phenotype are favored by natural selection. Predict what would happen over time to the frequency of the *p* allele in the population, and explain your reasoning.

For suggested answers, see Appendix A.

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

21 Chapter Review

Go to **MasteringBiology**™ for Videos, Animations, Vocab Self-Quiz, Practice Tests, and more in the Study Area.

SUMMARY OF KEY CONCEPTS

CONCEPT 21.1

The Darwinian revolution challenged traditional views of a young Earth inhabited by unchanging species *(pp. 501–503)*

VOCAB SELF-QUIZ

- Darwin proposed that life's diversity arose from ancestral species through natural selection, a departure from prevailing views.
- Cuvier studied **fossils** but denied that evolution occurs; he proposed that sudden catastrophic events in the past caused species to disappear from an area.
- Hutton and Lyell thought that geologic change could result from gradual mechanisms that operated in the past in the same manner as they do today.
- Lamarck hypothesized that species evolve, but the underlying mechanisms he proposed are not supported by evidence.

? *Why was the age of Earth important for Darwin's ideas about evolution?*

CONCEPT 21.2

Descent with modification by natural selection explains the adaptations of organisms and the unity and diversity of life *(pp. 503–508)*

- Darwin's experiences during the voyage of the *Beagle* gave rise to his idea that new species originate from ancestral forms through the accumulation of **adaptations**. He refined his theory for many years and finally published it in 1859 after learning that Wallace had come to the same idea.
- In *The Origin of Species*, Darwin proposed that over long periods of time, descent with modification produced the rich diversity of life through the mechanism of **natural selection**.

Observations

Individuals in a population vary in their heritable characteristics. | Organisms produce more offspring than the environment can support.

Inferences

Individuals that are well suited to their environment tend to leave more offspring than other individuals.

and

Over time, favorable traits accumulate in the population.

? *Describe how overreproduction and heritable variation relate to evolution by natural selection.*

CONCEPT 21.3

Evolution is supported by an overwhelming amount of scientific evidence *(pp. 509–516)*

- Researchers have directly observed natural selection leading to adaptive evolution in many studies, including research on soapberry bug populations and on MRSA.

516 UNIT FOUR Evolution

Summary of Key Concepts Questions check students' understanding of a key idea from each concept.

Summary Figures recap key information visually.

VOCAB SELF-QUIZ
goo.gl/Rn5Uax

PRACTICE TEST
goo.gl/iAsVgL

NEW! QR codes and URLs at the end of every chapter give students quick access to **Vocabulary Self-Quizzes and Practice Tests** on their smartphones, tablets, and computers.

- Organisms share characteristics because of common descent (**homology**) or because natural selection affects independently evolving species in similar environments in similar ways (**convergent evolution**).
- Fossils show that past organisms differed from living organisms, that many species have become extinct, and that species have evolved over long periods of time; fossils also document the evolutionary origin of new groups of organisms.
- Evolutionary theory can explain some biogeographic patterns.

? *Summarize the different lines of evidence supporting the hypothesis that cetaceans descended from land mammals and are closely related to even-toed ungulates.*

TEST YOUR UNDERSTANDING

Multiple-choice Self-Quiz questions 1–5 can be found in the Study Area in MasteringBiology.

6. **EVOLUTION CONNECTION** Explain why anatomical and molecular features often fit a similar nested pattern. In addition, describe a process that can cause this not to be the case.

7. **SCIENTIFIC INQUIRY • DRAW IT** Mosquitoes resistant to the pesticide DDT first appeared in India in 1959, but now are found throughout the world. (a) Graph the data in the table below. (b) Examine the graph, then hypothesize why the percentage of mosquitoes resistant to DDT rose rapidly. (c) Suggest an explanation for the global spread of DDT resistance.

Month	0	8	12
Mosquitoes Resistant* to DDT	4%	45%	77%

*Mosquitoes were considered resistant if they were not killed within 1 hour of receiving a dose of 4% DDT.

Data from C. F. Curtis et al., Selection for and against insecticide resistance and possible methods of inhibiting the evolution of resistance in mosquitoes, *Ecological Entomology* 3:273–287 (1978).

8. **WRITE ABOUT A THEME: INTERACTIONS** Write a short essay (about 100–150 words) evaluating whether changes to an organism's physical environment are likely to result in evolutionary change. Use an example to support your reasoning.

9. **SYNTHESIZE YOUR KNOWLEDGE**

This honeypot ant (genus *Myrmecocystus*) can store liquid food inside its expandable abdomen. Consider other ants you are familiar with, and explain how a honeypot ant exemplifies three key features of life: adaptation, unity, and diversity.

For selected answers, see Appendix A.

For additional practice questions, check out the **Dynamic Study Modules** in MasteringBiology. You can use them to study on your smartphone, tablet, or computer anytime, anywhere!

Evolution, the fundamental theme of biology, is emphasized throughout. Every chapter has a section explicitly relating the chapter content to evolution:

Evolution of the Genetic Code

EVOLUTION The genetic code is nearly universal, shared by organisms from the simplest bacteria to the most comple[x] plants and animals. The mRNA codon CCG, for instan[ce, is] translated as the amino acid proline in all organisms w[hose] genetic code has been examined. In laboratory experi[ments,] genes can be transcribed and translated after being tra[ns]planted from one species to another, sometimes with [...] striking results, as shown in **Figure 17.7**. Bacteria can [be] programmed by the insertion of human genes to synth[esize] certain human proteins for medical use, such as insuli[n...] applications have produced many exciting developme[nts in] the area of biotechnology (see Concept 19.4).

Evolution Connection Questions are included in every Chapter Review.

▼ Figure 17.7 Evidence for evolution: expression of genes from different species. Because diverse forms of life share a common genetic code due to their shared ancestry, one species can be programmed to produce proteins characteristic of a second species by introducing DNA from the second species into the first.

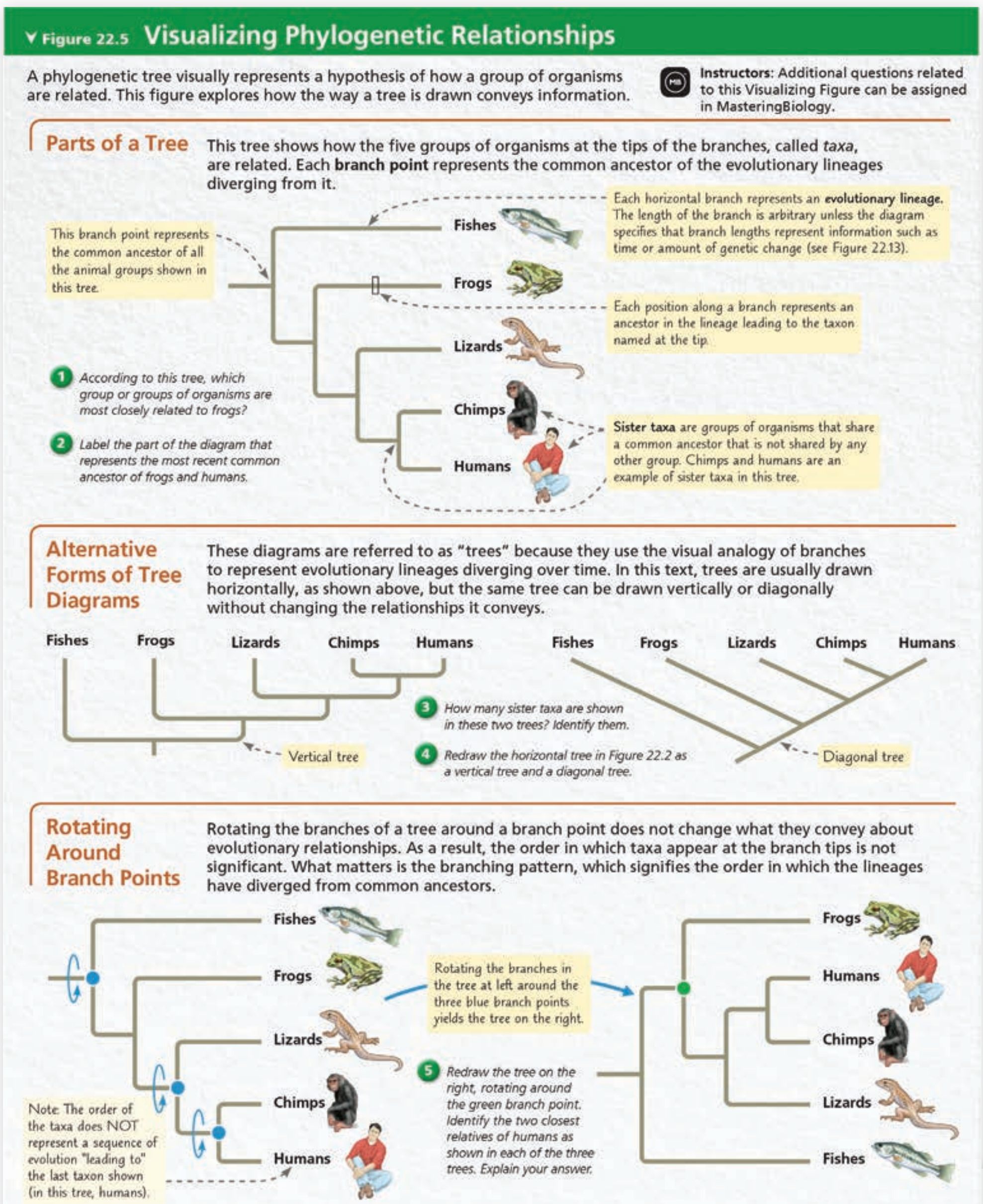
(a) Tobacco plant expressing a firefly gene. The yellow glow is produced by a chemical reaction catalyzed by the protein product of the firefly gene.

(b) Pig expressing a jellyfish gene. Researchers injected a jellyfish gene for a fluorescent protein into fertilized pig eggs. One developed into this fluorescent pig.

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

Build Visual Skills

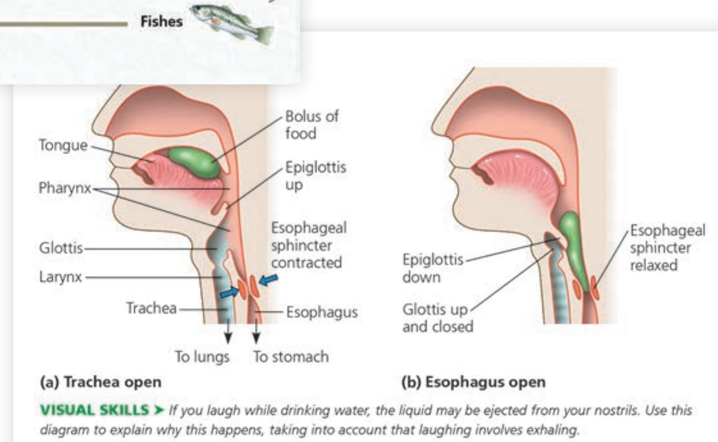
NEW! Visualizing Figures teach students how to interpret diagrams and models in biology. Embedded questions give students practice applying visual skills as they read the figure.



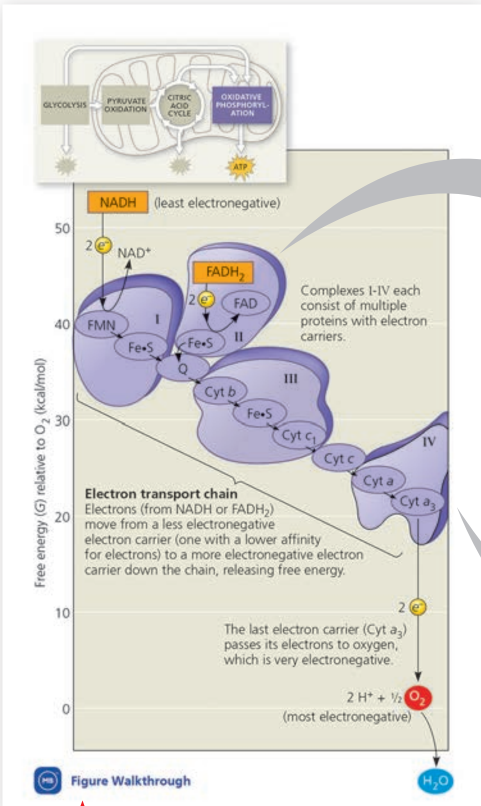
For more practice, each Visualizing Figure is accompanied by an automatically graded assignment in MasteringBiology with feedback for students.

Visualizing Figures include:

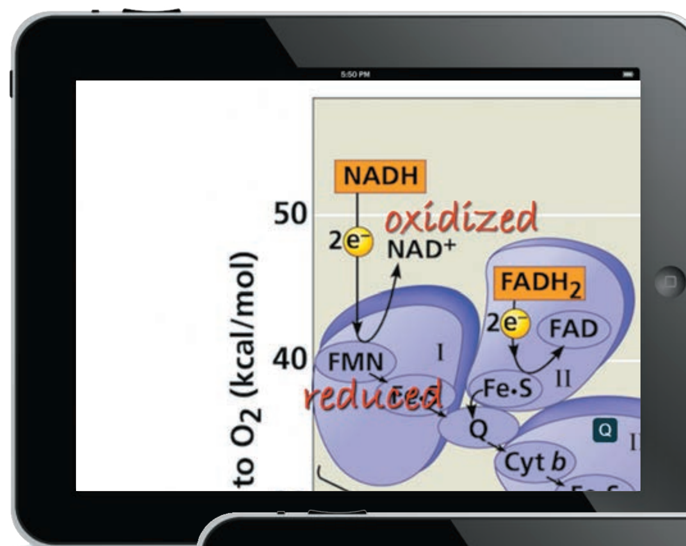
NEW! Visual Skills Questions give students practice interpreting illustrations and photos in the text.

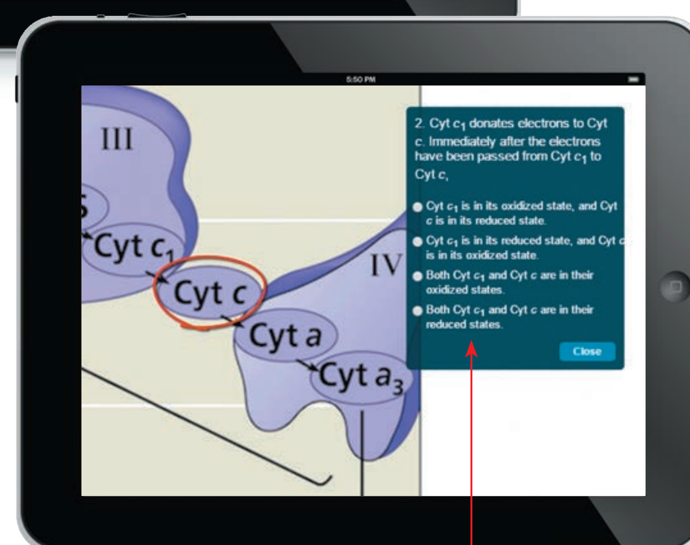


NEW! Figure Walkthroughs guide students through key figures with narrated explanations, figure markups, and questions that reinforce important points.



A note in the print book lets students and instructors know when a Figure Walkthrough is available in the Study Area.





Questions embedded in each Figure Walkthrough encourage students to be active participants in their learning. The Figure Walkthroughs can also be assigned in MasteringBiology with higher-level questions.

Figure 2.17
Photosynthesis: a solar-powered rearrangement of matter. *Elodea*, a freshwater plant, produces sugar by rearranging the atoms of carbon dioxide and water in the chemical process known as photosynthesis, which is powered by sunlight. Much of the sugar is then converted to other food molecules. Oxygen gas (O_2) is a by-product of photosynthesis; notice the bubbles of O_2 gas escaping from the leaves submerged in water.

DRAW IT ➤ *Add labels and arrows on the photo showing the reactants and products of photosynthesis as it takes place in a leaf.*

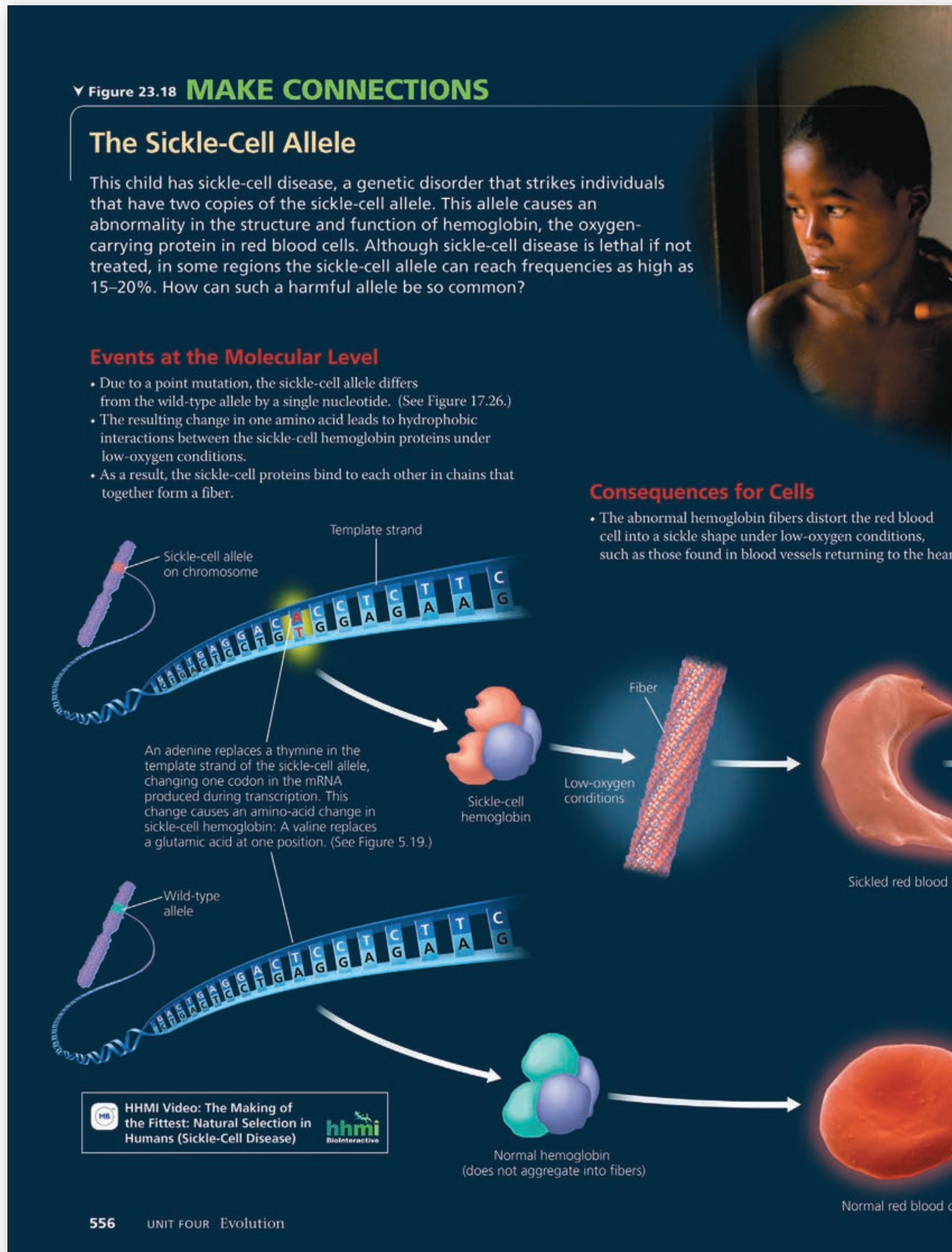
EXPANDED! Draw It exercises give students practice creating visuals. Students are asked to put pencil to paper and draw a structure, annotate a figure, or graph experimental data.

Make Connections Visually

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

Make Connections Figures include:

NEW! Media references integrated into the text direct students to digital content in the MasteringBiology Study Area that will help them prepare for class and succeed on exams. Video resources include HHMI BioInteractive Short Films (documentary-quality movies from the Howard Hughes Medical Institute) and much more.



▼ Figure 23.18 MAKE CONNECTIONS

The Sickle-Cell Allele

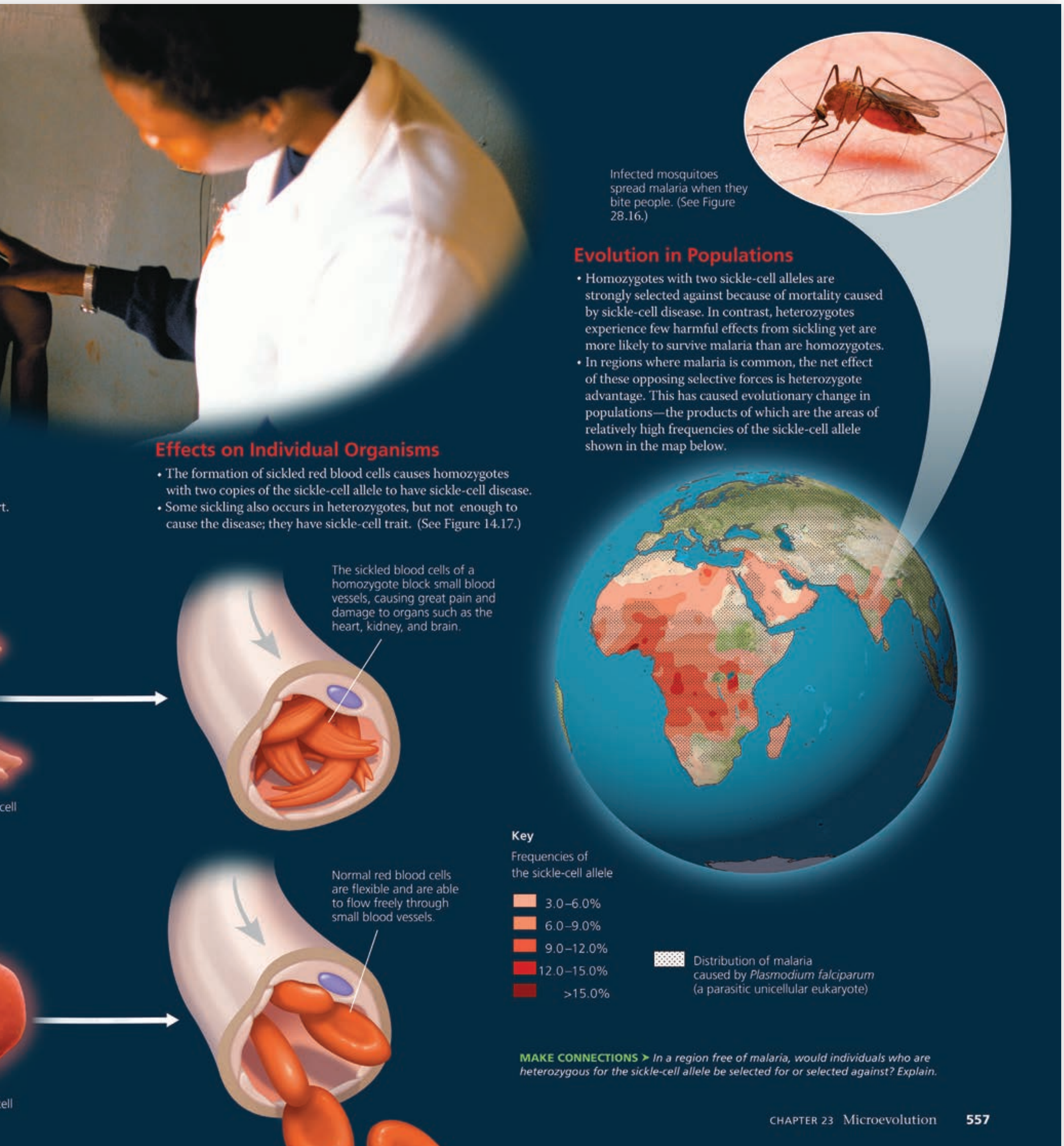
This child has sickle-cell disease, a genetic disorder that strikes individuals that have two copies of the sickle-cell allele. This allele causes an abnormality in the structure and function of hemoglobin, the oxygen-carrying protein in red blood cells. Although sickle-cell disease is lethal if not treated, in some regions the sickle-cell allele can reach frequencies as high as 15–20%. How can such a harmful allele be so common?

Events at the Molecular Level

- Due to a point mutation, the sickle-cell allele differs from the wild-type allele by a single nucleotide. (See Figure 17.26.)
- The resulting change in one amino acid leads to hydrophobic interactions between the sickle-cell hemoglobin proteins under low-oxygen conditions.
- As a result, the sickle-cell proteins bind to each other in chains that together form a fiber.

Consequences for Cells

- The abnormal hemoglobin fibers distort the red blood cell into a sickle shape under low-oxygen conditions, such as those found in blood vessels returning to the hear



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

Practice Scientific Skills

Scientific Skills Exercises use real data to build key skills needed for biology, including **data analysis**, **graphing**, **experimental design**, and **math skills**.

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

Most Scientific Skills Exercises use **data from published research,** which is cited in the exercise.

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

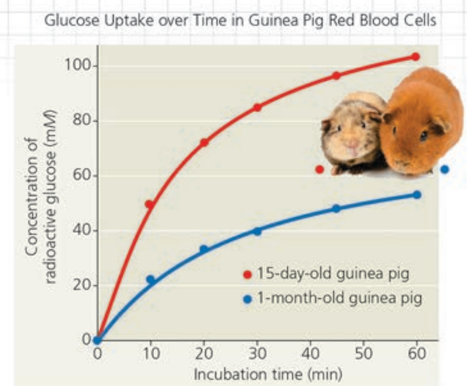
SCIENTIFIC SKILLS EXERCISE

Interpreting a Scatter Plot with Two Sets of Data

Is Glucose Uptake into Cells Affected by Age? Glucose, an important energy source for animals, is transported into cells by facilitated diffusion using protein carriers. In this exercise, you will interpret a graph with two sets of data from an experiment that examined glucose uptake over time in red blood cells from guinea pigs of different ages. You will determine if the cells' rate of glucose uptake depended on the age of the guinea pigs.

How the Experiment Was Done Researchers incubated guinea pig red blood cells in a 300 m*M* (millimolar) radioactive glucose solution at pH 7.4 at 25°C. Every 10 or 15 minutes, they removed a sample of cells and measured the concentration of radioactive glucose inside those cells. The cells came from either a 15-day-old or a 1-month-old guinea pig.

Data from the Experiment When you have multiple sets of data, it can be useful to plot them on the same graph for comparison. In the graph here, each set of dots (of the same color) forms a *scatter plot*, in which every data point represents two numerical values, one for each variable. For each data set, a curve that best fits the points has been drawn to make it easier to see the trends. (For additional information about graphs, see the Scientific Skills Review in Appendix F.)



Data from T. Kondo and E. Beutler, Developmental changes in glucose transport of guinea pig erythrocytes, *Journal of Clinical Investigation* 65:1–4 (1980).

INTERPRET THE DATA

1. First make sure you understand the parts of the graph. (a) Which variable is the independent variable—the variable controlled by the researchers? (b) Which variable is the dependent variable—the variable that depended on the treatment and was measured by the researchers? (c) What do the red dots represent? (d) The blue dots?
2. From the data points on the graph, construct a table of the data. Put "Incubation Time (min)" in the left column of the table.
3. What does the graph show? Compare and contrast glucose uptake in red blood cells from 15-day-old and 1-month-old guinea pigs.
4. Develop a hypothesis to explain the difference between glucose uptake in red blood cells from 15-day-old and 1-month-old guinea pigs. (Think about how glucose gets into cells.)
5. Design an experiment to test your hypothesis.

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

All Scientific Skills Exercises are available as **interactive assignments in MasteringBiology** that are automatically graded.

SCIENTIFIC SKILLS EXERCISES are available for every chapter:

Apply Scientific Skills to Solving Problems

NEW! Problem-Solving Exercises guide students in applying scientific skills and interpreting real data in the context of solving a real-world problem.

PROBLEM-SOLVING EXERCISE

Are you a victim of fish fraud?

When buying salmon, perhaps you prefer the more expensive wild-caught Pacific salmon (*Oncorhynchus* species) over farmed Atlantic salmon (*Salmo salar*). But studies reveal that about 40% of the time, you aren't getting the fish you paid for! Watch the video in the MasteringBiology Study Area for more information.

ABC News Video: Fake Fish in Stores and Restaurants

Instructors: A version of this Problem-Solving Exercise can be assigned in Chapter 5 of MasteringBiology. A more extensive investigation is in Chapter 22 of MasteringBiology.

In this exercise, you will investigate whether a piece of salmon has been fraudulently labeled.

Your Approach The principle guiding your investigation is that DNA sequences from within a species or from closely related species are more similar to each other than are sequences from more distantly related species.

Your Data You've been sold a piece of salmon labeled as coho salmon (*Oncorhynchus kisutch*). To see whether your fish was labeled correctly, you will compare a short DNA sequence from your sample to standard sequences from the same gene for three salmon species. The sequences are:

	Sample labeled as *O. kisutch* (coho salmon)	5′-CGGCACCGCCCTAAGTCTCT-3′
Standard sequences	Sequence for *O. kisutch* (coho salmon)	5′-AGGCACCGCCCTAAGTCTAC-3′
	Sequence for *O. keta* (chum salmon)	5′-AGGCACCGCCCTGAGCCTAC-3′
	Sequence for *Salmo salar* (Atlantic salmon)	5′-CGGCACCGCCCTAAGTCTCT-3′

Your Analysis

1. Scan along the standard sequences (*O. kisutch*, *O. keta*, and *S. salar*), base by base, circling any bases that do not match the sequence from your fish sample.
2. How many bases differ between (a) *O. kisutch* and your fish sample? (b) *O. keta* and the sample? (c) *S. salar* and the sample?
3. For each standard, what percentage of its bases are identical to your sample?
4. Based on these data alone, state a hypothesis for the species identity of your sample. What is your reasoning?

A version of each Problem-Solving Exercise can also be assigned in MasteringBiology.

Problem-Solving Exercises include:

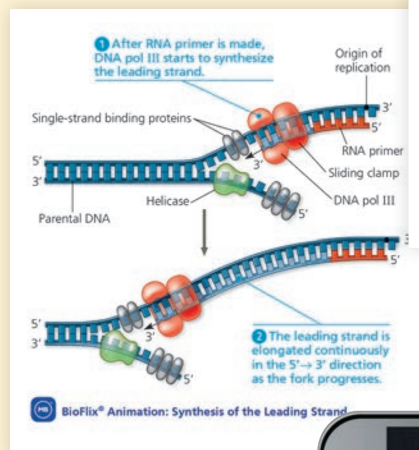
* Available only in MasteringBiology. All other Scientific Skills Exercises are in the print book, eText, and MasteringBiology.

Bring Biology to Life

NEW! Over 450 carefully chosen and edited **videos and animations** have been integrated into the print book, MasteringBiology Study Area, and eText at point of use to help students learn biology visually.

Media references in the print book direct students to digital resources in the Study Area and eText:

- **NEW!** Get Ready for This Chapter questions
- **NEW!** Figure Walkthroughs
- **NEW!** HHMI BioInteractive Videos and Animations
- **NEW!** QR codes and URLs for easy access to Vocabulary Self-Quizzes and Practice Tests
- BioFlix Animations
- ABC News Videos
- Campbell Interviews *and much more*



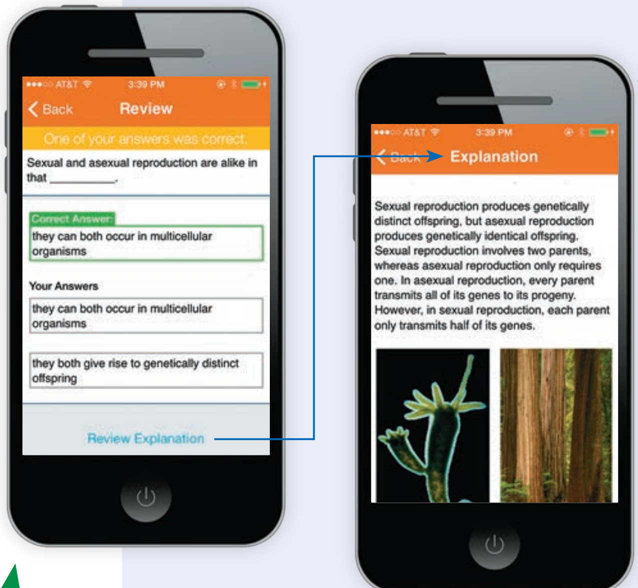
In April 1953, Watson and Crick surprised the scientific world with a succinct, one-page paper that reported their molecular model for DNA: the double helix, which has since become the symbol of molecular biology. Watson and Crick, along with Maurice Wilkins, were awarded the Nobel Prize in 1962 for this work. (Sadly, Rosalind Franklin had died at the age of 37 in 1958 and was thus ineligible for the prize.) The beauty of the double helix model was that the structure of DNA suggested the basic mechanism of its replication.

HHMI Video: Great Discoveries in Science: The Double Helix

Access the complete textbook online! The Campbell eText includes powerful interactive and customization functions, such as instructor and student note-taking, highlighting, bookmarking, search, and links to glossary terms.

Succeed with MasteringBiology

MasteringBiology improves results by engaging students before, during, and after class.



Before Class

Dynamic Study Modules provide students with multiple sets of questions with extensive feedback so that they can **test, learn, and retest** until they achieve mastery of the textbook material.

NEW! Get Ready for This Chapter quizzes help students review content they need to understand from previous chapters (see p. 10).

Pre-Class Reading Quizzes help students pinpoint concepts that they understand and concepts that they need to review.

During Class

NEW! For ideas for in-class activities, see the **Ready-to-Go Teaching Modules** (see p. 9).

After Class

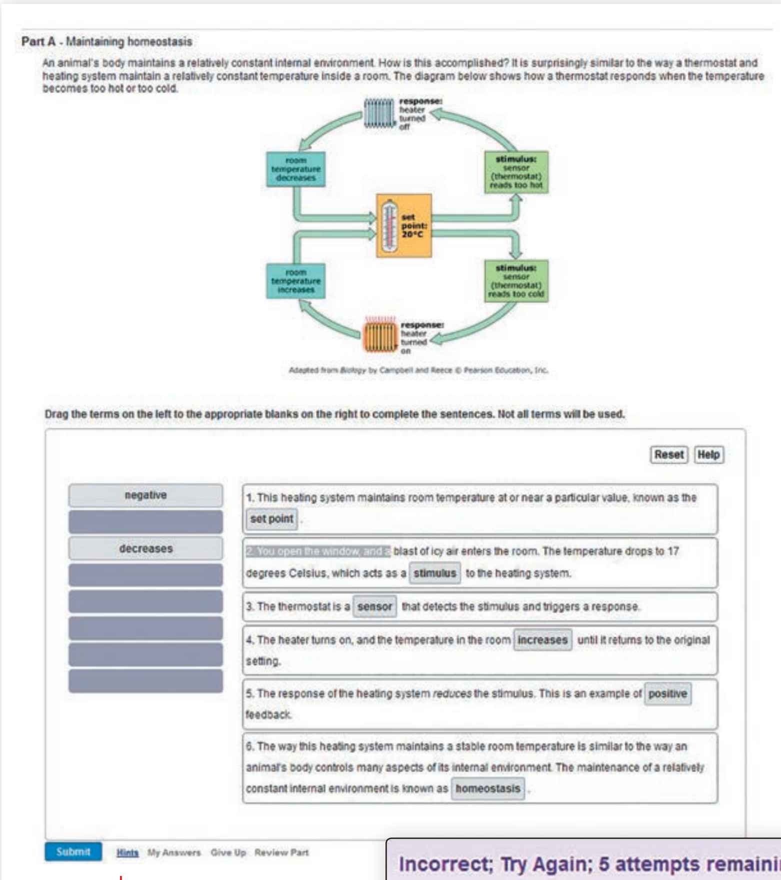
Hundreds of self-paced tutorials and coaching activities provide students with individualized coaching with specific hints and feedback on the toughest topics in the course.

Optional Adaptive Follow-up Assignments are based on each student's performance on the original MasteringBiology assignment and provide additional questions and activities tailored to each student's needs.

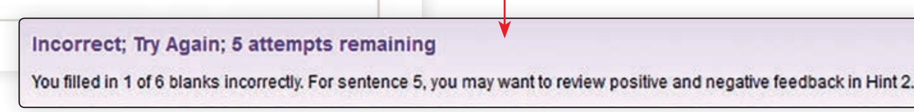
Learning Catalytics™ allows students to use their smartphone, tablet, or laptop to respond individually or in groups to questions in class. Visit **learningcatalytics.com** to learn more.

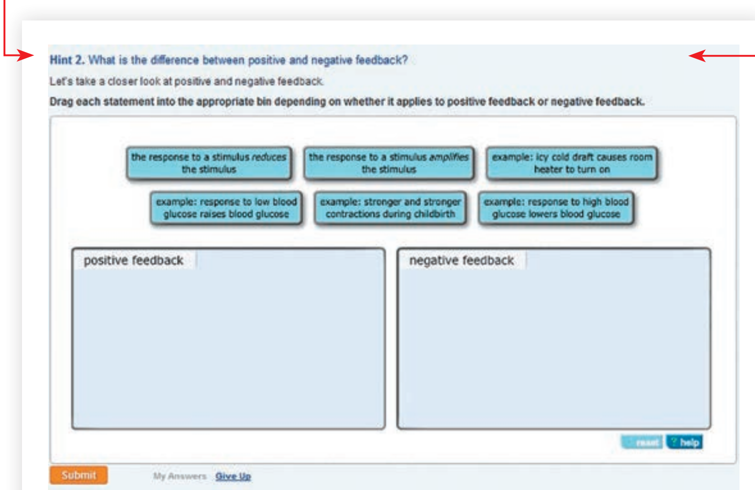
Personalized Coaching in MasteringBiology

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.

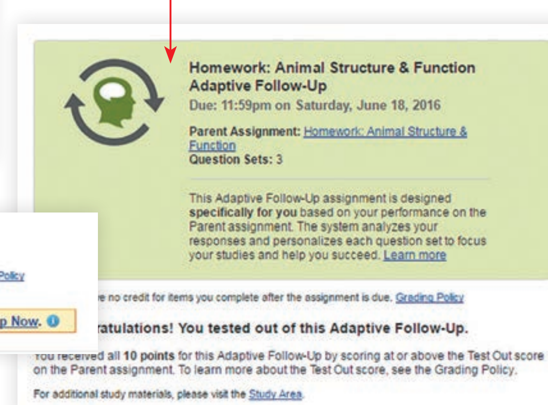


1. If a student gets stuck...
2. Specific wrong-answer **feedback** appears in the purple feedback box.

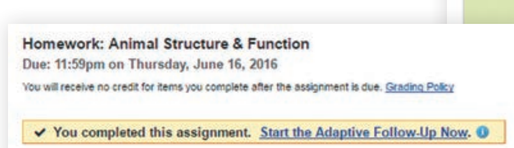




3. **Hints** coach students to the correct response.
4. Optional **Adaptive Follow-Up Assignments** are based on the original homework assignment and provide additional coaching and practice as needed.

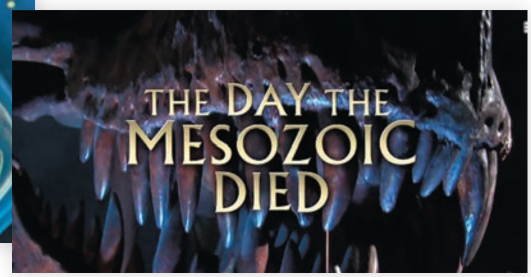


Question sets in the Adaptive Follow-Up Assignments **continuously adapt** to each student's needs, making efficient use of study time.



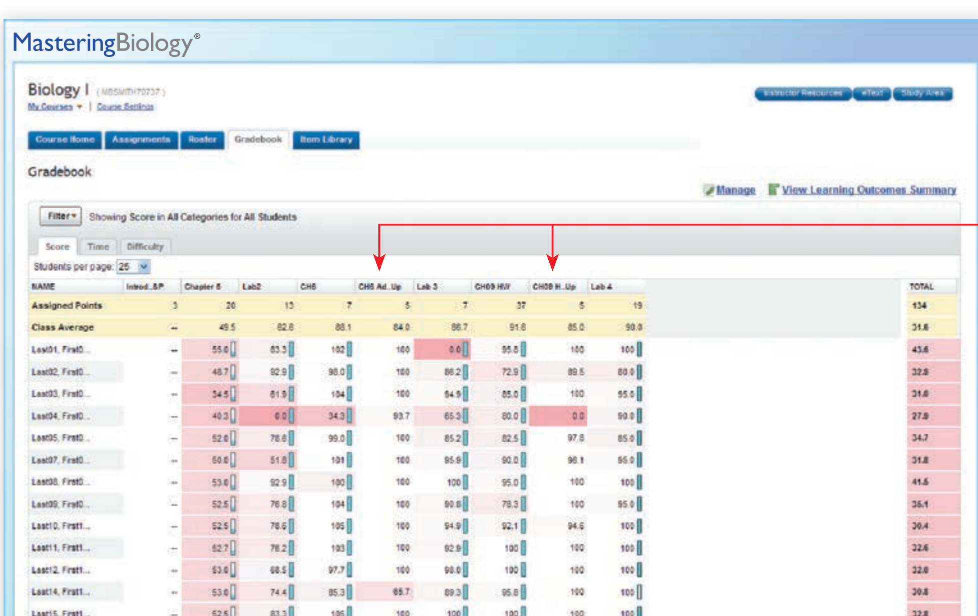
MasteringBiology offers thousands of tutorials, activities, and questions that can be assigned as homework. A few examples are shown below.

BioFlix Tutorials use 3-D, movie-quality animations and coaching exercises to help students master tough topics outside of class. Animations are also available in the Study Area and eText, and can be shown in class.



EXPANDED! HHMI BioInteractive Short Films, documentary-quality movies from the Howard Hughes Medical Institute, engage students in topics from the discovery of the double helix to evolution, with assignable questions.

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.



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.

Student and Lab Supplements

For Students

Spanish Glossary for Biology

By Laura P. Zanello, University of California, Riverside

978-0-32183498-0 / 0-321-83498-4

This resource provides definitions in Spanish for the glossary terms.

Into The Jungle: Great Adventures in the Search for Evolution

by Sean B. Carroll, University of Wisconsin, Madison

978-0-32155671-4 / 0-321-55671-2

These nine short tales vividly depict key discoveries in evolutionary biology and the excitement of the scientific process.

Get Ready for Biology

by Lori K. Garrett, Parkland College

978-0-32150057-1 / 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. Also available in MasteringBiology.

A Short Guide to Writing About Biology, Ninth Edition

by Jan A. Pechenik, Tufts University

978-1-292-12083-6 / 1-292-12083-5

This best-selling writing guide teaches students to think as biologists and to express ideas clearly and concisely through their writing.

For Lab

Investigating Biology Laboratory Manual, Eighth Edition

by Judith Giles Morgan, Emory University, and
M. Eloise Brown Carter, Oxford College of Emory University

978-1-292-06130-6 / 1-292-06130-8

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. The lab manual encourages students to participate in the process of science and develop creative and critical-reasoning skills.

Preparation Guide for Investigating Biology

Contains materials lists, suggested vendors, instructions for preparing solutions and constructing materials, schedules for planning advance preparation, and more. Available for downloading through the "Instructor Resources" area of MasteringBiology.

MasteringBiology® Virtual Labs is an online environment that promotes critical thinking skills using virtual experiments and explorations that can supplement or substitute for existing wet labs in microscopy, molecular biology, genetics, ecology, and systematics.

Instructor Resources

Instructor's Resource Materials for Biology, Eleventh Edition

The Instructor's Resource Materials consist of multiple sets of assets for each chapter. Specific features include:

- Editable figures (art and photos) and tables from the text in PowerPoint®
- Prepared PowerPoint Lecture Presentations for each chapter with lecture notes, editable figures (art and photos), tables
- JPEG images, including labeled and unlabeled art, photos from the text, and extra photos
- Clicker Questions in PowerPoint
- Test Bank questions in TestGen® software and Microsoft® Word
- Digital Transparencies

The Instructor Resources area of MasteringBiology includes:

- **NEW!** Ready-to-Go Teaching Modules help instructors efficiently make use of the available teaching tools for the toughest topics. Before-class assignments, in-class activities, and after-class assignments are provided for ease of use. Instructors can incorporate active learning into their course with the suggested activity ideas and clicker questions or Learning Catalytics questions.
- Editable figures (art and photos) and tables from the text in PowerPoint
- Prepared PowerPoint Lecture Presentations for each chapter with lecture notes, editable figures (art and photos), tables, and links to animations and videos
- JPEG images, including labeled and unlabeled art, photos from the text, and extra photos
- Clicker Questions in PowerPoint
- 400 instructor animations and videos, including BioFlix 3-D animations and ABC News Videos
- Test Bank (in Word and TestGen)
- Digital Transparencies
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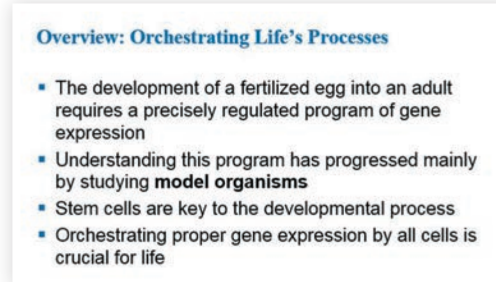

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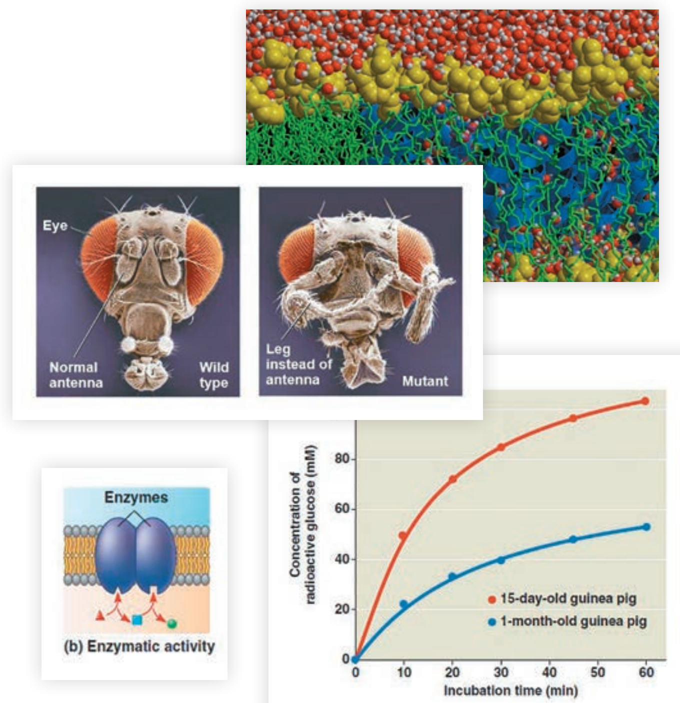

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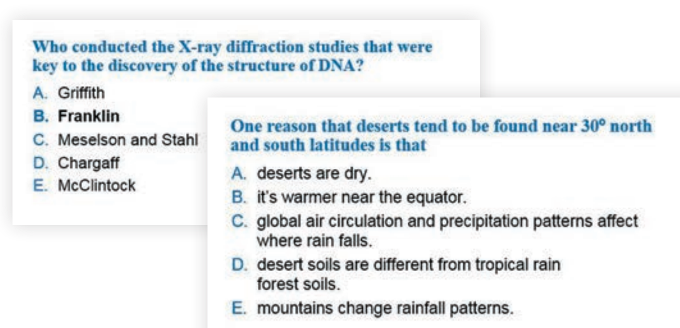

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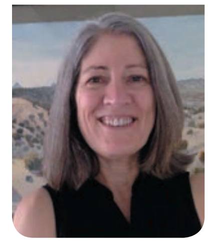

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Interviews with prominent scientists have been a hallmark of *CAMPBELL BIOLOGY* since its inception, and conducting these interviews was again one of the great pleasures of revising the book. To open the eight units of this edition, we are proud to include interviews with Lovell Jones, Elba Serrano, Shirley Tilghman, Jack Szostak, Nancy Moran, Philip Benfey, Harald zur Hausen, and Tracy Langkilde.

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The value of *CAMPBELL 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 22. We are also grateful to Kathleen Fitzpatrick and Nicole Tunbridge (PowerPoint® Lecture Presentations); Roberta Batorsky, Douglas Darnowski, James Langeland, and David Knochel (Clicker Questions); Sonish Azam, Kevin Friesen, Murty Kambhampati, Janet Lanza, Ford Lux, Chris Romero, Ruth Sporers, and David Knochel (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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