

AP<sup>®</sup> EDITION  
CAMPBELL  
BIOLOGY IN FOCUS

SECOND EDITION



URRY • CAIN • WASSERMAN • MINORSKY • REECE

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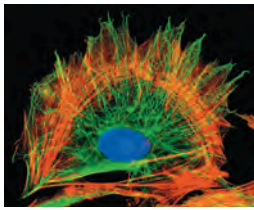
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# Brief Contents



- 1 Introduction: Evolution and the Foundations of Biology 2

## UNIT 1 Chemistry and Cells

- 2 The Chemical Context of Life 22
- 3 Carbon and the Molecular Diversity of Life 43
- 4 A Tour of the Cell 72
- 5 Membrane Transport and Cell Signaling 100
- 6 An Introduction to Metabolism 122
- 7 Cellular Respiration and Fermentation 141
- 8 Photosynthesis 161
- 9 The Cell Cycle 182

## UNIT 2 Genetics

- 10 Meiosis and Sexual Life Cycles 200
- 11 Mendel and the Gene Idea 214
- 12 The Chromosomal Basis of Inheritance 236
- 13 The Molecular Basis of Inheritance 253
- 14 Gene Expression: From Gene to Protein 278
- 15 Regulation of Gene Expression 303
- 16 Development, Stem Cells, and Cancer 321
- 17 Viruses 342
- 18 Genomes and Their Evolution 357

## UNIT 3 Evolution

- 19 Descent with Modification 379
- 20 Phylogeny 395
- 21 The Evolution of Populations 413
- 22 The Origin of Species 434
- 23 Broad Patterns of Evolution 452

## UNIT 4 The Evolutionary History of Life

- 24 Early Life and the Diversification of Prokaryotes 474
- 25 The Origin and Diversification of Eukaryotes 497
- 26 The Colonization of Land 520
- 27 The Rise of Animal Diversity 545

## UNIT 5 Plant Form and Function

- 28 Plant Structure and Growth 575
- 29 Resource Acquisition, Nutrition, and Transport in Vascular Plants 593
- 30 Reproduction and Domestication of Flowering Plants 619
- 31 Plant Responses to Internal and External Signals 639

## UNIT 6 Animal Form and Function

- 32 The Internal Environment of Animals: Organization and Regulation 663
- 33 Animal Nutrition 688
- 34 Circulation and Gas Exchange 706
- 35 The Immune System 733
- 36 Reproduction and Development 751
- 37 Neurons, Synapses, and Signaling 772
- 38 Nervous and Sensory Systems 790
- 39 Motor Mechanisms and Behavior 814

## UNIT 7 Ecology

- 40 Population Ecology and the Distribution of Organisms 840
- 41 Species Interactions 867
- 42 Ecosystems and Energy 886
- 43 Global Ecology and Conservation Biology 906

# Preface

The snow leopard (*Panthera uncia*) that peers intently from the cover of this book has a suite of evolutionary adaptations that enable it to spot, track, and ambush its prey. The snow leopard's keen eye is a metaphor for our goal in writing this text: to focus with high intensity on the core concepts and scientific skills AP Biology students need to succeed.

The current explosion of biological information, while exhilarating in its scope, poses a significant challenge—how best to teach a subject that is constantly expanding its boundaries. In particular, instructors have become increasingly concerned that their students are overwhelmed by a growing volume of detail and are losing sight of the big ideas in biology. In response to this challenge, various groups of biologists have initiated efforts to refine and in some cases redesign the introductory college biology course. In particular, the report *Vision and Change in Undergraduate Biology Education: A Call to Action*<sup>\*</sup> advocates focusing course material and instruction on key ideas while transforming the classroom through active learning and scientific inquiry. Similarly, the College Board's Advanced Placement program, in conjunction with the National Science Foundation, undertook a revision of the AP Biology program. In 2011, the College Board published the new AP Biology Framework, which ensures the right breadth of content coverage so teachers and students have time to focus on developing and practicing the scientific inquiry and reasoning skills so crucial to future careers in science.

We were inspired by these ongoing changes in biology education to write the first edition of *CAMPBELL BIOLOGY IN FOCUS*, AP Edition, a new, shorter textbook that was received with widespread excitement by instructors. Guided by their feedback, we honed the Second Edition so that it does an even better job of helping students explore the key questions, approaches, and ideas of modern biology.

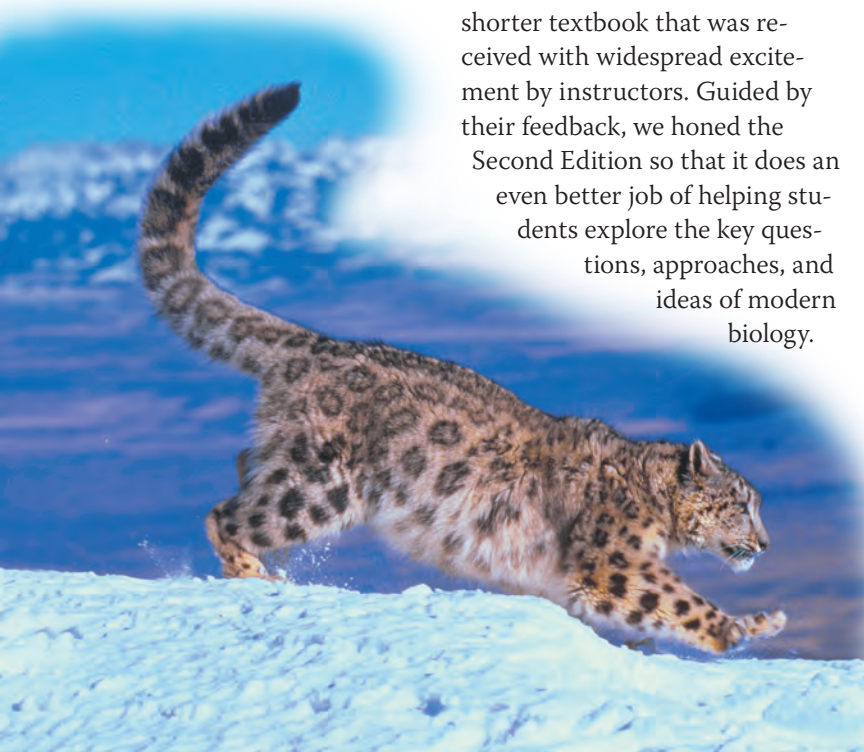
## New to This Edition

Here we briefly describe the new features that we have developed for the Second Edition, but we invite you to explore pages xvi–xxix for more information and examples.

### New in the Text

- The impact of **genomics** across biology is explored throughout the Second Edition with examples that reveal how our ability to rapidly sequence DNA and proteins on a massive scale is transforming all areas of biology, from molecular and cell biology to phylogenetics, physiology, and ecology. Illustrative examples are distributed throughout the text.
- The Second Edition provides increased coverage of the urgent issue of **global climate change**. Starting with a new figure (Figure 1.11) and discussion in Chapter 1 and concluding with significantly expanded material on causes and effects of climate change in Chapter 43, including a new Make Connections Figure (Figure 43.28), the text explores the impact of climate change at all levels of the biological hierarchy.
- **AP<sup>®</sup> Icons** throughout the text highlight connections to the College Board's Curriculum Framework for AP Biology.
- **AP<sup>®</sup> Big Ideas** included at the beginning of each chapter help students link the chapter concepts to the Framework's four Big Ideas.
- **AP<sup>®</sup> Make Connections Figures** pull together content from different chapters, providing a visual representation of “big picture” relationships, helping students to connect and relate knowledge across domains.
- **Interpret the Data Questions** throughout the text engage students in scientific inquiry by asking them to analyze data presented in a graph, figure, or table. The Interpret the Data Questions can be assigned and automatically graded in MasteringBiology.<sup>®</sup>
- **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.
- Scannable QR codes and URLs at the end of every chapter give students quick access to **Vocabulary Self-Quizzes** and **Practice Tests** that students can use on a smartphone, tablet, or computer.
- Detailed information about the organization of the text and new content in the Second Edition is provided on pages vi–ix, following this Preface.

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## New in MasteringBiology®

- **Ready-to-Go Teaching Modules** in the Instructor Resources area help instructors efficiently make use of the available teaching tools for many key topics. Before-class assignments, in-class activities, and after-class assignments are provided for ease of use.
- **AP® Exam-style Practice Questions** test student mastery of the Framework’s Learning Objectives and their companion Science Practices. These questions are assignable in MasteringBiology.
- **MasteringBiology Tutorials** extend the power of MasteringBiology:
  - **Interpret the Data Questions** ask students to analyze a graph, figure, or table.
  - **Solve It Tutorials** engage students in a multistep investigation of a “mystery” or open question in which they must analyze real data.
  - **HHMI 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.

## Our Guiding Principles

Our key objective in creating *CAMPBELL BIOLOGY IN FOCUS*, AP Edition, was to produce a shorter text by streamlining selected material, while emphasizing conceptual understanding and maintaining clarity, proper pacing, and rigor. Here, briefly, are the five guiding principles of our approach:

### 1. Focus on Core Concepts

We developed this text to help AP students master the fundamental content and scientific skills necessary for success on the AP Exam. In structuring the text, we were guided by discussions with biology professors across the country, analysis of hundreds of syllabi, study of the debates in the literature of scientific pedagogy, and our experience as instructors at a range of institutions. The result is a briefer book, crafted to address the AP Biology curriculum, that informs, engages, and inspires.

### 2. Establish Evolution as the Foundation of Biology

Evolution is the central theme of all biology, and it is the core theme of this text, as exemplified by the various ways that evolution is integrated into the text:

- Every chapter explicitly addresses the topic of evolution through an **Evolution section** that leads students to consider the material in the context of natural selection and adaptation.
- Each Chapter Review includes a **Connect to Big Idea 1 Question** that asks students to think critically about how an aspect of the chapter relates to evolution.

- Evolution is the unifying idea of **Chapter 1, Introduction: Evolution and the Foundations of Biology**, which devotes Concept 1.2 to the core theme of evolution, providing students with a foundation in evolution early in their study.
- Following the in-depth coverage of **evolutionary mechanisms in Unit 3**, evolution also provides the storyline for the novel approach to presenting biological diversity in **Unit 4, The Evolutionary History of Life**. Focusing on landmark events in the history of life, Unit 4 highlights how key adaptations arose within groups of organisms and how evolutionary events led to today’s diversity of life.

### 3. Engage Students in Scientific Thinking

Helping students learn to “think like a scientist” is a primary goal of AP Biology. Students need to understand how to formulate and test hypotheses, design experiments, and interpret data. Scientific thinking and data interpretation skills top lists of learning outcomes and foundational skills desired for students entering higher-level courses. The Second Edition of *CAMPBELL BIOLOGY IN FOCUS*, AP Edition, meets this need in several ways:

- **Scientific Skills Exercises** in every chapter are correlated to the Framework’s Science Practices. Using real data, students will build skills, including data analysis, graphing, experimental design, and math skills. These exercises can also be assigned and automatically graded in MasteringBiology.
- New **Interpret the Data Questions** ask students to analyze a graph, figure, or table. These questions are also assignable in MasteringBiology.
- **Scientific Inquiry Questions** in the end-of-chapter material give students further opportunity to master Science Practices.
- **Inquiry Figures** and **Research Method Figures** reveal *how* we know *what* we know and model the process of scientific inquiry.

### 4. Use Outstanding Pedagogy to Aid Learning

*CAMPBELL BIOLOGY IN FOCUS*, AP Edition, builds on our hallmarks of clear and engaging text and superior pedagogy to promote student learning:

- In each chapter, a framework of carefully selected **Key Concepts** helps students distinguish the “forest” from the “trees.” These **Key Concepts** focus on the **Big Ideas** and provide a context for the supporting details.
- Questions throughout the text catalyze learning by encouraging students to **actively engage with and synthesize key material**. Active learning questions include Concept Check Questions, Make Connections Questions, What If? Questions, Figure Legend Questions, Draw It Exercises, Summary Questions, and the new Synthesize Your Knowledge and Interpret the Data Questions.

- **Test Your Understanding Questions** at the end of each chapter are presented in standard **AP Exam format** and are organized into three levels based on **Bloom's Taxonomy**.

## 5. Create Art and Animations That Teach

Biology is a visual science, and students learn from the art as much as the text. Therefore, we have developed our art and animations to teach with clarity and focus. Here are some of the ways our art and animations serve as superior teaching tools:

- The new **Make Connections Figures** help students make important connections across units, across levels of organization, and across the **Framework's Big Ideas**.
- Each unit in *CAMPBELL BIOLOGY IN FOCUS*, AP Edition, opens with a **visual preview** that tells the story of the chapters' contents, showing how the material in the unit fits into a larger context.
- **BioFlix® 3-D Animations** help students visualize biology with movie-quality animations that can be shown in class and reviewed by students in the Study Area. **BioFlix Tutorials** use the animations as a jumping-off point for MasteringBiology coaching assignments with feedback.
- By integrating text, art, and photos, **Exploring Figures** help students access information efficiently.
- **Guided Tour Figures** use descriptions in blue type to walk students through complex figures as an instructor would, pointing out key structures, functions, and steps of processes.
- Because text and illustrations are equally important for learning biology, the **page layouts** are carefully designed to place figures together with their discussions in the text.
- **PowerPoint®** slides are painstakingly developed for optimum presentation in classrooms, with enlarged editable labels, art broken into steps, and links to animations and videos.
- Many **Tutorials** and **Activities** in MasteringBiology integrate art from the text, providing a unified learning experience.

## MasteringBiology®

**MasteringBiology** is the most widely used online assessment and tutorial program for biology, providing an extensive library of homework assignments that are graded automatically. **Self-paced tutorials provide individualized coaching with specific hints and feedback** on the most difficult topics in the course. In addition to the new tutorials already mentioned, MasteringBiology includes hundreds of online exercises that can be assigned. For example:

- The **Scientific Skills Exercises** from the text can be assigned and automatically graded in MasteringBiology.
- **BioFlix® Tutorials** use 3-D animations to help students master tough topics.
- **Make Connections Tutorials** help students connect what they are learning in one chapter with material they have learned in another chapter.

- **BLAST Data Analysis Tutorials** teach students how to work with real data from the BLAST database.
- **Experimental Inquiry Tutorials** allow students to replicate a classic biology experiment and learn the conceptual aspects of experimental design.
- **Reading Quiz Questions** and approximately 3,000 **Test Bank Questions** are available for assignment.
- **AP® Exam-style Practice Questions** that test student mastery of the Framework's Learning Objectives and their companion Science Practices are assignable in MasteringBiology.
- Optional **Adaptive Follow-up Assignments** are based on each student's performance on the original MasteringBiology assignment and provide additional coaching and practice.

Every assignment is automatically graded and entered into a **gradebook**. Instructors can check the gradebook to see what topics students are struggling with and then address those topics in class.

MasteringBiology and the text work together to provide an unparalleled learning experience. For more information about MasteringBiology and to explore additional resources it provides, see pages xxiv–xxix.

## AP Advisory Group

Many expert reviewers (listed in the college edition) contributed to this textbook. In addition, an Advisory Group of experienced teachers provided valuable advice for the AP Edition:

Jean DeSaix, *University of North Carolina, Chapel Hill*  
 Fred Holtzclaw, *The Webb School of Knoxville*  
 Theresa Holtzclaw, *The Webb School of Knoxville*  
 Mike Judge, *Sacred Heart Schools*  
 Rachel Kalish, *San Rafael High School*  
 Jack Kay, *Iolani School*  
 Nancy Monson, *West Linn High School*  
 Nancy Ramos, *Northside Health Careers High School*  
 Peggy O'Neill Skinner, *The Bush School*  
 Diane Sweeney, *Sacred Heart Schools*  
 Brad Williamson, *University of Kansas*

Our overall goal in developing and revising this text was to assist instructors and students in their exploration of biology by emphasizing essential content and skills while maintaining rigor. Although this Second Edition is now completed, we recognize that *CAMPBELL BIOLOGY IN FOCUS*, AP Edition, like its subject, will evolve. As its authors, we are eager to hear your thoughts, questions, comments, and suggestions for improvement. We are counting on you—our teaching colleagues and all students using this book—to provide us with this feedback, and we encourage you to contact us by e-mail:

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# Organization and New Content

*CAMPBELL BIOLOGY IN FOCUS*, AP Edition, is organized into an introductory chapter and seven units that cover core concepts of biology at a thoughtful pace. When we adapted *CAMPBELL BIOLOGY* to write the first edition of this text, we made informed choices about how to design each chapter to meet the needs of teachers and students. In some chapters, we retained most of the material; in other chapters, we pruned material; and in still others, we completely reconfigured the material. In creating the Second Edition, we solicited feedback from reviewers and used their thoughtful critiques to further fine-tune the content and pedagogy. We have also updated the content wherever appropriate, and in a few cases reintroduced material. Here, we present synopses of the seven units and highlight the major revisions made to the Second Edition of *CAMPBELL BIOLOGY IN FOCUS*, AP Edition.

## CHAPTER 1 Introduction: Evolution and the Foundations of Biology

Chapter 1 introduces the **five biological themes** woven throughout the text:

the core theme of **Evolution**, together with **Organization, Information, Energy and Matter**, and **Interactions**.

Chapter 1 also explores the process of scientific inquiry through a case study describing experiments on the evolution of coat color in the beach mouse. The chapter concludes with a discussion of the importance of diversity within the scientific community.

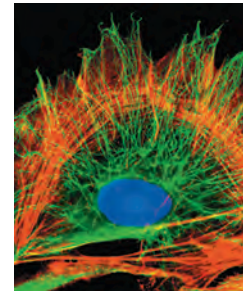
In the Second Edition, a new figure (Figure 1.8) on gene expression uses lens cells in the eye as an example of DNA → RNA → protein and introduces the terms transcription and translation. This new figure and text equip students from the outset with an understanding of how gene sequences determine an organism's characteristics. New text and a new photo (Figure 1.11) inform students about the effects of climate change in general, and global warming in particular, on species survival and diversity. Concept 1.3 has been thoroughly revised to more realistically reflect the process of science. A new section has been added on the Flexibility of the Scientific Process, accompanied by a new Figure 1.19 that depicts the more realistic and complex process of science. The text now discusses searching the scientific literature, and a new question in the Chapter Review asks students to use PubMed.



## UNIT 1 Chemistry and Cells

A succinct, two-chapter treatment of basic chemistry (Chapters 2 and 3) provides the foundation for this unit focused on cell structure and function. The related topics of cell membranes and cell signaling are consolidated into one chapter (Chapter 5). Due to the importance of the fundamental concepts in Units 1 and 2, much of the material in the rest of these two units has been retained from *CAMPBELL BIOLOGY*.

For the Second Edition, a new table has been added to Chapter 2 detailing the elements in the human body, with an associated Interpret the Data question. Chapter 3 includes a new section on isomers, with an accompanying figure (Figure 3.5), and ends with a new Concept 3.7 that includes cutting-edge coverage of DNA sequencing and introduces genomics and proteomics, as well as bioinformatics. A new Make Connections Figure (Figure 3.30) entitled “Contributions of Genomics and Proteomics to Biology” provides an overview of areas in which genomics and proteomics have had significant impacts—including evolution, conservation biology, paleontology, medical science, and species interactions—with the aim of inspiring and motivating students. A striking photo of thermophilic cyanobacteria has been added to Figure 6.16 on environmental factors affecting enzyme activity. In Chapter 7, a computer model of ATP synthase has been added to Figure 7.13. The icon for this enzyme in Chapters 7 and 8 has been re-drawn to more closely represent its structure. A new Make Connections Figure (Figure 8.20, “The Working Cell”) integrates all the cellular activities covered in Chapters 3–8 in the context of a single working plant cell.



## UNIT 2 Genetics

Topics in this unit include meiosis and classical genetics as well as the chromosomal and molecular basis for genetics and gene expression (Chapters 10–14). We also include a chapter on the regulation of gene expression (Chapter 15) and one on the role of gene regulation in development, stem cells, and cancer



(Chapter 16). Methods in biotechnology are integrated into appropriate chapters. The stand-alone chapter on viruses (Chapter 17) can be taught at any point in the course. The final chapter in the unit, on genome evolution (Chapter 18), provides both a capstone for the study of genetics and a bridge to the evolution unit.

Chapter 10 of the Second Edition includes a new section on “Crossing Over and Synapsis During Prophase I” that explains the events of prophase I in more detail, supported by new Figure 10.9, which clearly shows and describes these events. In Chapter 11, to incorporate more molecular biology into the discussion of Mendelian genetics, Figure 11.4 on alleles has been enhanced and a new Figure 11.16 on sickle-cell disease has been added. Chapter 13 includes new text and two new figures (Figures 13.29 and 13.30) covering advances in sequencing technology. Also in this chapter, a new section, including new Figure 13.31, describes gene editing using the CRISPR-Cas9 system. In Chapter 15, the section on noncoding RNAs has been updated, and Figure 15.14 on *in situ* hybridization has been expanded and enhanced to help students understand this important technique. Chapter 16 includes a new Inquiry Figure (Figure 16.16) on induced pluripotent stem cells (iPS cells). Material on embryonic stem cells and induced pluripotent stem cells has been significantly updated. A new Make Connections Figure (Figure 16.21), “Genomics, Cell Signaling, and Cancer,” illustrates recent research on subtypes of breast cancer, connecting content that students have learned in Chapters 5, 9, and 16. It also addresses treatment for one subtype of breast cancer as an example. In Chapter 17, the discussion of the importance of cell-surface proteins in determining host range has been enhanced. A new figure (Figure 17.9) presents the example of the receptor and co-receptor proteins for HIV. Coverage of the CRISPR system, as a bacterial “immune” system, has been added, supported by new Figure 17.6. Coverage of recent epidemics has been inserted (Ebola) or updated (H5N1). Chapter 18 has been significantly updated to reflect recent sequencing advances, including a discussion of the results of the ENCODE project, information on the bonobo genome, and use of high-throughput techniques to address the problem of cancer. Regarding protein structure, the discussion of BLAST searches has been enhanced, and computer models of lysozyme and  $\alpha$ -lactalbumin have been added to support the discussion of the evolution of genes with novel functions.

## UNIT 3 Evolution

This unit provides in-depth coverage of essential evolutionary topics, such as mechanisms of natural selection, population genetics, and speciation. Early in the unit, Chapter 20 introduces “tree thinking” to support students in interpreting phylogenetic trees and thinking about the big picture of evolution. Chapter 23 focuses on mechanisms that have influenced long-term patterns of evolutionary change. Throughout the unit, new discoveries in fields ranging from paleontology to phylogenomics highlight the interdisciplinary nature of modern biology.

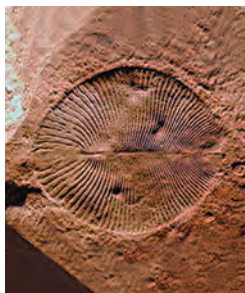


Revisions in the Second Edition aim to strengthen connections among fundamental evolutionary concepts. For example, Concept 20.5 includes new text on horizontal gene transfer among eukaryotes, reinforcing the overall discussion of how horizontal gene transfer has played an important role in the evolutionary history of life. Also in Concept 20.5, a new Scientific Skills Exercise walks students through the process of comparing and interpreting amino acid sequences to determine whether horizontal gene transfer may have occurred in certain organisms. Chapter 20 also includes more discussion of tree thinking, as well as a new figure (Figure 20.11) that distinguishes between paraphyletic and polyphyletic taxa. New material in Chapter 21 clarifies the interplay between mutation, genetic variation, and natural selection. A new Make Connections Figure (Figure 21.15, “The Sickle-Cell Allele”) integrates material from chapters across the book in exploring the sickle-cell allele and its impact from the molecular and cellular levels to the allele’s global distribution in the human population. Other changes in the unit include new examples and figures that reinforce evolutionary concepts. For example, a new introduction to Chapter 23 tells the story of the discovery of whale fossils from the Sahara Desert, striking evidence of how organisms in the past differed from organisms living today. In Chapter 22, a new figure (Figure 22.11) has been added to support the expanded text discussion of allopolyploid speciation in *Tragopogon* in the Pacific Northwest. Dates have also been revised in the text, Table 23.1 (The Geologic Record), and figures in Chapter 23 and throughout the Second Edition to reflect the International Commission on Stratigraphy 2013 revision of the Geologic Time Scale.



## UNIT 4 The Evolutionary History of Life

This unit employs a novel approach to studying the evolutionary history of biodiversity. Each chapter focuses on one or more major steps in the history of life, such as the origin of cells or the colonization of land. Likewise, the coverage of natural history and biological diversity emphasizes the evolutionary process—how factors such as the origin of key adaptations have influenced the rise and fall of different groups of organisms over time.



In the Second Edition, we have expanded our coverage of genomic and other molecular studies. Examples include a new figure (Figure 24.25) and text on the potential use and significance of CRISPR-Cas systems, a new Scientific Skills Exercise in Chapter 26 on genomic analyses of mycorrhizal and nonmycorrhizal fungi, and a new figure (Figure 27.36) and text related to evidence of gene flow between Neanderthals and modern humans. In addition, many phylogenies have been revised to reflect recent miRNA and genomic data. The unit also includes more connections to other chapters. For instance, a new Make Connections Question in Figure 24.4 asks students to apply material from Chapter 3 to explain how a membrane-like bilayer can self-assemble and form a vesicle, and a new Make Connections Figure (Figure 26.14) explores the diverse structural solutions for maximizing surface area that have evolved in cells, organ systems, and whole organisms. Other changes enhance the evolutionary storyline of the unit. For example, in Chapter 26, the chapter title, Figure 26.2, Key Concept 26.2, and text in Concepts 26.1 and 26.2 have all been revised to emphasize and explain that fungi are not closely related to plants, although they likely played a role in facilitating the colonization of land by plants, and that fungi possess their own novel adaptations for terrestrial life. Likewise, in Chapter 27, the discussion of the evolutionary impact of animals has been expanded, and new text and four new figures (Figures 27.12, 27.13, 27.30, and 27.31) on molluscs, birds, and mammals have been added. The chapter also includes expanded coverage of human evolution, including three new figures (Figures 27.34, 27.35, and 27.36). Supporting the extensive revision of Chapter 27, the number of Key Concepts in this chapter has increased from five to seven.

## UNIT 5 Plant Form and Function

The form and function of higher plants are often treated as separate topics, thereby making it difficult for students to make connections between the two. In Unit 5, plant anatomy (Chapter 28) and the acquisition and transport of resources (Chapter 29) are bridged by a discussion of how plant architecture influences resource acquisition.



Chapter 30 provides an introduction to plant reproduction and examines controversies surrounding the genetic engineering of crop plants. The final chapter (Chapter 31) explores how plants respond to environmental challenges and opportunities and how the integration of this diverse information by plant hormones influences plant growth and reproduction.

In the Second Edition, a new micrograph of parenchyma cells and new information relating to root hair density, length, and function have been added to Chapter 28. In Chapter 29, a new Make Connections Figure (Figure 29.10, “Mutualism Across Kingdoms and Domains”) enables students to integrate what they have learned about plant mutualisms with other examples across the natural realm. A new Inquiry Figure (Figure 29.11) examines the metagenomics of soil bacteria. A discussion on mycorrhizae and plant evolution has also been added in Chapter 29. In Chapter 30, the angiosperm life cycle figure and related text are more closely integrated, with all the numbered steps now identified in the text. Also, a discussion of coevolution of flowers and pollinators has been added. The in-depth discussion of the development from seed to flowering plant has been expanded to include the transition from vegetative growth to reproductive growth, making a connection to what students learned about development in Chapter 28. In addition, the depictions of the structure of maize root systems and raspberry fruit development have been improved. The information in Concept 31.4 concerning plant defenses against disease has been thoroughly revised and updated to reflect rapid advances in our understanding of plant immunity. Updated information relates to the two types of plant immunity: PAMP-triggered immunity and effector-triggered immunity. New Figure 31.23 highlights examples of physical, chemical, and behavioral defenses against herbivory.

## UNIT 6 Animal Form and Function

In this unit, a focused exploration of animal physiology and anatomy applies a comparative approach to a limited set of examples to bring out fundamental principles and conserved mechanisms. Students are first introduced to the closely related topics of endocrine signaling and homeostasis in an integrative introductory chapter (Chapter 32). Additional melding of interconnected material is reflected in chapters that combine treatment of circulation and gas exchange, reproduction and development, neurons and nervous systems, and motor mechanisms and behavior.

In the Second Edition, we re-envisioned the introductory chapter of this unit (Chapter 32), as conveyed by its new title, “The Internal Environment of Animals: Organization and Regulation.” Endocrine signaling and the integration of nervous and endocrine system function now precede the introduction of homeostasis and the consideration of the two major examples: thermoregulation and osmoregulation. Figures on simple hormone and neurohormone pathways (Figures 32.6 and 32.7) and hormone cascades (Figure 32.8) have been substantially revised to provide clear and consistent presentation of hormone function and of the regulation of hormone secretion. The presentation of the mechanism for filtrate processing in the kidney has been substantially revised, with a single figure (Figure 32.22) in place of two and with the accompanying numbered text walking students through a carefully paced tour of the nephron. In this chapter and throughout the unit, figures illustrating homeostatic regulation have been revised to highlight the common principles and features of homeostatic mechanisms. The unit includes two new Make Connections Figures: Figure 32.3 illustrates shared and divergent solutions to fundamental challenges common to plants and animals, and Figure 37.8, on ion movements and gradients, explores the fundamental role of concentration gradients in life processes ranging from osmoregulation and gas exchange to locomotion. Also in Chapter 37, the treatments of synaptic signaling, summation, modulating signaling, and neurotransmitters have been revised to highlight key ideas, ensuring appropriate pacing and helping students focus on fundamental principles rather than memorization. Updates in Unit 6 informed by current research include new Figure 33.15 and text highlighting the explosion of interest in and understanding of the microbiome. Chapter 38 opens with a new photograph and introductory text that showcase the “brainbow” technique for labeling individual brain neurons.



## UNIT 7 Ecology

This unit applies the key themes of the text, including evolution, interactions, and energy and matter, to help students learn ecological principles. Chapter 40 integrates material on population growth and Earth’s environment, highlighting the importance of both biological and physical processes in determining where species are found. Chapter 43 ends the book with a focus on global ecology and conservation biology. This chapter illustrates the threats to all species from increased human population growth and resource use. It begins with local factors that threaten individual species and ends with global factors that alter ecosystems, landscapes, and biomes.

The increased emphasis throughout the Second Edition on global climate change is capped by new discussions and figures in Unit 7. Chapter 43, for example, includes a new figure on the greenhouse effect (Figure 43.26) as well as new text examining aspects of climate change other than global warming. The chapter explores documented examples of the impacts to organisms in a new section on “Biological Effects of Climate Change” and a new Make Connections Figure (Figure 43.28, “Climate Change Has Effects at All Levels of Biological Organization”). Throughout the unit, the presentation of several other key topics has been revised. For example, in Chapter 40, the discussion of each of the following concepts or models was revised to standardize and clarify their meaning: life tables, per capita population growth, the per capita rate of increase ( $r$ ), exponential population growth, and logistic population growth. The discussion of species interactions in Chapter 41 was modified to group species interactions according to whether they have positive (+) or negative (–) effects on survival and reproduction; as a result, there is a new section on “Exploitation” (which includes predation, herbivory, and parasitism) and another new section on “Positive Interactions” (which includes mutualism and commensalism). Material throughout Chapter 42 was revised to reinforce the fact that energy flows through ecosystems, whereas chemical elements cycle within ecosystems. New Figure Legend Questions give students practice in actively interpreting results; see, for example, the new questions with Figure 43.22 (biological magnification of PCBs) and Figure 43.31 (a new figure on per capita ecological footprints). The unit also includes a new Make Connections Figure (Figure 42.18, “The Working Ecosystem”) that ties together population, community, and ecosystem processes in the arctic tundra.



# AP Biology Curriculum Framework

## Correlation to the AP Biology Curriculum Framework

This chart correlates the College Board’s Advanced Placement Biology Curriculum Framework to the corresponding chapters and Key Concept numbers in *CAMPBELL BIOLOGY IN FOCUS*, AP Edition. A complete correlation that includes all levels of the Framework and specific textbook page numbers can be found at [PearsonSchool.com/AdvancedCorrelations](http://PearsonSchool.com/AdvancedCorrelations).

<b>Big Idea 1: The process of evolution drives the diversity and unity of life.</b>	
<b>Enduring understanding 1.A:</b> Change in the genetic makeup of a population over time is evolution.	<b>Key Concepts:</b>
1.A.1: Natural selection is a major mechanism of evolution. SP 1.5, 2.2, 5.3	1.1, 1.2, 19.1, 19.2, 19.3, 21.1, 21.3, 21.4, 23.4, 31.4, 32.5
1.A.2: Natural selection acts on phenotypic variations in populations. SP 5.3, 7.1	1.1, 1.2, 20.1, 20.2, 21.2, 21.3, 21.4, 37.3, 39.6
1.A.3: Evolutionary change is also driven by random processes. SP 1.4, 2.1, 4.1, 6.4	1.2, 19.3, 21.2, 22.4
1.A.4: Biological evolution is supported by scientific evidence from many disciplines, including mathematics. SP 5.3, 5.2, 4.2, 7.1, 1.1, 2.1	1.2, 19.1, 21.1, 21.2, 21.3, 21.4, 24.1, 27.1, 27.2
<b>Enduring understanding 1.B:</b> Organisms are linked by lines of descent from common ancestry.	<b>Key Concepts:</b>
1.B.1: Organisms share many conserved core processes and features that evolved and are widely distributed among organisms today. SP 3.1, 7.2, 6.1	1.2, 4.5, 5.1, 20.1, 20.2, 20.3, 20.4, 20.5, 21.1, 23.4, 26.2, 26.4, 26.5, 27.1, 27.2, 27.3, 27.4, 27.5, 27.6, 27.7, 32.2, 33.4, 39.6
1.B.2: Phylogenetic trees and cladograms are graphical representations (models) of evolutionary history that can be tested. SP 3.1, 5.3, 1.1	1.2, 19.2, 19.3, 20.1, 20.2, 20.3, 20.4, 20.5, 22.1, 22.4, 24.4, 25.3, 26.2, 26.3, 27.2, 27.3, 27.4, 27.5, 27.6, 27.7
<b>Enduring understanding 1.C:</b> Life continues to evolve within a changing environment.	<b>Key Concepts:</b>
1.C.1: Speciation and extinction have occurred throughout the Earth’s history. SP 5.1, 4.2	22.1, 22.4, 23.1, 23.2, 23.3, 26.1, 26.2, 43.1, 43.2
1.C.2: Speciation may occur when two populations become reproductively isolated from each other. SP 6.4, 4.1, 7.2	22.1, 22.2, 22.3, 40.3, 40.6
1.C.3: Populations of organisms continue to evolve. SP 1.2, 5.3	1.2, 2.1, 19.1, 20.5, 21.2, 22.2, 22.4, 23.3, 23.4, 25.1, 25.2, 27.1, 27.2, 27.3, 27.4, 27.5, 27.6, 32.2, 40.6
<b>Enduring understanding 1.D:</b> The origin of living systems is explained by natural processes.	<b>Key Concepts:</b>
1.D.1: There are several hypotheses about the natural origin of life on Earth, each with supporting scientific evidence. SP 1.2, 3.3, 6.3, 6.5, 4.4	19.1, 23.1, 24.1, 24.2
1.D.2: Scientific evidence from many different disciplines supports models of the origin of life. SP 4.1	19.1, 23.1, 24.1, 24.2, 26.1

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<b>Big Idea 2: Biological systems utilize free energy and molecular building blocks to grow, to reproduce and to maintain dynamic homeostasis.</b>	
<b>Enduring understanding 2.A:</b> Growth, reproduction and maintenance of the organization of living systems require free energy and matter.	<b>Key Concepts:</b>
2.A.1: All living systems require constant input of free energy. SP 6.2, 6.1, 6.4	1.1, 4.5, 6.1, 6.2, 6.3, 25.4, 41.1, 41.2, 41.3, 42.1, 42.2, 42.3, 42.4, 42.5
2.A.2: Organisms capture and store free energy for use in biological processes. SP 1.4, 3.1, 6.2, 5.3, 7.1	1.1, 3.1, 4.5, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 8.1, 8.2, 8.3, 25.4, 31.2, 41.1, 41.2, 41.3, 42.1
2.A.3: Organisms must exchange matter with the environment to grow, reproduce and maintain organization. SP 2.2, 6.2, 4.1, 1.1, 1.4	1.1, 2.1, 2.2, 2.5, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 4.2, 16.1, 24.2, 29.4, 31.1, 31.3, 32.3, 32.4, 42.1, 42.2, 42.3, 42.4, 42.5
<b>Enduring understanding 2.B:</b> Growth, reproduction and dynamic homeostasis require that cells create and maintain internal environments that are different from their external environments.	<b>Key Concepts:</b>
2.B.1: Cell membranes are selectively permeable due to their structure. SP 1.4, 3.1, 1.1, 7.1, 7.2	1.1, 4.2, 4.4, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 29.1, 29.2, 29.3, 29.5, 32.1, 32.3
2.B.2: Growth and dynamic homeostasis are maintained by the constant movement of molecules across membranes. SP 1.4	5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 32.1, 32.2, 32.3, 32.4, 32.5
2.B.3: Eukaryotic cells maintain internal membranes that partition the cell into specialized regions. SP 6.2, 1.4, 1.2	4.1, 4.2, 4.3, 4.4, 4.6, 4.7, 25.1
<b>Enduring understanding 2.C:</b> Organisms use feedback mechanisms to regulate growth and reproduction, and to maintain dynamic homeostasis.	<b>Key Concepts:</b>
2.C.1: Organisms use feedback mechanisms to maintain their internal environments and respond to external environmental changes. SP 6.1, 7.2, 5.3, 6.4, 6.1	4.5, 29.6, 31.1, 31.2, 31.3, 32.1, 32.2, 32.3, 32.4, 32.5, 33.5, 36.1, 38.1
2.C.2: Organisms respond to changes in their external environments. SP 4.1, 3.1	15.1, 25.4, 26.5, 27.5, 31.1, 31.2, 31.3, 32.1, 32.2, 32.3, 32.4, 36.1, 38.1, 43.5
<b>Enduring understanding 2.D:</b> Growth and dynamic homeostasis of a biological system are influenced by changes in the system's environment.	<b>Key Concepts:</b>
2.D.1: All biological systems from cells and organisms to populations, communities and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy. SP 1.3, 3.2, 4.2, 7.2, 5.1	24.1, 32.1, 32.5, 40.1, 40.2, 40.3, 40.4, 41.3, 41.4
2.D.2: Homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments. SP 6.2, 5.1, 7.1	32.1, 32.2, 32.3, 32.4, 32.5, 38.1, 42.5
2.D.3: Biological systems are affected by disruptions to their dynamic homeostasis. SP 1.4	32.2
2.D.4: Plants and animals have a variety of chemical defenses against infections that affect dynamic homeostasis. SP 1.1, 1.2, 7.2	29.2, 31.4, 35.1, 35.2, 35.3, 38.4

<b>Enduring understanding 2.E:</b> Many biological processes involved in growth, reproduction and dynamic homeostasis include temporal regulation and coordination.	<b>Key Concepts:</b>
2.E.1: Timing and coordination of specific events are necessary for the normal development of an organism, and these events are regulated by a variety of mechanisms. SP 7.2, 1.4, 6.1, 7.1	14.1, 14.2, 14.3, 14.4, 14.5, 14.6, 15.2, 15.3, 16.1, 16.3, 18.6, 28.2, 30.1, 30.2, 32.1, 32.2
2.E.2: Timing and coordination of physiological events are regulated by multiple mechanisms. SP 4.2, 6.1, 7.2	24.2, 24.3, 24.4, 24.5, 26.2, 31.2, 34.1, 37.1, 37.2, 37.3, 37.4, 38.1, 38.2, 38.3, 38.4, 38.5, 38.6, 39.1, 39.2, 39.3
2.E.3: Timing and coordination of behavior are regulated by various mechanisms and are important in natural selection. SP 5.1, 6.1, 7.2	36.1, 36.3, 39.1, 39.2, 39.3, 39.4, 39.5, 39.6
<b>Big Idea 3: Living systems store, retrieve, transmit, and respond to information essential to life processes.</b>	
<b>Enduring understanding 3.A:</b> Heritable information provides for continuity of life.	<b>Key Concepts:</b>
3.A.1: DNA, and in some cases RNA, is the primary source of heritable information. SP 6.2, 6.5, 4.1, 1.2, 6.4	1.1, 4.3, 11.1, 11.2, 11.3, 11.4, 12.4, 13.1, 13.2, 13.3, 13.4, 14.1, 14.2, 14.3, 14.4, 14.5, 14.6, 15.1, 15.3, 15.4, 16.1, 16.2, 16.3, 17.1, 17.2, 17.3, 24.1, 24.2, 24.3, 30.3, 39.6
3.A.2: In eukaryotes, heritable information is passed to the next generation via processes that include the cell cycle and mitosis or meiosis plus fertilization. SP 6.5, 6.4, 1.2, 6.2, 7.1, 5.3	9.1, 9.2, 9.3, 10.1, 10.2, 10.3, 15.2, 30.1, 30.2, 36.2
3.A.3: The chromosomal basis of inheritance provides an understanding of the pattern of passage (transmission) of genes from parent to offspring. SP 1.1, 7.2, 3.1, 2.2	1.1, 3.6, 3.7, 10.1, 10.2, 10.3, 10.4, 11.1, 11.2, 11.3, 11.4, 12.2, 12.3, 12.4, 13.1, 13.2, 13.3, 13.4, 21.1, 36.2
3.A.4: The inheritance pattern of many traits cannot be explained by simple Mendelian genetics. SP 6.2, 6.5, 6.3, 1.2	1.3, 11.4, 12.4, 14.1, 14.2, 14.3, 14.4, 14.5, 17.1, 17.2
<b>Enduring understanding 3.B:</b> Expression of genetic information involves cellular and molecular mechanisms.	<b>Key Concepts:</b>
3.B.1: Gene regulation results in differential gene expression, leading to cell specialization. SP 7.1, 6.2, 1.4	13.2, 13.4, 15.1, 15.2, 16.1, 16.2, 16.3, 28.2, 36.3, 36.4
3.B.2: A variety of intercellular and intracellular signal transmissions mediate gene expression. SP 6.2, 1.4	12.1, 12.2, 12.3, 15.4, 26.2
<b>Enduring understanding 3.C:</b> The processing of genetic information is imperfect and is a source of genetic variation.	<b>Key Concepts:</b>
3.C.1: Changes in genotype can result in changes in phenotype. SP 6.4, 7.2, 1.1	10.4, 11.1, 11.2, 11.3, 11.4, 12.1, 12.2, 12.3, 12.4, 13.4, 16.2, 17.3, 23.3, 30.3
3.C.2: Biological systems have multiple processes that increase genetic variation. SP 7.2, 6.2	10.4, 13.4, 14.5, 18.1, 18.2, 18.3, 18.4, 18.5, 18.6, 21.1, 21.2, 30.3
3.C.3: Viral replication results in genetic variation and viral infection can introduce genetic variation into the hosts. SP 6.2, 1.4	13.1, 17.1, 17.2, 17.3

<b>Enduring understanding 3.D:</b> Cells communicate by generating, transmitting and receiving chemical signals.	<b>Key Concepts:</b>
3.D.1: Cell communication processes share common features that reflect a shared evolutionary history. SP 7.2, 3.1, 1.4	5.6, 34.1, 35.3, 37.3, 38.6
3.D.2: Cells communicate with each other through direct contact with other cells or from a distance via chemical signaling. SP 6.2, 1.1	4.7, 5.6, 26.2, 37.4
3.D.3: Signal transduction pathways link signal reception with cellular response. SP 1.5	24.3
3.D.4: Changes in signal transduction pathways can alter cellular response. SP 6.1, 1.5, 6.2	24.3
<b>Enduring understanding 3.E:</b> Transmission of information results in changes within and between biological systems.	<b>Key Concepts:</b>
3.E.1: Individuals can act on information and communicate it to others. SP 5.1, 1.1, 7.1	41.1, 41.2, 41.3
3.E.2: Animals have nervous systems that detect external and internal signals, transmit and integrate information, and produce responses. SP 6.2, 7.1, 1.2, 1.1	32.2, 37.1, 37.2, 37.3, 37.4, 38.1, 38.2, 38.3, 38.4, 38.5, 38.6, 39.1, 39.2, 39.3, 39.4, 39.5, 39.6
<b>Big Idea 4: Biological systems interact, and these systems and their interactions possess complex properties.</b>	
<b>Enduring understanding 4.A:</b> Interactions within biological systems lead to complex properties.	<b>Key Concepts:</b>
4.A.1: The subcomponents of biological molecules and their sequence determine the properties of that molecule. SP 7.1, 1.3, 6.4, 6.1	2.1, 2.2, 2.3, 2.4, 2.5, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7
4.A.2: The structure and function of subcellular components, and their interactions, provide essential cellular processes. SP 6.4, 6.2, 1.4	1.1, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 25.1
4.A.3: Interactions between external stimuli and regulated gene expression result in specialization of cells, tissues and organs. SP 1.3	1.1, 16.1, 16.2, 28.1, 28.2, 28.3, 28.4, 29.3, 32.1
4.A.4: Organisms exhibit complex properties due to interactions between their constituent parts. SP 3.3, 6.4, 1.3	41.2, 41.3
4.A.5: Communities are composed of populations of organisms that interact in complex ways. SP 1.4, 4.1, 2.2, 6.4	40.2, 40.3, 40.4, 40.5, 40.6, 41.1, 41.2, 41.3, 41.4, 43.2, 43.5
4.A.6: Interactions among living systems and with their environment result in the movement of matter and energy. SP 2.2, 1.4, 6.4	25.4, 29.1, 29.2, 29.3, 29.4, 29.5, 29.6, 29.7, 41.2, 41.3, 41.5, 42.1, 42.2, 42.3, 42.4, 42.5, 43.1, 43.2, 43.3, 43.4, 43.5, 43.6
<b>Enduring understanding 4.B:</b> Competition and cooperation are important aspects of biological systems.	<b>Key Concepts:</b>
4.B.1: Interactions between molecules affect their structure and function. SP 5.1	3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 6.1, 6.4, 6.5, 15.1, 33.1, 33.2, 33.3, 33.5
4.B.2: Cooperative interactions within organisms promote efficiency in the use of energy and matter. SP 1.4	32.1, 32.2, 32.3, 32.4, 32.5, 33.1, 33.2, 33.3, 33.4, 33.5, 34.1, 34.2, 34.3, 34.4, 34.5, 34.6, 34.7
4.B.3: Interactions between and within populations influence patterns of species distribution and abundance. SP 2.2, 5.2	40.3, 40.4, 40.6, 41.1, 43.1, 43.2, 43.3, 43.4, 43.5, 43.6
4.B.4: Distribution of local and global ecosystems changes over time. SP 6.2, 6.3, 6.4	40.1, 41.4

**Enduring understanding 4.C:** Naturally occurring diversity among and between components within biological systems affects interactions with the environment.

**Key Concepts:**

4.C.1: Variation in molecular units provides cells with a wider range of functions.  
SP 6.2

4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7

4.C.2: Environmental factors influence the expression of the genotype in an organism.  
SP 6.2, 6.4

15.1, 41.4, 41.5

4.C.3: The level of variation in a population affects population dynamics.  
SP 6.1, 6.4

1.1, 1.2, 40.6, 41.2, 43.1, 43.2, 43.3

4.C.4: The diversity of species within an ecosystem may influence the stability of the ecosystem.  
SP 6.4

1.2, 40.4, 40.5, 40.6, 41.2, 41.3, 43.1, 43.2, 43.3

## A Visual Overview of the AP Biology Curriculum Framework

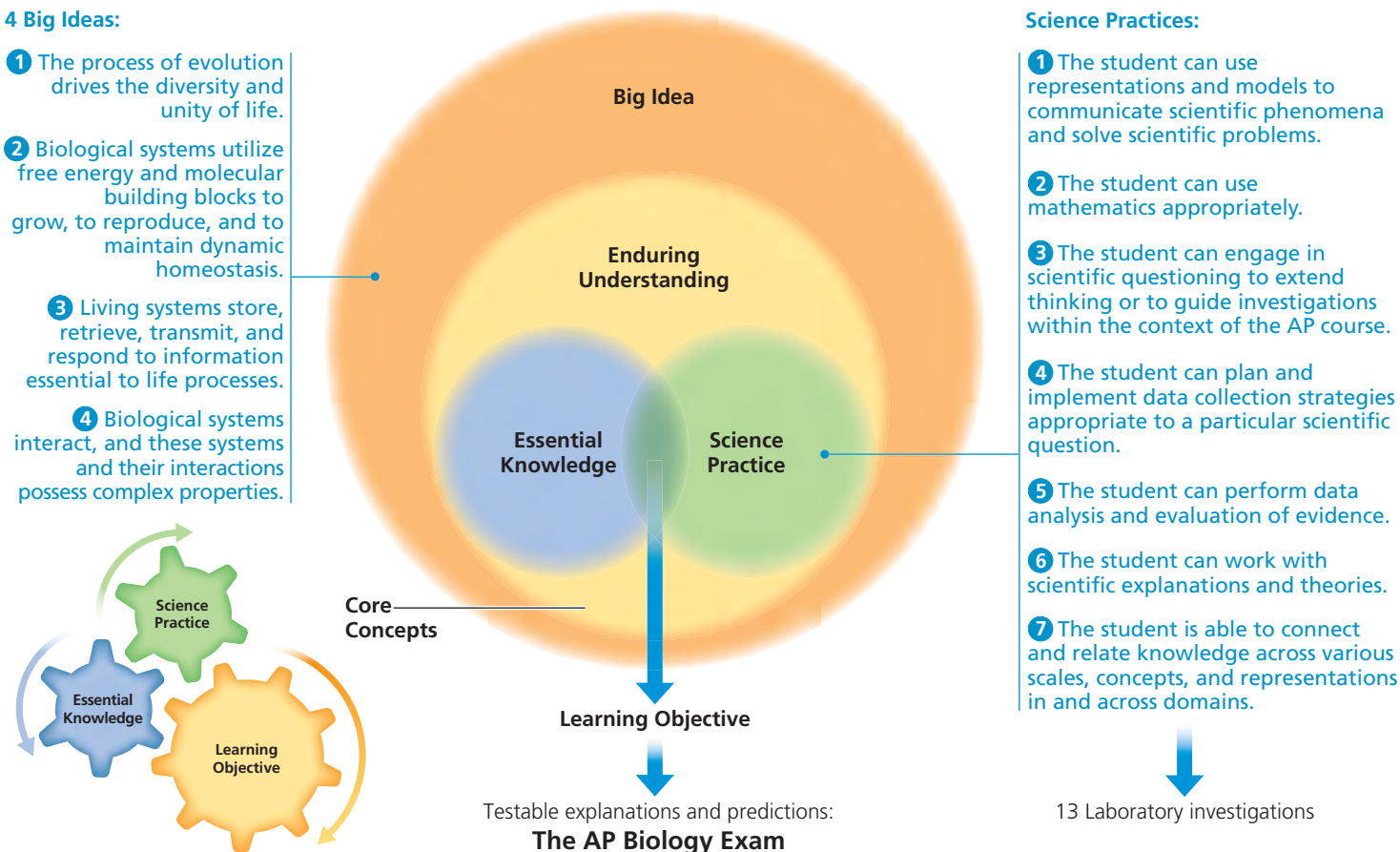
The curriculum framework supports **Essential Knowledge** with **Science Practice**.

### 4 Big Ideas:

- 1 The process of evolution drives the diversity and unity of life.
- 2 Biological systems utilize free energy and molecular building blocks to grow, to reproduce, and to maintain dynamic homeostasis.
- 3 Living systems store, retrieve, transmit, and respond to information essential to life processes.
- 4 Biological systems interact, and these systems and their interactions possess complex properties.

### Science Practices:

- 1 The student can use representations and models to communicate scientific phenomena and solve scientific problems.
- 2 The student can use mathematics appropriately.
- 3 The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course.
- 4 The student can plan and implement data collection strategies appropriate to a particular scientific question.
- 5 The student can perform data analysis and evaluation of evidence.
- 6 The student can work with scientific explanations and theories.
- 7 The student is able to connect and relate knowledge across various scales, concepts, and representations in and across domains.



Graphic courtesy of Peggy O'Neill Skinner, Megan Skinner, and Jason Herndon

# About the Authors

The author team's contributions reflect their biological expertise as researchers and their teaching sensibilities gained from years of experience as instructors at diverse institutions and as authors of *CAMPBELL BIOLOGY*.

## Lisa A. Urry



Lisa Urry (Units 1 and 2) is Professor of Biology and Chair of the Biology Department at Mills College in Oakland, California, and a Visiting Scholar at the University of California, Berkeley. After graduating from Tufts University, Lisa completed her Ph.D. at Massachusetts Institute of Technology (MIT) in the MIT/Woods Hole Oceanographic Institution Joint Program. She has published a number of research papers focused on gene expression during embryonic and larval development in sea urchins. Lisa has taught a variety of courses, from introductory biology to developmental biology, senior seminar, and a nonmajors course called Evolution for Future Presidents. Lisa is also deeply committed to promoting opportunities for women and underrepresented minorities in science.

## Michael L. Cain



Michael Cain (Units 3, 4 and 7) 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, Michael taught courses ranging from introductory biology to ecology to evolution. In addition to his work on this book, Michael is also the lead author of an ecology textbook.

## Steven A. Wasserman



Steven Wasserman (Unit 6) is Professor of Biology at the University of California, San Diego (UCSD). He earned his A.B. in biology from Harvard and his Ph.D. in biological sciences from MIT. Through research on the fruit fly *Drosophila*, Steven has contributed significantly to the fields of developmental biology, reproduction, and immunity. As a faculty member at the UT Southwestern Medical Center and now UC San Diego, he has taught undergraduate, graduate, and medical students. He has been the research mentor for more than a dozen doctoral students and nearly 60 undergraduate and high school trainees. Steven has received

distinguished scholar awards from the Markey Charitable Trust and the David and Lucille Packard Foundation, as well as a UCSD Distinguished Teaching Award.

## Peter V. Minorsky



Peter Minorsky (Unit 5) is Professor of Biology at Mercy College in New York, where he teaches introductory biology, 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*. His research interests concern how plants sense environmental change. Peter received the 2008 Award for Teaching Excellence at Mercy College.

## Jane B. Reece



The head of the author team for Editions 8–10 of *CAMPBELL BIOLOGY*, Jane Reece was Neil Campbell's longtime collaborator. Jane holds an A.B. in biology from Harvard, an M.S. in from Rutgers, and a Ph.D. from the University of California, Berkeley. Jane's research focused on genetic recombination in bacteria. She has been a coauthor on all the *CAMPBELL* texts.

## Neil A. Campbell



Neil Campbell (1946–2004) 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. His research focused on desert and coastal plants. His 30 years of teaching in diverse environments included introductory biology courses at Cornell, Pomona, and San Bernardino Valley College, where he received the college's first Outstanding Professor Award in 1986. For many years he was a visiting scholar in the Department of Botany and Plant Sciences at UC Riverside. Neil was the founding author of *CAMPBELL BIOLOGY*, upon which this book is based, and several other popular introductory biology texts.



# Make Connections Visually

**NEW! Make Connections Figures** pull together content from different chapters, helping students connect and relate knowledge across various scales, concepts, and representations in and across domains.

## Make Connections Figures include:

Figure 3.30 Contributions of Genomics and Proteomics to Biology, p. 68

Figure 8.20 The Working Cell, pp. 178–179

Figure 16.21 Genomics, Cell Signaling, and Cancer, pp. 338–339

Figure 21.15 The Sickle-Cell Allele, pp. 428–429

Figure 26.14 Maximizing Surface Area, p. 526

Figure 29.10 Mutualism Across Kingdoms and Domains, p. 603

Figure 32.3 Life Challenges and Solutions in Plants and Animals, shown at right and on pp. 666–667

Figure 37.8 Ion Movement and Gradients, p. 777

Figure 42.18 The Working Ecosystem, pp. 902–903

Figure 43.28 Climate Change Has Effects at All Levels of Biological Organization, pp. 924–925

▼ Figure 32.3

AP®

## MAKE CONNECTIONS

### Life Challenges and Solutions in Plants and Animals

Multicellular organisms face a common set of challenges. Comparing the solutions that have evolved in plants and animals reveals both unity (shared elements) and diversity (distinct features) across these two lineages.



#### Environmental Response

All forms of life must detect and respond appropriately to conditions in their environment. Specialized organs sense environmental signals. For example, the floral head of a sunflower (left) and an insect's eyes (right) both contain photoreceptors that detect light. Environmental signals activate specific receptor proteins, triggering signal transduction pathways that initiate cellular responses coordinated by chemical and electrical communication. (See Figure 31.12 and Figure 38.26.)

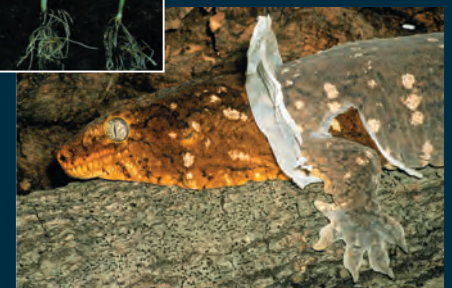


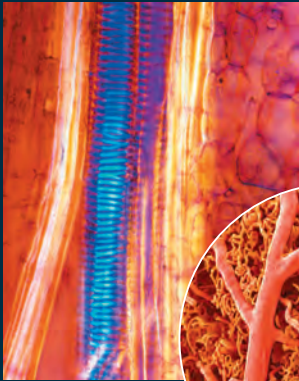
#### Nutritional Mode

All living things must obtain energy and carbon from the environment to grow, survive, and reproduce. Plants are autotrophs, obtaining their energy through photosynthesis and their carbon from inorganic sources, whereas animals are heterotrophs, obtaining their energy and carbon from food. Evolutionary adaptations in plants and animals support these different nutritional modes. The broad surface of many leaves (left) enhances light capture for photosynthesis. When hunting, a bobcat relies on stealth, speed, and sharp claws (right). (See Figure 29.2 and Figure 33.14.)

#### Growth and Regulation

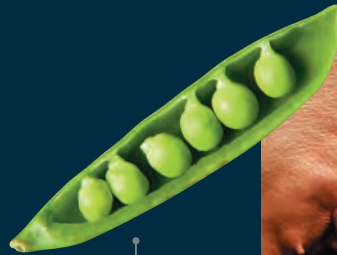
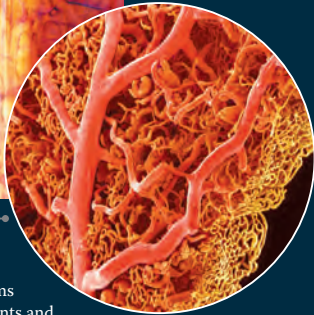
The growth and physiology of both plants and animals are regulated by hormones. In plants, hormones may act in a local area or be transported in the body. They control growth patterns, flowering, fruit development, and more (left). In animals, hormones circulate throughout the body and act in specific target tissues, controlling homeostatic processes and developmental events such as molting (below). (See Table 31.1 and Figure 33.19.)





### Transport

All but the simplest multicellular organisms must transport nutrients and waste products between locations in the body. A system of tubelike vessels is the common evolutionary solution, while the mechanism of circulation varies. Plants harness solar energy to transport water, minerals, and sugars through specialized tubes (left). In animals, a pump (heart) moves circulatory fluid through vessels (right). (See Figure 28.9 and Figure 34.3.)



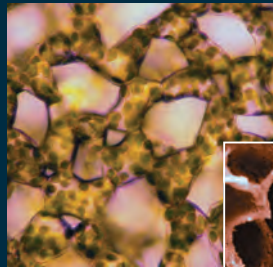
### Reproduction

In sexual reproduction, specialized tissues and structures produce and exchange gametes. Offspring are generally supplied with nutritional stores that facilitate rapid growth and development. For example, seeds (left) have stored food reserves that supply energy to the young seedling, while milk provides sustenance for juvenile mammals (right). (See Figure 30.8 and Figure 32.7.)



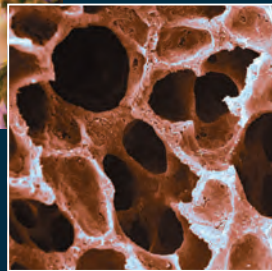
### Absorption

Organisms need to absorb nutrients. The root hairs of plants (left) and the villi (projections) that line the intestines of vertebrates (right) increase the surface area available for absorption. (See Figure 28.4 and Figure 33.10.)



### Gas Exchange

The exchange of certain gases with the environment is essential for life. Respiration by plants and animals requires taking up oxygen ( $O_2$ ) and releasing carbon dioxide ( $CO_2$ ). In photosynthesis, net exchange occurs in the opposite direction:  $CO_2$  uptake and  $O_2$  release. In both plants and animals, highly convoluted surfaces that increase the area available for gas exchange have evolved, such as the spongy mesophyll of leaves (left) and the alveoli of lungs (right). (See Figure 28.17 and Figure 34.20.)



**MAKE CONNECTIONS** Compare the adaptations that enable plants and animals to respond to the challenges of living in hot and cold environments. See Concepts 31.3 and 32.3.

### ANIMATION



Visit the Study Area in **MasteringBiology** for the BioFlix® 3-D Animations on Water Transport in Plants (Chapter 29), Homeostasis: Regulating Blood Sugar (Chapter 33), and Gas Exchange (Chapter 34).

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

# Practice Scientific Skills

Scientific Skills Exercises in every chapter help students master the Science Practices of the AP Biology Curriculum Framework.

Each Scientific Skills Exercise is based on an experiment related to the chapter content. Students will build skills in data analysis, graphing, experimental design, and math.

### Scientific Skills Exercise

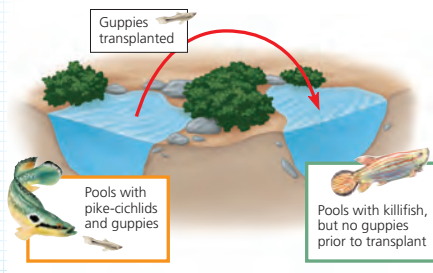
AP<sup>®</sup> SPs 1.4, 4.1, 4.2, 5.1, 5.3, 6.4, 7.2

#### Making and Testing Predictions

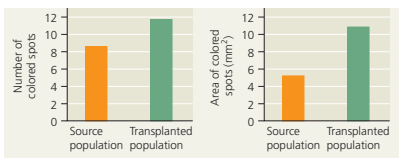
**Can Predation Result in Natural Selection for Color Patterns in Guppies?** What we know about evolution changes constantly as new observations lead to new hypotheses—and hence to new ways to test our understanding of evolutionary theory. Consider the wild guppies (*Poecilia reticulata*) that live in pools connected by streams on the Caribbean island of Trinidad. Male guppies have highly varied color patterns that are controlled by genes that are only expressed in adult males. Female guppies choose males with bright color patterns as mates more often than they choose males with drab coloring. But the bright colors that attract females also can make the males more conspicuous to predators. Researchers observed that in pools with few predator species, the benefits of bright colors appear to “win out,” and males are more brightly colored than in pools where predation is more intense.

One guppy predator, the killifish, preys on juvenile guppies that have not yet displayed their adult coloration. Researchers predicted that if adult guppies with drab colors were transferred to a pool with only killifish, eventually the descendants of these guppies would be more brightly colored (because of the female preference for brightly colored males).

**How the Experiment Was Done** Researchers transplanted 200 guppies from pools containing pike-cichlid fish, intense predators of adult guppies, to pools containing killifish, less active predators that prey mainly on juvenile guppies. They tracked the number of bright-colored spots and the total area of those spots on male guppies in each generation.



**Data from the Experiment** After 22 months (15 generations), researchers compared the color pattern data for guppies from the source and transplanted populations.



Population	Number of colored spots	Area of colored spots (mm <sup>2</sup> )
Source population	9	5
Transplanted population	11	10

**Data from** J. A. Endler, Natural selection on color patterns in *Poecilia reticulata*, *Evolution* 34:76–91 (1980).

**INTERPRET THE DATA**

- Identify the following elements of hypothesis-based science in this example: (a) question, (b) hypothesis, (c) prediction, (d) control group, and (e) experimental group. (For additional information about hypothesis-based science, see Chapter 1 and the Scientific Skills Review in Appendix F and the Study Area of MasteringBiology.)
- Explain how the types of data the researchers chose to collect enabled them to test their prediction.
- What conclusion do you draw from the data presented above?
- Predict what would happen if, after 22 months, guppies from the transplanted population were returned to the source pool. Describe an experiment to test your prediction.

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

AP Biology Framework Science Practices are highlighted at point of use.

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

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

## Every chapter has a Scientific Skills Exercise:

1. Interpreting a Pair of Bar Graphs, p. 18
2. Interpreting a Scatter Plot with a Regression Line, p. 40
3. Analyzing Polypeptide Sequence Data, p. 69
4. Using a Scale Bar to Calculate Volume and Surface Area of a Cell, p. 80
5. Interpreting a Scatter Plot with Two Sets of Data, p. 109
6. Making a Line Graph and Calculating a Slope, p. 134
7. Making a Bar Graph and Evaluating a Hypothesis, p. 155
8. Making Scatter Plots with Regression Lines, p. 176
9. Interpreting Histograms, p. 196
10. Making a Line Graph and Converting Between Units of Data, p. 210
11. Making a Histogram and Analyzing a Distribution Pattern, p. 227
12. Using the Chi-Square ( $\chi^2$ ) Test, p. 246
13. Working with Data in a Table, p. 257
14. Interpreting a Sequence Logo, p. 294
15. Analyzing DNA Deletion Experiments, p. 313
16. Analyzing Quantitative and Spatial Gene Expression Data, p. 325
17. Analyzing a Sequence-Based Phylogenetic Tree to Understand Viral Evolution, p. 353
18. Reading an Amino Acid Sequence Identity Table, p. 370
19. **Making and Testing Predictions**, shown above and on p. 392
20. **NEW!** Using Protein Sequence Data to Test an Evolutionary Hypothesis, p. 410
21. Using the Hardy-Weinberg Equation to Interpret Data and Make Predictions, p. 420
22. Identifying Independent and Dependent Variables, Making a Scatter Plot, and Interpreting Data, p. 441
23. Estimating Quantitative Data from a Graph and Developing Hypotheses, p. 459

Each Scientific Skills Exercise from the text also has an **assignable, interactive tutorial version in MasteringBiology®** that is automatically graded and includes coaching feedback.

MasteringBiology®

34: Circulation and Gas Exchange Scientific Skills Exercise: Interpreting Data in Histograms Resources

Item Type: Tutorial | Difficulty: 1 | Time: 5m | Learning Outcomes | Contact the Publisher Manage this item: Standard View

Scientific Skills Exercise: Interpreting Data in Histograms

Individuals with an inactivating mutation in one copy of PCSK9 gene (study group)

Individuals with two functional copies of PCSK9 gene (control group)

Data from J. C. Cohen et al., Sequence variations in PCSK9, low LDL, and protection against coronary heart disease. *New England Journal of Medicine* 354:1264–1272 (2006).

**Part A - Reading the histograms**

The results are presented using a form of bar graph called a *histogram*. In a histogram, the variable on the x-axis is grouped into ranges. The height of each bar in this histogram represents the percentage of samples that fall into the range specified on the x-axis for that bar. For example, in the top histogram, about 4% of individuals studied had plasma LDL cholesterol levels in the 25–50 mg/dL (milligrams per deciliter) range.

What percentage of individuals in the study group had an LDL level *below* 100 mg/dL? (Hint: Add the percentages for the relevant bars.)

about 17%  
 about 35%  
 about 58%  
 about 79%

Submit My Answers Give Up

**Incorrect; Try Again**

Make sure you add the values of the *three* bars representing plasma LDL levels below 100 mg/dL (the bars to the left of 100 mg/dL on the x-axis).

**Part B**

What percentage of individuals in the control group had an LDL level *below* 100 mg/dL?

about 5%  
 about 17%  
 about 40%  
 about 58%

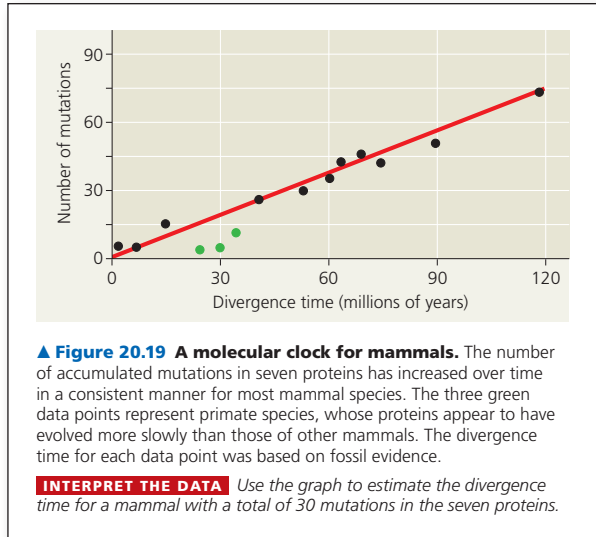
Submit My Answers Give Up

**AP®** Includes **NEW AP® Exam-style Practice Questions** that test students' mastery of the Framework's Learning Objectives and companion Science Practices. These questions can be found in both MasteringBiology and ExamView.

24. Making a Bar Graph and Interpreting Data, p. 493
25. Interpreting Comparisons of Genetic Sequences, p. 501
26. **NEW!** Interpreting Genomic Data and Generating Hypotheses, p. 529
27. Understanding Experimental Design and Interpreting Data, p. 570
28. Using Bar Graphs to Interpret Data, p. 582
29. Calculating and Interpreting Temperature Coefficients, p. 597
30. Using Positive and Negative Correlations to Interpret Data, p. 632
31. Interpreting Experimental Results from a Bar Graph, p. 656
32. Describing and Interpreting Quantitative Data, p. 679
33. Interpreting Data from an Experiment with Genetic Mutants, p. 704
34. **Interpreting Data in Histograms**, shown above and on p. 721
35. Comparing Two Variables on a Common x-Axis, p. 748
36. Making Inferences and Designing an Experiment, p. 761
37. Interpreting Data Values Expressed in Scientific Notation, p. 787
38. Designing an Experiment Using Genetic Mutants, p. 797
39. Interpreting a Graph with Log Scales, p. 825
40. Using the Logistic Equation to Model Population Growth, p. 860
41. Using Bar Graphs and Scatter Plots to Present and Interpret Data, p. 870
42. Interpreting Quantitative Data in a Table, p. 893
43. Graphing Cyclic Data, p. 922

# Interpret Data

CAMPBELL BIOLOGY IN FOCUS, AP Edition, and MasteringBiology® offer a wide variety of ways for students to move beyond memorization and to **think like a scientist**. These features reinforce the College Board's Curriculum Framework Science Practices.



◀ **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**.

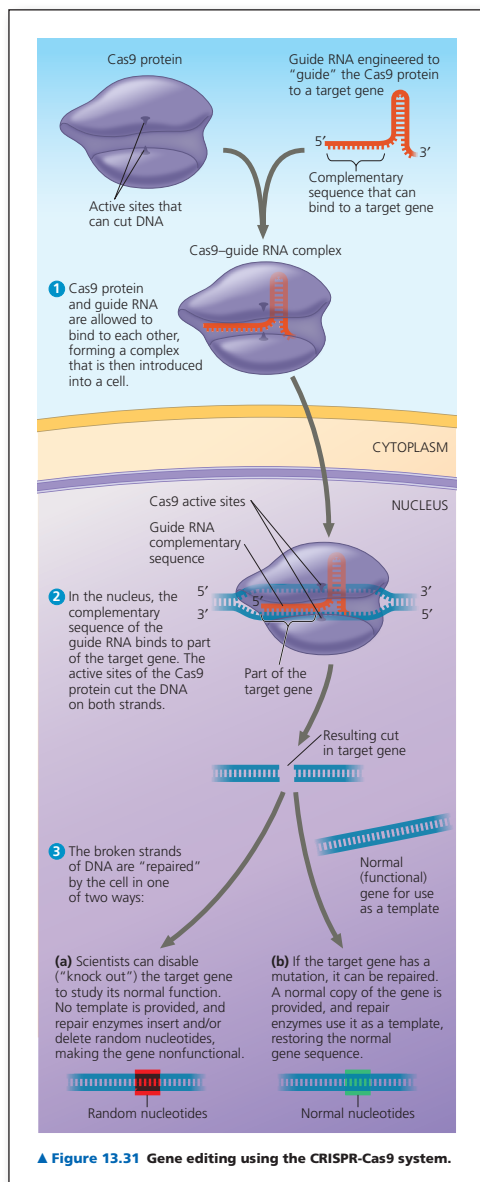
◀ **NEW! Solve It Tutorials** engage students in a multi-step investigation of a “mystery” or open question in which they must analyze real data. These are assignable in MasteringBiology. Topics include:

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

# Keep Current with New Scientific Advances

**NEW!** The Second Edition incorporates **up-to-date content** on genomics, gene editing, human evolution, microbiomes, climate change, and more.

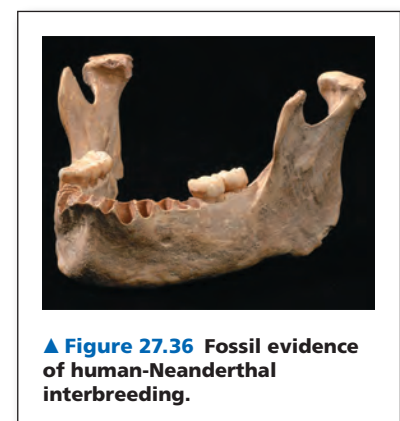
**NEW!** The Second Edition shows students how our ability to **sequence DNA and proteins rapidly and inexpensively** is transforming every subfield of biology, from cell biology to physiology to ecology. For instance, the examples in this figure from Chapter 3 are explored in greater depth later in the text.



**▲ Figure 13.31** Gene editing using the CRISPR-Cas9 system.

◀ **NEW!** Chapter 13 describes **gene editing using the CRISPR-Cas9 system**, and Chapter 17 describes the basic biology of this system in bacteria.

**NEW!** Chapter 27 includes new material on human origins, including how sequencing DNA extracted from this fossil jawbone recently revealed **evidence of human-Neanderthal interbreeding**.



**AP**  
**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 27.36.)

**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 Concept 9.3 and Figure 16.21.)

**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 19.20.)

**Species Interactions**  
Most plant species exist in a mutually beneficial partnership with fungi (right) and bacteria associated with the plants' roots; these interactions improve plant growth. Genome sequencing and analysis of gene expression have allowed characterization of plant-associated communities. Such studies will help advance our understanding of such interactions and may improve agricultural practices. (See the Chapter 26 Scientific Skills Exercise and Figure 29.11.)

**Conservation Biology**  
The tools of molecular genetics and genomics are increasingly used by forensic 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 43.8.)

**MAKE CONNECTIONS** Considering the examples provided here, describe how the approaches of genomics and proteomics help us to address a variety of biological questions.

68 UNIT ONE CHEMISTRY AND CELLS

# Connect to the Big Ideas

Each chapter is organized around a framework of three to seven **Key Concepts** that focus on the **Big Ideas** and provide a context for the supporting details.

The list of **Key Concepts** ▶ introduces the main ideas covered in the chapter.

**AP<sup>®</sup>** An overview at the beginning of each chapter connects the chapter content to the AP Curriculum Framework's **Big Ideas**. ▶

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

CHAPTER

## 14

## Gene Expression: From Gene to Protein

### KEY CONCEPTS

- 14.1 Genes specify proteins via transcription and translation
- 14.2 Transcription is the DNA-directed synthesis of RNA: a *closer look*
- 14.3 Eukaryotic cells modify RNA after transcription
- 14.4 Translation is the RNA-directed synthesis of a polypeptide: a *closer look*
- 14.5 Mutations of one or a few nucleotides can affect protein structure and function

**AP<sup>®</sup>** **BIG IDEAS:** The highly conserved processes of gene transcription and translation (**Big Idea 3**) shared by all domains (**Big Idea 1**) result from molecular interactions that include specific enzymes (**Big Idea 4**) and transcription factors that act as control mechanisms (**Big Idea 2**).



▲ **Figure 14.1** How does a single faulty gene result in the dramatic appearance of an albino donkey?

### The Flow of Genetic Information

The island of Asinara lies off the coast of Sardinia, an Italian island. The name Asinara probably originated from the Latin word *sinuaria*, which means “sinus-shaped.” A second meaning of Asinara is “donkey-inhabited,” which is particularly appropriate because Asinara is home to a wild population of albino donkeys (**Figure 14.1**). The donkeys were brought to Asinara in the early 1800s and abandoned there in 1885 when the 500 residents were forced to leave the island so it could be used as a penal colony. What is responsible for the phenotype of the albino donkey, strikingly different from its pigmented relative?

Inherited traits are determined by genes, and the trait of albinism is caused by a recessive allele of a pigmentation gene (see Concept 11.4). The information content of genes is in the form of specific sequences of nucleotides along strands of DNA, the genetic material. But how does this information determine an organism's traits? Put another way, what does a gene actually say? And how is its message

translated by cells into a specific trait, such as brown hair, type A blood, or, in the case of an albino donkey, a total lack of pigment? The albino donkey has a faulty version of a key protein, an enzyme required for pigment synthesis, and this protein is faulty because the gene that codes for it contains incorrect information.

This example illustrates the main point of this chapter: The DNA inherited by an organism leads to specific traits by dictating the synthesis of proteins and of RNA molecules involved in protein synthesis. In other words, proteins are the link between genotype and phenotype. **Gene expression** is the process by which DNA directs the synthesis of proteins (or, in some cases, just RNAs). The expression of genes that code for proteins includes two stages: transcription and translation. This chapter describes the flow of information from gene to protein and explains how genetic mutations affect organisms through their proteins. Understanding the processes of gene expression, which are similar in all three domains of life, will allow us to revisit the concept of the gene in more detail at the end of the chapter.

278

After reading a Key Concept section, ▶ students can check their understanding using the **Concept Check questions**:

**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.

**Draw It Exercises** ask students to put pencil to paper and draw a structure, annotate a figure, or graph experimental data.

### CONCEPT CHECK 14.5

1. What happens when one nucleotide pair is lost from the middle of the coding sequence of a gene?
2. **MAKE CONNECTIONS** Individuals heterozygous for the sickle-cell allele show effects of the allele under some circumstances (see Concept 11.4). Explain in terms of gene expression.
3. **WHAT IF? DRAW IT** The template strand of a gene includes this sequence: 3'-TACTTGTCGGATATC-5'. It is mutated to 3'-TACTTGTC CAATATC-5'. For both versions, draw the DNA, the mRNA, and the encoded amino acid sequence. What is the effect on the amino acid sequence?

For suggested answers, see Appendix A.

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

**AP<sup>®</sup>** Every chapter closes with a **critical-thinking question** that invites students to relate chapter content to one or more **Big Ideas**.

## 14 Chapter Review

### SUMMARY OF KEY CONCEPTS

**CONCEPT 14.1**  
Genes specify proteins via transcription and translation (pp. 279–284)

- Beadle and Tatum's studies of mutant strains of *Neurospora* led to the one gene–one polypeptide hypothesis. During **gene expression**, the information encoded in genes is used to make specific polypeptide chains (enzymes and other proteins) or RNA molecules.
- Transcription** is the synthesis of RNA complementary to a **template strand of DNA**. Translation is the synthesis of a polypeptide whose amino acid sequence is specified by the nucleotide sequence in mRNA.
- Genetic information is encoded as a sequence of nonoverlapping nucleotide triplets, or **codons**. A codon in messenger RNA (mRNA) either is translated into an amino acid (61 of the 64 codons) or serves as a stop signal (3 codons). Codons must be read in the correct **reading frame**.

**2** Describe the process of gene expression, by which a gene affects the phenotype of an organism.

**CONCEPT 14.2**  
Transcription is the DNA-directed synthesis of RNA: a closer look (pp. 284–286)

- RNA synthesis is catalyzed by **RNA polymerase**, which links together RNA nucleotides complementary to a DNA template strand. This process follows the same base-pairing rules as DNA replication, except that in RNA, uracil substitutes for thymine.

The three stages of transcription are initiation, elongation, and termination. A **promoter**, often including a **TATA box** in eukaryotes, establishes where RNA synthesis is initiated. **Transcription factors** help eukaryotic RNA polymerase recognize promoter sequences, forming a **transcription initiation complex**. Termination differs in bacteria and eukaryotes.

**2** What are the similarities and differences in the initiation of gene transcription in bacteria and eukaryotes?

**CONCEPT 14.3**  
Eukaryotic cells modify RNA after transcription (pp. 286–288)

**CONCEPT 14.4**  
Translation is the RNA-directed synthesis of a polypeptide: a closer look (pp. 288–298)

- A cell translates an mRNA message into protein using **transfer RNAs (tRNAs)**. After being bound to a specific amino acid by an **aminoacyl-tRNA synthetase**, a tRNA lines up via its **anticodon** at the complementary codon on mRNA. A ribosome, made up of **ribosomal RNAs (rRNAs)** and proteins, facilitates this coupling with binding sites for mRNA and tRNA.
- Ribosomes coordinate the three stages of translation: initiation, elongation, and termination. The formation of peptide bonds between amino acids is catalyzed by ribosomal RNAs as rRNAs move through the **A** and **P** sites and exit through the **E** site.
- After translation, modifications to proteins can affect their shape. Free ribosomes in the cytosol initiate synthesis of all proteins, but proteins with a **signal peptide** are synthesized on the ER.
- A gene can be transcribed by multiple RNA polymerases simultaneously. Also, a single mRNA molecule can be translated simultaneously by a number of ribosomes, forming a **polysome**. In bacteria, these processes are coupled, but in eukaryotes they are separated in time and space by the nuclear membrane.

**2** What function do tRNAs serve in the process of translation?

**CONCEPT 14.5**  
Mutations of one or a few nucleotides can affect protein structure and function (pp. 298–300)

- Small-scale **mutations** include **point mutations**, changes in one DNA nucleotide pair, which may lead to production of non-functional proteins. **Nucleotide-pair substitutions** can cause **missense** or **nonsense mutations**. **Nucleotide-pair insertions** or **deletions** may produce **frameshift mutations**.
- Spontaneous mutations can occur during DNA replication, recombination, or repair. **Chemical and physical mutagens** cause DNA damage that can alter genes.

CHAPTER 14 GENE EXPRESSION: FROM GENE TO PROTEIN 301

**VOCAB SELF-QUIZ**

goo.gl/gbai8v

**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.

**PRACTICE TEST**

goo.gl/CRZjvS

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

**Evolution**, the fundamental theme of biology, is emphasized throughout. For example:

- Each Chapter Review includes at least one **Connect to Big Idea 1 Question** that asks students to think critically about how an aspect of the chapter relates to evolution.
- Every chapter has a section explicitly relating the chapter content to evolution (shown at right).

**Evolution of the Genetic Code**

**EVOLUTION** The genetic code is nearly universal, shared by organisms from the simplest bacteria to the most complex plants and animals. The mRNA codon CCG, for instance, is translated as the amino acid proline in all organisms whose genetic code has been examined. In laboratory experiments, genes can be transcribed and translated after being transplanted from one species to another, sometimes with quite striking results, as shown in **Figure 14.7**. Bacteria can be programmed by the insertion of human genes to synthesize certain human proteins for medical use, such as insulin. Such applications have produced many exciting developments in the area of genetic engineering (see Concept 13.4).

Despite a small number of exceptions in which a few codons differ from the standard ones, the evolutionary significance of the code's *near* universality is clear. A language shared by all living things must have been operating very early in the

**2** What will be the results of chemically modifying one nucleotide base of a gene? What role is played by DNA repair systems in the cell?

**TEST YOUR UNDERSTANDING**

- Level 1: Knowledge/Comprehension**
- In eukaryotic cells, transcription cannot begin until
    - the two DNA strands have completely separated and exposed the promoter.
    - several transcription factors have bound to the promoter.
    - the 5' caps are removed from the mRNA.
    - the DNA introns are removed from the template.
  - Which of the following is NOT true of a codon?
    - It may code for the same amino acid as another codon.
    - It never codes for more than one amino acid.
    - It extends from one end of a tRNA molecule.
    - It is the basic unit of the genetic code.
  - The anticodon of a particular tRNA molecule is
    - complementary to the corresponding mRNA codon.
    - complementary to the corresponding triplet in rRNA.
    - the part of tRNA that bonds with a specific amino acid.
    - catalytic, making the tRNA a ribozyme.
  - Which of the following is NOT true of RNA processing?
    - Exons are cut out before mRNA leaves the nucleus.
    - Nucleotides may be added at both ends of the RNA.
    - Ribozymes may function in RNA splicing.
    - DNA splicing can be catalyzed by spliceosomes.
  - Which component is NOT directly involved in translation?
    - GTP
    - DNA
    - tRNA
    - ribosomes
- Level 2: Application/Analysis**
- Using Figure 14.6, identify a 5' → 3' sequence of nucleotides in the DNA template strand for an mRNA coding for the polypeptide sequence Phe-Pro-Lys.
    - 5'-UUUCCCAAA-3'
    - 5'-GAACCCCTT-3'
    - 5'-CTTCGGGAA-3'
    - 5'-AAACCCUUU-3'
  - Which of the following mutations would be MOST likely to have a harmful effect on an organism?
    - A deletion of three nucleotides near the middle of a gene
    - A single nucleotide deletion in the middle of an intron
    - A single nucleotide deletion near the end of the coding sequence
    - A single nucleotide insertion downstream of, and close to, the start of the coding sequence
  - Figure the coupling of the processes shown in Figure 14.22b be found in a eukaryotic cell? Explain why or why not.

**9. Complete the following table:**

Type of RNA	Functions
Messenger RNA (mRNA)	
Transfer RNA (tRNA)	Plays catalytic (ribozyme) roles and structural roles in ribosomes
Primary transcript	
Small RNAs in the spliceosome	

**Level 3: Synthesis/Evaluation AP<sup>®</sup>**

**10. SCIENTIFIC INQUIRY/Science Practice 6**  
Knowing that the genetic code is almost universal, a scientist uses molecular biological methods to insert the human  $\beta$ -globin gene (shown in Figure 14.12) into bacterial cells, hoping the cells will express it and synthesize functional  $\beta$ -globin protein. Instead, the protein produced is nonfunctional and is found to contain many fewer amino acids than does  $\beta$ -globin made by a eukaryotic cell. Explain why.

**11. CONNECT TO BIG IDEA 1**  
Most amino acids are coded for by a set of similar codons (see Figure 14.6). Propose at least one evolutionary explanation to account for this pattern.

**12. CONNECT TO BIG IDEA 3**  
Evolution accounts for the unity and diversity of life, and the continuity of life is based on heritable information in the form of DNA. In a short essay (100–150 words), discuss how the fidelity with which DNA is inherited is related to the processes of evolution. (Review the discussion of proofreading and DNA repair in Concept 13.2.)

**13. SYNTHESIZE YOUR KNOWLEDGE**

**SCIENTIFIC INQUIRY/Science Practice 6**  
Some mutations result in proteins that function well at one temperature but are nonfunctional at a different (usually higher) temperature. Siamese cats have such a "temperature-sensitive" mutation in a gene encoding an enzyme that makes dark pigment in the fur. The mutation results in the breed's distinctive point markings and lighter body color (see the photo). Using this information and what you learned in the chapter, explain the pattern of the cat's fur pigmentation.

For selected answers, see Appendix A.

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

**AP<sup>®</sup>** Level 3 questions include two types of questions correlated to the AP Curriculum Framework:

- Scientific Inquiry Questions** ask students to practice scientific thinking by developing hypotheses, designing experiments, and analyzing real research data in accordance with the **seven Science Practices outlined in the Framework**.
- Connect to the Big Idea Questions** give students practice connecting the chapter's content to the **four Big Ideas outlined in the Framework**.



# Personalized Coaching in MasteringBiology®

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Part A - Glycolysis

From the following compounds involved in cellular respiration, choose those that are the net inputs and net outputs of glycolysis. Drag each compound to the appropriate bin. If the compound is not involved in glycolysis, drag it to the "not input or output" bin.

net input: glucose, ATP, NADH, O<sub>2</sub>

net output: pyruvate, H<sub>2</sub>O, NAD<sup>+</sup>, acetyl CoA

not input or output: CO<sub>2</sub>, creatine-A

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

**Incorrect; Try Again**

You sorted 4 out of 10 items incorrectly. Although O<sub>2</sub> is the final electron acceptor in cellular respiration, it is not an electron acceptor in glycolysis. Some other compound functions as an intermediate electron acceptor, eventually transferring its electrons to O<sub>2</sub> in the last stage of cellular respiration.

**Hint 1: Review the Glycolysis animation**

**Hint 2: Is there a net input or net output of ATP in glycolysis?**

If a compound is both consumed (input) and produced (output) in a process, you need to consider whether more of the compound is consumed or produced. If more of the compound is consumed than produced, there is a net input of the compound in that process. If more of the compound is produced than consumed, there is a net output of the compound. Recall that in the first steps of glycolysis, 2 ATP are consumed per glucose molecule. As glycolysis progresses, 4 ATP are produced per glucose molecule. Which statement correctly describes the net change in ATP during glycolysis?

There is a net output of ATP.  
 There is a net input of ATP.  
 There is no net input or net output of ATP.

3. **Hints** coach the student to the correct response.
4. 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.

**NEW!** Give students valuable exam practice with **AP® Exam-style Practice Questions** correlated to the AP Biology Curriculum Framework. Available in both MasteringBiology and ExamView.

**AP Exam Practice**

Description: Concept 17.5; Bloom's Taxonomy: Application/Analysis; Essential Knowledge 3.A.1; Science Practice 6.4; Learning Objective 3.6

A Northern blot is a technique used to detect gene expression with radioactive probes that bind to specific mRNA transcripts. Lanes 1-5 show RNA sample extracts from 5 different individuals. Panel A indicates the presence and relative amount of "geneR" mRNA and Panel B serves as a control to show that quality RNA was extracted from each sample by showing the same relative amounts of ribosomal RNA.

If each individual from this experiment contained a different mutation within the same gene (geneR), which statement is the most likely explanation of the results viewed in the Northern blot for geneR?

**ANSWER:**

Individual 1 has a substitution at the 3rd DNA base nucleotide of the first exon.  
 Individual 5 has a deletion at the 3rd DNA base nucleotide of the first exon.  
 Individual 1 has a deletion at the 3rd DNA base nucleotide of the first exon.  
 Individual 5 has a substitution at the 3rd DNA base nucleotide of the first exon.

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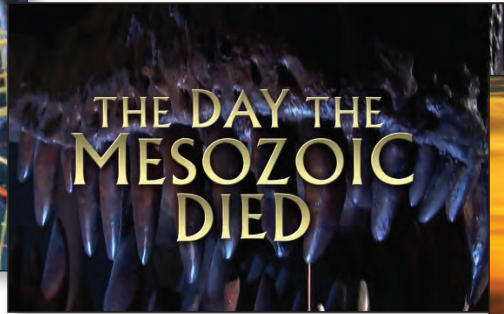
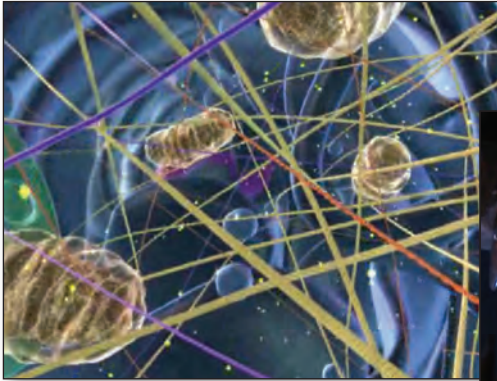
Submit My Answers Give Up

Provide Feedback Continue

▲ **Instructor View** correlates the question and provides the answer.

▲ **Student View** provides practice questions correlated to Framework Learning Objectives and Science Practices.

- ▼ MasteringBiology® offers a wide variety of **tutorials** that can be assigned as homework. Some examples are shown below.



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- ▼ 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.

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Filter\* Showing Score in All Categories for All Students

Scores | Time | Difficulty

Students per page: 25

NAME	Instr. AP	Chapter 8	Lab 2	CH8	CH8 Ad. Up	Lab 3	CH89 HW	CH89 H. Up	Lab 4	TOTAL
Assigned Points	5	20	15	7	5	7	37	5	19	154
Class Average	—	49.5	82.8	88.1	84.0	88.7	91.8	95.0	90.0	31.8
Lea01, Pract...	—	55.0	85.0	100	100	50	95.0	100	100	43.8
Lea02, Pract...	—	48.7	92.9	95.0	100	88.2	72.8	88.5	80.0	32.8
Lea03, Pract...	—	34.5	61.9	104	100	54.0	85.0	100	55.0	31.8
Lea04, Pract...	—	48.0	80.0	34.3	93.7	65.3	80.0	0.0	90.0	27.8
Lea05, Pract...	—	52.0	79.0	99.0	100	95.2	82.5	97.8	85.0	34.7
Lea07, Pract...	—	58.0	51.8	101	100	95.8	90.0	98.1	95.0	31.8
Lea08, Pract...	—	53.0	82.9	100	100	100	95.0	100	100	41.6
Lea09, Pract...	—	82.6	78.0	104	100	80.8	78.3	100	95.0	35.1
Lea10, Pract...	—	52.5	78.0	100	100	84.9	82.1	94.8	100	28.4
Lea11, Pract...	—	52.7	78.2	100	100	82.9	100	100	100	22.6
Lea12, Pract...	—	50.0	66.0	97.7	100	96.0	100	100	100	22.6
Lea14, Pract...	—	53.0	74.4	85.3	88.7	89.3	95.6	100	100	39.8
Lea15, Pract...	—	82.6	83.3	100	100	100	100	100	100	22.8

**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.

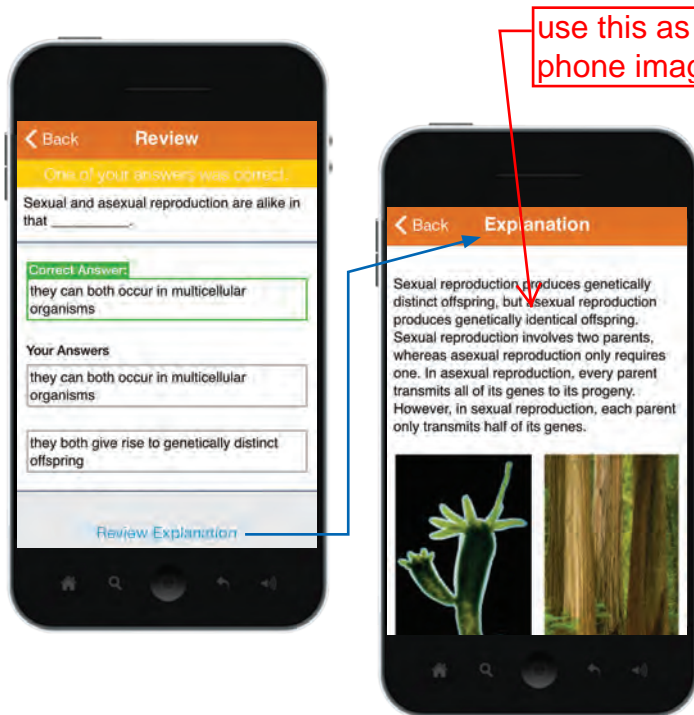
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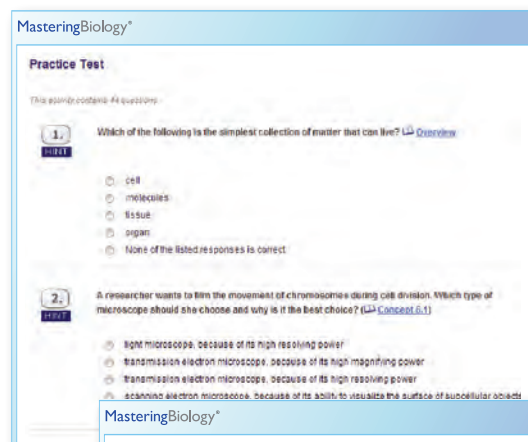
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 Oxidative Phosphorylation CONCEPT 3.4	 The Light Reactions CONCEPT 6.2	 Mitosis CONCEPT 9.2
 Meiosis CONCEPT 9.3	 Mutations CONCEPT 14.5	 Phylogenetic Trees CONCEPT 16.3
 Mechanisms of Evolution CONCEPT 21.9	 Water Transport in Plants CONCEPT 28.2	 Action Potentials CONCEPT 35.3
 Population Growth Models CONCEPT 48.5		

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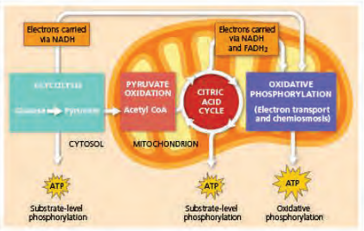


The following conditions were detected in a mutant cell:

The cell is running out of ATP, while ADP is building up to very high levels. NADH is building up to very high levels, while the level of NAD<sup>+</sup> is becoming very low.

The amount of protons in the intermembrane space and in the matrix is becoming more equal (the strength of the proton gradient is decreasing/weakening).

Use this information to predict which stage of cellular respiration is not functioning normally in this mutant cell.



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## FOR STUDENTS

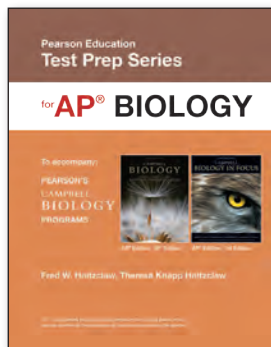
The following resources are available for purchase.

### Pearson Education Test Prep Series for AP<sup>®</sup> Biology

by Fred and Theresa Holtzclaw, *The Webb School of Knoxville*

This workbook is designed to support the AP<sup>®</sup> Biology Curriculum Framework. It is based on the comprehensive content of *CAMPBELL BIOLOGY* 10th Edition AP<sup>®</sup> Edition and can accompany *CAMPBELL BIOLOGY IN FOCUS* 1st Edition and 2nd Edition, AP<sup>®</sup> Editions.

Each chapter reviews content that is Essential Knowledge and makes connections to the Framework. Material that may be used as Illustrative Examples is included and clearly distinguished from the required content. This workbook will help students become familiar with the Big Ideas, apply the Science Practices, gain insight into the AP<sup>®</sup> labs, and prepare for the AP<sup>®</sup> Exam with practice tests. In addition to its student-friendly features—You Must Know boxes, Tip from the Readers boxes, and practice problems—the workbook now integrates



## (FOR STUDENTS, continued)

Science Practices throughout and includes an emphasis on making connections between topics.

### *Inquiry in Action: Interpreting Scientific Papers, Third Edition\**

by Ruth Buskirk, *University of Texas at Austin*, and Christopher M. Gillen, *Kenyon College*

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.

### *Practicing Biology: A Student Workbook, Fifth Edition\**

by Jean Heitz and Cynthia Giffen, *University of Wisconsin, Madison*

This workbook offers a variety of activities to suit different learning styles. Activities such as modeling and concept mapping allow students to visualize and understand biological processes. Other activities focus on basic skills, such as reading and drawing graphs.

### *Biological Inquiry: A Workbook of Investigative Cases, Fourth Edition\**

by Margaret Waterman, *Southeast Missouri State University*, and Ethel Stanley, *BioQUEST Curriculum Consortium and Beloit College*

This workbook offers ten investigative cases. Each case study requires students to synthesize information from multiple chapters of the text and apply that knowledge to a real-world scenario as they pose hypotheses, gather new information, analyze evidence, graph data, and draw conclusions. A link to a student website is in the Study Area in MasteringBiology.

### *Study Card*

This quick-reference card provides students with an overview of the entire field of biology, helping them see the connections among topics.

### *Spanish Glossary*

by Laura P. Zanello, *University of California, Riverside*

This resource provides definitions in Spanish for glossary terms.

### *A Short Guide to Writing About Biology, Ninth Edition*

by Jan A. Pechenik, *Tufts University*

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

\*An Instructor Guide is available for download in the Instructor Resources Area in MasteringBiology.

## Welcome to Advanced Placement Biology!

Fred and Theresa Holtzclaw, pictured at right, have been involved with AP<sup>®</sup> Biology for many years. Besides teaching hundreds of students, they helped write the AP<sup>®</sup> Biology Exam, prepared rubrics for questions, and assisted with its grading. They have prepared a letter to you that offers their experiences and advice, which can be found in the Study Area of [MasteringBiology.com](http://MasteringBiology.com) for *CAMPBELL BIOLOGY IN FOCUS*, AP<sup>®</sup> Edition.



## FOR TEACHERS

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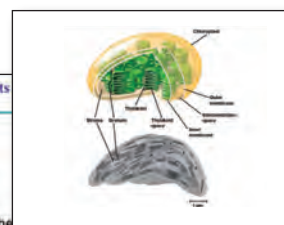
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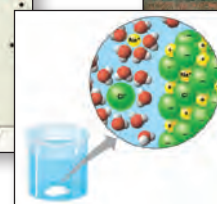
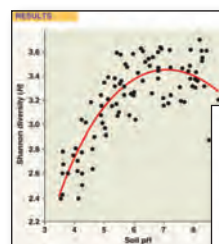
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- Instructor Guides for Supplements
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#### Chloroplasts: The Sites of Photosynthesis in Plants

- Leaves are the major locations of photosynthesis
- Their green color is from chlorophyll, the green pigment within chloroplasts
- Light energy absorbed by chlorophyll drives the synthesis of organic molecules in the chloroplast
- CO<sub>2</sub> enters and O<sub>2</sub> exits the leaf through microscopic pores called stomata



- ▲ 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.

#### Energy Transfer

Like jackrabbits, elephants have many blood vessels in their ears that help them cool their bodies by radiating heat. Which of the following statements about this radiated energy would be accurate?

- The original source of the energy was the sun.
- The energy will be recycled through the ecosystem.
- The radiated energy will be trapped by predators of the elephants.
- More energy is radiated in cold conditions than in hot conditions.
- More energy is radiated at night than during the day.

#### Experiments: Data Interpretation

Water snakes on islands in Lake Erie vary in coloration from banded to unbanded. Researchers hypothesized that unbanded snakes escape predation from hawks at higher rates than do banded snakes. Imagine that you tested survival rates on four different islands by measuring recapture rates of banded and unbanded snakes and collected the data shown below. Which of the following conclusions best derive from the data shown?

Islands	Unbanded	Banded
1	~10%	~15%
2	~15%	~20%
3	~20%	~25%
4	~25%	~30%

- Lack of bands helps snakes escape predation by hawks.
- Lack of bands improves snake survival but the mechanism is unknown.
- Lack of bands decreases snake survival rate.
- The two groups do not differ in survival rate.
- Survival rates of banded snakes differ among islands.

- ▲ 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: Clicker Questions, Student Misconception
- Questions, end-of-chapter essay questions, and activities and case studies from the student supplements.

# Featured Figures

## Make Connections Figures

- 3.30 Contributions of Genomics and Proteomics to Biology 68
- 8.20 The Working Cell 178
- 16.21 Genomics, Cell Signaling, and Cancer 338
- 21.15 The Sickle-Cell Allele 428
- 26.14 Maximizing Surface Area 526
- 29.10 Mutualism Across Kingdoms and Domains 603
- 32.3 Life Challenges and Solutions in Plants and Animals 666
- 37.8 Ion Movement and Gradients 777
- 42.18 The Working Ecosystem 902
- 43.28 Climate Change Has Effects at All Levels of Biological Organization 924

## Exploring Figures

- 1.3 Levels of Biological Organization 4
- 3.22 Levels of Protein Structure 60
- 4.3 Microscopy 74
- 4.7 Eukaryotic Cells 78
- 4.27 Cell Junctions in Animal Tissues 96
- 5.18 Endocytosis in Animal Cells 113
- 9.7 Mitosis in an Animal Cell 186
- 10.8 Meiosis in an Animal Cell 206
- 13.23 Chromatin Packing in a Eukaryotic Chromosome 268
- 22.3 Reproductive Barriers 436
- 23.5 The Origin of Mammals 457
- 24.19 Selected Major Groups of Bacteria 488
- 25.2 The Early Evolution of Eukaryotes 498
- 25.9 Eukaryotic Diversity 506
- 26.6 Alternation of Generations 522
- 26.16 Fungal Diversity 528
- 26.28 Angiosperm Phylogeny 538
- 27.11 The Diversity of Invertebrate Bilaterians 552
- 27.19 Vertebrate Diversity 556
- 27.29 Reptilian Diversity 564
- 28.9 Examples of Differentiated Plant Cells 580
- 29.15 Unusual Nutritional Adaptations in Plants 608
- 30.6 Flower Pollination 624
- 30.11 Fruit and Seed Dispersal 629
- 32.2 Structure and Function in Animal Tissues 665
- 32.21 The Mammalian Excretory System 681
- 36.9 Human Gametogenesis 758
- 38.7 The Organization of the Human Brain 794
- 38.21 The Structure of the Human Ear 805
- 38.26 The Structure of the Human Eye 808
- 40.2 The Scope of Ecological Research 841
- 40.3 Global Climate Patterns 842
- 40.9 Terrestrial Biomes 846
- 40.11 Aquatic Biomes 849
- 40.23 Mechanisms of Density-Dependent Regulation 863
- 42.13 Water and Nutrient Cycling 896
- 42.16 Restoration Ecology Worldwide 900

## Inquiry Figures

- 1.21 Does camouflage affect predation rates on two populations of mice? 17
- 5.4 Do membrane proteins move? 102
- <sup>†</sup>8.9 Which wavelengths of light are most effective in driving photosynthesis? 167
- 9.9 At which end do kinetochore microtubules shorten during anaphase? 189
- 9.14 Do molecular signals in the cytoplasm regulate the cell cycle? 192
- 11.3 When F<sub>1</sub> hybrid pea plants self- or cross-pollinate, which traits appear in the F<sub>2</sub> generation? 216
- 11.8 Do the alleles for one character segregate into gametes dependently or independently of the alleles for a different character? 220
- <sup>†</sup>12.4 In a cross between a wild-type female fruit fly and a mutant white-eyed male, what color eyes will the F<sub>1</sub> and F<sub>2</sub> offspring have? 239
- 12.9 How does linkage between two genes affect inheritance of characters? 243
- 13.3 Can a genetic trait be transferred between different bacterial strains? 254
- 13.5 Is protein or DNA the genetic material of phage T2? 255
- <sup>\*</sup>13.13 Does DNA replication follow the conservative, semiconservative, or dispersive model? 261
- 16.10 Could Bicoid be a morphogen that determines the anterior end of a fruit fly? 329
- 16.11 Can the nucleus from a differentiated animal cell direct development of an organism? 330
- 16.16 Can a fully differentiated human cell be “deprogrammed” to become a stem cell? 333
- 19.14 Can a change in a population's food source result in evolution by natural selection? 387
- 20.6 What is the species identity of food being sold as whale meat? 398
- <sup>\*</sup>21.18 Do females select mates based on traits indicative of “good genes”? 430
- 22.7 Can divergence of allopatric populations lead to reproductive isolation? 440
- 22.12 Does sexual selection in cichlids result in reproductive isolation? 443
- 22.18 How does hybridization lead to speciation in sunflowers? 448
- 23.21 What causes the loss of spines in lake stickleback fish? 468
- 24.14 Can prokaryotes evolve rapidly in response to environmental change? 483
- 25.21 What is the root of the eukaryotic tree? 513
- 26.31 Do endophytes benefit a woody plant? 541
- 27.15 Did the arthropod body plan result from new *Hox* genes? 554

- 29.11 How variable are the compositions of bacterial communities inside and outside of roots? 604
- 31.2 What part of a grass coleoptile senses light, and how is the signal transmitted? 641
- <sup>†</sup>31.3 Does asymmetric distribution of a growth-promoting chemical cause a coleoptile to bend? 641
- 31.4 What causes polar movement of auxin from shoot tip to base? 643
- 31.13 How does the order of red and far-red illumination affect seed germination? 650
- 34.21 What causes respiratory distress syndrome? 726
- 39.20 Does a digger wasp use landmarks to find her nest? 830
- 40.13 Does feeding by sea urchins limit seaweed distribution? 853
- <sup>†</sup>41.3 Can a species' niche be influenced by interspecific competition? 869
- 41.15 Is *Pisaster ochraceus* a keystone predator? 876
- 41.23 How does species richness relate to area? 882
- 42.7 Which nutrient limits phytoplankton production along the coast of Long Island? 891
- 42.12 How does temperature affect litter decomposition in an ecosystem? 895
- <sup>\*</sup>43.12 What caused the drastic decline of the Illinois greater prairie chicken population? 913

## Research Method Figures

- 3.25 X-Ray Crystallography 63
- 8.8 Determining an Absorption Spectrum 167
- 10.3 Preparing a Karyotype 202
- 11.2 Crossing Pea Plants 215
- 11.7 The Testcross 219
- 12.11 Constructing a Linkage Map 247
- 13.27 The Polymerase Chain Reaction (PCR) 273
- 15.16 RT-PCR Analysis of the Expression of Single Genes 318
- 20.15 Applying Parsimony to a Problem in Molecular Systematics 404
- 29.7 Hydroponic Culture 599
- 37.9 Intracellular Recording 778
- 41.11 Determining Microbial Diversity Using Molecular Tools 874
- 42.5 Determining Primary Production with Satellites 889

<sup>\*</sup>The Inquiry Figure, original research paper, and a worksheet to guide you through the paper are provided in *Inquiry in Action: Interpreting Scientific Papers*, Second Edition.

<sup>†</sup>A related Experimental Inquiry Tutorial can be assigned in MasteringBiology.

# Detailed Contents



## 1 Introduction: Evolution and the Foundations of Biology 2

**OVERVIEW** Inquiring About Life 2

**CONCEPT 1.1** The study of life reveals common themes 3

Theme: New Properties Emerge at Successive Levels of Biological Organization 3

Theme: Life's Processes Involve the Expression and Transmission of Genetic Information 6

Theme: Life Requires the Transfer and Transformation of Energy and Matter 8

Theme: Organisms Interact with Other Organisms and the Physical Environment 8

Evolution, the Core Theme of Biology 9

**CONCEPT 1.2** The Core Theme: Evolution accounts for the unity and diversity of life 10

Classifying the Diversity of Life 10

Unity in the Diversity of Life 11

Charles Darwin and the Theory of Natural Selection 11

The Tree of Life 12

**CONCEPT 1.3** In studying nature, scientists form and test hypotheses 13

Exploration and Discovery 13

Gathering and Analyzing Data 13

Forming and Testing Hypotheses 14

The Flexibility of the Scientific Process 15

*A Case Study in Scientific Inquiry: Investigating Coat Coloration in Mouse Populations* 16

Experimental Variables and Controls 16

Theories in Science 17

Science as a Social Process 18

## UNIT 1 Chemistry and Cells 21

## 2 The Chemical Context of Life 22

**OVERVIEW** A Chemical Connection to Biology 22

**CONCEPT 2.1** Matter consists of chemical elements in pure form and in combinations called compounds 22

Elements and Compounds 22

The Elements of Life 23

Evolution of Tolerance to Toxic Elements 23

**CONCEPT 2.2** An element's properties depend on the structure of its atoms 23

Subatomic Particles 24

Atomic Number and Atomic Mass 24

Isotopes 24

The Energy Levels of Electrons 25

Electron Distribution and Chemical Properties 26



**CONCEPT 2.3** The formation and function of molecules depend on chemical bonding between atoms 27

Covalent Bonds 27

Ionic Bonds 29

Weak Chemical Bonds 30

Molecular Shape and Function 30

**CONCEPT 2.4** Chemical reactions make and break chemical bonds 31

**CONCEPT 2.5** Hydrogen bonding gives water properties that help make life possible on Earth 32

Cohesion of Water Molecules 33

Moderation of Temperature by Water 34

Floating of Ice on Liquid Water 35

Water: The Solvent of Life 36

Acids and Bases 37

## 3 Carbon and the Molecular Diversity of Life 43

**OVERVIEW** Carbon Compounds and Life 43

**CONCEPT 3.1** Carbon atoms can form diverse molecules by bonding to four other atoms 44

The Formation of Bonds with Carbon 44

Molecular Diversity Arising from Variation in Carbon

Skeletons 45

The Chemical Groups Most Important to Life 46

ATP: An Important Source of Energy for Cellular Processes 48

**CONCEPT 3.2** Macromolecules are polymers, built from monomers 48

The Synthesis and Breakdown of Polymers 48

The Diversity of Polymers 49

**CONCEPT 3.3** Carbohydrates serve as fuel and building material 49

Sugars 49

Polysaccharides 51

**CONCEPT 3.4** Lipids are a diverse group of hydrophobic molecules 53

Fats 53

Phospholipids 54

Steroids 55

**CONCEPT 3.5** Proteins include a diversity of structures, resulting in a wide range of functions 55

Amino Acid Monomers 56

Polypeptides (Amino Acid Polymers) 58

Protein Structure and Function 58

**CONCEPT 3.6** Nucleic acids store, transmit, and help express hereditary information 64

The Roles of Nucleic Acids 64

The Components of Nucleic Acids 64

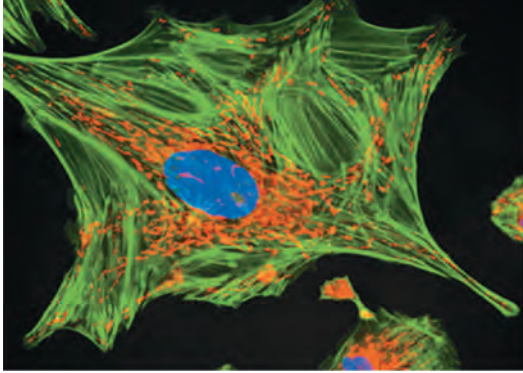
Nucleotide Polymers 65

The Structures of DNA and RNA Molecules 66

**CONCEPT 3.7** Genomics and proteomics have transformed biological inquiry and applications 66

DNA and Proteins as Tape Measures of Evolution 67





## 4

### A Tour of the Cell 72

**OVERVIEW** The Fundamental Units of Life 72

**CONCEPT 4.1** Biologists use microscopes and the tools of biochemistry to study cells 73

- Microscopy 73
- Cell Fractionation 75

**CONCEPT 4.2** Eukaryotic cells have internal membranes that compartmentalize their functions 75

- Comparing Prokaryotic and Eukaryotic Cells 75
- A Panoramic View of the Eukaryotic Cell 77

**CONCEPT 4.3** The eukaryotic cell's genetic instructions are housed in the nucleus and carried out by the ribosomes 80

- The Nucleus: Information Central 80
- Ribosomes: Protein Factories 82

**CONCEPT 4.4** The endomembrane system regulates protein traffic and performs metabolic functions in the cell 82

- The Endoplasmic Reticulum: Biosynthetic Factory 83
- The Golgi Apparatus: Shipping and Receiving Center 84
- Lysosomes: Digestive Compartments 85
- Vacuoles: Diverse Maintenance Compartments 86
- The Endomembrane System: *A Review* 87

**CONCEPT 4.5** Mitochondria and chloroplasts change energy from one form to another 87

- The Evolutionary Origins of Mitochondria and Chloroplasts 88
- Mitochondria: Chemical Energy Conversion 88
- Chloroplasts: Capture of Light Energy 89
- Peroxisomes: Oxidation 90

**CONCEPT 4.6** The cytoskeleton is a network of fibers that organizes structures and activities in the cell 90

- Roles of the Cytoskeleton: Support and Motility 90
- Components of the Cytoskeleton 91

**CONCEPT 4.7** Extracellular components and connections between cells help coordinate cellular activities 94

- Cell Walls of Plants 94
- The Extracellular Matrix (ECM) of Animal Cells 95
- Cell Junctions 96
- The Cell: A Living Unit Greater Than the Sum of Its Parts 97

## 5

### Membrane Transport and Cell Signaling 100

**OVERVIEW** Life at the Edge 100

**CONCEPT 5.1** Cellular membranes are fluid mosaics of lipids and proteins 100

- The Fluidity of Membranes 101
- Evolution of Differences in Membrane Lipid Composition 102
- Membrane Proteins and Their Functions 103
- The Role of Membrane Carbohydrates in Cell-Cell Recognition 104
- Synthesis and Sidedness of Membranes 104

**CONCEPT 5.2** Membrane structure results in selective permeability 105

- The Permeability of the Lipid Bilayer 105
- Transport Proteins 105

**CONCEPT 5.3** Passive transport is diffusion of a substance across a membrane with no energy investment 105

- Effects of Osmosis on Water Balance 106
- Facilitated Diffusion: Passive Transport Aided by Proteins 108

**CONCEPT 5.4** Active transport uses energy to move solutes against their gradients 109

- The Need for Energy in Active Transport 109
- How Ion Pumps Maintain Membrane Potential 110
- Cotransport: Coupled Transport by a Membrane Protein 111

**CONCEPT 5.5** Bulk transport across the plasma membrane occurs by exocytosis and endocytosis 112

- Exocytosis 112
- Endocytosis 112

**CONCEPT 5.6** The plasma membrane plays a key role in most cell signaling 114

- Local and Long-Distance Signaling 114
- The Three Stages of Cell Signaling: *A Preview* 115
- Reception, the Binding of a Signaling Molecule to a Receptor Protein 115
- Transduction by Cascades of Molecular Interactions 117
- Response: Regulation of Transcription or Cytoplasmic Activities 119

## 6

### An Introduction to Metabolism 122

**OVERVIEW** The Energy of Life 122

**CONCEPT 6.1** An organism's metabolism transforms matter and energy 122

- Metabolic Pathways 122
- Forms of Energy 123
- The Laws of Energy Transformation 124

**CONCEPT 6.2** The free-energy change of a reaction tells us whether or not the reaction occurs spontaneously 125

- Free-Energy Change ( $\Delta G$ ), Stability, and Equilibrium 125
- Free Energy and Metabolism 126

**CONCEPT 6.3** ATP powers cellular work by coupling exergonic reactions to endergonic reactions 128

- The Structure and Hydrolysis of ATP 128
- How the Hydrolysis of ATP Performs Work 129
- The Regeneration of ATP 130

**CONCEPT 6.4** Enzymes speed up metabolic reactions by lowering energy barriers 131

- The Activation Energy Barrier 131
- How Enzymes Speed Up Reactions 132
- Substrate Specificity of Enzymes 132
- Catalysis in the Enzyme's Active Site 133
- Effects of Local Conditions on Enzyme Activity 135
- The Evolution of Enzymes 136



**CONCEPT 6.5** Regulation of enzyme activity helps control metabolism 136

Allosteric Regulation of Enzymes 137

Organization of Enzymes Within the Cell 138

## 7 Cellular Respiration and Fermentation 141

**OVERVIEW** Life Is Work 141

**CONCEPT 7.1** Catabolic pathways yield energy by oxidizing organic fuels 142

Catabolic Pathways and Production of ATP 142

Redox Reactions: Oxidation and Reduction 142

The Stages of Cellular Respiration: *A Preview* 145

**CONCEPT 7.2** Glycolysis harvests chemical energy by oxidizing glucose to pyruvate 147

**CONCEPT 7.3** After pyruvate is oxidized, the citric acid cycle completes the energy-yielding oxidation of organic molecules 148

**CONCEPT 7.4** During oxidative phosphorylation, chemiosmosis couples electron transport to ATP synthesis 149

The Pathway of Electron Transport 150

Chemiosmosis: The Energy-Coupling Mechanism 151

An Accounting of ATP Production by Cellular Respiration 153

**CONCEPT 7.5** Fermentation and anaerobic respiration enable cells to produce ATP without the use of oxygen 154

Types of Fermentation 156

Comparing Fermentation with Anaerobic and Aerobic Respiration 156

The Evolutionary Significance of Glycolysis 157

**CONCEPT 7.6** Glycolysis and the citric acid cycle connect to many other metabolic pathways 157

The Versatility of Catabolism 157

Biosynthesis (Anabolic Pathways) 158

## 8 Photosynthesis 161

**OVERVIEW** The Process That Feeds the Biosphere 161

**CONCEPT 8.1** Photosynthesis converts light energy to the chemical energy of food 162

Chloroplasts: The Sites of Photosynthesis in Plants 162

Tracking Atoms Through Photosynthesis:

*Scientific Inquiry* 163

The Two Stages of Photosynthesis: *A Preview* 164

**CONCEPT 8.2** The light reactions convert solar energy to the chemical energy of ATP and NADPH 165

The Nature of Sunlight 165

Photosynthetic Pigments: The Light Receptors 166

Excitation of Chlorophyll by Light 168

A Photosystem: A Reaction-Center Complex Associated with Light-Harvesting Complexes 169



Linear Electron Flow 170

A Comparison of Chemiosmosis in Chloroplasts and Mitochondria 171

**CONCEPT 8.3** The Calvin cycle uses the chemical energy of ATP and NADPH to reduce CO<sub>2</sub> to sugar 173

Evolution of Alternative Mechanisms of Carbon Fixation in Hot, Arid Climates 175

The Importance of Photosynthesis: *A Review* 176

## 9 The Cell Cycle 182

**OVERVIEW** The Key Roles of Cell Division 182

**CONCEPT 9.1** Most cell division results in genetically identical daughter cells 183

Cellular Organization of the Genetic Material 183

Distribution of Chromosomes During Eukaryotic Cell Division 183

**CONCEPT 9.2** The mitotic phase alternates with interphase in the cell cycle 185

Phases of the Cell Cycle 185

The Mitotic Spindle: *A Closer Look* 185

Cytokinesis: *A Closer Look* 188

Binary Fission in Bacteria 190

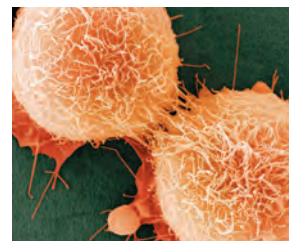
The Evolution of Mitosis 191

**CONCEPT 9.3** The eukaryotic cell cycle is regulated by a molecular control system 192

Evidence for Cytoplasmic Signals 192

Checkpoints of the Cell Cycle Control System 192

Loss of Cell Cycle Controls in Cancer Cells 195



## UNIT 2 Genetics 199

### 10 Meiosis and Sexual Life Cycles 200

**OVERVIEW** Variations on a Theme 200

**CONCEPT 10.1** Offspring acquire genes from parents by inheriting chromosomes 201

Inheritance of Genes 201

Comparison of Asexual and Sexual Reproduction 201

**CONCEPT 10.2** Fertilization and meiosis alternate in sexual life cycles 202

Sets of Chromosomes in Human Cells 202

Behavior of Chromosome Sets in the Human Life Cycle 203

The Variety of Sexual Life Cycles 204

**CONCEPT 10.3** Meiosis reduces the number of chromosome sets from diploid to haploid 205

The Stages of Meiosis 205

Crossing Over and Synapsis During Prophase I 208

A Comparison of Mitosis and Meiosis 208

**CONCEPT 10.4** Genetic variation produced in sexual life cycles contributes to evolution 210

Origins of Genetic Variation Among Offspring 210

The Evolutionary Significance of Genetic Variation Within Populations 212

## Mendel and the Gene Idea 214

**OVERVIEW** Drawing from the Deck of Genes 214

**CONCEPT 11.1** Mendel used the scientific approach to identify two laws of inheritance 215

Mendel's Experimental, Quantitative Approach 215

The Law of Segregation 215

The Law of Independent Assortment 219

**CONCEPT 11.2** Probability laws govern Mendelian inheritance 221

The Multiplication and Addition Rules Applied to Monohybrid Crosses 221

Solving Complex Genetics Problems with the Rules of Probability 222

**CONCEPT 11.3** Inheritance patterns are often more complex than predicted by simple Mendelian genetics 223

Extending Mendelian Genetics for a Single Gene 223

Extending Mendelian Genetics for Two or More Genes 225

Nature and Nurture: The Environmental Impact on Phenotype 226

A Mendelian View of Heredity and Variation 226

**CONCEPT 11.4** Many human traits follow Mendelian patterns of inheritance 228

Pedigree Analysis 228

Recessively Inherited Disorders 229

Dominantly Inherited Disorders 231

Multifactorial Disorders 231

Genetic Counseling Based on Mendelian Genetics 231

## The Chromosomal Basis of Inheritance 236

**OVERVIEW** Locating Genes Along Chromosomes 236

**CONCEPT 12.1** Morgan showed that Mendelian inheritance has its physical basis in the behavior of chromosomes: *scientific inquiry* 238

Morgan's Choice of Experimental Organism 238

Correlating Behavior of a Gene's Alleles with Behavior of a Chromosome Pair 238

**CONCEPT 12.2** Sex-linked genes exhibit unique patterns of inheritance 239

The Chromosomal Basis of Sex 239

Inheritance of X-Linked Genes 240

X Inactivation in Female Mammals 241

**CONCEPT 12.3** Linked genes tend to be inherited together because they are located near each other on the same chromosome 242

How Linkage Affects Inheritance 242

Genetic Recombination and Linkage 243

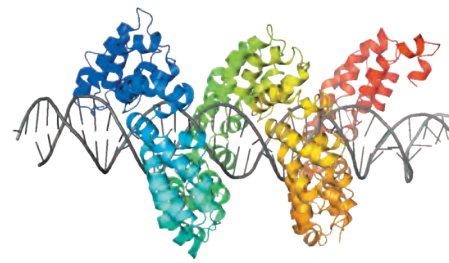
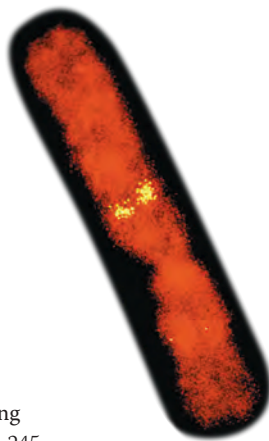
Mapping the Distance Between Genes Using Recombination Data: *Scientific Inquiry* 245

**CONCEPT 12.4** Alterations of chromosome number or structure cause some genetic disorders 248

Abnormal Chromosome Number 248

Alterations of Chromosome Structure 249

Human Disorders Due to Chromosomal Alterations 249



## The Molecular Basis of Inheritance 253

**OVERVIEW** Life's Operating Instructions 253

**CONCEPT 13.1** DNA is the genetic material 254

The Search for the Genetic Material: *Scientific Inquiry* 254

Building a Structural Model of DNA: *Scientific Inquiry* 256

**CONCEPT 13.2** Many proteins work together in DNA replication and repair 259

The Basic Principle: Base Pairing to a Template Strand 260

DNA Replication: *A Closer Look* 260

Proofreading and Repairing DNA 266

Evolutionary Significance of Altered DNA Nucleotides 266

Replicating the Ends of DNA Molecules 267

**CONCEPT 13.3** A chromosome consists of a DNA molecule packed together with proteins 267

**CONCEPT 13.4** Understanding DNA structure and replication makes genetic engineering possible 270

DNA Cloning: Making Multiple Copies of a Gene or Other DNA Segment 270

Using Restriction Enzymes to Make a Recombinant DNA Plasmid 271

Amplifying DNA: The Polymerase Chain Reaction (PCR) and Its Use in Cloning 272

DNA Sequencing 273

Editing Genes and Genomes 274

## Gene Expression: From Gene to Protein 278

**OVERVIEW** The Flow of Genetic Information 278

**CONCEPT 14.1** Genes specify proteins via transcription and translation 279

Evidence from the Study of Metabolic Defects 279

Basic Principles of Transcription and Translation 280

The Genetic Code 282

**CONCEPT 14.2** Transcription is the DNA-directed synthesis of RNA: *a closer look* 284

Molecular Components of Transcription 284

Synthesis of an RNA Transcript 284

**CONCEPT 14.3** Eukaryotic cells modify RNA after transcription 286

Alteration of mRNA Ends 286

Split Genes and RNA Splicing 287

**CONCEPT 14.4** Translation is the RNA-directed synthesis of a polypeptide: *a closer look* 288

Molecular Components of Translation 288

Building a Polypeptide 291

Completing and Targeting the Functional Protein 292

Making Multiple Polypeptides in Bacteria and Eukaryotes 296

**CONCEPT 14.5** Mutations of one or a few nucleotides can affect protein structure and function 298

Types of Small-Scale Mutations 298

New Mutations and Mutagens 300

What Is a Gene? *Revisiting the Question* 300

## 15 Regulation of Gene Expression 303

**OVERVIEW** Beauty in the Eye of the Beholder 303

**CONCEPT 15.1** Bacteria often respond to environmental change by regulating transcription 303

- Operons: The Basic Concept 304
- Repressible and Inducible Operons: Two Types of Negative Gene Regulation 305
- Positive Gene Regulation 307

**CONCEPT 15.2** Eukaryotic gene expression is regulated at many stages 308

- Differential Gene Expression 308
- Regulation of Chromatin Structure 309
- Regulation of Transcription Initiation 309
- Mechanisms of Post-transcriptional Regulation 314

**CONCEPT 15.3** Noncoding RNAs play multiple roles in controlling gene expression 315

- Effects on mRNAs by MicroRNAs and Small Interfering RNAs 315
- Chromatin Remodeling and Effects on Transcription by Noncoding RNAs 316

**CONCEPT 15.4** Researchers can monitor expression of specific genes 316

- Studying the Expression of Single Genes 317
- Studying the Expression of Groups of Genes 318

## 16 Development, Stem Cells, and Cancer 321

**OVERVIEW** Orchestrating Life's Processes 321

**CONCEPT 16.1** A program of differential gene expression leads to the different cell types in a multicellular organism 322

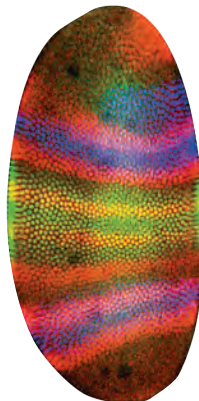
- A Genetic Program for Embryonic Development 322
- Cytoplasmic Determinants and Inductive Signals 322
- Sequential Regulation of Gene Expression during Cellular Differentiation 323
- Pattern Formation: Setting Up the Body Plan 326
- Genetic Analysis of Early Development: *Scientific Inquiry* 327

**CONCEPT 16.2** Cloning of organisms showed that differentiated cells could be “reprogrammed” and ultimately led to the production of stem cells 330

- Cloning Plants: Single-Cell Cultures 330
- Cloning Animals: Nuclear Transplantation 330
- Stem Cells of Animals 332

**CONCEPT 16.3** Abnormal regulation of genes that affect the cell cycle can lead to cancer 334

- Types of Genes Associated with Cancer 334
- Interference with Cell-Signaling Pathways 335
- The Multistep Model of Cancer Development 336
- Inherited Predisposition and Other Factors Contributing to Cancer 337



## 17 Viruses 342

**OVERVIEW** A Borrowed Life 342

**CONCEPT 17.1** A virus consists of a nucleic acid surrounded by a protein coat 342

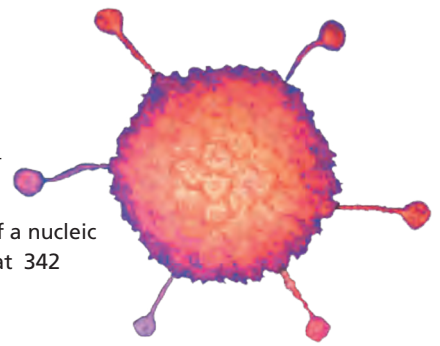
- Viral Genomes 343
- Capsids and Envelopes 343

**CONCEPT 17.2** Viruses replicate only in host cells 344

- General Features of Viral Replicative Cycles 344
- Replicative Cycles of Phages 345
- Bacterial Defenses Against Phages 347
- Replicative Cycles of Animal Viruses 347
- Evolution of Viruses 349

**CONCEPT 17.3** Viruses and prions are formidable pathogens in animals and plants 351

- Viral Diseases in Animals 351
- Emerging Viruses 352
- Viral Diseases in Plants 354
- Prions: Proteins as Infectious Agents 355



## 18 Genomes and Their Evolution 357

**OVERVIEW** Reading Leaves from the Tree of Life 357

**CONCEPT 18.1** The Human Genome Project fostered development of faster, less expensive sequencing techniques 358

**CONCEPT 18.2** Scientists use bioinformatics to analyze genomes and their functions 359

- Centralized Resources for Analyzing Genome Sequences 359
- Understanding the Functions of Protein-Coding Genes 359
- Understanding Genes and Gene Expression at the Systems Level 360

**CONCEPT 18.3** Genomes vary in size, number of genes, and gene density 361

- Genome Size 362
- Number of Genes 362
- Gene Density and Noncoding DNA 363

**CONCEPT 18.4** Multicellular eukaryotes have much noncoding DNA and many multigene families 363

- Transposable Elements and Related Sequences 364
- Other Repetitive DNA, Including Simple Sequence DNA 365
- Genes and Multigene Families 365

**CONCEPT 18.5** Duplication, rearrangement, and mutation of DNA contribute to genome evolution 367

- Duplication of Entire Chromosome Sets 367
- Alterations of Chromosome Structure 367
- Duplication and Divergence of Gene-Sized Regions of DNA 368
- Rearrangements of Parts of Genes: Exon Duplication and Exon Shuffling 369
- How Transposable Elements Contribute to Genome Evolution 371

**CONCEPT 18.6** Comparing genome sequences provides clues to evolution and development 371

- Comparing Genomes 372
- Widespread Conservation of Developmental Genes Among Animals 374



## UNIT 3 Evolution 378

### 19 Descent with Modification 379

**OVERVIEW** Endless Forms Most Beautiful 379

**CONCEPT 19.1** The Darwinian revolution challenged traditional views of a young Earth inhabited by unchanging species 380

*Scala Naturae* and Classification of Species 380

Ideas About Change over Time 380

Lamarck's Hypothesis of Evolution 381

**CONCEPT 19.2** Descent with modification by natural selection explains the adaptations of organisms and the unity and diversity of life 382

Darwin's Research 382

Ideas from *The Origin of Species* 384

**CONCEPT 19.3** Evolution is supported by an overwhelming amount of scientific evidence 387

Direct Observations of Evolutionary Change 387

Homology 389

The Fossil Record 390

Biogeography 391

What Is Theoretical About Darwin's View of Life? 392

### 20 Phylogeny 395

**OVERVIEW** Investigating the Evolutionary History of Life 395

**CONCEPT 20.1** Phylogenies show evolutionary relationships 396

Binomial Nomenclature 396

Hierarchical Classification 397

Linking Classification and Phylogeny 397

What We Can and Cannot Learn from Phylogenetic Trees 398

Applying Phylogenies 398

**CONCEPT 20.2** Phylogenies are inferred from morphological and molecular data 399

Morphological and Molecular Homologies 399

Sorting Homology from Analogy 399

Evaluating Molecular Homologies 400

**CONCEPT 20.3** Shared characters are used to construct phylogenetic trees 401

Cladistics 401

Phylogenetic Trees with Proportional Branch Lengths 402

Maximum Parsimony 405

Phylogenetic Trees as Hypotheses 405

**CONCEPT 20.4** Molecular clocks help track evolutionary time 406

Molecular Clocks 406

Applying a Molecular Clock: Dating the Origin of HIV 407

**CONCEPT 20.5** New information continues to revise our understanding of evolutionary history 408

From Two Kingdoms to Three Domains 408

The Important Role of Horizontal Gene Transfer 409

## 21 The Evolution of Populations 413

**OVERVIEW** The Smallest Unit of Evolution 413

**CONCEPT 21.1** Genetic variation makes evolution possible 414

Genetic Variation 414

Sources of Genetic Variation 415

**CONCEPT 21.2** The Hardy-Weinberg equation can be used to test whether a population is evolving 417

Gene Pools and Allele Frequencies 417

The Hardy-Weinberg Equation 417

**CONCEPT 21.3** Natural selection, genetic drift, and gene flow can alter allele frequencies in a population 421

Natural Selection 421

Genetic Drift 421

Gene Flow 423

**CONCEPT 21.4** Natural selection is the only mechanism that consistently causes adaptive evolution 424

Natural Selection: *A Closer Look* 424

The Key Role of Natural Selection in Adaptive Evolution 426

Balancing Selection 426

Sexual Selection 427

Why Natural Selection Cannot Fashion Perfect Organisms 430

## 22 The Origin of Species 434

**OVERVIEW** That "Mystery of Mysteries" 434

**CONCEPT 22.1** The biological species concept emphasizes reproductive isolation 434

The Biological Species Concept 435

Other Definitions of Species 438

**CONCEPT 22.2** Speciation can take place with or without geographic separation 439

Allopatric ("Other Country") Speciation 439

Sympatric ("Same Country") Speciation 440

Allopatric and Sympatric Speciation: *A Review* 443

**CONCEPT 22.3** Hybrid zones reveal factors that cause reproductive isolation 444

Patterns Within Hybrid Zones 445

Hybrid Zones over Time 445

**CONCEPT 22.4** Speciation can occur rapidly or slowly and can result from changes in few or many genes 446

The Time Course of Speciation 447

Studying the Genetics of Speciation 448

From Speciation to Macroevolution 449



## 23

### Broad Patterns of Evolution 452

**OVERVIEW** A Surprise in the Desert 452

**CONCEPT 23.1** The fossil record documents life's history 452

- The Fossil Record 454
- How Rocks and Fossils Are Dated 454
- Fossils Frame the Geologic Record 454
- The Origin of New Groups of Organisms 456

**CONCEPT 23.2** The rise and fall of groups of organisms reflect differences in speciation and extinction rates 456

- Plate Tectonics 458
- Mass Extinctions 460
- Adaptive Radiations 463

**CONCEPT 23.3** Major changes in body form can result from changes in the sequences and regulation of developmental genes 465

- Effects of Developmental Genes 465
- The Evolution of Development 466

**CONCEPT 23.4** Evolution is not goal oriented 468

- Evolutionary Novelties 469
- Evolutionary Trends 470

## UNIT 4 The Evolutionary History of Life 473

## 24

### Early Life and the Diversification of Prokaryotes 474

**OVERVIEW** The First Cells 474

**CONCEPT 24.1** Conditions on early Earth made the origin of life possible 475

- Synthesis of Organic Compounds on Early Earth 475
- Abiotic Synthesis of Macromolecules 476
- Protocells 476
- Self-Replicating RNA 476
- Fossil Evidence of Early Life 477

**CONCEPT 24.2** Diverse structural and metabolic adaptations have evolved in prokaryotes 478

- Cell-Surface Structures 478
- Motility 480
- Internal Organization and DNA 480
- Nutritional and Metabolic Adaptations 481
- Reproduction 482
- Adaptations of Prokaryotes: *A Summary* 482

**CONCEPT 24.3** Rapid reproduction, mutation, and genetic recombination promote genetic diversity in prokaryotes 483

- Rapid Reproduction and Mutation 483
- Genetic Recombination 484

**CONCEPT 24.4** Prokaryotes have radiated into a diverse set of lineages 486

- An Overview of Prokaryotic Diversity 486
- Bacteria 487
- Archaea 487

**CONCEPT 24.5** Prokaryotes play crucial roles in the biosphere 490

- Chemical Recycling 490
- Ecological Interactions 491
- Impact on Humans 491

## 25

### The Origin and Diversification of Eukaryotes 497

**OVERVIEW** Shape Changers 497

**CONCEPT 25.1** Eukaryotes arose by endosymbiosis more than 1.8 billion years ago 497

- The Fossil Record of Early Eukaryotes 499
- Endosymbiosis in Eukaryotic Evolution 500

**CONCEPT 25.2** Multicellularity has originated several times in eukaryotes 503

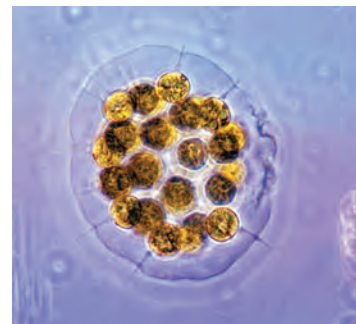
- Multicellular Colonies 503
- Independent Origins of Complex Multicellularity 503
- Steps in the Origin of Multicellular Animals 504

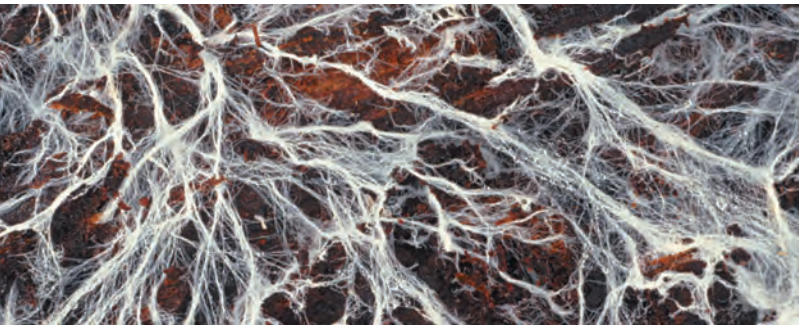
**CONCEPT 25.3** Four "supergroups" of eukaryotes have been proposed based on morphological and molecular data 505

- Four Supergroups of Eukaryotes 505
- Excavates 508
- SAR: Stramenopiles, Alveolates, and Rhizarians 509
- Archaeplastids 511
- Unikonts 512

**CONCEPT 25.4** Single-celled eukaryotes play key roles in ecological communities and affect human health 515

- Structural and Functional Diversity in Protists 515
- Photosynthetic Protists 515
- Symbiotic Protists 516
- Effects on Human Health 516





## 26

### The Colonization of Land 520

**OVERVIEW** The Greening of Earth 520

**CONCEPT 26.1** Fossils show that plants colonized land more than 470 million years ago 521

- Evidence of Algal Ancestry 521
- Adaptations Enabling the Move to Land 521
- Derived Traits of Plants 523
- Early Plants 523

**CONCEPT 26.2** Though not closely related to plants, fungi played a key role in the colonization of land 524

- The Origin of Fungi 525
- Fungal Adaptations for Life on Land 525
- Diversification of Fungi 527

**CONCEPT 26.3** Early plants radiated into a diverse set of lineages 530

- Bryophytes: A Collection of Basal Plant Lineages 530
- Seedless Vascular Plants: The First Plants to Grow Tall 531

**CONCEPT 26.4** Seeds and pollen grains are key adaptations for life on land 533

- Terrestrial Adaptations in Seed Plants 533
- Early Seed Plants and the Rise of Gymnosperms 535
- The Origin and Diversification of Angiosperms 536

**CONCEPT 26.5** Plants and fungi fundamentally changed chemical cycling and biotic interactions 539

- Physical Environment and Chemical Cycling 539
- Biotic Interactions 540



## 27

### The Rise of Animal Diversity 545

**OVERVIEW** Life Becomes Dangerous 545

**CONCEPT 27.1** Animals originated more than 700 million years ago 545

- Fossil and Molecular Evidence 546
- Early-Diverging Animal Groups 546

**CONCEPT 27.2** The diversity of large animals increased dramatically during the “Cambrian explosion” 547

- Evolutionary Change in the Cambrian Explosion 547
- Dating the Origin of Bilaterians 548

**CONCEPT 27.3** Diverse animal groups radiated in aquatic environments 549

- Animal Body Plans 549
- The Diversification of Animals 550
- Bilaterian Radiation I: Diverse Invertebrates 551

**CONCEPT 27.4** Vertebrates have been the ocean’s dominant predators for more than 400 million years 554

- Bilaterian Radiation II: Aquatic Vertebrates 554
- Summary: Effects of Bilaterian Radiations I and II* 557

**CONCEPT 27.5** Several animal groups had features facilitating their colonization of land 558

- Early Land Animals 558
- Colonization of Land by Arthropods 559
- Terrestrial Vertebrates 560

**CONCEPT 27.6** Amniotes have key adaptations for life in a wide range of terrestrial environments 562

- Terrestrial Adaptations in Amniotes 562
- The Origin and Radiation of Amniotes 563
- Human Evolution 567

**CONCEPT 27.7** Animals have transformed ecosystems and altered the course of evolution 568

- Ecological Effects of Animals 568
- Evolutionary Effects of Animals 569



## UNIT 5 Plant Form and Function 574

## 28

### Plant Structure and Growth 575

**OVERVIEW** Are Plants Computers? 575

**CONCEPT 28.1** Plants have a hierarchical organization consisting of organs, tissues, and cells 576

- The Three Basic Plant Organs: Roots, Stems, and Leaves 576
- Dermal, Vascular, and Ground Tissue Systems 578
- Common Types of Plant Cells 579

- CONCEPT 28.2** Different meristems generate new cells for primary and secondary growth 582  
 Gene Expression and Control of Cell Differentiation 583  
 Meristematic Control of the Transition to Flowering and the Life Spans of Plants 584
- CONCEPT 28.3** Primary growth lengthens roots and shoots 584  
 Primary Growth of Roots 584  
 Primary Growth of Shoots 586
- CONCEPT 28.4** Secondary growth increases the diameter of stems and roots in woody plants 588  
 The Vascular Cambium and Secondary Vascular Tissue 590  
 The Cork Cambium and the Production of Periderm 591

## 29

### Resource Acquisition, Nutrition, and Transport in Vascular Plants 593

- OVERVIEW** A Whole Lot of Shaking Going On 593
- CONCEPT 29.1** Adaptations for acquiring resources were key steps in the evolution of vascular plants 594  
 Shoot Architecture and Light Capture 594  
 Root Architecture and Acquisition of Water and Minerals 595
- CONCEPT 29.2** Different mechanisms transport substances over short or long distances 596  
 The Apoplast and Symplast: Transport Continuums 596  
 Short-Distance Transport of Solutes Across Plasma Membranes 596  
 Short-Distance Transport of Water Across Plasma Membranes 597  
 Long-Distance Transport: The Role of Bulk Flow 599
- CONCEPT 29.3** Plant roots absorb essential elements from the soil 599  
 Macronutrients and Micronutrients 599  
 Symptoms of Mineral Deficiency 600  
 Soil Management 601  
 The Living, Complex Ecosystem of Soil 601
- CONCEPT 29.4** Plant nutrition often involves relationships with other organisms 602  
 Bacteria and Plant Nutrition 604  
 Fungi and Plant Nutrition 606  
 Epiphytes, Parasitic Plants, and Carnivorous Plants 607
- CONCEPT 29.5** Transpiration drives the transport of water and minerals from roots to shoots via the xylem 609  
 Absorption of Water and Minerals by Root Cells 609  
 Transport of Water and Minerals into the Xylem 609  
 Bulk Flow Transport via the Xylem 610  
 Xylem Sap Ascent by Bulk Flow: *A Review* 612



- CONCEPT 29.6** The rate of transpiration is regulated by stomata 612  
 Stomata: Major Pathways for Water Loss 612  
 Mechanisms of Stomatal Opening and Closing 613  
 Stimuli for Stomatal Opening and Closing 613  
 Effects of Transpiration on Wilting and Leaf Temperature 614  
 Adaptations That Reduce Evaporative Water Loss 614
- CONCEPT 29.7** Sugars are transported from sources to sinks via the phloem 615  
 Movement from Sugar Sources to Sugar Sinks 615  
 Bulk Flow by Positive Pressure: The Mechanism of Translocation in Angiosperms 616

## 30

### Reproduction and Domestication of Flowering Plants 619

- OVERVIEW** Flowers of Deceit 619
- CONCEPT 30.1** Flowers, double fertilization, and fruits are unique features of the angiosperm life cycle 620  
 Flower Structure and Function 620  
 Flower Formation 620  
 The Angiosperm Life Cycle: An Overview 622  
 Pollination: *A Closer Look* 624  
 Seed Development and Structure 625  
 Germination, Growth, and Flowering 627  
 Fruit Structure and Function 627
- CONCEPT 30.2** Flowering plants reproduce sexually, asexually, or both 630  
 Mechanisms of Asexual Reproduction 630  
 Advantages and Disadvantages of Asexual Versus Sexual Reproduction 630  
 Mechanisms That Prevent Self-Fertilization 631  
 Totipotency, Vegetative Reproduction, and Tissue Culture 631
- CONCEPT 30.3** People modify crops through breeding and genetic engineering 633  
 Plant Breeding 633  
 Plant Biotechnology and Genetic Engineering 634  
 The Debate over Plant Biotechnology 635

## 31

### Plant Responses to Internal and External Signals 639

- OVERVIEW** A Chameleon Vine 639
- CONCEPT 31.1** Plant hormones help coordinate growth, development, and responses to stimuli 640  
 The Discovery of Plant Hormones 640  
 A Survey of Plant Hormones 642
- CONCEPT 31.2** Responses to light are critical for plant success 648  
 Photomorphogenesis 648  
 Biological Clocks and Circadian Rhythms 650  
 Photoperiodism and Responses to Seasons 651
- CONCEPT 31.3** Plants respond to a wide variety of stimuli other than light 653  
 Gravity 654  
 Mechanical Stimuli 654  
 Environmental Stresses 655
- CONCEPT 31.4** Plants respond to attacks by herbivores and pathogens 657  
 Defenses Against Herbivores 658  
 Defenses Against Pathogens 658





## UNIT 6 Animal Form and Function 662

### 32 The Internal Environment of Animals: Organization and Regulation 663

**OVERVIEW** Diverse Forms, Common Challenges 663

**CONCEPT 32.1** Animal form and function are correlated at all levels of organization 664

**CONCEPT 32.2** The endocrine and nervous systems act individually and together in regulating animal physiology 668

- An Overview of Coordination and Control 668
- Endocrine Glands and Hormones 669
- Regulation of Endocrine Signaling 669
- Simple Endocrine Pathways 670
- Neuroendocrine Signaling 670
- Hormone Solubility 671
- Multiple Effects of Hormones 672
- Evolution of Hormone Function 672

**CONCEPT 32.3** Feedback control maintains the internal environment in many animals 673

- Regulating and Conforming 673
- Homeostasis 673
- Thermoregulation: *A Closer Look* 674

**CONCEPT 32.4** A shared system mediates osmoregulation and excretion in many animals 677

- Osmosis and Osmolarity 677
- Osmoregulatory Challenges and Mechanisms 678
- Nitrogenous Wastes 678
- Excretory Processes 679

**CONCEPT 32.5** The mammalian kidney's ability to conserve water is a key terrestrial adaptation 682

- From Blood Filtrate to Urine: *A Closer Look* 682
- Concentrating Urine in the Mammalian Kidney 684
- Adaptations of the Vertebrate Kidney to Diverse Environments 684
- Homeostatic Regulation of the Kidney 684

## 33

### Animal Nutrition 688

**OVERVIEW** The Need to Feed 688

**CONCEPT 33.1** An animal's diet must supply chemical energy, organic building blocks, and essential nutrients 689

- Essential Nutrients 689
- Dietary Deficiencies 690

**CONCEPT 33.2** Food processing involves ingestion, digestion, absorption, and elimination 691

- Digestive Compartments 691

**CONCEPT 33.3** Organs specialized for sequential stages of food processing form the mammalian digestive system 693

- The Oral Cavity, Pharynx, and Esophagus 693
- Digestion in the Stomach 694
- Digestion in the Small Intestine 695
- Absorption in the Small Intestine 696
- Processing in the Large Intestine 697

**CONCEPT 33.4** Evolutionary adaptations of vertebrate digestive systems correlate with diet 698

- Dental Adaptations 698
- Stomach and Intestinal Adaptations 698
- Mutualistic Adaptations in Humans 698
- Mutualistic Adaptations in Herbivores 699

**CONCEPT 33.5** Feedback circuits regulate digestion, energy allocation, and appetite 700

- Regulation of Digestion 700
- Energy Allocation 700
- Regulation of Appetite and Consumption 703

## 34

### Circulation and Gas Exchange 706

**OVERVIEW** Trading Places 706

**CONCEPT 34.1** Circulatory systems link exchange surfaces with cells throughout the body 707

- Open and Closed Circulatory Systems 707
- Organization of Vertebrate Circulatory Systems 708

**CONCEPT 34.2** Coordinated cycles of heart contraction drive double circulation in mammals 710

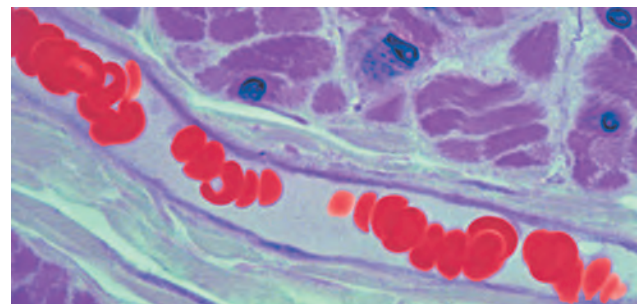
- Mammalian Circulation 710
- The Mammalian Heart: *A Closer Look* 710
- Maintaining the Heart's Rhythmic Beat 712

**CONCEPT 34.3** Patterns of blood pressure and flow reflect the structure and arrangement of blood vessels 712

- Blood Vessel Structure and Function 713
- Blood Flow Velocity 713
- Blood Pressure 714
- Capillary Function 715
- Fluid Return by the Lymphatic System 715

**CONCEPT 34.4** Blood components function in exchange, transport, and defense 717

- Blood Composition and Function 717
- Cardiovascular Disease 719



**CONCEPT 34.5** Gas exchange occurs across specialized respiratory surfaces 720

Partial Pressure Gradients in Gas Exchange 721  
Respiratory Media 722  
Respiratory Surfaces 722  
Gills in Aquatic Animals 723  
Tracheal Systems in Insects 723  
Lungs 724

**CONCEPT 34.6** Breathing ventilates the lungs 726

How a Mammal Breathes 726  
Control of Breathing in Humans 727

**CONCEPT 34.7** Adaptations for gas exchange include pigments that bind and transport gases 728

Coordination of Circulation and Gas Exchange 728  
Respiratory Pigments 728  
Carbon Dioxide Transport 729  
Respiratory Adaptations of Diving Mammals 730



## 35 The Immune System 733

**OVERVIEW** Recognition and Response 733

**CONCEPT 35.1** In innate immunity, recognition and response rely on traits common to groups of pathogens 734

Innate Immunity of Invertebrates 734  
Innate Immunity of Vertebrates 734  
Evasion of Innate Immunity by Pathogens 737

**CONCEPT 35.2** In adaptive immunity, receptors provide pathogen-specific recognition 737

Antigen Recognition by B Cells and Antibodies 738  
Antigen Recognition by T Cells 739  
B Cell and T Cell Development 739

**CONCEPT 35.3** Adaptive immunity defends against infection of body fluids and body cells 742

Helper T Cells: Activating Adaptive Immunity 742  
B Cells and Antibodies: A Response to Extracellular Pathogens 743  
Cytotoxic T Cells: A Response to Infected Host Cells 744  
Summary of the Humoral and Cell-Mediated Immune Responses 744  
Active and Passive Immunity 745  
Antibodies as Tools 746  
Immune Rejection 746  
Disruptions in Immune System Function 746  
Cancer and Immunity 748

## 36 Reproduction and Development 751

**OVERVIEW** Let Me Count the Ways 751

**CONCEPT 36.1** Both asexual and sexual reproduction occur in the animal kingdom 752

Mechanisms of Asexual Reproduction 752  
Sexual Reproduction: An Evolutionary Enigma 752  
Reproductive Cycles 753  
Variation in Patterns of Sexual Reproduction 753  
External and Internal Fertilization 754  
Ensuring the Survival of Offspring 754

**CONCEPT 36.2** Reproductive organs produce and transport gametes 755

Variation in Reproductive Systems 755  
Human Male Reproductive Anatomy 756  
Human Female Reproductive Anatomy 757  
Gametogenesis 757

**CONCEPT 36.3** The interplay of tropic and sex hormones regulates reproduction in mammals 760

Hormonal Control of the Male Reproductive System 761  
Hormonal Control of Female Reproductive Cycles 761  
Human Sexual Response 763

**CONCEPT 36.4** Development of an egg into a mature embryo requires fertilization, cleavage, gastrulation, and organogenesis 764

Fertilization 765  
Cleavage and Gastrulation 765  
Organogenesis 767  
Conception and Embryo Implantation in Humans 767  
Human Development and Birth 768  
Contraception 768  
Infertility and *In Vitro* Fertilization 770

## 37 Neurons, Synapses, and Signaling 772

**OVERVIEW** Lines of Communication 772

**CONCEPT 37.1** Neuron structure and organization reflect function in information transfer 773

Neuron Structure and Function 773  
Introduction to Information Processing 774

**CONCEPT 37.2** Ion pumps and ion channels establish the resting potential of a neuron 775

Formation of the Resting Potential 775  
Modeling the Resting Potential 776

**CONCEPT 37.3** Action potentials are the signals conducted by axons 778

Hyperpolarization and Depolarization 778  
Graded Potentials and Action Potentials 778  
Generation of Action Potentials: *A Closer Look* 779  
Conduction of Action Potentials 781

**CONCEPT 37.4** Neurons communicate with other cells at synapses 783

Generation of Postsynaptic Potentials 784  
Summation of Postsynaptic Potentials 784  
Modulated Signaling at Synapses 784  
Neurotransmitters 785

**OVERVIEW** Command and Control Center 790**CONCEPT 38.1** Nervous systems consist of circuits of neurons and supporting cells 790

Glia 791

Organization of the Vertebrate Nervous System 792

The Peripheral Nervous System 792

**CONCEPT 38.2** The vertebrate brain is regionally specialized 793

Functional Imaging of the Brain 793

Arousal and Sleep 793

Biological Clock Regulation 796

Emotions 796

The Brain's Reward System and Drug Addiction 797

**CONCEPT 38.3** The cerebral cortex controls voluntary movement and cognitive functions 798

Language and Speech 798

Lateralization of Cortical Function 798

Information Processing 799

Frontal Lobe Function 799

Evolution of Cognition in Vertebrates 799

Neuronal Plasticity 800

Memory and Learning 801

**CONCEPT 38.4** Sensory receptors transduce stimulus energy and transmit signals to the central nervous system 801

Sensory Reception and Transduction 801

Transmission 802

Perception 802

Amplification and Adaptation 802

Types of Sensory Receptors 802

**CONCEPT 38.5** In hearing and equilibrium, mechanoreceptors detect moving fluid or settling particles 804

Sensing of Gravity and Sound in Invertebrates 804

Hearing and Equilibrium in Mammals 804

**CONCEPT 38.6** The diverse visual receptors of animals depend on light-absorbing pigments 807

Evolution of Visual Perception 807

The Vertebrate Visual System 809

**OVERVIEW** The How and Why of Animal Activity 814**CONCEPT 39.1** The physical interaction of protein filaments is required for muscle function 815

Vertebrate Skeletal Muscle 815

Other Types of Vertebrate Muscle 820

Invertebrate Muscle 821

**CONCEPT 39.2** Skeletal systems transform muscle contraction into locomotion 821

Types of Skeletal Systems 821

Types of Locomotion 823

**CONCEPT 39.3** Discrete sensory inputs can stimulate both simple and complex behaviors 825

Fixed Action Patterns 826

Migration 826

Behavioral Rhythms 826

Animal Signals and Communication 826

**CONCEPT 39.4** Learning establishes specific links between experience and behavior 828

Experience and Behavior 828

Learning 828

**CONCEPT 39.5** Selection for individual survival and reproductive success can explain diverse behaviors 831

Evolution of Foraging Behavior 831

Mating Behavior and Mate Choice 832

**CONCEPT 39.6** Genetic analyses and the concept of inclusive fitness provide a basis for studying the evolution of behavior 834

Genetic Basis of Behavior 834

Genetic Variation and the Evolution of Behavior 834

Case Study: *Variation in Prey Selection* 834

Altruism 835

Inclusive Fitness 835

## UNIT 7 Ecology 839

**OVERVIEW** Discovering Ecology 840**CONCEPT 40.1** Earth's climate influences the distribution of terrestrial biomes 843

Global Climate Patterns 843

Regional Effects on Climate 843

Climate and Terrestrial Biomes 844

General Features of Terrestrial Biomes 845

**CONCEPT 40.2** Aquatic biomes are diverse and dynamic systems that cover most of Earth 849**CONCEPT 40.3** Interactions between organisms and the environment limit the distribution of species 852

Dispersal and Distribution 852

Biotic Factors 853

Abiotic Factors 853

**CONCEPT 40.4** Biotic and abiotic factors affect population density, dispersion, and demographics 854

Density and Dispersion 854

Demographics 856

**CONCEPT 40.5** The exponential and logistic models describe the growth of populations 857

Changes in Population Size 857

Exponential Growth 858

Carrying Capacity 858

The Logistic Growth Model 859

The Logistic Model and Real Populations 860



- CONCEPT 40.6** Population dynamics are influenced strongly by life history traits and population density 861  
 “Trade-offs” and Life Histories 861  
 Population Change and Population Density 862  
 Mechanisms of Density-Dependent Population Regulation 862  
 Population Dynamics 862

## 41

### Species Interactions 867

**OVERVIEW** Communities in Motion 867

**CONCEPT 41.1** Interactions within a community may help, harm, or have no effect on the species involved 868

- Competition 868
- Exploitation 869
- Positive Interactions 872

**CONCEPT 41.2** Diversity and trophic structure characterize biological communities 873

- Species Diversity 873
- Diversity and Community Stability 875
- Trophic Structure 875
- Species with a Large Impact 876
- Bottom-Up and Top-Down Controls 877

**CONCEPT 41.3** Disturbance influences species diversity and composition 878

- Characterizing Disturbance 878
- Ecological Succession 879
- Human Disturbance 880

**CONCEPT 41.4** Biogeographic factors affect community diversity 881

- Latitudinal Gradients 881
- Area Effects 882

**CONCEPT 41.5** Pathogens alter community structure locally and globally 883

- Effects on Community Structure 883
- Community Ecology and Zoonotic Diseases 883

## 42

### Ecosystems and Energy 886

**OVERVIEW** Transformed to Tundra 886

**CONCEPT 42.1** Physical laws govern energy flow and chemical cycling in ecosystems 887

- Conservation of Energy 887
- Conservation of Mass 887
- Energy, Mass, and Trophic Levels 888

**CONCEPT 42.2** Energy and other limiting factors control primary production in ecosystems 888

- Ecosystem Energy Budgets 889
- Primary Production in Aquatic Ecosystems 890
- Primary Production in Terrestrial Ecosystems 891

**CONCEPT 42.3** Energy transfer between trophic levels is typically only 10% efficient 892

- Production Efficiency 892
- Trophic Efficiency and Ecological Pyramids 893

**CONCEPT 42.4** Biological and geochemical processes cycle nutrients and water in ecosystems 895

- Decomposition and Nutrient Cycling Rates 895
- Biogeochemical Cycles 895
- Case Study: Nutrient Cycling in the Hubbard Brook Experimental Forest* 898



**CONCEPT 42.5** Restoration ecologists return degraded ecosystems to a more natural state 899

- Bioremediation 899
- Biological Augmentation 901
- Ecosystems: A Review* 901

## 43

### Global Ecology and Conservation Biology 906

**OVERVIEW** Psychedelic Treasure 906

**CONCEPT 43.1** Human activities threaten Earth’s biodiversity 907

- Three Levels of Biodiversity 907
- Biodiversity and Human Welfare 908
- Threats to Biodiversity 909

**CONCEPT 43.2** Population conservation focuses on population size, genetic diversity, and critical habitat 912

- Small-Population Approach 912
- Declining-Population Approach 914
- Weighing Conflicting Demands 915

**CONCEPT 43.3** Landscape and regional conservation help sustain biodiversity 915

- Landscape Structure and Biodiversity 916
- Establishing Protected Areas 917

**CONCEPT 43.4** Earth is changing rapidly as a result of human actions 919

- Nutrient Enrichment 919
- Toxins in the Environment 920
- Greenhouse Gases and Climate Change 921

**CONCEPT 43.5** The human population is no longer growing exponentially but is still increasing rapidly 926

- The Global Human Population 926
- Global Carrying Capacity 927

**CONCEPT 43.6** Sustainable development can improve human lives while conserving biodiversity 928

- Sustainable Development 928
- The Future of the Biosphere 929

**Appendix A** Answers A-1

**Appendix B** Periodic Table of the Elements B-1

**Appendix C** The Metric System C-1

**Appendix D** A Comparison of the Light Microscope and the Electron Microscope D-1

**Appendix E** Classification of Life E-1

**Appendix F** Scientific Skills Review F-1

**Credits** CR-1

**Glossary** G-1

**Index** I-1

**AP Biology Appendix** AP Biology Equations and Formulas AP-1  
 Science Practices for AP Biology AP-3