AP® EDITION

CAMPBELL BIOLOGY IN FOCUS

SECOND EDITION

URRY • CAIN • WASSERMAN • MINORSKY • REECE

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Library of Congress Cataloging-in-Publication Data

Campbell biology in focus. – Second edition / Lisa A. Urry, Michael L. Cain, Steve A. Wasserman, and Peter V. Minorsky.
pages cm
Includes index.
ISBN 978-0-321-96275-1
ISBN 0-321-96275-3
1. Biology. I. Urry, Lisa A. II. Cain, Michael L. (Michael Lee), 1956- III. Wasserman, Steven Alexander IV. Minorsky, Peter V. V. Title: Biology in focus.

QH308.2C347 2016

570—dc23

2015005641

ISBN 10: 0-13-427891-7 (High School Binding)

ISBN 13: 978-0-13-427891-9 (High School Binding)

1 2 3 4 5 6 7 8 9 10—V311—20 19 18 17 16

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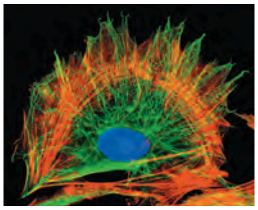
Brief Contents





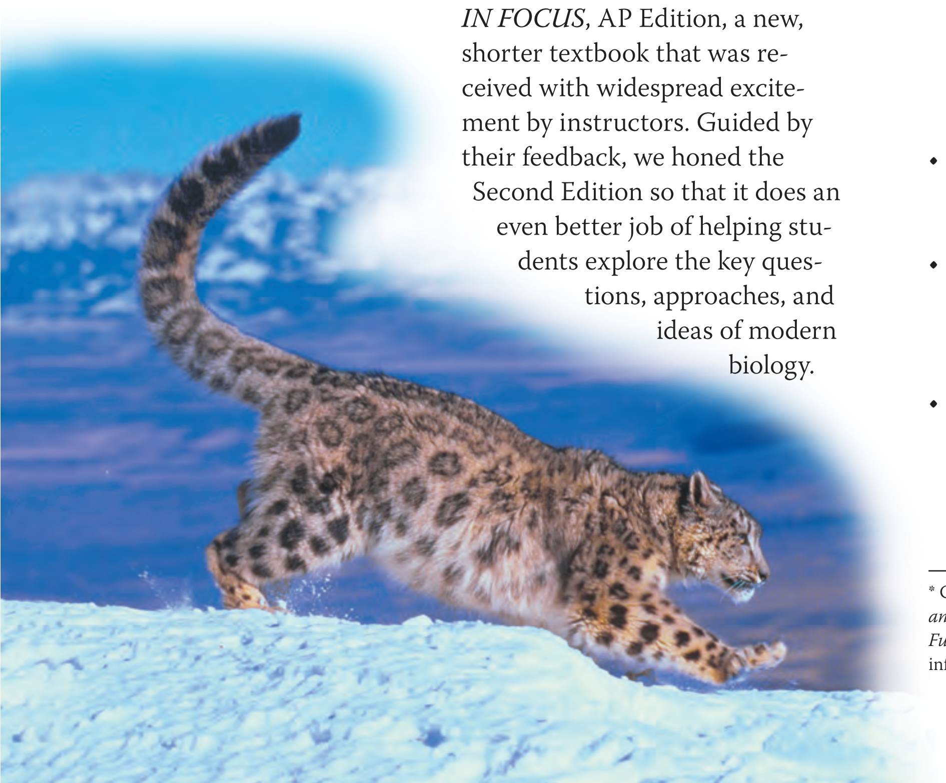


Preface

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** 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® **Icons** throughout the text highlight connections to the College Board's Curriculum Framework for AP Biology.
- AP® **Big Ideas** included at the beginning of each chapter help students link the chapter concepts to the Framework's four Big Ideas.
- AP® **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.®
- **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:

Lisa Urry (Chapter 1, Units 1 and 2): lurry@mills.edu
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Jane Reece: janereece@cal.berkeley.edu

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.

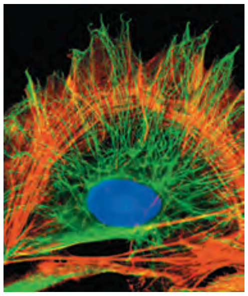
CHAPTER 1 Introduction: Evolution and the Foundations of Biology

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.

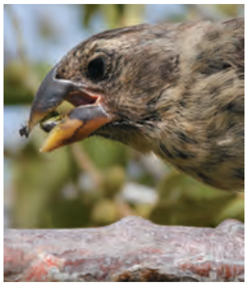
UNIT 2 Genetics

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 α-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.

Big Idea 1: The process of evolution drives the diversity and unity of life.	
Enduring understanding 1.A: Change in the genetic makeup of a population over time is evolution.	**Key Concepts:**
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
Enduring understanding 1.B: Organisms are linked by lines of descent from common ancestry.	**Key Concepts:**
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
Enduring understanding 1.C: Life continues to evolve within a changing environment.	**Key Concepts:**
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
Enduring understanding 1.D: The origin of living systems is explained by natural processes.	**Key Concepts:**
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

Big Idea 2: Biological systems utilize free energy and molecular building blocks to grow, to reproduce and to maintain dynamic homeostasis.	
Enduring understanding 2.A: Growth, reproduction and maintenance of the organization of living systems require free energy and matter.	**Key Concepts:**
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
Enduring understanding 2.B: Growth, reproduction and dynamic homeostasis require that cells create and maintain internal environments that are different from their external environments.	**Key Concepts:**
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
Enduring understanding 2.C: Organisms use feedback mechanisms to regulate growth and reproduction, and to maintain dynamic homeostasis.	**Key Concepts:**
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
Enduring understanding 2.D: Growth and dynamic homeostasis of a biological system are influenced by changes in the system's environment.	**Key Concepts:**
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

Enduring understanding 2.E: Many biological processes involved in growth, reproduction and dynamic homeostasis include temporal regulation and coordination.	**Key Concepts:**
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

Big Idea 3: Living systems store, retrieve, transmit, and respond to information essential to life processes.

Enduring understanding 3.A: Heritable information provides for continuity of life.	**Key Concepts:**
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

Enduring understanding 3.B: Expression of genetic information involves cellular and molecular mechanisms.	**Key Concepts:**
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

Enduring understanding 3.C: The processing of genetic information is imperfect and is a source of genetic variation.	**Key Concepts:**
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

Enduring understanding 3.D: Cells communicate by generating, transmitting and receiving chemical signals.	**Key Concepts:**
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
Enduring understanding 3.E: Transmission of information results in changes within and between biological systems.	**Key Concepts:**
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

Big Idea 4: Biological systems interact, and these systems and their interactions possess complex properties.

Enduring understanding 4.A: Interactions within biological systems lead to complex properties.	**Key Concepts:**
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
Enduring understanding 4.B: Competition and cooperation are important aspects of biological systems.	**Key Concepts:**
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

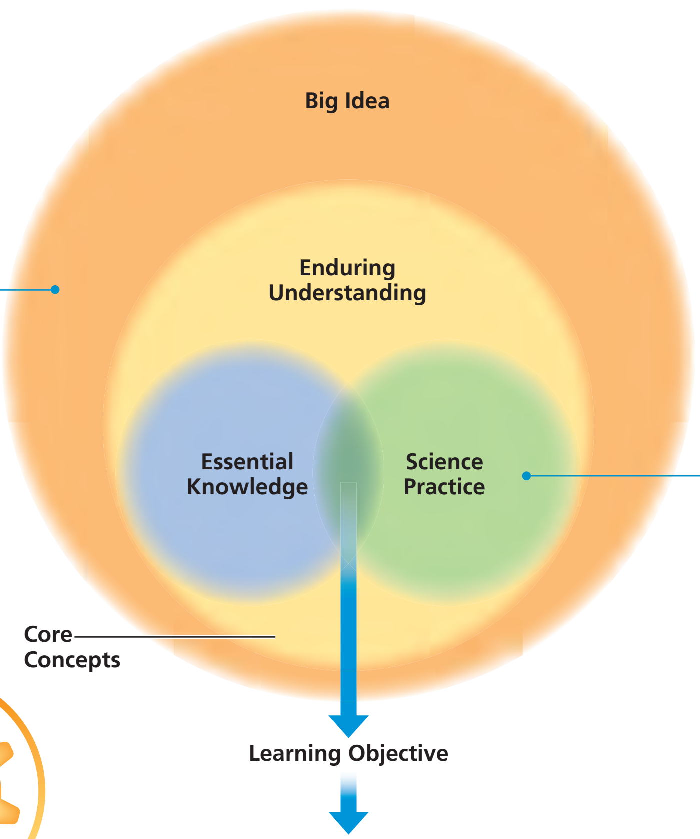
Enduring understanding 4.C: Naturally occurring diversity among and between components within biological systems affects interactions with the environment.	**Key Concepts:**
4.C.1: Variation in molecular units provides cells with a wider range of functions. SP 6.2	4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7
4.C.2: 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

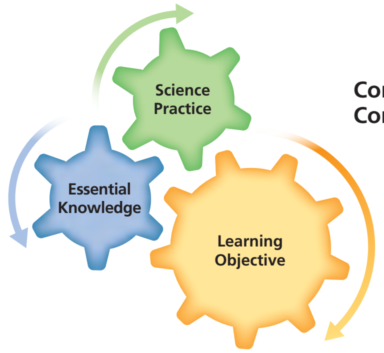
The curriculum framework supports **Essential Knowledge** with **Science Practice**.

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.



Testable explanations and predictions:
The AP Biology Exam



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.

13 Laboratory investigations

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 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.

Nutritional Mode

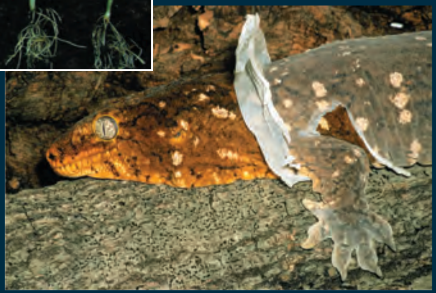
All living things must obtain energy and carbon from the environment to grow, survive, and reproduce. Plants are autotrophs, obtaining their energy through photosynthesis and their carbon from inorganic sources, whereas animals are heterotrophs, obtaining their energy and carbon from food. Evolutionary 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

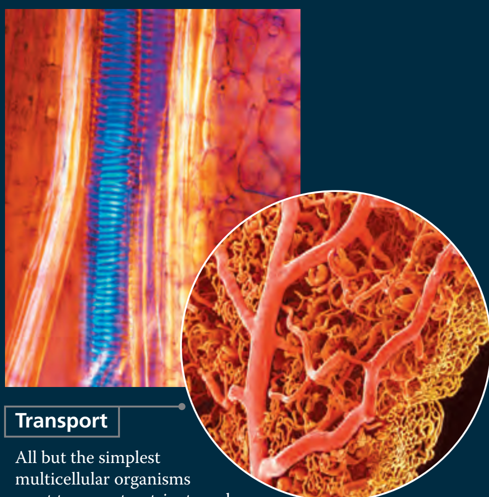
The growth and physiology of both plants and animals are regulated by hormones. In plants, hormones may act in a local area or be transported in the body. They control growth patterns, flowering, fruit development, and more (left). In animals, hormones circulate throughout the body and act in specific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

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.)



666 UNIT SIX ANIMAL FORM AND FUNCTION

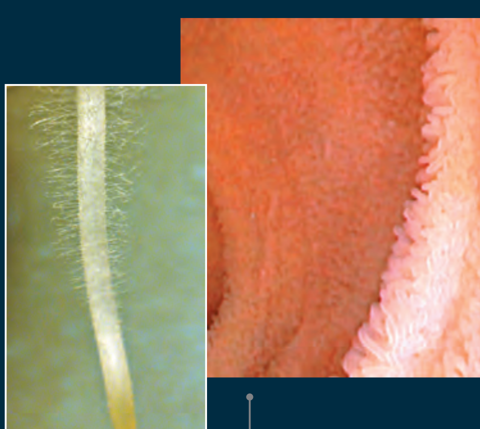


Transport

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.)

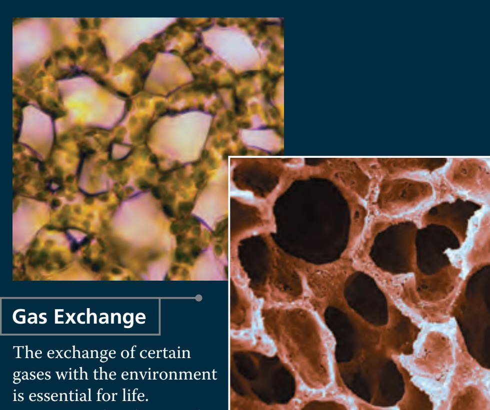
Reproduction

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.)

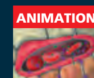


Gas Exchange

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).

CHAPTER 32 THE INTERNAL ENVIRONMENT OF ANIMALS: ORGANIZATION AND REGULATION 667

◀ **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.

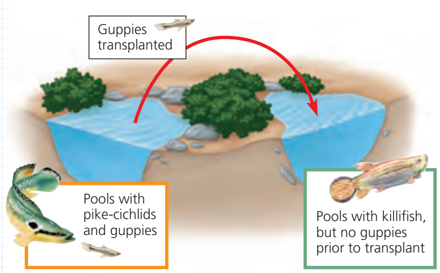
Scientific Skills Exercise AP® SPs 1.4, 4.1, 4.2, 5.1, 5.3, 6.4, 7.2

Making and Testing Predictions

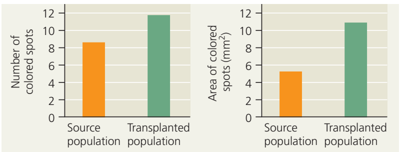
Can Predation Result in Natural Selection for Color Patterns in Guppies? What we know about evolution changes constantly as new observations lead to new hypotheses—and hence to new ways to test our understanding of evolutionary theory. Consider the wild guppies (*Poecilia reticulata*) that live in pools 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.



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

INTERPRET THE DATA

1. 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.)
2. Explain how the types of data the researchers chose to collect enabled them to test their prediction.
3. What conclusion do you draw from the data presented above?
4. 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.

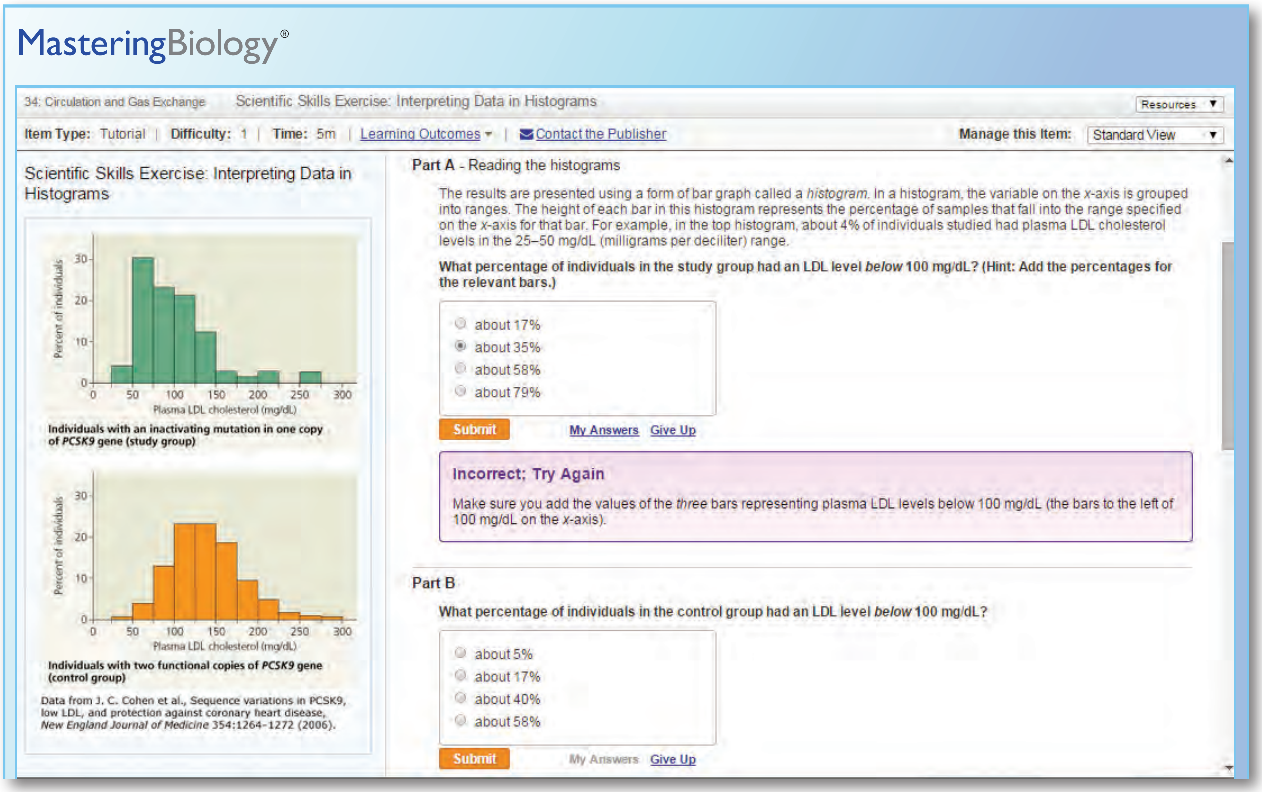
◀ **AP Biology Framework Science Practices** are highlighted at point of use.

◀ 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:

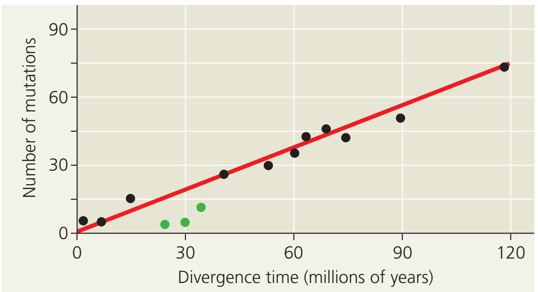
Each Scientific Skills Exercise from the text also has an **assignable, interactive tutorial version in MasteringBiology®** that is automatically graded and includes coaching feedback.



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.

Interpret Data

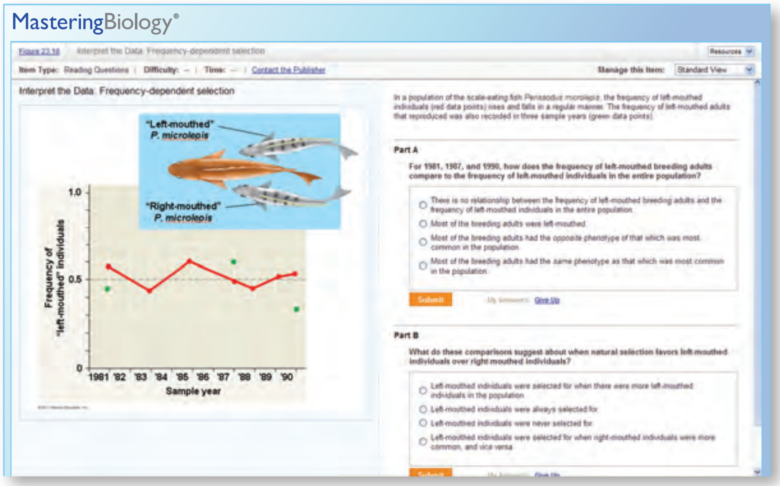
Campbell Biology in Focus, AP Edition, and MasteringBiology® offer a wide variety of ways for students to move beyond memorization and to **think like a scientist**. These features reinforce the College Board's Curriculum Framework Science Practices.



▲ **Figure 20.19 A molecular clock for mammals.** The number of accumulated mutations in seven proteins has increased over time in a consistent manner for most mammal species. The three green data points represent primate species, whose proteins appear to have evolved more slowly than those of other mammals. The divergence time for each data point was based on fossil evidence.

INTERPRET THE DATA *Use the graph to estimate the divergence time for a mammal with a total of 30 mutations in the seven proteins.*

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



MasteringBiology®

Learn more at www.masteringbiology.com

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

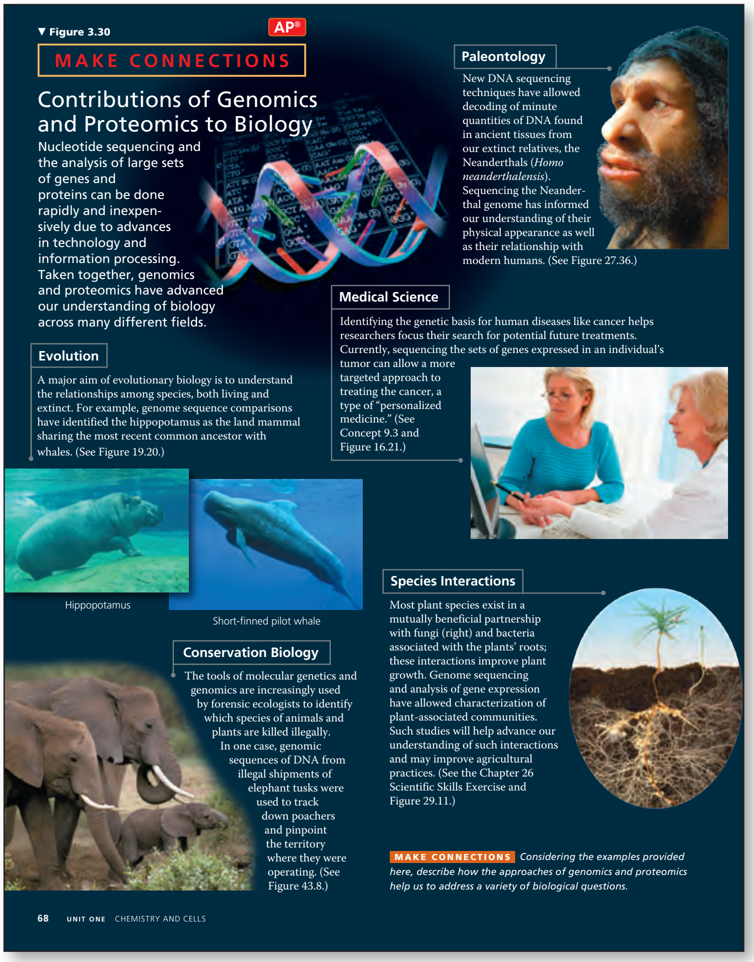
◀ **NEW! Solve It Tutorials** engage students in a multi-step investigation of a "mystery" or open question in which they must analyze real data. These are assignable in MasteringBiology. Topics include:

- 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 3.30 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.)

Hippopotamus

Short-finned pilot whale

Conservation Biology

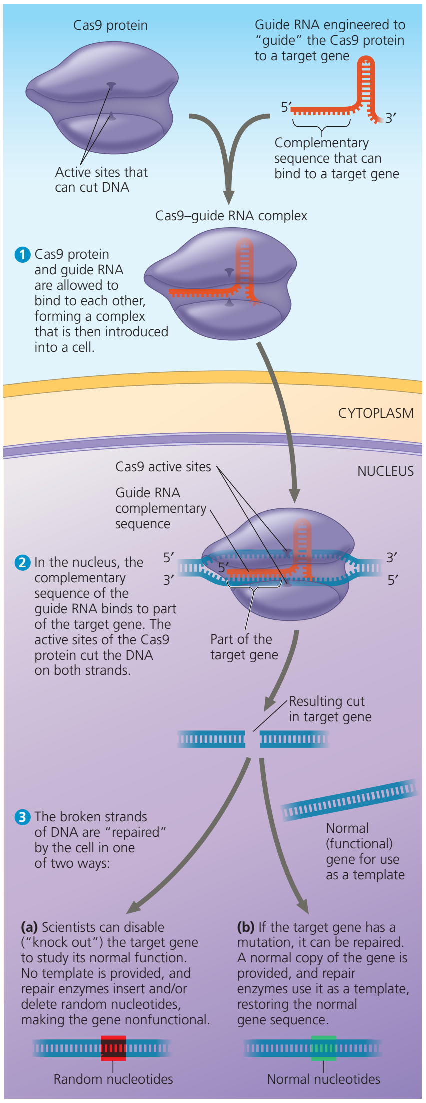
The tools of molecular genetics and genomics are increasingly used by forensic ecologists to identify which species of animals and plants are killed illegally. In one case, genomic sequences of DNA from illegal shipments of elephant tusks were used to track down poachers and pinpoint the territory where they were operating. (See Figure 43.8.)

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.)

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



▲ **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.

▲ **Figure 27.36 Fossil evidence of human-Neanderthal interbreeding.**

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**.

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® 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® **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.

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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′-TACTTGTCCGATATC-5′. It is mutated to 3′-TACTTGTCCAATATC-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.

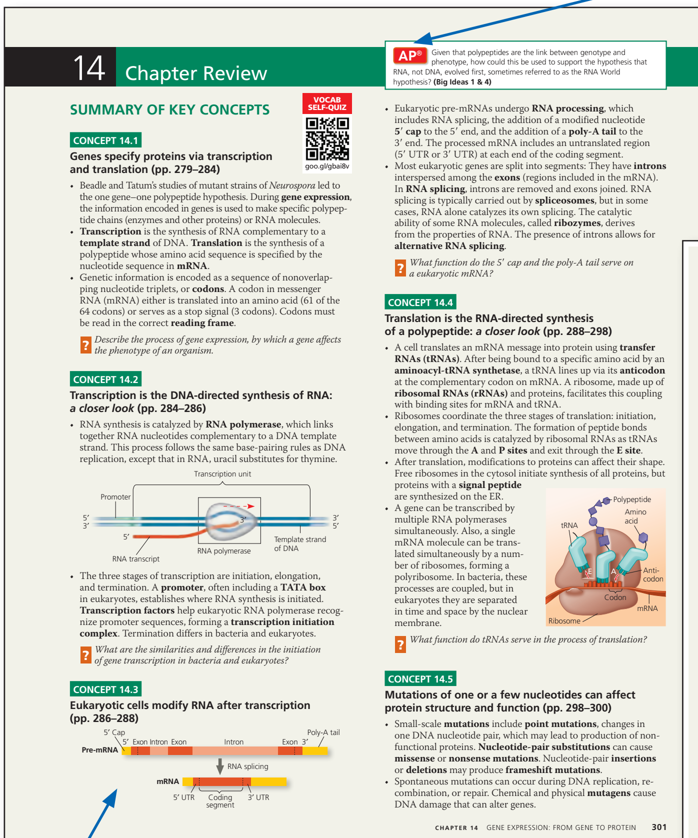
The **Summary of Key Concepts** refocuses students on the main points of the chapter.

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

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


14 Chapter Review

AP® Given that polypeptides are the link between genotype and phenotype, how could this be used to support the hypothesis that RNA, not DNA, evolved first, sometimes referred to as the RNA World hypothesis? (Big Ideas 1 & 4)

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**.

? *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.

? *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)

- Eukaryotic pre-mRNAs undergo **RNA processing**, which includes RNA splicing, the addition of a modified nucleotide **5′ cap** to the 5′ end, and the addition of a **poly-A tail** to the 3′ end. The processed mRNA includes an untranslated region (5′ UTR or 3′ UTR) at each end of the coding segment.
- Most eukaryotic genes are split into segments: They have **introns** interspersed among the **exons** (regions included in the mRNA). In **RNA splicing**, introns are removed and exons joined. RNA splicing is typically carried out by **spliceosomes**, but in some cases, RNA alone catalyzes its own splicing. The catalytic ability of some RNA molecules, called **ribozymes**, derives from the properties of RNA. The presence of introns allows for **alternative RNA splicing**.

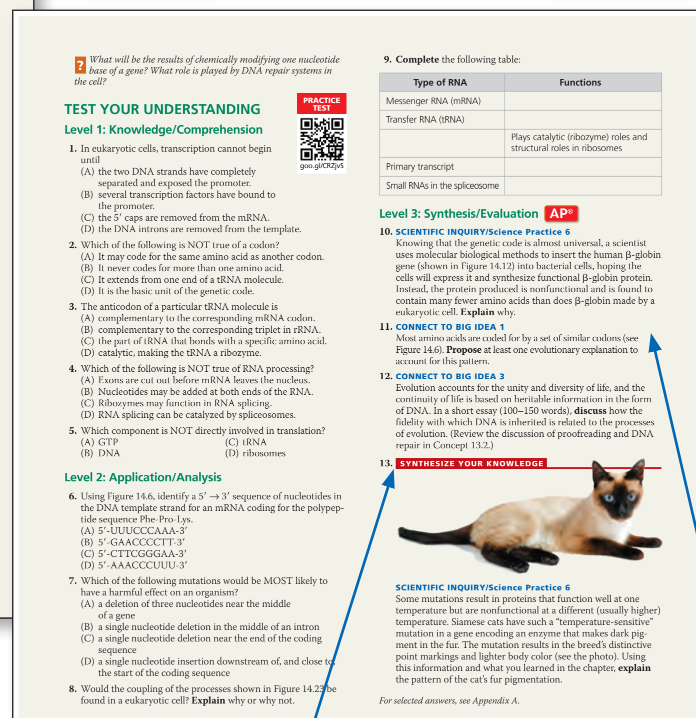
? *What function do the 5′ cap and the poly-A tail serve on a eukaryotic mRNA?*

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 tRNAs 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 polyribosome. In bacteria, these processes are coupled, but in eukaryotes they are separated in time and space by the nuclear membrane.

? *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 nonfunctional 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


? *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

1. In eukaryotic cells, transcription cannot begin until
(A) the two DNA strands have completely separated and exposed the promoter.
(B) several transcription factors have bound to the promoter.
(C) the 5′ caps are removed from the mRNA.
(D) the DNA introns are removed from the template.

2. Which of the following is NOT true of a codon?
(A) It may code for the same amino acid as another codon.
(B) It never codes for more than one amino acid.
(C) It extends from one end of a tRNA molecule.
(D) It is the basic unit of the genetic code.

3. The anticodon of a particular tRNA molecule is
(A) complementary to the corresponding mRNA codon.
(B) complementary to the corresponding triplet in rRNA.
(C) the part of tRNA that bonds with a specific amino acid.
(D) catalytic, making the tRNA a ribozyme.

4. Which of the following is NOT true of RNA processing?
(A) Exons are cut out before mRNA leaves the nucleus.
(B) Nucleotides may be added at both ends of the RNA.
(C) Ribozymes may function in RNA splicing.
(D) RNA splicing can be catalyzed by spliceosomes.

5. Which component is NOT directly involved in translation?
(A) GTP (C) tRNA
(B) DNA (D) ribosomes

Level 2: Application/Analysis

6. 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.
(A) 5′-UUUCCCAAA-3′
(B) 5′-GAACCCCTT-3′
(C) 5′-CTTCGGGAA-3′
(D) 5′-AAACCCUUU-3′

7. Which of the following mutations would be MOST likely to have a harmful effect on an organism?
(A) a deletion of three nucleotides near the middle of a gene
(B) a single nucleotide deletion in the middle of an intron
(C) a single nucleotide deletion near the end of the coding sequence
(D) a single nucleotide insertion downstream of, and close to, the start of the coding sequence

8. Would the coupling of the processes shown in Figure 14.23 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®

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

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

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

AP® **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.**

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).

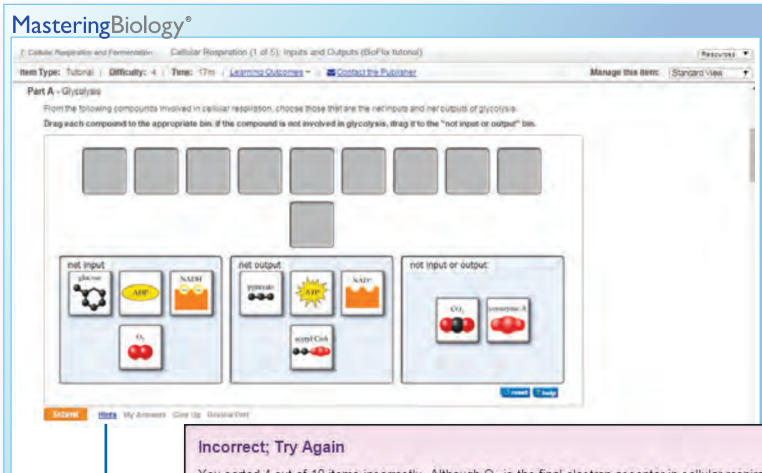
Evolution of the Genetic Code

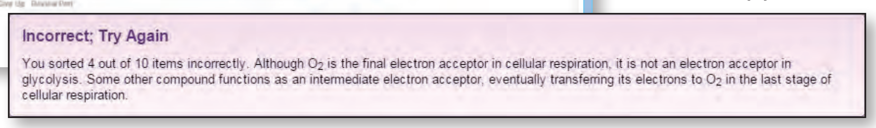
EVOLUTION The genetic code is nearly universal, shared by organisms from the simplest bacteria to the most complex plants and animals. The mRNA codon CCG, for instance, is translated as the amino acid proline in all organisms whose genetic code has been examined. In laboratory experiments, genes can 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

Personalized Coaching in MasteringBiology®

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





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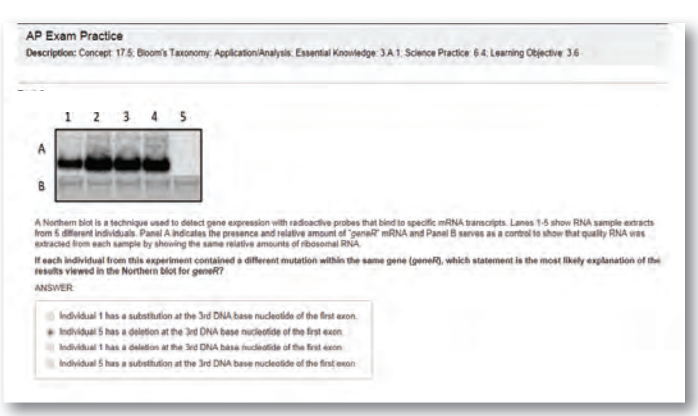
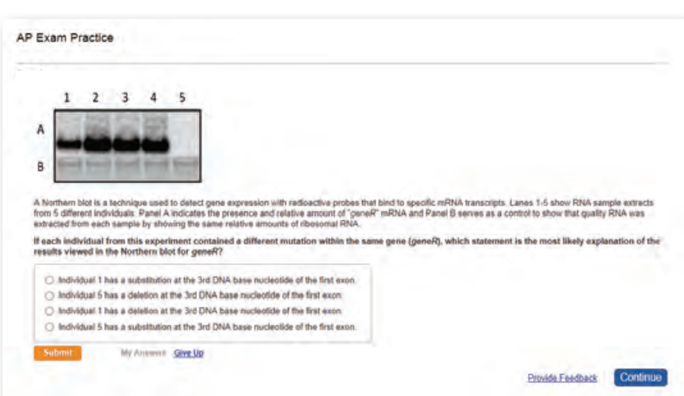
1. If a student gets stuck...
2. specific wrong-answer **feedback** appears in the purple feedback box.
3. **Hints** coach the student to the correct response.
4. Optional **Adaptive Follow-Up Assignments** are based on each student's performance on the original homework assignment and provide additional 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.

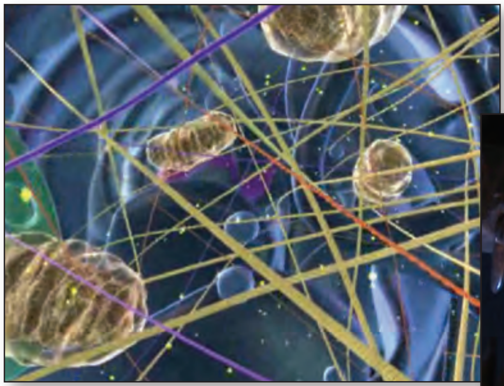


▲ **Instructor View** correlates the question and provides the answer.

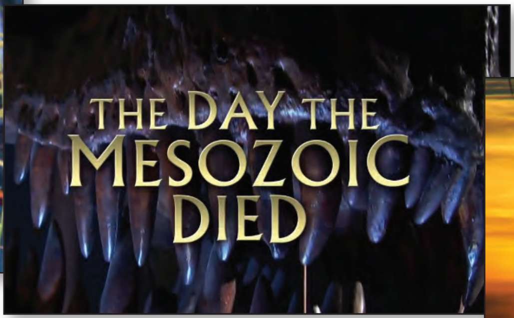


▲ **Student View** provides practice questions correlated to Framework Learning Objectives and Science Practices.

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



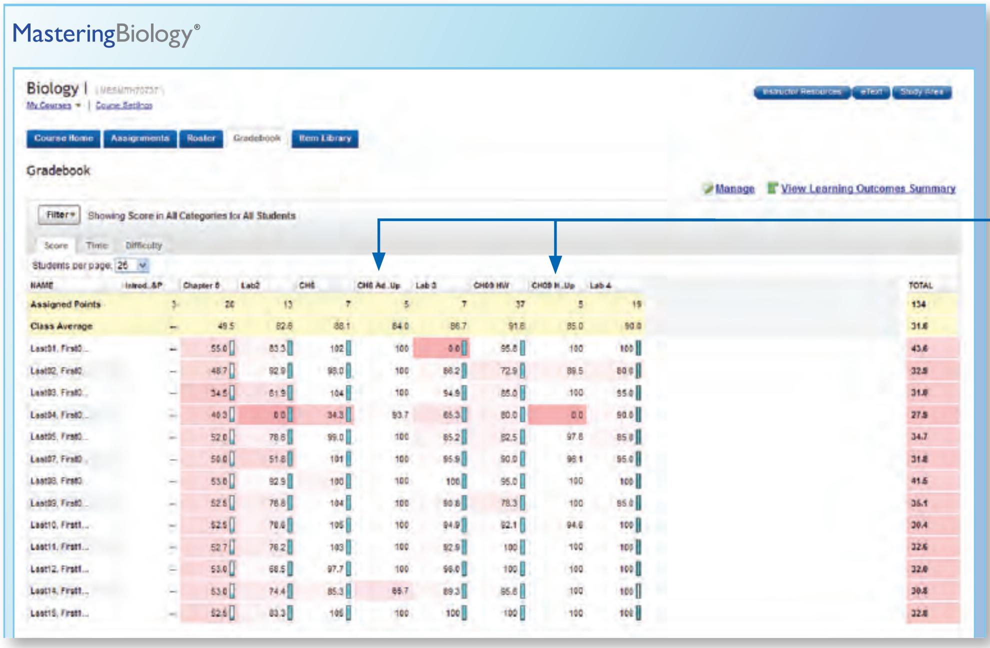
Tutorials use 3-D, movie-quality **animations** and **coaching exercises** to help students master tough topics outside of class. Animations can also be shown in class.



NEW! 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.

Video Field Trips allow students to study ecology by taking virtual field trips and answering follow-up questions.

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



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

Self-Study Tools in MasteringBiology®

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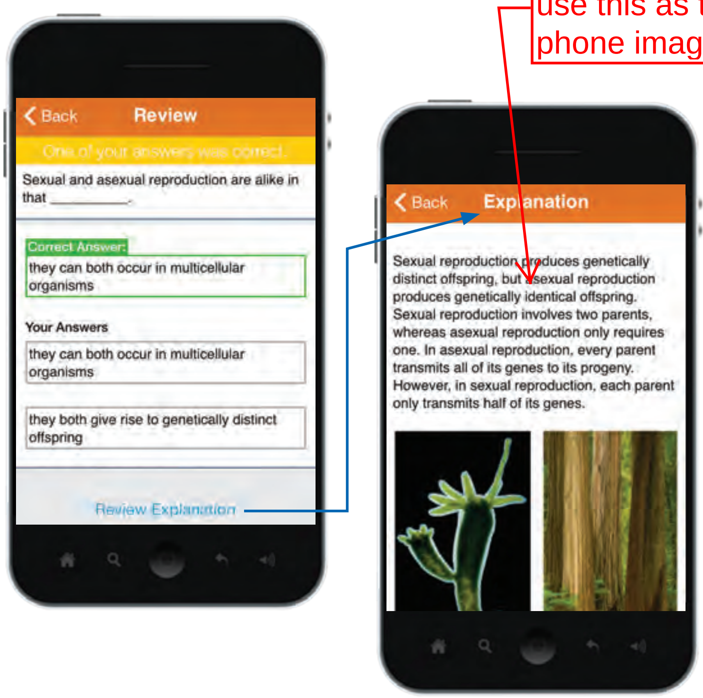


▲ **NEW! Dynamic Study Modules** help students acquire, retain, and recall information faster and more efficiently than ever before. The modules are available as a self-study tool or can be assigned by the instructor.

▲ **Study Area**

The Study Area includes:

- Practice Tests
- MP3 Tutors
- Animations
- Videos
- Activities

and much more!

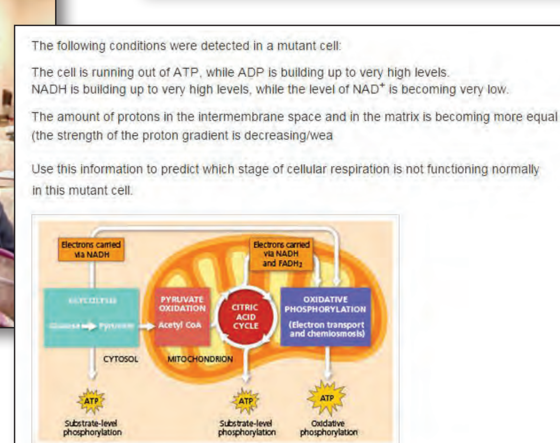
NEW! Ready-to-Go Teaching Modules

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

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

Instructors can easily incorporate **active learning** into their courses using suggested activity ideas and questions for use with classroom response systems, including Learning Catalytics. ▶

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



MasteringBiology® Access/Supplements

MASTERINGBIOLOGY®

Upon textbook purchase, students and teachers are granted access to MasteringBiology. High school teachers can obtain preview or adoption access to MasteringBiology in one of the following ways:

Preview Access

- Teachers can request preview access online by visiting www.PearsonSchool.com/Access_Request. Select Science, choose Initial Access, and complete the form under Option 2. Preview Access information will be sent to the teacher via e-mail.

Adoption Access

- With the purchase of this program, a Pearson Adoption Access Card with Instructor Manual will be delivered with your textbook purchase. (ISBN: 978-0-13-353986-8)
- Ask your sales representative for a Pearson Adoption Access Card with Instructor Manual. (ISBN: 978-0-13-353986-8)

OR

- Visit PearsonSchool.com/Access_Request, select Science, choose initial Access, and complete the form under Option 3—MyLab/Mastering Class Adoption Access. Adoption access information will be sent to the teacher via e-mail.

Students, ask your teacher for access.

FOR STUDENTS

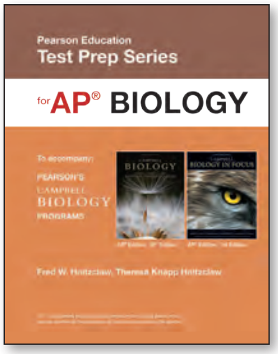
The following resources are available for purchase.

Pearson Education Test Prep Series for AP® Biology

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

This workbook is designed to support the AP® Biology Curriculum Framework. It is based on the comprehensive content of *Campbell Biology* 10th Edition AP® Edition and can accompany *Campbell Biology in Focus* 1st Edition and 2nd Edition, AP® 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® labs, and prepare for the AP® 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 Science Practices throughout and includes an emphasis on making connections between topics.



(FOR STUDENTS, continued)

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® Biology for many years. Besides teaching hundreds of students, they helped write the AP® 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 for *Campbell Biology in Focus*, AP® Edition.

FOR TEACHERS

Campbell Biology FAQ's for AP Biology Instructors

Learn more about Pearson's Campbell Biology programs for the AP curriculum and additional details for using MasteringBiology.com in your classroom. Visit PearsonSchool.com/Advanced, select the Campbell Biology AP program of your choice, and read the FAQ section posted.

Instructor's Resource DVD (IRDVD) Package

The instructor resources for ***Campbell Biology in Focus,* Second Edition,** are combined into one chapter-by-chapter resource that includes DVDs of all chapter visual resources. Assets include:

- Editable figures (art and photos) and tables from the text in PowerPoint®
- Prepared PowerPoint® Lecture Presentations for each chapter, with lecture notes, editable figures, tables, and links to animations and videos
- 250+ Instructor Animations and Videos, including BioFlix® 3-D Animations and *ABC News* Videos
- JPEG Images, including labeled and unlabeled art, photos from the text, and extra photos
- Digital Transparencies
- Clicker Questions in PowerPoint®
- Quick Reference Guide
- Test Bank questions in TestGen® software and Microsoft® Word. This invaluable resource contains more than 3,000 questions, including scenario-based questions and art, graph, and data interpretation questions.

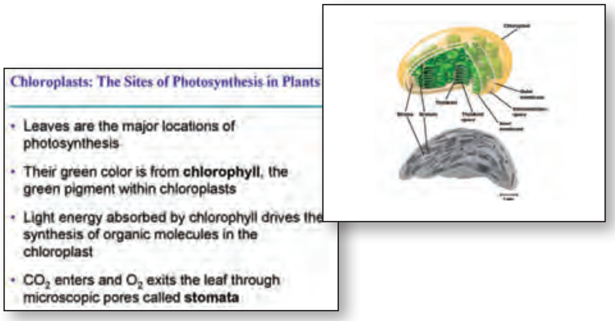
ExamView® CD-ROM

The ExamView computerized test bank CD-ROM allows teachers to build, edit, print, and administer tests based on text objectives. In addition to hundreds of test bank questions, ExamView now offers **NEW** AP® Exam-style Practice Questions that test student mastery of the Framework's Learning Objectives with their companion Science Practices.

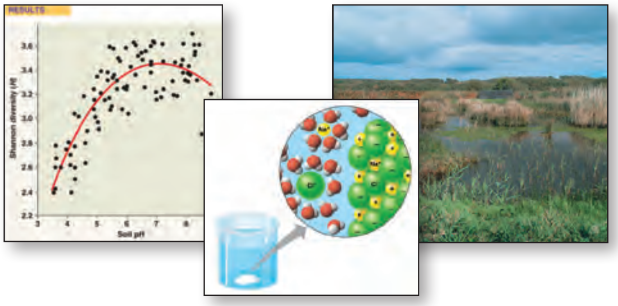
Instructor Resources Area in MasteringBiology®

This area includes:

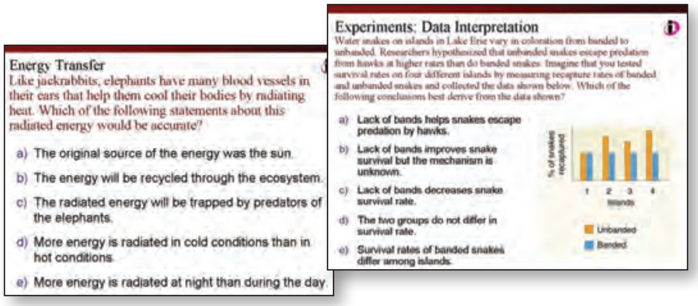
- Ready-to-Go Teaching Modules Art and Photos in PowerPoint®
- Lecture Presentations in PowerPoint®
- Animations and Videos, including BioFlix®
- JPEG Images
- Digital Transparencies
- Clicker Questions
- IRDVD Quick Reference Guide
- Test Bank Files
- Learning Objectives
- Instructor Answers for Scientific Skills Exercises, Interpret the Data Questions, and Short-Answer Essay Questions; also includes a rubric and tips for grading short-answer essays
- Instructor Guides for Supplements
- Video Field Trips



▲ **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.



▲ **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

Exploring Figures

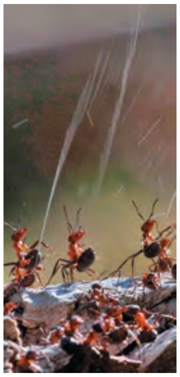
Inquiry Figures

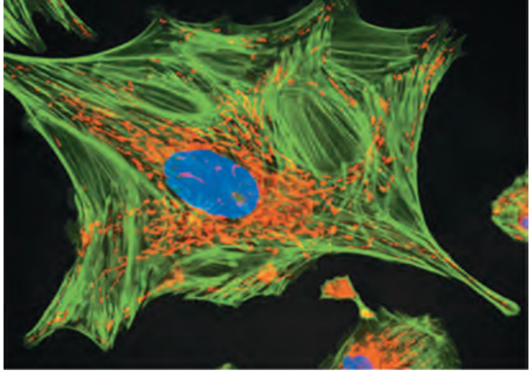
Research Method Figures

*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.

†A related Experimental Inquiry Tutorial can be assigned in MasteringBiology.

Detailed Contents





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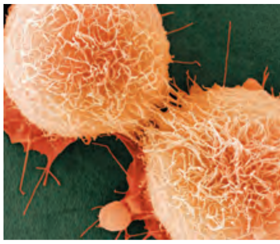

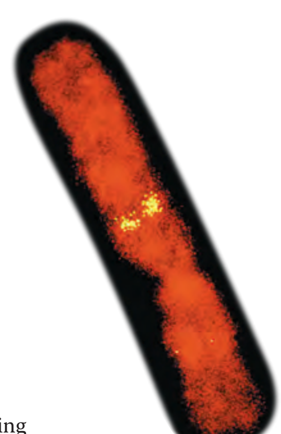

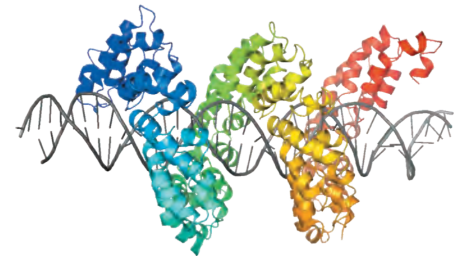

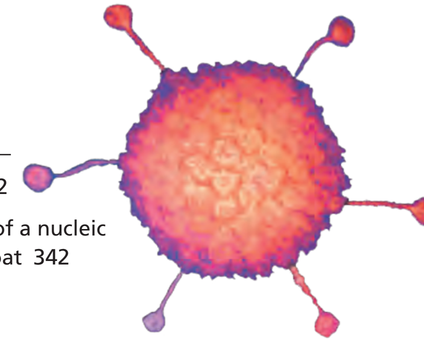

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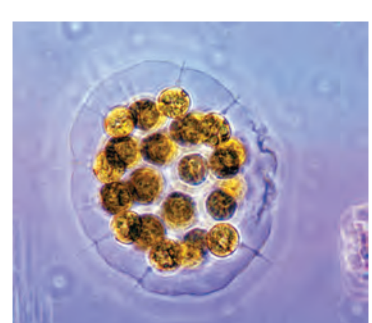

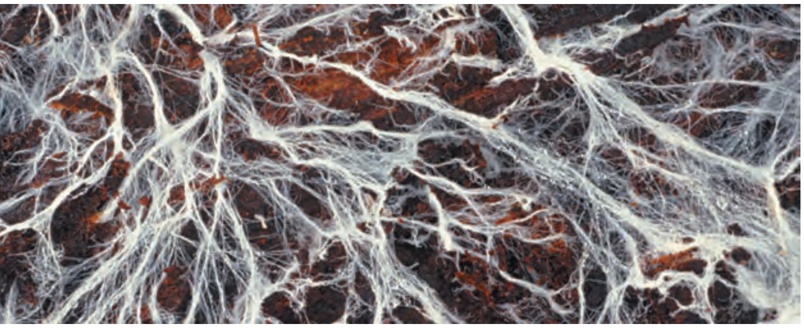

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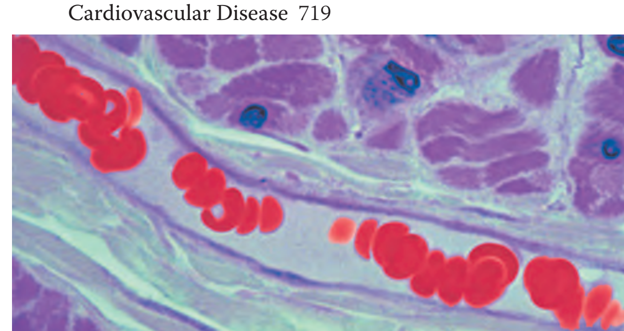

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