FOURTH EDITION

BIOLOGY

The Essentials

Mariëlle Hoefnagels

THE UNIVERSITY OF OKLAHOMA

MEDIA CONTRIBUTIONS BY

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Brief Contents

About the Author

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Mariëlle Hoefnagels is a professor in the Department of Biology and the Department of Microbiology and Plant Biology at the University of Oklahoma, where she teaches courses in introductory biology and science writing. She has received the University of Oklahoma General Education Teaching Award, the Longmire Prize (the Teaching Scholars Award from the College of Arts and Sciences), and the Holden Faculty Award (recognizing outstanding faculty who teach freshmen and sophomores). Her textbook *Biology: Concepts and Investigations,* 4th edition, was recognized with a 2018 Textbook Excellence Award from the Textbook and Academic Authors Association. She has also been awarded honorary memberships in several student honor societies.

Dr. Hoefnagels received her BS in environmental science from the University of California at Riverside, her MS in soil science from North Carolina State University, and her PhD in plant pathology from Oregon State University. Her dissertation work focused on the use of bacterial biological control agents to reduce the spread of fungal pathogens on seeds. In addition to authoring *Biology: The Essentials* and *Biology: Concepts and Investigations,* her recent publications have focused on creating investigative teaching laboratories and integrating technology into introductory biology classes. She also maintains a blog on teaching nonmajors biology, and she frequently gives presentations on study skills and related topics to student groups across campus.

DEDICATION

To my students

Mariëlle Hoefnagels

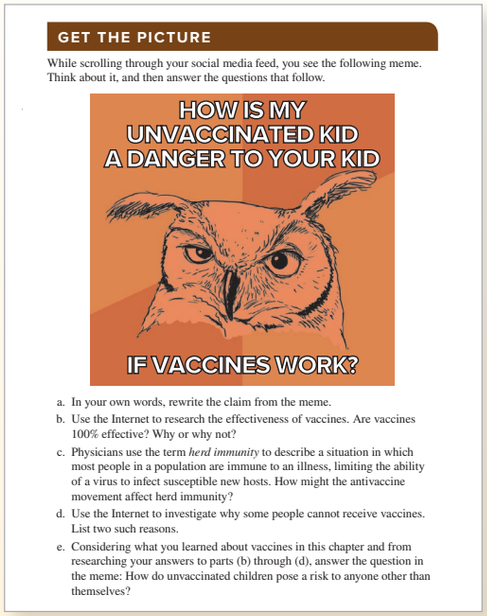
An Introduction for Students Using This Textbook

I have been teaching nonmajors biology at the University of Oklahoma since 1997 and over that time have encountered many students who fear science in general and biology in particular. The complexity, abstractions, and unfamiliar terms can seem overwhelming at first, but with practice, I know that anyone can think like a scientist.

Learning to think scientifically is important well beyond passing a biology class. After all, scientific issues confront you every day as you navigate your life and your social media accounts. How do you know if a claim about climate change is scientific? Will you be able to identify misinformation and interpret graphs during the next global health crisis? This book will teach you not only to *understand* the scientific terms you encounter but also to distinguish "good science" from unscientific claims.

I've created the following features to help you make the transition from memorizing facts to understanding concepts—from accepting scientific claims to analyzing them for yourself. These tools will help you to pass your class and to be an informed citizen.

- **Concept Maps** The Survey the Landscape concept map at the start of each chapter illustrates how the pieces of the entire unit fit together. Each chapter ends with a Pull It Together concept map that makes connections between key terms within the chapter. Using these concept maps together will help you understand how the major topics covered throughout the book relate to one another.
- **Learn How to Learn** Each chapter in this book contains a tip that focuses on study skills that build understanding. Don't try to implement them all at once; choose one that appeals to you and add more as you determine what works best for you.
- **What's the Point?** This brief introduction helps explain the importance of the chapter topic. A companion feature is *What's the Point? Applied,* which appears near the end of each chapter and builds on the chapter's content by explaining a wide-ranging topic that is relevant to your life.
- **Progress Bars** The bars found at the bottom of most pages should help you keep in mind where you are in the chapter's big picture.
- **Why We Care** These boxes reinforce the applications of specific topics to the real world.
- **Burning Question** In this feature, I answer questions from students who are either in my classes or who have written to me with a "burning question" of their own.
- **Miniglossaries** Most chapters have one or more miniglossaries, brief lists of key terms that help you define and distinguish between interrelated ideas. You can use the miniglossaries to create flashcards, concept maps, and other study aids.
- **Scientific Literacy** These thought questions at the end of each chapter will help you practice thinking like a scientist about relevant social, political, or ethical issues.



GET THE PICTURE

While scrolling through your social media feed, you see the following meme. Think about it, and then answer the questions that follow.

a. In your own words, rewrite the claim from the meme.
b. Use the Internet to research the effectiveness of vaccines. Are vaccines 100% effective? Why or why not?
c. Physicians use the term *herd immunity* to describe a situation in which most people in a population are immune to an illness, limiting the ability of a virus to infect susceptible new hosts. How might the antivaccine movement affect herd immunity?
d. Use the Internet to investigate why some people cannot receive vaccines. List two such reasons.
e. Considering what you learned about vaccines in this chapter and from researching your answers to parts (b) through (d), answer the question in the meme: How do unvaccinated children pose a risk to anyone other than themselves?

- **Get the Picture** These new end-of-chapter questions challenge you to interpret an image. They are designed to apply the chapter's content to a photo, graph, or diagram. Learning to think about images scientifically will help you navigate your digital (and real) world.
- **Summary Illustrations** Created specifically for the summary, these figures tie together the material in a visual way to help you learn relationships among the topics in the chapter. See if you can explain the relationships in your own words, then go back to review any sections you have trouble explaining.
- **Connect®** The content in this textbook is integrated with a wide variety of digital tools available in Connect that will help you learn the connections and relationships that are critical to understanding how biology really works.

Using this textbook's resources as you study can help you build scientific literacy. Investing time in your studies is essential, but your mindset matters too. If you believe that you can develop your talents for biology—even if it takes some hard work—then you set the stage for a successful semester. Anyone can be a "science person."

I hope that you enjoy this text and find that the study tips and tools help you develop an understanding of biology.

Mariëlle Hoefnagels

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Author's Guide to Using This Textbook

This guide lists key chapter features and describes some of the ways that I use them in my own classes.

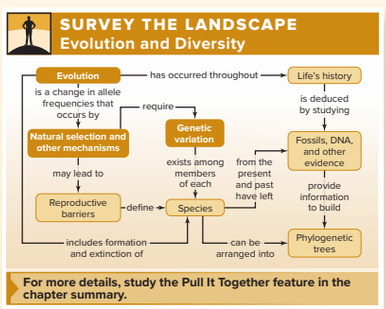
Learn How to Learn

Focus on Understanding, Not Memorizing

When you are learning the language of biology, be sure to concentrate on how each new term fits with the others. Are you studying multiple components of a complex system? Different steps in a process? The levels of a hierarchy? As you study, always make sure you understand how each part relates to the whole. For example, you might jot down brief summaries in the margins of your notes, or you could use lists of boldfaced terms in a chapter to make your own concept map.

Learn How to Learn study tips help students develop their study skills.

Each chapter has one *Learn How to Learn* study tip, and a complete list is in Appendix E. I present a *Study Minute* in class each week, with examples of how to use these study tips.



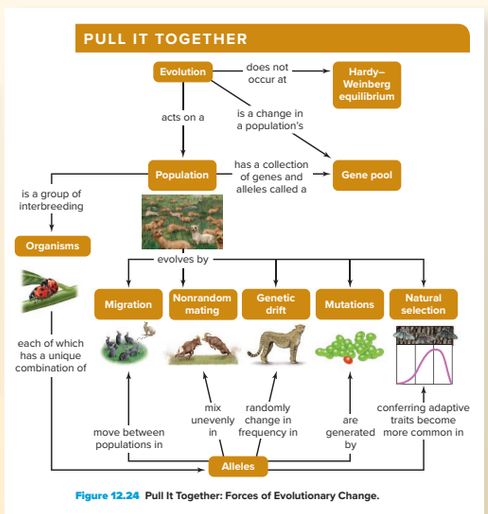


Figure 12.24 Pull It Together: Forces of Evolutionary Change.

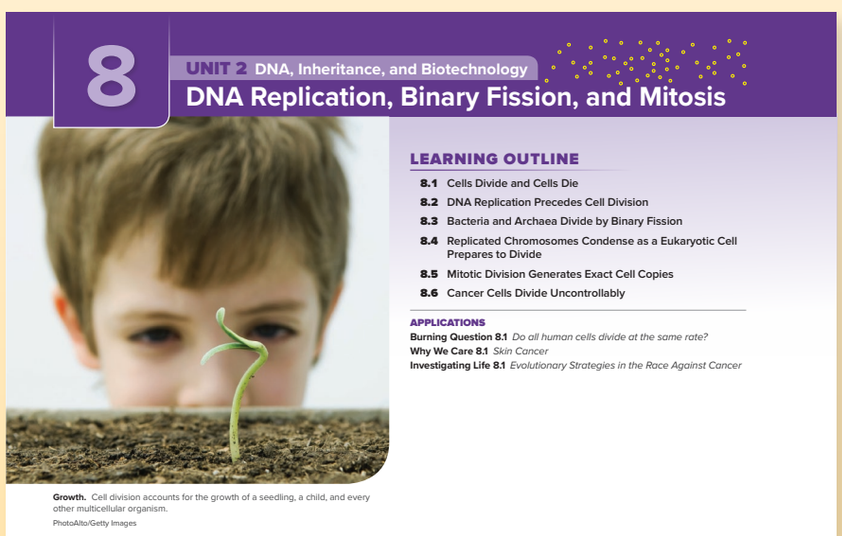
Concept maps help students see the big picture.

Survey the Landscape concept maps at the start of each chapter illustrate how the pieces of the entire unit fit together. These figures integrate with the existing Pull It Together concept maps in the chapter summary.

After spending class time discussing the key features of concept maps, I have my students draw concept maps of their own.

The Learning Outline introduces the chapter's main headings and helps students keep the big picture in mind.

Each heading is a complete sentence that summarizes the most important idea of the section. Students can also flip to the end of the chapter before starting to read; the chapter summary and Pull It Together concept map can serve as a review or provide a preview of what's to come.



Growth. Cell division accounts for the growth of a seedling, a child, and every other multicellular organism.
PhotoAlto/Getty Images

Investigating Life 29.1 | Can a House Be Too Clean?

Healthy immune function requires a delicate balance. On the one hand, the immune system must be strong enough to protect the body from dangerous pathogens. But if the immune response is too strong, it may overreact to harmless substances—as in allergies—or launch an autoimmune attack against the body's own cells.

People who live in developed countries have a high incidence of allergies, asthma, and autoimmune disorders when compared to their counterparts in developing countries. According to the hygiene hypothesis, the difference may stem from the sanitation, vaccines, antibiotics, and ultraclean surroundings that are typical of wealthy countries. For millions of years, the human immune system has coevolved with countless bacteria, viruses, and other parasites. Perhaps constant exposure to these pathogens keeps the human immune system in check.

To test whether exposure to microbes affects the incidence of allergies and asthma, a large team of European researchers gathered data on thousands of German children. Some of the children lived on farms and therefore had ample exposure to bacteria and fungi associated with soil and animals. Other children lived in nearby suburbs. The researchers predicted that farm life would expose children to the greatest diversity of microbes; farm children should therefore have a lower incidence of allergies and asthma than their suburban counterparts.

The research team used both questionnaires and medical tests to determine if each child had allergies or asthma. For example, children were exposed to allergens, and their blood was subsequently tested for allergy-related antibodies. Each child's lung function was also evaluated to test for asthma.

The data revealed that farm children were significantly less likely to have allergies or asthma than their suburban counterparts (figure 29.A). But was that difference related to microbial exposure? To find out, the researchers analyzed the bacteria and fungi in dust collected from the homes of some of the children. They found that the greater the variety of microbes, the lower the incidence of asthma. Surprisingly, however, microbial diversity could not explain the low incidence of allergies among farm children. Other differences between farm life and city life must affect the risk of developing allergies.

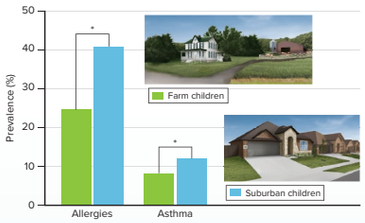


Figure 29.A A Little Dirt May Be Good for You. Allergies and asthma are more common among children in suburbs than those who live on farms. (Asterisks indicate a statistically significant difference within a group; see appendix A.)

Studies such as this one suggest that immune system overreactions may be the price we pay to live a cleaner life. While good hygiene undoubtedly helps protect children from disease-causing microbes, it is interesting to know that a little dust may not be so bad after all.

Source: Ege, Markus J. and eight coauthors. 2011. Exposure to environmental microorganisms and childhood asthma. *The New England Journal of Medicine*, vol. 364, pages 701–709.

Investigating Life boxes focus on what introductory science students need.

Biological literacy requires an understanding of the process of science, an ability to interpret data, and an awareness of how scientific research contributes to our understanding of evolution.

Each box describes a real experiment focusing on an evolutionary topic related to the chapter's content. The studies touch on concepts found in other units; you can encourage students to draw a concept map illustrating the relationships between ideas. You might also use the case as a basis for discussion of the nature of science.

Assignable Connect activities contain questions focused on the process of science, data interpretation, and how the study contributed to our understanding of evolution.

What's the **Point?**

Comstock Images/Getty Images

"I wish I had your metabolism!" Perhaps you have overheard a calorie-counting friend make a similar comment to someone who stays slim on a diet of fattening foods.

In that context, the word *metabolism* means how fast a person burns food. But biochemists define metabolism as all of the chemical reactions that build and break down molecules within any cell. How are these two meanings related?

Interlocking networks of metabolic reactions supply the energy that every cell needs to stay alive. In humans, teams of metabolizing cells perform specialized functions such as digestion, muscle movement, hormone production, and countless other activities. It all takes a reliable energy supply—food, which each of us "burns" at a different rate.

This chapter describes the fundamentals of metabolism, including how cells organize, regulate, and fuel the chemical reactions that sustain life.

What's the Point? and *What's the Point? Applied* boxes help relate chapter topics to life outside the classroom.

These boxes can be used as a starting point for traditional lecture or as the basis for class discussion.

What's the **Point?** APPLIED

Metabolism describes all the chemical reactions in a cell. Because our cells always lose energy as heat, they require constant energy input to continue fueling their reactions. So the familiar definition of metabolism—how fast a person burns calories in food—relates to the rate at which cellular reactions are occurring. What can you do to make your cells use the energy in food more quickly?

Exercise speeds up the body's energy metabolism in several ways. Immediately after exercise, cells work to rebuild ATP and other energy reserves, so caloric demands are high. Another short-term effect of exercise is to raise body temperature, which remains elevated for hours after exercise. During that time, chemical reactions proceed more quickly than they otherwise would, contributing to an elevated metabolic rate. In the long term, regular exercise increases the size of muscle cells, which require more energy than fat cells even when at rest. An exercise routine also increases the abundance of enzymes and other proteins that regulate energy metabolism. For example, proteins that transport fatty acids into cells become more numerous after 1 to 2 weeks of exercise, providing cells with easier access to energy.

Corbis

Caffeine may accelerate metabolism, too. Although caffeine contains zero calories, many people can attest to the "energy boost" that it provides. Caffeine increases the release of fatty acids into the blood and raises the heart rate, giving cells quick access to energy reserves. However, studies have shown that getting too little sleep (a side effect of excess caffeine) disturbs normal metabolism.

Finally, metabolism slows down when the body receives too few calories. Hormones then signal the body that it is entering a starved state. In response, cells begin to conserve energy via several mechanisms. One way to keep your metabolism high is therefore to maintain your blood sugar level by eating multiple small, healthy meals throughout the day.

Burning Questions cover topics that students wonder about.

Every chapter in the book answers one or more Burning Questions, encouraging readers to ask questions of their own. I ask my students to write down a Burning Question on the first day of class. I answer all of them during the semester, whenever a relevant topic comes up in class.

5.1 Burning Question

Why do leaves change colors in the fall?

Most leaves are green throughout a plant's growing season, although there are exceptions; some ornamental plants, for example, have yellow or purple foliage. The familiar green color comes from chlorophyll *a*, the most abundant pigment in photosynthetic plant parts.

But the leaf also has other photosynthetic pigments. Carotenoids contribute brilliant yellow, orange, and red hues. Purple pigments, such as anthocyanins, are not photosynthetically active, but they do protect leaves from damage by ultraviolet radiation.

Carotenoids are less abundant than chlorophyll, so they usually remain invisible to the naked eye during the growing season. As winter approaches, however, deciduous plants prepare to shed their leaves. Anthocyanins accumulate while chlorophyll degrades, and the now "unmasked" accessory pigments reveal their colors for a short time as a spectacular autumn display. These pigments soon disappear as well, and the dead leaves turn brown and fall to the ground.

Spring brings a flush of fresh green leaves. The energy to produce the foliage comes from glucose the plant produced during the last growing season and stored as starch. The new leaves make food throughout the spring and summer, so the tree can grow—both above the ground and below—and produce fruits and seeds.

As the days grow shorter and cooler in autumn, the cycle will continue, and the colorful pigments will again participate in one of nature's great disappearing acts.

Submit your burning question to marielle.hoefnagels@mheducation.com

Photo: Shutterstock/Carlos E. Santa Maria

Why We Care 2.1 | Acids and Bases in Everyday Life

Stockdisc/PunchStock

Both acids and bases are important in everyday life. The tart flavors of yogurt, sour cream, and spoiled milk come from acid-producing bacteria. Also, some pigments in fruits and flowers are pH-sensitive, turning blue when basic and red when acidic. When baking cherry muffins, the fruit can turn blue when it reacts with the alkaline baking soda or baking powder. You can prevent this reaction by using sour cream (pH 4.5) instead of milk (pH 6.6) in the recipe; the acidic sour cream lowers the pH of the batter.

Acids also aid in digestion. Your stomach produces hydrochloric acid that kills microbes and activates enzymes that begin the digestion of proteins in food. Antacids contain bases that neutralize excess acid, relieving an upset stomach. ⓘ *stomach acid*, section 28.6C

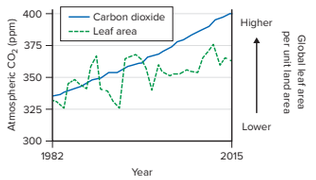
In the environment, some air pollutants return to Earth as acid precipitation. The acidic rainfall kills plants and aquatic life, and it damages buildings and outdoor sculptures. ⓘ *acid deposition*, section 20.3B

In addition, Why We Care boxes apply each chapter's topics to everyday life.

GET THE PICTURE

During a discussion of climate change on a news program, one of the panelists argues that the increase in atmospheric CO_2 concentration has been good for plants. The argument makes sense to you because CO_2 is one of the reactants of photosynthesis, but you think the issue might be more nuanced than the argument you heard.

Searching the Internet, you find countless assertions about how the rising concentration of atmospheric CO_2 is affecting the climate and life on Earth. The following image shows one notable graph, based on satellite images of leaf area across Earth.



a. What can you conclude from this graph?
b. How might you evaluate whether the website presenting these scientific findings is trustworthy? Should you consider *when* the research was conducted?
c. Why would an increase in atmospheric CO_2 concentration allow plants to produce more leaf tissue?
d. Are plants compensating for the increasing availability of CO_2 by using it to make more leaves? How do you know?
e. If a rising CO_2 concentration is good for plants, then is it good for people? Explain why this question does not have a simple answer.

Get the Picture questions help students learn to interpret images and graphs.

Instructors can use these new questions to stimulate discussion in both in-class and virtual settings.

CHAPTER SUMMARY

5.1 Life Depends on Photosynthesis

- **Autotrophs** produce their own organic compounds from inorganic starting materials such as CO_2 and water. **Heterotrophs** rely on organic molecules produced by other organisms.
- **Photosynthesis** converts kinetic energy in light to potential energy in the bonds of carbohydrates, according to the following chemical equation:

$$6CO_2 + 6H_2O \xrightarrow{\text{light energy}} C_6H_{12}O_6 + 6O_2$$

- Plants, algae, and some bacteria are autotrophs. Food and oxygen produced in photosynthesis are critical to life in terrestrial and aquatic habitats.

5.2 Photosynthetic Pigments Capture Sunlight

- Visible light is a small part of the **electromagnetic spectrum.**
- **Photons** move in waves. The shorter the **wavelength,** the more kinetic energy per photon.
- **Chlorophyll *a*** is the primary photosynthetic pigment in plants. **Accessory pigments** absorb wavelengths of light that chlorophyll *a* cannot absorb.

5.3 Chloroplasts Are the Sites of Photosynthesis

- Plants exchange gases with the environment through pores called **stomata.**
- Leaf **mesophyll** cells contain abundant **chloroplasts.**
- A chloroplast contains a gelatinous fluid called the **stroma.** This fluid surrounds the **grana,** which are stacks of pancake-shaped **thylakoid** membranes. Photosynthetic pigments are embedded in the thylakoid membranes, which enclose the **thylakoid space.**
- A **photosystem** consists of proteins, **antenna pigments,** and a **reaction center.**

5.4 Photosynthesis Occurs in Two Stages

- The **light reactions** of photosynthesis produce **ATP** and **NADPH;** these molecules provide energy and electrons for the sugar-producing **carbon reactions** (Figure 5.13).
- In photosynthesis, water is oxidized and CO_2 is reduced to glucose.

5.5 The Light Reactions Begin Photosynthesis

- ATP synthesis in the light reactions relies on **electron transport chains** and **ATP synthase** enzymes in chloroplast membranes. Proteins in the electron transport chain use energy from electrons to create a proton (H^+) gradient by active transport. The protons subsequently diffuse out through channels in ATP synthase. This movement powers the production of ATP.

A. Light Striking Photosystem II Provides the Energy to Produce ATP

- In the thylakoid membrane, photosystem II captures light energy and sends electrons from reactive chlorophyll *a* along the electron transport chain, creating the proton gradient that ATP synthase uses to make ATP.
- Electrons from chlorophyll are replaced with electrons from water. O_2 is the waste product.

B. Electrons from Photosystem I Reduce $NADP^+$ to NADPH

- Light striking photosystem I re-energizes the electrons, which pass to an enzyme that uses them to reduce $NADP^+$. The product of this reaction is NADPH.

5.6 The Carbon Reactions Produce Carbohydrates

- The carbon reactions use energy from ATP and electrons from NADPH in **carbon fixation** reactions that add CO_2 to organic compounds.
- In the **Calvin cycle, rubisco** catalyzes the reaction of CO_2 with **RuBP (ribulose bisphosphate)** to yield two molecules of PGA. These are converted to PGAL, the immediate product of photosynthesis. PGAL later becomes glucose and other carbohydrates.

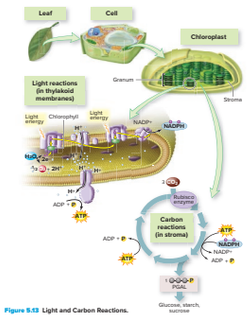


Figure 5.13 Light and Carbon Reactions.

- Plants use sugar produced in photosynthesis to generate ATP, grow, nourish nonphotosynthetic plant parts, and produce many biochemicals.

5.7 C_3, C_4, and CAM Plants Use Different Carbon Fixation Pathways

- The Calvin cycle is also called the **C_3 pathway.** Most plant species are C_3 plants, which use only this pathway to fix carbon.
- **Photorespiration** wastes carbon and energy when rubisco reacts with O_2 instead of CO_2.
- The **C_4 pathway** reduces photorespiration by separating two carbon fixation reactions into different cells. In mesophyll cells, CO_2 is fixed as a four-carbon molecule, which moves to a **bundle-sheath cell** and liberates CO_2 to be fixed again in the Calvin cycle.
- In the **CAM pathway,** desert plants such as cacti open their stomata and take in CO_2 at night, storing the fixed carbon in vacuoles. During the day, they split off CO_2 and fix it in chloroplasts in the same cells.

SCIENTIFIC LITERACY

Review Why We Care 5.1, which describes how several chemical weed killers work. What potential consequences to yourself, to your family, to your neighbors, and to the environment might you consider before using chemical weed killers? Use the Internet to determine if your concerns are justified. Which websites did you use? Do you think those sites are convincing? Why or why not?

The chapter summary highlights key points and terminology from the chapter.

Chapter summary illustrations help students see the big picture.

SCIENTIFIC LITERACY

Review Burning Question 10.1, which describes the inheritance pattern of the metabolic disease called PKU. Today, genetic testing for many disorders is relatively easy and inexpensive. Do prospective parents have an obligation to determine how likely they are to conceive a child with a genetic disorder? What are some possible drawbacks of learning more about one's own genetics? What are some possible advantages to oneself and to society?

Scientific Literacy questions help students understand where biology intersects with ethics, politics, and social issues.

Write It Out and Mastering Concepts questions are useful for student review or as short in-class writing assignments.

I compile them into a list of practice questions that help students focus on material I cover in class. I also use them as discussion questions in Action Centers, where students can come for additional help with course material.

11.3 Mastering Concepts

1. How do DNA-testing services analyze a person's ancestry?
2. How are short tandem repeats used in DNA profiling?
3. What are the pros and cons of mitochondrial DNA analysis?

Figure It Out 6.1

Compare the number of molecules of ATP generated from 100 glucose molecules undergoing aerobic respiration versus fermentation.

Answer: 3600 (theoretical yield) for aerobic respiration; 200 for fermentation.

Figure It Out questions reinforce chapter concepts and typically have numeric answers (supporting student math skills).

Students can work on these in small groups, in class, or in Action Centers. Most could easily be used as clicker questions as well.

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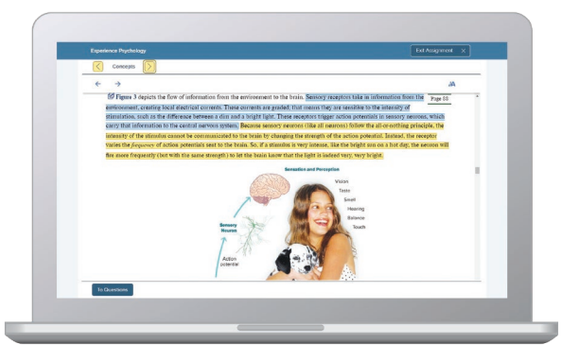

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Changes by Chapter

Chapter 1 (The Scientific Study of Life):

In section 1.1, added a new figure showing unicellular and multicellular life; distinguished between development and growth; in Burning Question 1.1, improved connection between viral features and properties of life; clarified the common ancestry of animals and fungi in figure 1.10 (and in derivative figures throughout the book); updated the figure showing the taxonomic hierarchy to better illustrate nested groups; wrote new Why We Care 1.1 on why understanding science is important; added a figure to illustrate how science can be applied in everyday life; in figure 1.15, added a line graph to complement the bar graph; described the anatomy of a line graph in the chapter summary; added new assessment questions challenging students to think like a scientist and to think of ways they have used scientific thinking in everyday life.

Chapter 2 (The Chemistry of Life):

Clarified that electrons move in every direction within a large cloud, not in circular "orbits"; reworked table 2.2 to include polar and nonpolar covalent bonds; added an explanation of the prefix *co-* in covalent; added an analogy of a battery to a polar covalent bond; clarified why a change in pH can cause cell death; reworked figure 2.16 to better depict acidic, neutral, and alkaline solutions; added key information to table 2.4, which summarizes life's macromolecules; omitted the term *hydrocarbon*; noted that coconut oil and palm oil are high in saturated fat, and later, challenged students to take a stand on whether the fats in coconut oil are healthy or unhealthy; listed foods that are good sources of unsaturated fats; clarified that the animal body produces all the cholesterol it needs; cut the content on trans fats, which are no longer common in processed foods; added content about "junk" foods. Added a new learning tool to ebook: a video showing oil and water separation in section 2.3.

Chapter 3 (Cells):

Clarified the difference between compound and confocal microscopes; defined *organelle* and *nucleus* at first use; explained why organelles are adaptive in eukaryotic cells; reorganized Why We Care 3.1 to begin with the number of cells in the human body and expand to nonhuman cells; clarified the description of starch-storing plastids; improved labeling in figure 3.21; based on SmartBook user data, clarified composition of cytoskeleton and added photo to figure 3.22; clarified the description of the plasmodesma's structure and reorganized figure 3.24. Added a new learning tool to the ebook: a digital-only table summarizing cell theory.

Chapter 4 (The Energy of Life):

In response to a reviewer comment, avoided referring to cellular respiration and photosynthesis as "reactions" and instead called them "processes"; at a reviewer's request, brought back table 4.1 (types of energy) from the first edition; added a brief explanation of concentration gradients early in the chapter; clarified the reactants in redox reactions; described muscle contraction, light, and molecular movement as examples of kinetic energy; clarified how electron carriers participate in the electron transport chain; clarified why ATP hydrolysis occurs and which bond in ATP breaks; made *coupled reactions* a boldfaced term; connected enzymes to the energy transformations in the cell; distinguished between the short-term and long-term effects of exercise in *What's the Point? Applied*.

Chapter 5 (Photosynthesis):

Based on SmartBook user data, rearranged section 5.5 and added new figure 5.7 showing relationship between electron transport chain and ATP synthase; clarified numerous labels in figure 5.8; added new figure 5.10 showing how photorespiration pulls carbon out of the Calvin cycle; clarified description of the C_4 pathway; reworked figure 5.12, comparing C_3, C_4, and CAM plants; reworked figure 5.A, showing experimental results in Investigating Life 5.1. Added new learning tools to the ebook: new digital-only tables titled "Redox Reactions in Photosynthesis" and "Carbon Fixation Pathways."

Chapter 6 (Respiration and Fermentation):

Added inputs and outputs to figure 6.7, showing the mitochondrial electron transport chain; based on SmartBook user data, referred back to chapter 5's new figure showing the relationship between the electron transport chain and ATP synthase; extrapolated the ATP yield from one glucose molecule to explain the immense numbers of ATPs generated from a day's worth of food; based on reviewer feedback, added *anaerobic respiration* as a boldfaced term; added a Get the Picture question using an analogy of a check and cash for glucose and ATP. Added new learning tools to the ebook: tables summarizing redox reactions in aerobic cellular respiration and the products of cellular respiration.

Chapter 7 (DNA Structure and Gene Function):

Throughout the chapter, substituted *gene expression* where it would be more accurate than *protein synthesis*; updated Burning Question 7.1 to incorporate current views of the influence of genes on sexual orientation; clarified the structure and function of the mRNA cap; improved the position and shape of RNA polymerase in figure 7.5 (and subsequent figures depicting RNA polymerase); clarified that each codon specifies one amino acid or a stop codon; added new figure 7.8, an illustration of a ribosome; improved the illustration and description of translation; explained the difference between proteins that misfold because of a genetic mutation and those that misfold for other reasons; clarified the role of transcription factors; added deletion frameshift mutations to table 7.1; clarified the role of the receptor and coreceptor in HIV infection; added

a passage and supporting photo on chronic wasting disease; clarified the role of Neandertal DNA in studies of *FOXP2*. Added new learning tools to the ebook: a digital-only figure showing the DNA scale from nucleotide to chromosome and a table of regulated points in gene expression.

Chapter 8 (DNA Replication, Binary Fission, and Mitosis):

Differentiated between growth and development; deleted the boldfaced term *semiconservative replication* (but still described the concept); clarified that the DNA in a typical eukaryotic cell consists of linear chromosomes; at a reviewer's request, simplified the terms related to chromosome structure; expanded upon the risk factors for cancer. Added a new learning tool to the ebook: a figure showing the DNA scale from nucleotide to chromosome.

Chapter 9 (Sexual Reproduction and Meiosis):

Boldfaced the terms *sperm cell* and *egg cell*; clarified that "typical" sex chromosomes are XX for females and XY for males; improved figure 9.3, differentiating between sister chromatids and homologous chromosomes; explained why DNA replication does not change chromosome number; improved labeling in figure 9.5; clarified the distinction between somatic cells and germ cells; based on SmartBook user data, clarified that X and Y are not homologous, even though they pair up during the early stages of meiosis; explained how homologous chromosomes are only slightly different from each other; added new Burning Question 9.1 on how males and females are defined in nonhuman species; boldfaced the terms *recombinant chromatid* and *parental chromatid*; added new table 9.1 comparing mitosis and meiosis; explicitly connected the variation in meiosis with evolutionary change; updated Why We Care 9.1 to reflect the declining incidence of multiple births; improved the labeling on figure 9.11; based on SmartBook user data, clarified that one way polyploidy can occur is if all chromosomes fail to separate (complete nondisjunction). Added new learning tools to the ebook: a table comparing asexual and sexual reproduction, a figure comparing homologous chromosomes to two editions of the same book, and a figure showing the DNA scale from nucleotide to chromosome.

Chapter 10 (Patterns of Inheritance):

Clarified that "typical" sex chromosomes are XX for females and XY for males; based on SmartBook user data, added the F_1 generation to figure 10.7; clarified the labels in figure 10.9; improved the explanation of Mendel's dihybrid cross experiment; clarified the explanation of the law of independent assortment; improved the labeling in figure 10.15; clarified the explanation of the *H* gene's role in the ABO blood type system; updated information on autosomes associated with male-pattern baldness in Burning Question 10.2; expanded the explanation for some of the disorders in table 10.2; expanded the passage on epigenetics. Added a new learning tool to the ebook: a figure showing the DNA scale from nucleotide to chromosome.

Chapter 11 (DNA Technology):

Added *genetically modified organism (GMO)* as a boldfaced term; added CRISPR to Burning Question 11.1; made *CRISPR* a boldfaced term and moved it to the section on DNA technology tools; added "golden rice" as an example of a genetically modified plant; added direct DNA injection as a way to produce genetically modified animals; made *DNA sequencing* and *DNA polymerase* boldfaced terms and simplified the explanation of DNA sequencing technology; added a new passage on direct-to-consumer DNA testing kits; simplified the explanation of DNA profiling in criminal justice; updated information about embryonic and adult stem cells; added *clone* as a boldfaced term; updated the information about gene doping; updated the passage on ethics to include CRISPR; added a paragraph to Investigating Life 11.1. Added a new learning tool to the ebook: a figure showing the DNA scale from nucleotide to chromosome.

Chapter 12 (Forces of Evolutionary Change):

Added "allele frequencies" to Survey the Landscape for unit 3; based on SmartBook user data, added Figure It Out 12.1 to support the idea of allele frequencies; reworked Why We Care 12.1 to focus on dog evolution; improved figure 12.5 to clarify how multiple crops are derived from a single ancestor; added "evolution is just a theory" to the misconceptions listed in table 12.2; based on reviewer feedback, added "intelligent design" to the misconceptions listed in table 12.2; explicitly defined the term *selective force* and added a Mastering Concepts question to reinforce the concept; reworked Burning Question 12.1 to emphasize accurate and inaccurate depictions of human evolution; clarified how the founder effect applies to the Amish population; based on SmartBook user data, clarified that migration makes a population more homogeneous.

Chapter 13 (Evidence of Evolution):

Based on SmartBook user data, added part labels and modified caption for figure 13.2 to emphasize the relative lengths of each eon/era; refreshed *What's the Point? Applied* to reflect current understanding of human and chimpanzee genomes.

Chapter 14 (Speciation and Extinction):

Added *reproductive barrier* as a boldfaced term; throughout section 14.2, emphasized the word *barrier* over *isolation* to avoid the misconception that reproductive isolation means a decrease in fitness; redrew figure 14.12 to show the crater on the Yucatan peninsula; reworked figure 14.13, showing the taxonomic hierarchy; updated the cladograms in figure 14.16 and figure 14.18 to reflect current understanding of reptile evolution.

Chapter 15 (Evolution and Diversity of Microbial Life):

Updated figure 15.1 to reflect discovery of the oldest fungal fossils; corrected the junction between animals and fungi in life's evolutionary tree (in figure 15.7 and similar figures throughout the book); made the ribosomes more prominent in figure 15.9; reworked figure 15.12 and connected metabolic diversity back to content on anaerobic respiration and fermentation; clarified figure 15.21, showing the relationship between *Chlamydomonas* and *Volvox;* improved figure 15.34 to include role of hyphal tips in feeding; expanded the definition of *endophyte* to include nonfungal microbes; improved figure 15.39 by adding spot illustrations for context. Added new learning tools to the ebook: live-action videos of *Volvox* and *Paramecium* and a time-lapse video of mold forming on food.

Chapter 16 (Evolution and Diversity of Plants):

Made numerous small changes in narrative and art to enhance clarity; added *spores* as a boldfaced term; clarified that a fern's sperm cells typically fertilize egg cells on a different gametophyte. Added a new learning tool to the ebook: a digital-only table comparing spores and seeds.

Chapter 17 (Evolution and Diversity of Animals):

Made numerous small changes to art and narrative for clarity; added examples of scientific research using *C. elegans*; made sure not to use *blood* for animals with open circulatory systems; added more photos of nematode diversity; added a figure showing molting; clarified that echinoderms have a complete digestive system and revised the passages relating to the water vascular system; clarified the passage on ectotherms and endotherms; updated the passage on selection pressure for bipedal locomotion; reworked figure 17.34, showing the human family tree; omitted *Homo ergaster* from the narrative; clarified that migration out of Africa has occurred multiple times and that human species interbred; added figure 17.38 to support the connection between UV radiation and skin pigmentation. Added new learning tools to the ebook: live-action videos of a hydra, a jellyfish, a sea slug, a snail, an octopus, an earthworm, a nematode, a barnacle, a sea star, a sting ray, a Komodo dragon, a snake, a slow loris, monkeys, and gibbons; and a new table of hagfish and lamprey characteristics.

Chapter 18 (Populations):

Updated statistics on human birth rates and death rates; based on SmartBook user data, improved the connection between figure 18.3 and its corresponding narrative; designated survivorship curves as late loss, constant loss, and early loss; modified population growth tables in figure 18.7 and figure 18.9 to show how the population in one row relates to the population in the next row; reworked age structure diagrams in figure 18.15 to include Uganda (growing population) and Japan (shrinking population); updated statistics on human population growth, life expectancy, and causes of death; updated figure 18.16 to include per country and per capita ecological footprints.

Chapter 19 (Communities and Ecosystems):

Added *climate* as a boldfaced term; clarified the definition of primary producers; explained that figure 19.8 shows the *potential* range of each biome, based on current climate; added lines for 30 and 60 degrees N and S to figure 19.8; added a new Burning Question 19.1 about cave ecosystems; modified all nutrient cycling figures so they highlight processes that are most directly affected by human activities; based on SmartBook user data, explicitly stated that respiration returns water to the atmosphere; connected the nitrogen cycle back to anaerobic respiration (in chapter 6). Added new learning tools to the ebook: a time-lapse video of a deciduous tree in four seasons; a video of coral reef biodiversity; a video of a chameleon catching a spider; and a table listing factors affecting climate.

Chapter 20 (Preserving Biodiversity):

Updated data on endangered species in figure 20.1; reworked the synopsis of the causes of the biodiversity crisis to better correspond to chapter content; added figure 20.8, the great Pacific Garbage Patch; updated data on the status of the ozone hole; boldfaced *ultraviolet radiation* and added examples of how UV light may affect ecosystems; mentioned cattle, landfills, and nitrogen fertilizers as sources of greenhouse gases; updated data on global climate change and the extent of sea ice; added a contrast between human contributions to climate change and natural variations in global climate; added more details about how climate change will affect agriculture; updated data on invasive species in the United States; used oyster bed reclamation as a recent example of habitat restoration; referred to CRISPR as a use of biotechnology in conservation biology; clarified the implications of reduced genetic diversity in Investigating Life 20.1.

Chapter 21 (Plant Form and Function):

Based on reviewer feedback, identified the plants used in the chapter illustrations when appropriate; included hormones as one of the substances carried in xylem sap and phloem sap; added more about plant diversity and useful plant-produced chemicals to *What's the Point?*; introduced the terms *primary growth* and *secondary growth* in the same paragraph with herbaceous and woody plants; reorganized section 21.3 so that tissue systems come before cell types; divided cell types into "nonconducting" and "conducting" categories; mentioned the role of companion cells in figure 21.22. Added new learning tools to the ebook: a live-action video of a Venus fly trap and a figure summarizing plant tissues.

Chapter 22 (Reproduction and Development of Flowering Plants):

Based on SmartBook user data, modified the miniglossary definition of gametes to prevent student confusion between gamete and gametophyte; improved the labeling in figure 22.7 to make the parts of the embryo more obvious; in Why We Care 22.1, elaborated on the potential use of jasmonic acid in agriculture; clarified that photoreceptors can trigger changes in gene expression in plants; in Investigating Life 22.1, added research showing that capsaicin protects against fungi. Added new learning tools to the ebook: a table comparing human reproductive structures with plant reproductive structures and time-lapse videos of wheat seeds germinating, phototropism, gravitropism, and thigmotropism.

Chapter 23 (Animal Tissues and Organ Systems):

Modified the study tip in the chapter opener to apply to both face-to-face and online classes; distinguished between *interstitial fluid* and *extracellular matrix*; mentioned roles of microbes in the digestive and immune systems; updated information about artificial organs; replaced essay in Investigating Life 23.1 with new content on dinosaur bone growth and metabolic rates. Added a new learning tool to the ebook: a table listing thermoregulatory adaptations.

Chapter 24 (The Nervous System and the Senses):

Added *myelin sheath* to the miniglossary of neuron anatomy; clarified that sensory neurons have different structures from the motor neuron

shown in figure 24.2; simplified the explanation of the role of K^+ in the resting potential; clarified that a strong stimulus or multiple simultaneous stimuli cause the membrane to reach threshold potential; based on SmartBook user data, clarified in narrative and figure 24.6 that Na^+ ions diffuse only a short distance along the membrane; added a new Burning Question 24.3 on the sensation of itch.

Chapter 25 (The Endocrine System):

Improved figure 25.1, showing metamorphosis in insects and amphibians; based on SmartBook user data, added new table 25.1 summarizing the types of hormones; updated data in figure 25.11, showing the correlation between obesity and diabetes; moved the miniglossary of the hormones and receptors to the ebook.

Chapter 26 (The Skeletal and Muscular Systems):

Reworked figure 26.1 to better depict the three types of skeletons; clarified that marrow is a type of tissue; added a micrograph to figure 26.10; reworked figure 26.12 to improve paging; based on multiple reviewer suggestions, added a "tug of war" analogy to the description of antagonistic muscles and trimmed content about slow- and fast-twitch fibers; added information about how exercise and sex hormone differences affect muscle growth; updated information about prosthetic limbs in *What's the Point? Applied.*

Chapter 27 (The Circulatory and Respiratory Systems):

Moved definition of *interstitial fluid* to section 27.1 to emphasize its connection to plasma; added labels to clarify figure 27.2; clarified the effects of leukemia; clarified how platelets form; explained why people can donate plasma more frequently than whole blood in Burning Question 27.1; expanded figure 27.9, showing the events of the heartbeat; added descriptive labels to figure 27.14; added "interstitial fluid" to the description of the alveolus–capillary interface; clarified labels in figure 27.A. Added a new learning tool to the ebook: a "Pathway of Respiration" miniglossary.

Chapter 28 (The Digestive and Urinary Systems):

Clarified the role of genes in regulating food intake; improved figure 28.10, showing intracellular digestion; omitted the term *alimentary canal;* in Burning Question 28.1, updated information about fad diets; based on a reviewer's suggestion, added stomach ulcers to Why We Care 28.1; clarified aldosterone's role in regulating blood pressure.

Chapter 29 (The Immune System):

Clarified the relationship between plasma, interstitial fluid, and lymph; improved figure 29.6, showing innate defenses; reversed the descriptions of effector cells and memory cells to clarify the adaptive immune response; added CRISPR-modified T cells to the paragraph on immunotherapy; added information about genetic vaccines, including COVID-19 mRNA vaccine; clarified in Burning Question 29.1 why the number of memory cells varies following vaccination; updated information about meat allergies and added a photo of a tick to Burning Question 29.2; based on SmartBook user data, modified labels in figure 29.14; replaced essay in Investigating Life 29.1 with new content comparing allergies and asthma in children living on farms and in cities; in the chapter summary, added a new figure 29.16 summarizing the primary and secondary immune response.

Chapter 30 (Animal Reproduction and Development):

Revised the paragraph describing prostate cancer and testicular cancer; clarified the events of the ovarian and menstrual cycles; explained how the egg cell enters the uterine tube; clarified the narrative and illustration in Burning Question 30.1; added a row to table 30.2, indicating the number of pregnancies in the absence of contraception; added a new Why We Care 30.1 on the rising incidence of STIs; clarified the passages on organ system development and the fetal stage.

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Detailed Contents

UNIT 2 DNA, Inheritance, and Biotechnology

7 DNA Structure and Gene Function 112

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8 DNA Replication, Binary Fission, and Mitosis 138

PhotoAlto/Getty Images

9 Sexual Reproduction and Meiosis 154

shene/Moment Open/Getty Images

UNIT 3 Evolution and Diversity

UNIT 4 Ecology

18 Populations 356

Lorado/Getty Images

19 Communities and Ecosystems 372

Pedro Ladeira/SambaPhoto/ Getty Images

25 The Endocrine System 502


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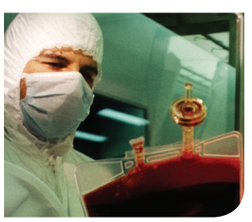
26 The Skeletal and Muscular Systems 516


Jeff J Mitchell/Getty Images

27 The Circulatory and Respiratory Systems 534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28 The Digestive and Urinary Systems 556


Ingram Publishing

29 The Immune System 580


CDC/James Gathany

30 Animal Reproduction and Development 598


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FOURTH EDITION

BIOLOGY

The Essentials

1

UNIT 1 Science, Chemistry, and Cells

The Scientific Study of Life

Biology Is Everywhere. Central Park is an oasis of green in New York City, but life thrives in the city's streets and buildings too.

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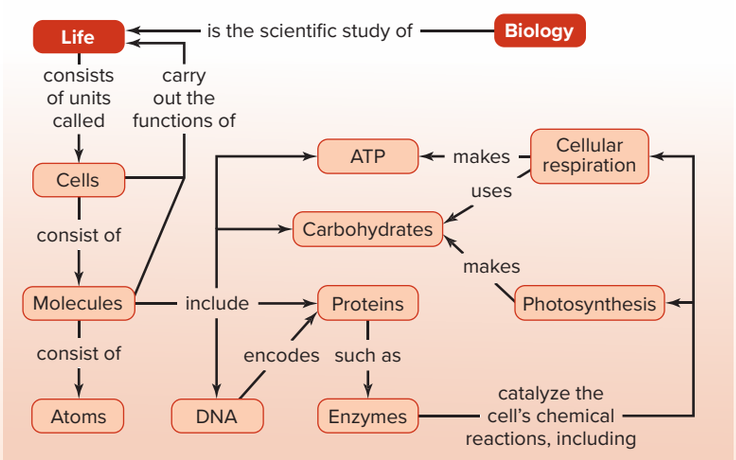
LEARNING OUTLINE

APPLICATIONS

Burning Question 1.1 *Are viruses alive?*
Why We Care 1.1 *Appreciating Science*
Why We Care 1.2 *It's Hard to Know What's Bad for You*
Burning Question 1.2 *Why am I here?*
Investigating Life 1.1 *The Orchid and the Moth*

SURVEY THE LANDSCAPE
Science, Chemistry, and Cells



The Scientific Study of Life. Organisms from all three branches of life share a unique combination of characteristics. Biologists are scientists who use evidence to test hypotheses about life.

For more details, study the Pull It Together feature in the chapter summary.

Learn How to Learn

Real Learning Takes Time

You got good at basketball, running, dancing, art, music, or video games by putting in lots of practice. Likewise, you will need to commit time to your biology course if you hope to do well. To get started, look for the Learn How to Learn tip in each chapter of this textbook. Each hint is designed to help you use your study time productively. With practice, you'll discover that all concepts in biology are connected. The Survey the Landscape figure in every chapter highlights each chapter's place in the "landscape" of the entire unit. Use it, along with the more detailed Pull It Together concept map in the chapter summary, to see how each chapter's content fits into the unit's big picture.