2024 RELEASE

BIOLOGY

Concepts and Investigations

Mariëlle Hoefnagels
THE UNIVERSITY OF OKLAHOMA

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Brief Contents

About the Author

Photo: Douglas D. Gaffin

Mariëlle Hoefnagels recently retired from the Department of Microbiology and Plant Biology at the University of Oklahoma, where she taught courses in introductory biology, science writing, mycology, and microbiology for about 25 years. During her career at OU, she 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 (to recognize outstanding faculty who teach freshmen and sophomores). Her textbook *Biology: Concepts and Investigations* has been recognized with a Textbook Excellence Award from the Textbook and Academic Authors Association. She was also awarded honorary memberships in several student honor societies.

Dr. Hoefnagels received her B.S. in environmental science from the University of California at Riverside, her M.S. in soil science from North Carolina State University, and her Ph.D. 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: Concepts and Investigations* and *Biology: The Essentials*, her recent publications and presentations have focused on boosting scientific literacy and helping students see how biology is relevant to their lives.

Preface

As biology instructors, we all want our students to form a personal connection with what they are learning. We can introduce each topic in the context of human health, nutrition, sports, or sex to build relevance and to help students anchor the content to a subject they know and care about. We can tell them, "Your own living body is proof that biology matters." Yet some students still have trouble seeing the big picture; they get mired in the details and lose their personal connection with biology.

I want all students to know that this book is *for* them and is *about* them. To move toward this goal, I worked with a specialist in diversity, equity, and inclusion who helped identify areas where the narrative or art could better represent all readers. I also consulted colleagues and read perspectives from students and instructors who have been marginalized by traditional biological instruction.

As a result of these experiences, I made several changes throughout the book. For example, I clarified the difference between biological sex and gender, and I removed gendered language wherever possible. I also rewrote passages to be inclusive of diverse identities and family structures. In addition, I used person-first language to describe disorders and diseases, and I have continued to improve the art and media so it is accessible to all users. Overall, the goal was to improve inclusivity while maintaining the clear and concise narrative that introductory students need.

The 2024 release retains what users have always loved about this book: clear writing, a beautiful art program, handy study tips, Investigating Life essays, tutorial animations, and concept maps. New to this release is an end-of-chapter question type called Get the Picture, which challenges students to interpret images and graphs related to the chapter content. Alongside the Scientific Literacy questions at the end of each chapter, Get the Picture helps students build reasoning skills and become biologically informed citizens. In my class, I have used probes such as these to teach students to ask scientific questions, critically examine evidence, and evaluate the credibility of scientific conclusions. Even if students eventually forget some core content after they leave my class, they can continue to apply these vital skills throughout life.

I believe that one set of tools and techniques does not work for every instructor. For that reason, my team and I are proud to create a package that gives you the flexibility to teach introductory biology in a way that works best for you. The following sections illustrate the features and resources that can help you meet your teaching goals.

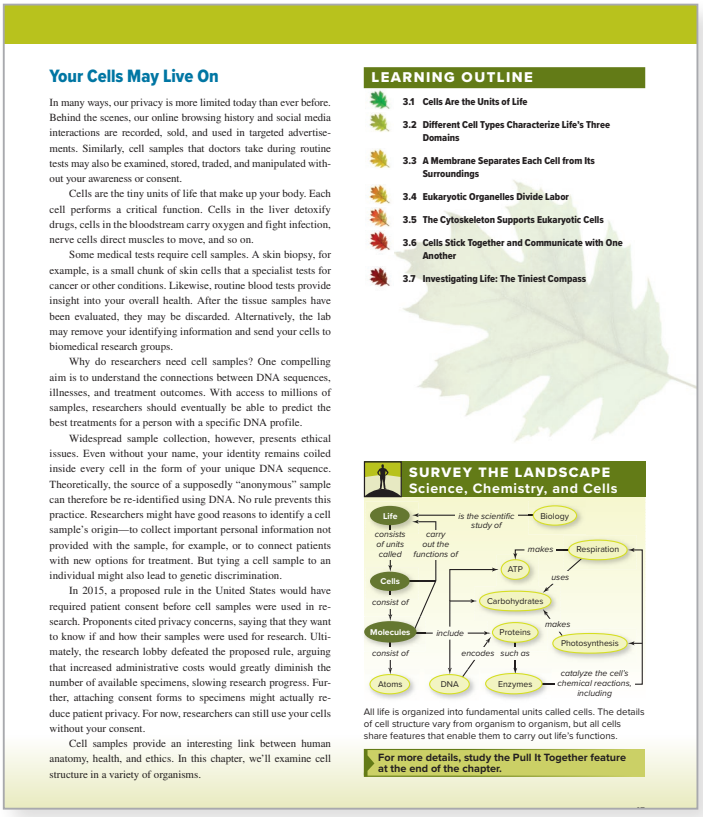
I hope that you and your students enjoy this text and that it helps cultivate an understanding of, and deep appreciation for, biology.

Mariëlle Hoefnagels
Professor Emerita, University of Oklahoma

Photo: Douglas D. Gaffin

Author's Guide *to Using this Textbook*

This guide lists the main features of each chapter and describes some of the ways that instructors can use them based on what worked well in my own classes.



Your Cells May Live On

In many ways, our privacy is more limited today than ever before. Behind the scenes, our online browsing history and social media interactions are recorded, sold, and used in targeted advertisements. Similarly, cell samples that doctors take during routine tests may also be examined, stored, traded, and manipulated without your awareness or consent.

Cells are the tiny units of life that make up your body. Each cell performs a critical function. Cells in the liver detoxify drugs, cells in the bloodstream carry oxygen and fight infection, nerve cells direct muscles to move, and so on.

Some medical tests require cell samples. A skin biopsy, for example, is a small chunk of skin cells that a specialist tests for cancer or other conditions. Likewise, routine blood tests provide insight into your overall health. After the tissue samples have been evaluated, they may be discarded. Alternatively, the lab may remove your identifying information and send your cells to biomedical research groups.

Why do researchers need cell samples? One compelling aim is to understand the connections between DNA sequences, illnesses, and treatment outcomes. With access to millions of samples, researchers should eventually be able to predict the best treatments for a person with a specific DNA profile.

Widespread sample collection, however, presents ethical issues. Even without your name, your identity remains coiled inside every cell in the form of your unique DNA sequence. Theoretically, the source of a supposedly "anonymous" sample can therefore be re-identified using DNA. No rule prevents this practice. Researchers might have good reasons to identify a cell sample's origin—to collect important personal information not provided with the sample, for example, or to connect patients with new options for treatment. But tying a cell sample to an individual might also lead to genetic discrimination.

In 2015, a proposed rule in the United States would have required patient consent before cell samples were used in research. Proponents cited privacy concerns, saying that they want to know if and how their samples were used for research. Ultimately, the research lobby defeated the proposed rule, arguing that increased administrative costs would greatly diminish the number of available specimens, slowing research progress. Further, attaching consent forms to specimens might actually reduce patient privacy. For now, researchers can still use your cells without your consent.

Cell samples provide an interesting link between human anatomy, health, and ethics. In this chapter, we'll examine cell structure in a variety of organisms.

LEARNING OUTLINE

- 3.1 Cells Are the Units of Life
- 3.2 Different Cell Types Characterize Life's Three Domains
- 3.3 A Membrane Separates Each Cell from Its Surroundings
- 3.4 Eukaryotic Organelles Divide Labor
- 3.5 The Cytoskeleton Supports Eukaryotic Cells
- 3.6 Cells Stick Together and Communicate with One Another
- 3.7 Investigating Life: The Tiniest Compass

SURVEY THE LANDSCAPE
Science, Chemistry, and Cells

All life is organized into fundamental units called cells. The details of cell structure vary from organism to organism, but all cells share features that enable them to carry out life's functions.

For more details, study the Pull It Together feature at the end of the chapter.

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.

The gradual change in leaf colors as a chapter unfolds indicates where the student is in the chapter's big picture.

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.

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 new figures integrate with the existing Pull It Together concept maps in the chapter summary.

After spending class time discussing the key points in constructing concept maps, consider having students draw concept maps of their own.

PULL IT TOGETHER

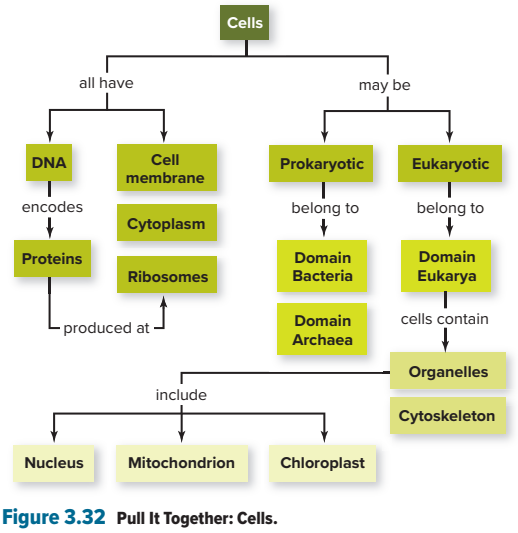


Figure 3.32 Pull It Together: Cells.

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.

Try highlighting a study tip in class each week, with examples of how students can implement them.

LEARN HOW TO LEARN
Real Learning Requires Real Effort

What are you good at? Whether it's basketball, running, dancing, art, music, video games, or something else, you built your skills 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. As you delve into the content, you'll discover that all concepts in biology are connected. The Survey the Landscape figure in every chapter helps you see these connections by using contrasting colors to highlight each chapter's place in the "landscape" of the entire unit. In addition, the Pull It Together concept map in the chapter summary makes connections between key terms within each chapter. As you study, try using both concept maps as tools for organizing your class notes.

Investigating Life describes a real experiment focusing on an evolutionary topic related to each chapter's content.

Each Investigating Life section concludes with critical thinking questions that can be used as an in-class group activity. 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 experiment as a basis for discussing the nature of science.

Selected questions in Connect focus on the Investigating Life studies, so you can assess students' understanding of the science behind the experiment and their ability to integrate those concepts with information from other units.

INVESTIGATING LIFE

3.7 The Tiniest Compass

Submarine captains steer their vessels through the dark ocean. They could wander in all directions in search of their destination, but that approach wastes time and fuel. Instead, they rely on navigation systems to find their way. Surprisingly, massive ships have something in common with marine bacteria: Compasses guide some of these tiny vessels as well.

Until recently, biologists thought that prokaryotic cells lacked any internal membranes. But microscopes revealed that some bacteria have small lipid bilayer spheres in their cytoplasm. Scientists found high concentrations of magnetic iron crystals within these membrane bubbles and aptly named them "magnetosomes" (figure 3.29). What is the function of these structures?

When scientists found magnetosomes, they already knew that Earth's magnetic field leaves the planet from the southern hemisphere, circles far into space, and returns to Earth in the northern hemisphere. In most parts of the ocean, the magnetic field lines are roughly vertical. Experiments on magnetic bacteria collected from oceans revealed that the magnetosomes align with magnetic field lines and that the bacteria swim either against or with the field.

These studies showed how bacteria respond to magnetism, but they did not explain why orienting to magnetic fields is adaptive. A team of four researchers led by Richard Frankel at California Polytechnic State University aimed to answer this question.

The observation that the bacteria do not always swim in the same direction along the magnetic field lines led them to hypothesize that another factor must influence bacterium movement. One clue was that these bacteria cannot survive if oxygen levels are too high or too low. So Frankel and his colleagues devised an experiment to test whether magnetism and oxygen concentration jointly guide bacterial movement.

The scientists put the bacteria in a solution. They then drew the mixture into narrow glass tubes and sealed one end. Within each tube, the dissolved oxygen concentration was lowest at the sealed end and increased toward the open end. When the team produced a magnetic field across one of the tubes, all of the bacteria turned toward the field. Some then swam forward, while others moved backward. They aggregated in a distinct band in the center of the tube, at their optimal oxygen concentration (figure 3.30). The scientists then switched the direction of the magnetic field. All of the bacteria turned 180°, but none migrated out of the band in the center of the tube.

These results indicate that magnetic fields influence the direction that magnetosome-containing bacteria face, helping the cells follow a straight line through the water. Since the dissolved oxygen concentration decreases with depth, and since Earth's magnetic field runs almost vertically through the water column, bacterial cells use magnetism to find the shortest path to their preferred oxygen concentration. Decreasing the swimming distance saves energy for other cellular tasks, such as reproduction.

Scientists used powerful microscopes and clever experiments to reveal how some bacteria avoid getting lost at sea. Lipid-enclosed magnetosomes guide them like compasses through the deep unknown.

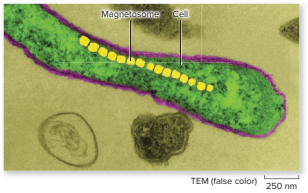


Figure 3.29 **Magnetosomes.** This bacterial cell contains a row of magnetosomes, which are lipid spheres containing iron crystals that align with Earth's magnetic field.

Dennis Kunkel Microscopy/Science Source

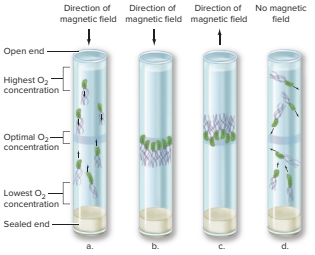


Figure 3.30 **Magnetic Orientation.** (a) Bacteria with magnetosomes turn toward magnetic fields and (b) move in straight lines toward their optimal oxygen concentration. (c) Switching the direction of the magnetic field rotates the bacteria. (d) Without a magnetic field, bacteria move toward an optimal O_2 concentration but do not take a direct path. Small arrows in (a) and (d) indicate the direction of bacterial movement within each tube.

Source: Frankel, Richard B., Dennis A. Bazylinski, Mark S. Johnson, and Barry L. Taylor. 1997. Magneto-aerotaxis in marine coccoid bacteria. *Biophysical Journal*, vol. 73, pages 994–1000.

3.7 MASTERING CONCEPTS

1. How did the researchers determine that both magnetism and oxygen guided bacteria movements?
2. How do magnetosomes help bacteria save energy?

The Chapter Summary highlights key points and terminology from the chapter.

CHAPTER SUMMARY

3.1 Cells Are the Units of Life

- **Cells** are the microscopic components of all organisms.

A. Simple Lenses Revealed the First Glimpses of Cells

- Robert Hooke and Antony van Leeuwenhoek pioneered cell biology.

B. The Cell Theory Emerges

- Schleiden, Schwann, and Virchow's formulation of the **cell theory** states that all life is composed of cells, that cells are the functional units of life, and that all cells come from preexisting cells.
- Contemporary cell biology focuses on the role of genetic information, the cell's chemical components, and the metabolic processes inside cells.

C. Microscopes Magnify Cell Structures

- Light microscopes, transmission electron microscopes, and scanning electron microscopes are essential tools for viewing the parts of a cell.

D. All Cells Have Features in Common

- All cells have DNA, RNA, **ribosomes** that build proteins, and a **cell membrane** that is the interface between the cell and the outside environment (figure 3.31). This membrane encloses the **cytoplasm,** which includes a fluid portion called the **cytosol.**
- The ratio of a cell's surface area to its volume must be large; this ratio is influenced by cell size, shape, and membrane folding.

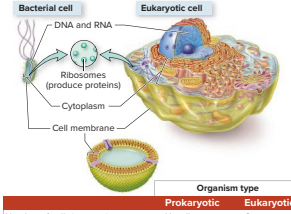
3.2 Different Cell Types Characterize Life's Three Domains

- **Eukaryotic** cells have a **nucleus** and other **organelles; prokaryotic** cells lack these structures. Prokaryotic cells include bacteria and archaea.

A. Domain Bacteria Contains Earth's Most Abundant Organisms

- **Bacteria** are structurally simple, but they are abundant and diverse. Most have a **cell wall** and one or more **flagella.** DNA occurs in an area called the **nucleoid.**

	Cell type	
	Prokaryotic	Eukaryotic
Nucleus	No	Yes
Membrane-bounded organelles	No	Yes
Typical size	1–10 μm	10–100 μm



	Organism type	
	Prokaryotic	Eukaryotic
Number of cells in organism	Usually one	One or more
Domain(s)	Bacteria and Archaea	Eukarya

Figure 3.31 **Cell Features: A Summary.**

B. Domain Archaea Includes Prokaryotes with Unique Biochemistry

- **Archaea** share some characteristics with bacteria and eukaryotes but also have unique structures and chemistry.

C. Domain Eukarya Contains Organisms with Complex Cells

- Domain **Eukarya** includes protists, plants, fungi, and animals. Most eukaryotic cells are larger than prokaryotic cells.

3.3 A Membrane Separates Each Cell from Its Surroundings

- A **phospholipid** consists of a phosphate group, a glycerol, and two fatty acids. A biological membrane consists of a **phospholipid bilayer** embedded with movable proteins and steroid molecules, forming a **fluid mosaic.**
- Membrane proteins carry out a variety of functions.

3.4 Eukaryotic Organelles Divide Labor

- The **endomembrane system** includes the nuclear envelope, endoplasmic reticulum, Golgi apparatus, lysosomes, vacuoles, cell membrane, and **vesicles** that transport materials within cells.

A. The Nucleus, Endoplasmic Reticulum, and Golgi Interact to Secrete Substances

- A eukaryotic cell houses DNA in a nucleus. **Nuclear pores** allow the exchange of materials through the two-layered **nuclear envelope;** assembly of the ribosome's subunits occurs in the **nucleolus.**
- The **smooth endoplasmic reticulum, rough endoplasmic reticulum,** and **Golgi apparatus** work together to synthesize, store, transport, and release molecules.

B. Lysosomes, Vacuoles, and Peroxisomes Are Cellular Digestion Centers

- A eukaryotic cell degrades wastes and digests nutrients in **lysosomes.**
- In plants, a watery **vacuole** degrades wastes, exerts turgor pressure, and stores acids and pigments.
- **Peroxisomes** help digest fatty acids and detoxify many substances.

C. Mitochondria Extract Energy from Nutrients

- **Mitochondria** house the reactions of cellular respiration. The **cristae** (folds) of the inner mitochondrial membrane add surface area.

D. Photosynthesis Occurs in Chloroplasts

- In the cells of plants and algae, **chloroplasts** use light energy to make food.

3.5 The Cytoskeleton Supports Eukaryotic Cells

- The **cytoskeleton** is a network of protein rods and tubules that provides cells with form, support, and the ability to move.

A. Proteins Form the Cytoskeleton

- **Microfilaments,** the thinnest components of the cytoskeleton, are composed of the protein actin. **Intermediate filaments** consist of various proteins that strengthen the cytoskeleton. **Microtubules** are made of tubulin subunits. They form an internal trackway and include the fibers that separate chromosomes during cell division.
- **Centrosomes** organize microtubules in animal cells.

B. Cilia and Flagella Help Cells Move

- **Cilia** are short, numerous extensions; flagella are less numerous but much longer. Both cilia and flagella aid in the movement of cells and materials.

3.6 Cells Stick Together and Communicate with One Another

A. Animal Cell Junctions Occur in Several Forms

- Groups of **tight junctions** create a seal between adjacent cells. **Anchoring junctions** secure cells in place. **Gap junctions** allow adjacent cells to exchange materials.

B. Plasmodesmata Are Channels in Plant Cell Walls

- Cell walls provide protection and shape.

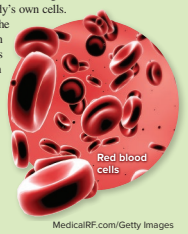
Apply It Now boxes reinforce the applications of specific topics to the real world.

3.1 / Apply It **Now**

Outnumbered! Your Body Has More Cells Than You Think

How many cells make up a person's body? For adults, estimates range from about 10 trillion to 100 trillion. No one knows for sure because counting living cells is very difficult. After all, the number of cells changes throughout life. A child's growth comes from cell division that adds new cells, not from the expansion of existing ones. Moreover, new cells arise as old cells die, so a "true" count is a moving target. Also, no one has found a good way to count them all. Cells come in so many different shapes and sizes that it is hard to extrapolate from a small sample to the whole body.

"Many trillions" may seem like a huge number, but nonhuman cells vastly outnumber the body's own cells. Microbiologists estimate that the number of bacteria living in and on a typical human is *10 times* the number of human cells! Although some of these bacteria can cause disease, most exist harmlessly on the skin and in the mouth and intestines. These inconspicuous guests also can help extract nutrients from food and prevent disease.



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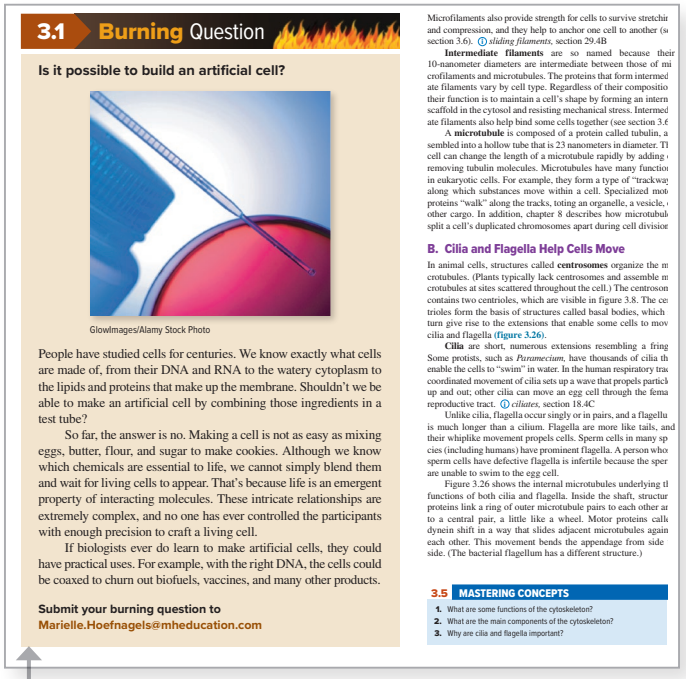


3.1 Burning Question

Is it possible to build an artificial cell?

GlowImages/Alamy Stock Photo

People have studied cells for centuries. We know exactly what cells are made of, from their DNA and RNA to the watery cytoplasm to the lipids and proteins that make up the membrane. Shouldn't we be able to make an artificial cell by combining those ingredients in a test tube?

So far, the answer is no. Making a cell is not as easy as mixing eggs, butter, flour, and sugar to make cookies. Although we know which chemicals are essential to life, we cannot simply blend them and wait for living cells to appear. That's because life is an emergent property of interacting molecules. These intricate relationships are extremely complex, and no one has ever controlled the participants with enough precision to craft a living cell.

If biologists ever do learn to make artificial cells, they could have practical uses. For example, with the right DNA, the cells could be coaxed to churn out biofuels, vaccines, and many other products.

Submit your burning question to
Marielle.Hoefnagels@mheducation.com

Microfilaments also provide strength for cells to survive stretchir and compression, and they help to anchor one cell to another (se section 3.6). *sliding filaments*, section 29.4B

Intermediate filaments are so named because their 10-nanometer diameters are intermediate between those of mi crofilaments and microtubules. The proteins that form intermed ate filaments vary by cell type. Regardless of their compositio their function is to maintain a cell's shape by forming an intern scaffold in the cytosol and resisting mechanical stress. Intermed ate filaments also help bind some cells together (see section 3.6

A **microtubule** is composed of a protein called tubulin, a sembled into a hollow tube that is 23 nanometers in diameter. Tl cell can change the length of a microtubule rapidly by adding removing tubulin molecules. Microtubules have many functio in eukaryotic cells. For example, they form a type of "trackwa along which substances move within a cell. Specialized mot proteins "walk" along the tracks, toting an organelle, a vesicle, other cargo. In addition, chapter 8 describes how microtubul split a cell's duplicated chromosomes apart during cell divisior

B. Cilia and Flagella Help Cells Move

In animal cells, structures called **centrosomes** organize the m crotubules. (Plants typically lack centrosomes and assemble m crotubules at sites scattered throughout the cell.) The centroson contains two centrioles, which are visible in figure 3.8. The ce trioles form the basis of structures called basal bodies, which turn give rise to the extensions that enable some cells to mov cilia and flagella (figure 3.26).

Cilia are short, numerous extensions resembling a fring Some protists, such as *Paramecium*, have thousands of cilia th enable the cells to "swim" in water. In the human respiratory tra coordinated movement of cilia sets up a wave that propels particl up and out; other cilia can move an egg cell through the fema reproductive tract. *ciliates*, section 18.4C

Unlike cilia, flagella occur singly or in pairs, and a flagellu is much longer than a cilium. Flagella are more like tails, and their whiplike movement propels cells. Sperm cells in many sp cies (including humans) have prominent flagella. A person who sperm cells have defective flagella is infertile because the sper are unable to swim to the egg cell.

Figure 3.26 shows the internal microtubules underlying tl functions of both cilia and flagella. Inside the shaft, structur proteins link a ring of outer microtubule pairs to each other ar to a central pair, a little like a wheel. Motor proteins calle dynein shift in a way that slides adjacent microtubules again each other. This movement bends the appendage from side side. (The bacterial flagellum has a different structure.)

3.5 MASTERING CONCEPTS

1. What are some functions of the cytoskeleton?
2. What are the main components of the cytoskeleton?
3. Why are cilia and flagella important?

Burning Questions cover topics that students wonder about.

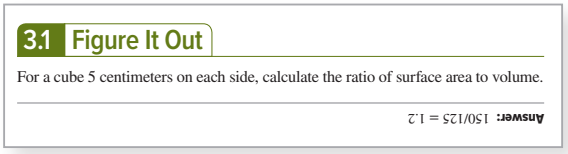
A fun way to get students thinking about biology is to have them write down a Burning Question on the first day of class. Answer them during the semester, whenever a relevant topic comes up in class.

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

Instructors can compile a list of Mastering Concepts and Write It Out questions that help students focus on material covered in class. They also make great discussion questions.

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

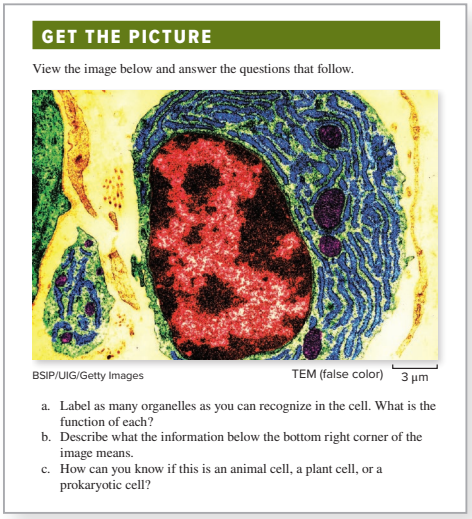
Students can work on these in small groups, inside or outside of class. Most could easily be used as clicker questions as well.



3.1 Figure It Out

For a cube 5 centimeters on each side, calculate the ratio of surface area to volume.

Answer: 150/125 = 1.2



GET THE PICTURE

View the image below and answer the questions that follow.

BSIP/UIG/Getty Images TEM (false color) 3 µm

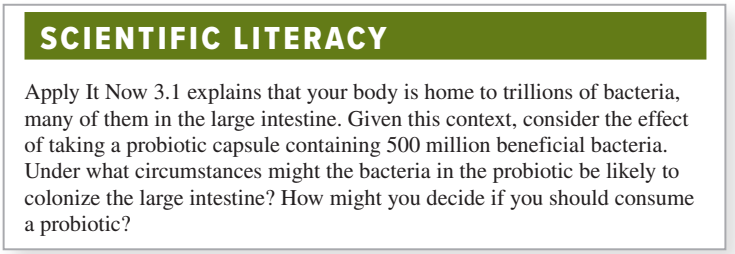
a. Label as many organelles as you can recognize in the cell. What is the function of each?
b. Describe what the information below the bottom right corner of the image means.
c. How can you know if this is an animal cell, a plant cell, or a prokaryotic cell?

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

Instructors can use these new questions to stimulate discussion, whether in person or virtual.

Scientific Literacy questions reveal why biology matters to everyone.

These thought questions at the end of each chapter encourage students to integrate biology with social, political, and ethical issues. They make great discussion and homework questions.



SCIENTIFIC LITERACY

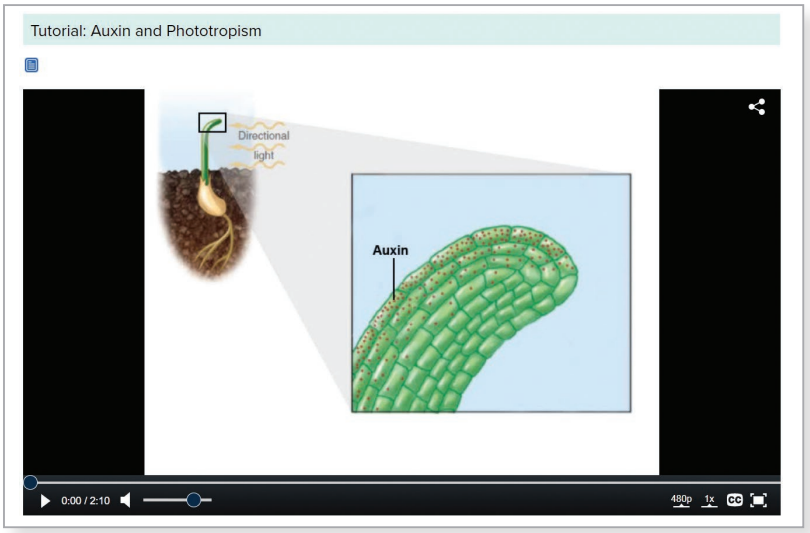
Apply It Now 3.1 explains that your body is home to trillions of bacteria, many of them in the large intestine. Given this context, consider the effect of taking a probiotic capsule containing 500 million beneficial bacteria. Under what circumstances might the bacteria in the probiotic be likely to colonize the large intestine? How might you decide if you should consume a probiotic?

Author's Guide *to Digital-Only Content*

Videos embedded in the ebook narrative bring relevance, clarity, and motion to difficult concepts.

ZygiStudio/Shutterstock

Live-action and time-lapse videos integrated within the narrative show textbook concepts at work in the real world.



Animated tutorials guide students through complicated topics, using illustrations and examples from the book.

Answers to all chapter questions are found at the end of the question stem within the ebook.

24.6 MASTERING CONCEPTS

1. How do statoliths and auxins participate in gravitropism?

Answer

2. How does thigmotropism help some plants climb?

Answer

Thigmotropism is a response to touch in a specialized structure such as a tendril. Hormones cause differential growth in the tendril, allowing it to encircle physical supports such as a trellis or the branches of another plant.

Digital-only tables, miniglossaries, and figures expand on content from the print textbook.

Digital-only tables and miniglossaries help students organize new information and serve as helpful study tools.

New digital-only figures focus extra attention on topics not illustrated in the print text. In addition, some print figures have been reformatted for better display on mobile devices.

DIGITAL EDITION PLANT TROPISMS: A SUMMARY

Type	Stimulus	Response	Example
Phototropism	Light	Photoreceptors absorb light energy; auxins move to shaded side of stem and stimulate cell elongation.	Stem bends toward window.
Gravitropism	Gravity	Starch-rich statoliths "sink" within root cap cells; auxins cause root to bend downward (hypothesized mechanism).	Roots grow downward into soil.
Thigmotropism	Touch	Unknown	Tendril coils around trellis.

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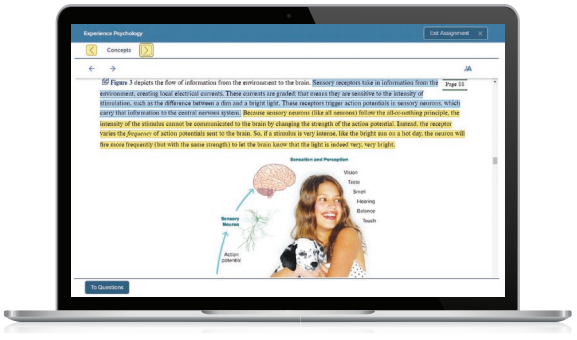

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Changes by Chapter

UNIT 1 Science, Chemistry, and Cells

- **Chapter 1 (The Scientific Study of Life):** Added a note under the first Survey the Landscape concept map explaining the significance of the different colored ovals; added a new figure showing the cell as the basic unit of life; added "development" as a boldface term; clarified conventions regarding genus and species names; added a new figure showing an experimental design related to variation in coffee flavor; clarified that "sample size" applies to each treatment group and control group; wrote a new Scientific Literacy question challenging students to apply the elements of the scientific method to an everyday observation; wrote a new Apply It Now on credible sources of scientific information; wrote a new Burning Question on why scientific literacy matters. In the ebook: added a figure showing the taxonomic hierarchy of humans; created a table explaining statistical significance; added a summary figure showing the anatomy of a bar graph and a line graph.
- **Chapter 2 (The Chemistry of Life):** Explained what proportion of the human body consists of bulk and trace elements; clarified the description of ionic bonds in the narrative; clarified the definitions of ionic, polar covalent, and nonpolar covalent bonds in the table of chemical bonding; defined "macronutrients" and made it a boldface term; wrote a new Apply It Now box about counting macronutrients; added information about carbohydrates and lipids to the table of organic molecules; updated information about olestra in the Apply It Now on fake fats; in Investigating Life, updated information about applications of research on ant chemical defenses; throughout chapter, omitted unneeded terminology for introductory students. In the ebook: clarified definitions in the Miniglossary of Matter and added definition for "radioactive isotope."
- **Chapter 3 (Cells):** Revised the Learn How to Learn blurb to explain the difference between stains and false color; clarified the description of light microscopes and the difference between compound and confocal microscopes; clarified the history of the two prokaryotic domains; defined and used boldface for "organelle" and "nucleus" at first use; clarified the composition of the cytoskeleton and the structure of cilia/flagella in narrative and art.
- **Chapter 4 (The Energy of Life):** Avoided calling photosynthesis and respiration "reactions" and referred to them as "processes" instead; elaborated on how exercise speeds metabolism; used boldface for food "Calorie" (with a capital C); defined "concentration gradient" upon first use; improved labeling to clarify the figure showing ATP use; mentioned ATP synthase and added it to figure showing facilitated diffusion; clarified receptor-mediated endocytosis and added entry of COVID-19 virus into host cell as example; added "coronavirus" to the Apply It Now on hand sanitizers. In the ebook: clarified terms in the Miniglossary of Energy.
- **Chapter 5 (Photosynthesis):** Added a new figure and accompanying narrative showing ATP synthase and its role in photosynthesis and respiration; explained the connection between absorbance and color; added a new figure showing the conditions under which photorespiration occurs; reworked the figure showing differences between C_3, C_4, and CAM photosynthesis; clarified the labels in the Investigating Life graph. In the ebook: clarified the table listing redox reactions in photosynthesis; added a table comparing C_3, C_4, and CAM.
- **Chapter 6 (Respiration and Fermentation):** Removed the "+ H^+" from figures showing NAD^+ and/or FAD^+; added a paragraph about the fate of water produced in cellular respiration; added an "inputs and outputs" box to the figure showing the mitochondrial electron transport chain; noted that for simplicity, the transition step and Krebs cycle are omitted from figure showing anaerobic respiration and fermentation; in fermentation section, changed "reduce" to "transferred electrons to" for clarity; in Investigating Life, clarified why active beetles use more energy in cold weather. In the ebook: reworked table listing redox reactions in respiration; clarified table of products of respiration.

UNIT 2 DNA, Inheritance, and Biotechnology

- **Chapter 7 (DNA Structure and Gene Function):** Added new concepts and connections to Survey the Landscape; added a paragraph on what proteins do that make them essential for life; based on user feedback, credited Crick (without Watson) with describing the "central dogma"; clarified that the 5′ cap consists of a single modified

nucleotide; modified the tRNA figure to better reflect depictions of tRNA in subsequent figures; improved the labeling on figure showing transcription; simplified the figure showing ribosome structure; mentioned anticancer drugs that interfere with transcription factors; wrote a new Burning Question about the development of mRNA COVID vaccines; added "protein folding" to the section on post-translational modifications; added boldface type for "silent mutation," "nonsense mutation," and "missense mutation"; in the table listing types of mutations, added "silent mutations" and clarified that nonsense mutations are substitution mutations; expanded on the role and abundance of transposons, while mentioning Barbara McClintock; added new Write It Out questions, including one using hypothetical gene fragments that translate into "words" made of one-letter amino acid abbreviations. In the ebook: created a new figure with steps showing how to use the genetic code.

- **Chapter 8 (DNA Replication, Binary Fission, and Mitosis):** Made label changes to several figures for consistency with narrative; added a paragraph about the frequency of mutations; described a centromere as a constriction in a chromosome; added "age" as a risk factor for cancer. In the ebook: added "mutations" to the table comparing cell division in prokaryotes and eukaryotes.
- **Chapter 9 (Sexual Reproduction and Meiosis):** In all figures with haploid and diploid color coding, changed lines to arrows for consistency; introduced the concept of intersex individuals; clarified that DNA replication does not make a cell diploid; clarified the origin of the term "germ cell"; clarified the explanation of polyploidy. In the ebook: added tables titled "Asexual and Sexual Reproduction Compared" and "Mitosis and Meiosis Compared."
- **Chapter 10 (Patterns of Inheritance):** Wrote a new opening essay on babies in the age of biotechnology; added haploid/diploid color keys to relevant figures; clarified the definitions of sex chromosomes and autosomes; improved the labeling on figures showing monohybrid cross and the law of segregation; clarified the explanation of epistasis; clarified the narrative and illustration of X inactivation; clarified that some pedigree diagrams do not distinguish between carriers and unaffected people; wrote a new Apply It Now on the heritability of pattern hair loss; clarified the figure showing polygenic inheritance of skin pigmentation; wrote a new Write It Out question on coat color in rabbits. In the ebook: reworked a figure defining the generations.
- **Chapter 11 (DNA Technology):** Added "genetically modified organisms" as a boldface term; added more examples of field crops that have been genetically engineered; clarified the caption of the gene comparison figure; updated and moved CRISPR to the section on DNA technology tools, expanded on its limitations, and mentioned how variations on CRISPR are helping overcome some of the limitations; promoted DNA profiling to its own section; added a section and figure on home DNA-testing kits (SNPs); updated the narrative and simplified the figure showing how STRs are used in criminal justice; clarified that embryonic stem cells are pluripotent and adult stem cells are multipotent; updated the section on gene therapy; added a new concluding passage on the importance of research into spread of genes from transgenic crop plants; added end-of-chapter questions about PCR in COVID-19 testing and the ethics of using CRISPR to modify human genomes.

UNIT 3 The Evolution of Life

- **Chapter 12 (The Forces of Evolutionary Change):** Added "population" and "common ancestry" to all Unit 3 Survey the Landscape figures; updated information about antibiotic-resistant bacteria in the chapter opening essay; added a new figure illustrating allele frequencies; changed "simple" to "concise" for the definition of evolution; added boldface type for "microevolution" and "macroevolution"; added fossils to figure showing the principle of superposition; added paragraph and end-of-chapter question introducing the potential role of epigenetics in evolution; added an entry about "acclimation" to the table listing misconceptions about evolution; improved labeling on Hardy–Weinberg figure; improved labeling on figure showing types of natural selection; wrote a new Investigating Life on human-driven selection for camouflage in harvested plants; added an end-of-chapter question on diversity in science.
- **Chapter 13 (Evidence of Evolution):** Clarified the section on the rise and fall of marsupials; wrote a new Investigating Life on the evolution of the long hindlimbs of the jerboa.
- **Chapter 14 (Speciation and Extinction):** In the chapter opening essay, added a paragraph on island patches created by human activities; referred back to section 1.2 for more information on formatting scientific names; clarified the introduction to reproductive barriers; clarified the explanation and illustration of sympatric speciation in cichlids; clarified the explanation and illustration of upland cotton origin; modified Apply It Now 14.1 to focus on why extinctions matter; inserted a new figure showing the meteorite crash 65 million years ago in the Yucatan; in caption of figure showing taxonomic hierarchy, explained that the species designator is never used alone; updated the classification of lizards/snakes and turtles in evolutionary trees.
- **Chapter 15 (The Origin and History of Life):** Added "prokaryotes," "eukaryotes," and domains "Bacteria," "Archaea," and "Eukarya" as boldface terms; clarified the explanation of endosymbiont theory; clarified in Burning Question 15.1 that coal naturally contains mercury and other heavy metals; updated map and information about early human migration out of Africa; added information about the bonobo genome to Investigating Life section.

UNIT 4 The Diversity of Life

- **Chapter 16 (Viruses):** Added COVID-19 to chapter opening essay; updated information about the largest known virus; added COVID-19 virus to examples of enveloped viruses and to figure showing virus variety; explained that the viral envelope can help viruses hide from the host's immune system; updated the passage on latent viruses to note that multiple sclerosis is associated with Epstein–Barr virus; updated information about HPV infection and vaccination; wrote a new Apply It Now on COVID-19 prevention and treatment. In the ebook: added "coronavirus" to the table of viruses that infect humans.
- **Chapter 17 (Bacteria and Archaea):** Clarified description of obligate and facultative anaerobes and improved corresponding figure; mentioned that DNA evidence is supporting reclassification of archaea based on evolutionary relationships.
- **Chapter 18 (Protists):** Clarified that not all red algae live in deep water; added a new Get the Picture question about visualizing the evolutionary tree as an "evolutionary thicket" and how that representation might relate to endosymbiosis and horizontal gene transfer.
- **Chapter 19 (Plants):** Added pronunciation guides for "xylem" and "phloem"; added approximate dates for evolution of pollen, seeds, flowers, and fruit; clarified that some bryophytes survive in dry habitats by entering dormancy; clarified the description of lycopods; updated the Burning Question on biofuels and added information on green algae as a possible source of biodiesel; added an estimate of the number of angiosperm species. In the ebook: added a new table comparing spores and seeds.
- **Chapter 20 (Fungi):** Added context to the figures showing arbuscular mycorrhizae, endophytes, and ectomycorrhizae; in response to student user question, added a Write It Out question about why seedlings sometimes become moldy. In the ebook: added a new figure showing the differences between arbuscular mycorrhizae and ectomycorrhizae.
- **Chapter 21 (Animals):** Revised and added photo to the Apply It Now about worm farming; clarified description of the echinoderm water vascular system; clarified labels on figure showing the amnion; updated figures and narrative pertaining to evolutionary relationships in reptiles; adapted and expanded on Investigating Life section on the burrowing origin of snakes. In the ebook: added a new table listing some of the major orders of insects.

UNIT 5 Plant Life

- **Chapter 22 (Plant Form and Function):** Wrote a new chapter opening essay on plants lacking chlorophyll; clarified arrows in the Survey the Landscape concept map; clarified language about axillary (lateral) buds; clarified in figure that an axillary bud is also called a lateral bud; added more common fruits (apples and peaches) to table 22.1; clarified the distinction between tissue systems and tissues; clarified that plants have many cell types and that section 22.2 covers the most common types; added boldface to the terms "parenchyma tissue," "parenchyma cell," "collenchyma tissue," "collenchyma cell," "sclerenchyma tissue," and "sclerenchyma cell"; clarified how leaves form at apical meristems.
- **Chapter 23 (Plant Nutrition and Transport):** Clarified how humidity and temperature affect whether stomata are open or closed, including the trade-off between water loss and CO_2 access; clarified label in figure showing phloem transport; in Burning Question about maple syrup, clarified how a maple tree's xylem sap rises in winter; in the section on parasitic plants, referred readers to chapter 22's opening essay. In the ebook: added a new table summarizing plant transport.
- **Chapter 24 (Reproduction and Development of Flowering Plants):** Updated information about bees in chapter opening essay; made "embryo" a boldface term; improved labels on figure comparing monocot and eudicot seeds; clarified the conditions that stimulate the production of abscisic acid; updated information about jasmonic acid in Apply It Now about plant defense chemicals; improved labeling on the figure showing gravitropism; clarified the meaning of the term "abscission"; reworked the Pull It Together figure to include more information about how fertilization works in flowering plants. In the ebook: added a new table comparing reproduction in plants and humans.

UNIT 6 Animal Life

- **Chapter 25 (Animal Tissues and Organ Systems):** Updated information in the Burning Question about artificial organs; clarified the definition of the "free" surface of epithelial tissue; added a Write It Out question inviting students to add the lymphatic system to the Survey the Landscape figure; added a new Scientific Literacy question about a recent transplant of a genetically modified pig heart into a human patient.
- **Chapter 26 (The Nervous System):** Clarified the direction of information flow in sensory neurons; clarified how ions are distributed during resting potential and how sodium channels open and close during an action potential; revised figure comparing sodium channels to firecrackers; divided figure showing human nervous system into two figures; added information about how neuroglia contribute to the blood–brain barrier; reworked Apply It Now about neurotransmitters to focus on mind- and mood-altering drugs; in response to student user suggestion, added a Scientific Literacy question on the role of genes and the environment in depression. In the ebook: added a new table listing selected disorders associated with neurotransmitter imbalances.

- **Chapter 27 (The Senses):** Clarified the diagram of the cochlear implant in the Apply It Now about hearing loss. In the ebook: added functions of rod cells and cone cells to the miniglossary explaining the pathway of visual information.
- **Chapter 28 (The Endocrine System):** Updated Burning Question with new information about BPA safety; added target cells for ADH and oxytocin in figure summarizing hormones from the hypothalamus; added information about amines to caption of figure summarizing hormones that regulate metabolism; clarified the relationship between cortisol, blood sugar, and diabetes; mentioned the connection between diabetes and Alzheimer disease; added a new figure showing ways to prevent type 2 diabetes; defined "puberty" and added a new Apply It Now box on puberty blockers; added target cells for estrogen and testosterone in the figure summarizing hormones from the ovaries and testes. In the ebook: added a new table summarizing the types of hormones.
- **Chapter 29 (The Skeletal and Muscular Systems):** Updated the chapter opening essay on prosthetic limbs; added a new figure comparing hydrostatic skeleton, exoskeleton, and endoskeleton; added "bone tissue" and "skeletal muscle tissue" as boldface terms; mentioned the range of muscle cell length; added a scale bar to the photo of sarcomere; added a Scientific Literacy question on whether coffee stunts growth. In the ebook: added "cartilage" to the miniglossary of the skeletal system.
- **Chapter 30 (The Circulatory System):** Clarified the connection between plasma and interstitial fluid; clarified the paragraph describing white blood cell counts; clarified the origin of platelets.
- **Chapter 31 (The Respiratory System):** Improved labeling on the figure showing respiratory surfaces; clarified the comparison of vertebrate lungs; clarified the direction of O_2 and CO_2 flow at the alveoli; clarified labels on the figure showing alveoli; added information about COVID-19 to the Apply It Now about respiratory issues.
- **Chapter 32 (Digestion and Nutrition):** Added "mouth" as a boldface term; clarified the source of a baby's microbiota; revised descriptions of anorexia nervosa and bulimia; added a new figure listing strategies for maintaining a healthy weight; added a Scientific Literacy question about diet plans and weight loss; added "blood" as a key term in the Pull It Together concept map.
- **Chapter 33 (Regulation of Temperature and Body Fluids):** Clarified how extreme cold inhibits membrane function; mentioned that heat can be generated in other ways besides shivering; added an example of how pigs thermoregulate by wallowing in mud; made "penis" a boldface term in the context of the urinary system; clarified how aldosterone causes blood pressure to rise; in Investigating Life, explained why some bones have growth rings. In the ebook: added heat from adipose tissue to the table listing thermoregulatory adaptations.
- **Chapter 34 (The Immune System):** Added SARS-CoV-2 and COVID-19 to chapter content where appropriate; clarified the origin of lymph and the infection-fighting role of lymph nodes; wrote a new Apply It Now box on COVID-19 tests; added updated information about mRNA vaccines and other genetic vaccines; added multiple sclerosis to the table listing autoimmune disorders; wrote a new Investigating Life section exploring the correlation between high microbial diversity and low incidence of allergies and asthma in children raised on farms; wrote new open-ended questions on cancer immunotherapy and the role of Epstein–Barr virus in multiple sclerosis. In the ebook: updated the animation on vaccines.
- **Chapter 35 (Animal Reproduction and Development):** Replaced gender-specific language with sex-specific language whenever possible; reworked the phrases "male sex hormones" and "female sex hormones" to be more inclusive; updated the chapter opening essay about sex determination in sports; added a new Burning Question on the difference between "sex" and "gender"; added "embryo" as a boldface term; updated the Burning Question box on when conception occurs; updated the table listing birth control methods; reworked the box on assisted reproductive technologies to be more inclusive; reworked the box on pregnancies that end before birth; expanded the explanation of cesarean sections; added Write It Out questions on the recent rise of STIs in the United States and on new reproductive technologies.

UNIT 7 The Ecology of Life

- **Chapter 36 (Animal Behavior):** Added a new Burning Question on parasites that control their host's behavior; added new figures showing mate-guarding, genetic relatedness within a human family, and haplodiploidy; omitted the subsection on human reproductive choices.
- **Chapter 37 (Populations):** Revised the chapter opening essay about managing wildlife populations to include ethical considerations; updated statistics about human population numbers, demographics, leading causes of death, and ecological footprint; replaced "developed" and "developing" country categories with income categories.
- **Chapter 38 (Communities and Ecosystems):** Wrote a new chapter opening essay on the future of meat; reworked the figure showing the pyramid of energy to include relative kilocalories per trophic level, losses to heat, and number of individuals per trophic level.
- **Chapter 39 (Biomes):** Added polar ice to the figure showing biome classifications; added a new Apply It Now on bottled water pros and cons. In the ebook: added a new table listing factors affecting climate.

- **Chapter 40 (Preserving Biodiversity):** Added content about the value of biodiversity; added "biodiversity hotspots" and "anthropogenic effects" to narrative; added a new figure showing examples of each category of ecosystem services; updated numbers of threatened species as estimated by IUCN; simplified the figure showing areas where human impacts on the biosphere are most intense; added information about microplastics; revised the section on eutrophication; added a few words on the origin of sediments in water pollution; updated information and satellite photo depicting the thinning ozone layer; updated information about atmospheric CO_2 concentrations and global climate change; added examples of ways climate change will affect humans; added information about characteristics of invasive species; reorganized list of invasive species in North America; added examples of species extinctions caused by overexploitation in North America; updated data in caption of figure showing bald eagle recovery; expanded on the explanation of captive breeding; added new questions about global climate change and microplastics to the end-of-chapter materials. In the ebook: added an animation titled "CO_2 and Earth's Average Temperature."

Contents

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