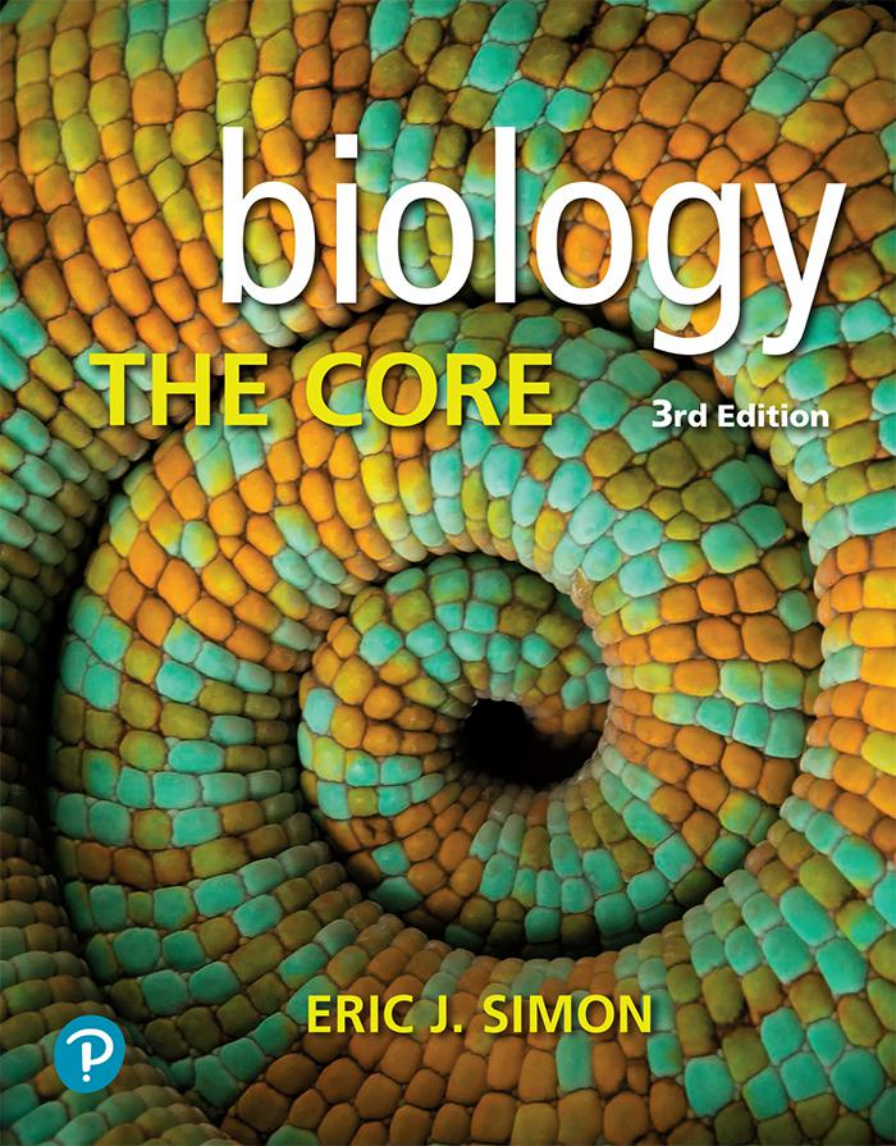
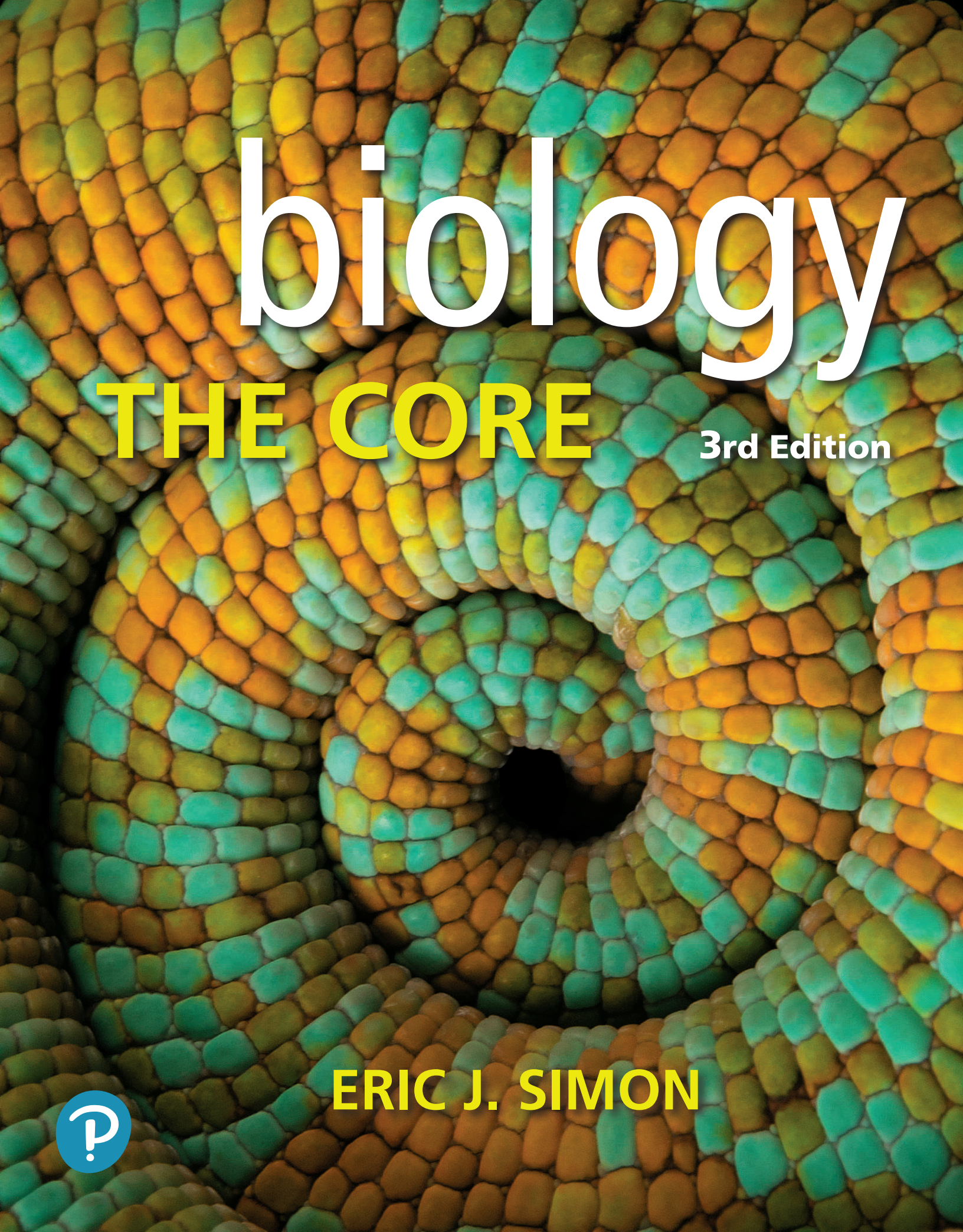

biology
THE CORE
3rd Edition
ERIC J. SIMON

BRIEF CONTENTS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ABOUT THE AUTHOR

Eric J. Simon is a professor

in the Department of Biology and Health Science at New England College in Henniker, New Hampshire. He teaches introductory biology and human biology to non-science majors, as well as a tropical marine biology course that introduces non-science-majors to underwater field work in Belize. Dr. Simon received a B.A. in biology and computer science and an M.A. in biology from Wesleyan University and a Ph.D. in biochemistry from Harvard University. His research focuses on innovative ways to use technology to improve the teaching and learning of science, particularly to non-science majors. He lives in rural New Hampshire with his wife, two boys, a rotating set of Cavalier King Charles Spaniels, a few dozen chickens, and a leopard gecko. Dr. Simon is the lead author of the introductory non-majors biology textbooks *Campbell Essential Biology* (7th ed.) and *Campbell Essential Biology with Physiology* (6th ed.), and a co-author of the introductory biology textbook *Campbell Biology: Concepts and Connections* (9th ed.), all published by Pearson Benjamin Cummings.

"I dedicate this book to my inspirational partners at Benjamin Cummings and Pearson Education, including (in order of appearance) Beth W., Frank R., Chalon B., Ginnie S.J, Josh F., Lauren H., Evelyn D., and Alison R. Thank you all for providing me with tremendous support and continuous inspiration to improve biology education."

PREFACE

To the Student,

Being a college student today means juggling many priorities: work, school, extracurricular activities, family. If you're reading this book, you've probably enrolled in your first college science course, and it may be the only one you'll ever take. With so many priorities competing for your attention, you may be unsure how to fit studying biology into your busy life. Good news: This book is written specifically for you!

Over the years, I've seen students in my classes striving to succeed while also wishing to be as productive as possible with their study time. *Biology: The Core* was designed from the ground up to help you learn efficiently and thrive in this course. Only the most important and relevant information—the core of biology content—is included. These biological concepts are displayed in highly visual, consistent, and approachable two-page modules that guide you along a clear learning path, so that reading your textbook is more a pleasure than a chore.

You might also be wondering how this course—and biology in general—applies to your own life. Luckily, this is easy to address, since issues like nutrition, cancer, vaccines, and genetically modified foods directly affect you and those you care about. For the Third Edition, new modules were added that address these and other current issues directly, so that you may better see how biology is relevant to your life. Other modules help you critically evaluate the scientific-sounding claims that constantly bombard you, and how to distinguish valid scientific claims from bogus ones.

The *Biology: The Core* textbook is paired with a robust online library, Mastering Biology, that contains videos, animations, current events, and interactive tutorials that help you draw connections between the course material and the world around you. Questions you might have about many topics will be addressed in this online complement to your textbook. It is filled with helpful multimedia tools that allow you to gain a thorough understanding of the content so that you can succeed in your course. References to Mastering Biology at the top of many modules point you to the most helpful online tools.

I hope that *Biology: The Core* meshes with your goals and your priorities, acting as a useful guide for this course and addressing questions you run into in your broader life. Please feel free to drop me an email to tell me about your experience with *Biology: The Core* or to provide feedback (good or bad!) regarding the text or online resources.

Best wishes for a successful semester—and enjoy the big adventure of biology! It's not only in the pages of this book, but everywhere around you.

ERIC J. SIMON, PH.D.
SimonBiology@gmail.com

To the Instructor,

In a world with so many options for non-major biology textbooks, what makes this one different? The answer is: a focus on today's students. We've all watched our non-science-major students struggle with the depth of material and relating biology to their lives. Which concepts do non-science students *need to know* in order to understand the relevance of biology? If we pare down the content and focus on the most important take-home lessons—the information that we hope students will remember 10 years after your course—what remains is the core: a set of essential biological concepts that presents the big picture, providing students with a scientific basis for the issues they will confront throughout their lives.

Biology: The Core is a different kind of textbook, one that presents information in small chunks using a nonlinear, engaging, visual style. The book contains only the most essential content for each topic. All information is presented in stand-alone two-page modules that fully integrate text and art into a single teaching tool. Modules can be read in any order and each module stands alone (without references to other modules), allowing you the flexibility to assign topics in whatever sequence best suits your course.

For the Third Edition of *Biology: The Core*, content was revised based on feedback received from professors and students using the text from around the country. The specific changes are detailed on the next page, but the overall approach is to ensure that the core content is approachable and clearly connected to students' lives. Included in this new edition are a series of "Core Issue" modules. These ten special modules highlight current topics that your students may hear about frequently—vaccines, antibiotic resistance, diabetes, and cancer, to name a few—and tie them to the core content, showing students the relevancy of basic biology knowledge.

Over the last few years, in my communication with many instructors around the country, I've also observed that those of us teaching biology to non-majors are increasingly emphasizing science literacy skills above all else. For this reason, the Third Edition places particular emphasis on teaching students to think scientifically and helping them appreciate and apply critical thinking skills to their own lives. A largely rewritten Chapter 1 brings many of these important skills together.

The printed text is paired with Mastering Biology, an online tutorial platform that allows you to reinforce the book content and expand on the basic concepts presented in each module as needed. The activities and resources in Mastering Biology also offer you the flexibility to incorporate a wide variety of applications and current issues—including several ones new to this edition—into your teaching. Unlimited by the particular set of examples printed in a static textbook, a rich collection of online resources—including Current Topic PowerPoint presentations, news videos, Current Events news articles, and interactive tutorials—enables you to connect the core content to interesting, relevant, and timely issues that are important to you and your students. Forty—including 18 brand new, Guided Video Tours found within Mastering Biology—are designed to help students learn to use the textbook and to hone their study skills.

I hope that the aims of *Biology: The Core* resonate with the teaching and learning goals of your non-major introductory biology course. Feel free to send an email telling me about your course and your students, to provide feedback regarding the text or the online resources, or just to chat about the non-major course in general—it's my favorite topic of conversation!

Best wishes for a successful semester,

ERIC J. SIMON, PH.D.
SimonBiology@gmail.com

Biology: The Core, Third Edition, contains many helpful updates

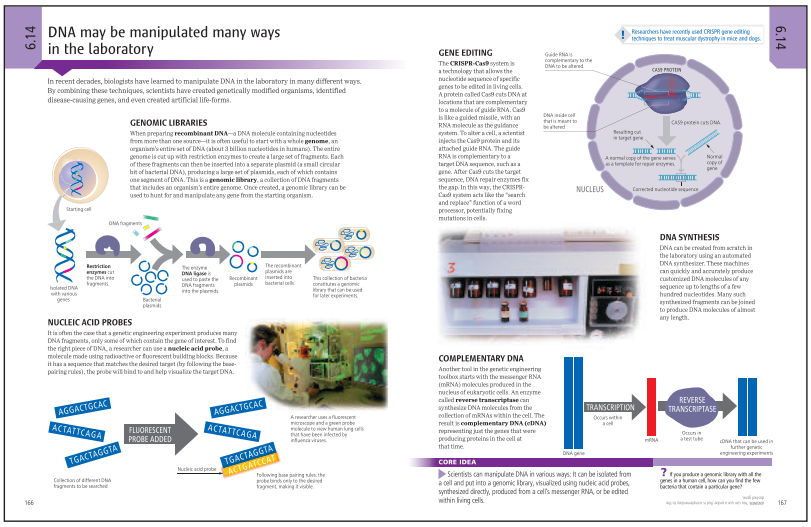
The Third Edition of *Biology: The Core* was created in response to extensive feedback from professors and students. The goal of the new edition is to enhance teaching and learning for non-major students by increasing the relevancy of the material and placing a greater emphasis on science literacy skills.

CHAPTER 1 AN INTRODUCTION TO THE SCIENCE OF LIFE

For many students, this introductory biology course is their only exposure to college-level science. Many instructors believe that the most important goal of such a course is to communicate how science is conducted and how the process of science can be used to make important decisions. In the Third Edition of *Biology: The Core*, we dedicate an entire chapter to covering this vital topic, with modules that present the process of science in a more realistic and relevant context. Chapter 1, "An Introduction to the Science of Life," promotes critical thinking and demystifies how science works. A new presentation of the process of science emphasizes the lack of formality in the process and how it proceeds in the real world.

Additional updated and new modules help students distinguish hypotheses from theories and explain the meaning of the word "fact"; discuss basic research methods; distinguish scientific thought from pseudoscience; and explain how to recognize reliable sources and the process of peer review. This chapter should help students obtain a clearer picture of how scientific thinking differs from other ways of viewing the world and how it can be applied in their own lives.

Module 1.4 presents the process of science as it actually occurs.



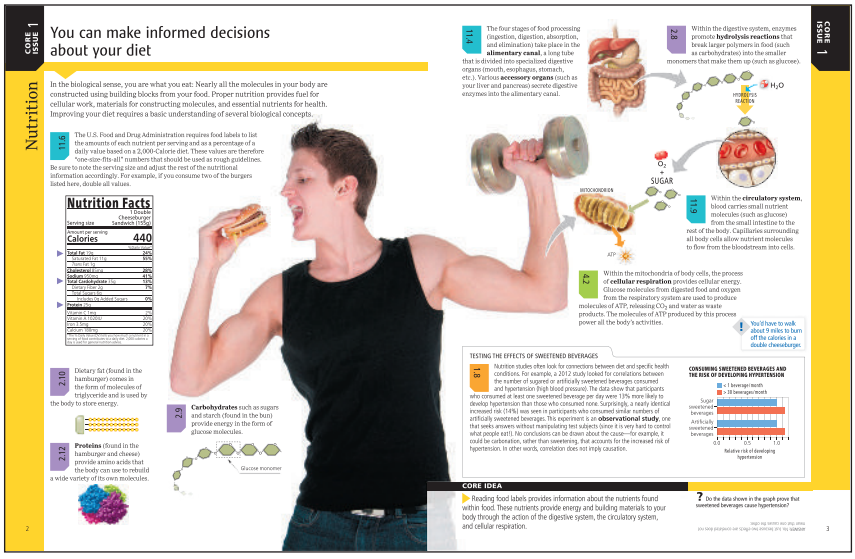
NEW EXAMPLES AND PEDAGOGICAL IMPROVEMENTS

In addition to those already mentioned, many changes in the book were implemented to increase accuracy and currency. For example, module 6.14 includes new information about the CRISPR-Cas9 gene editing system.

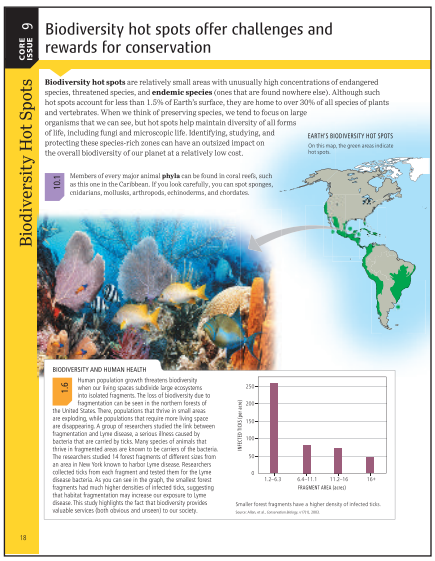
Other examples of content updates include new data on the links between obesity and cancer, changes to human population growth patterns, and new data on the reliability of various methods of contraception. Throughout the book, photos and art were improved and updated to make them more attractive and better able to convey the pedagogical points. Every module contains a "fun fact" intended to invoke a "That's cool!" reaction from your students; many of these have been updated to be even more engaging.

CORE ISSUE MODULES

New to this edition are ten Core Issue modules. Each one presents a current relevant topic. This edition includes modules on nutrition, cancer, vaccines, athletic cheating, genetically modified organisms, agriculture, MRSA, climate change, biodiversity hot spots and diabetes. Each Core Issue module helps relate the basic biology content to the issue at hand.



In this example, the Core Issue: Nutrition module shows how the digestive system (Module 11.4) delivers small molecules (Modules 2.9–2.12) through the circulatory system (Module 11.9) to the mitochondria (Module 4.2).



Additionally, every Core Issue module includes a description of one or more relevant scientific studies. Data is presented, and the larger lessons of that study are discussed in relation to the material presented in Chapter 1. For example, the Core Issue: Biodiversity Hot Spots module introduces a study showing the relationship between forest fragmentation in the northeastern United States and the prevalence of mosquitoes that carry Lyme disease. For each Core Issue module, the chosen study illustrates one or more science skill presented in Chapter 1. In this example, students are led to understand independent and dependent variables, as originally discussed in module 1.6.

NEW MULTIMEDIA

The *Biology: The Core* textbook is designed to pair with the online resources (videos, animations, current issues, practice assignments, and more) available in Mastering Biology. New references within many modules point students toward the most helpful multimedia supplements. This edition of *Biology: The Core* includes 18 new Guided Video Tours, for a total of 40 videos that walk students through modules, teaching them how to organize their studying. These videos can be particularly helpful to help students working on their own (as part of flipped classrooms or distance learning, for example).

Mastering Biology

▶ **WATCH** the Video Tutor Session for this module

Icons placed at the top of modules remind students to supplement their learning with online multimedia.

CORE IDEA

▶ In response to feedback, the Third Edition of *Biology: The Core* improves teaching and learning by making the material clearer and more relevant to non-science-major students.

? How are the Core Issue modules different from every other module in *The Core*?

ANSWER: The Core Issue modules contain cross-references to other modules; every other module in The Core stands alone.

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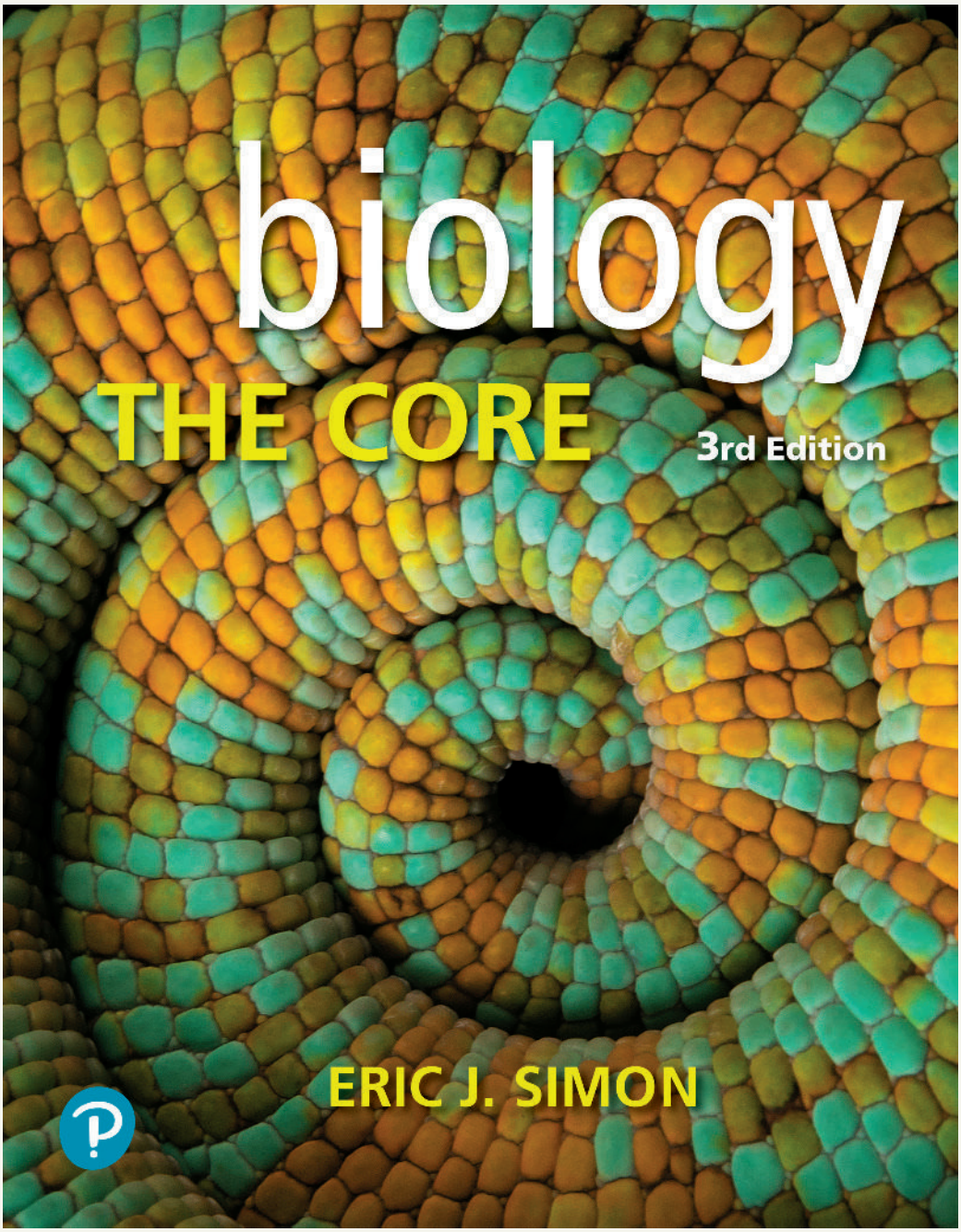
Help students see biology's relevance by focusing on core concepts

Biology: The Core **presents essential biological concepts, using a visual and hybrid approach. The 12-chapter textbook uses dynamic illustrations organized into concise, self-contained two-page modules that focus students' attention on what is most relevant. The text pairs with Mastering Biology to offer flexible assignment options and extensive support materials that allow instructors to tailor the content to the way they teach and maximize student engagement.**



Build your course around . . .

Each core biological concept is presented as a two-page module that can stand on its own and be read in any order. Each module in the text contains only the most essential content for any concept. The efficient organization of each module helps students focus their attention on key information and guides them through—from the clearly stated concept at the start to the "core question" that checks their understanding at the end.

CORE ISSUE 4

The evolution of antibiotic-resistant bacteria poses a significant health threat

MRSA

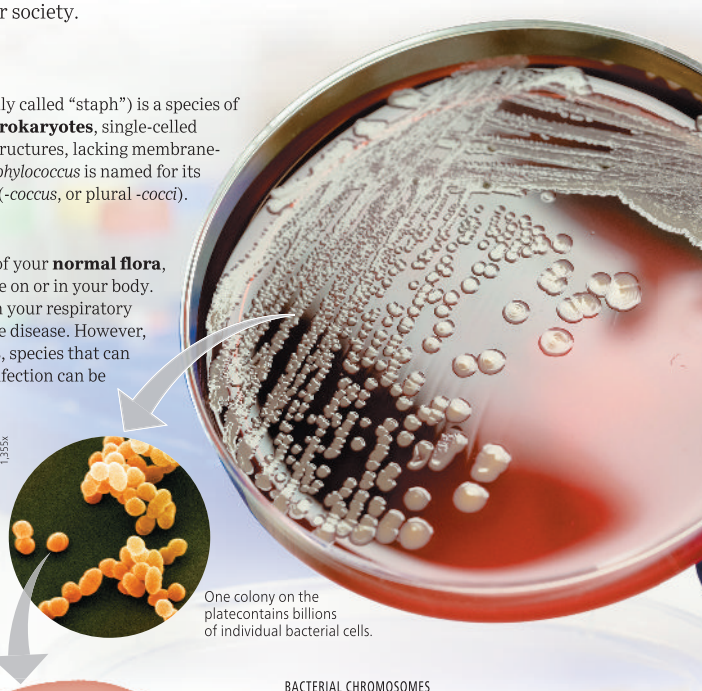
Penicillin and other **antibiotics**—drugs that inhibit or kill bacteria—have saved countless lives. The discovery of penicillin in the 1940s prevented the deaths of millions of people with common infections. However, within a few decades, penicillin had become virtually useless in hospitals because of the evolution of penicillin-resistant bacteria. In response, new antibiotics were developed. By the 1990s, doctors began to discover bacteria that were resistant to many, even all, known antibiotics. Responding to the evolution of such multidrug-resistant strains is one of the most important health challenges facing our society.

ANTIBIOTICS

8.2 *Staphylococcus aureus* (SA, commonly called "staph") is a species of bacteria. Like SA, all bacteria are **prokaryotes**, single-celled organisms with relatively simple structures, lacking membrane-enclosed organelles. The genus *Staphylococcus* is named for its shape: irregular clusters (*staph-*) of spheres (*-coccus*, or plural *-cocci*).

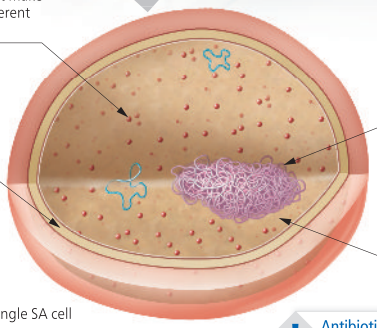
8.4 *Staphylococcus aureus* is a member of your **normal flora**, microorganisms that commonly live on or in your body. SA is found on your skin and within your respiratory tract, but it does not normally cause disease. However, certain mutant strains of SA are **pathogens**, species that can cause serious illness. If untreated, a staph infection can be life-threatening.

3.1 An antibiotic is a drug that kills or inhibits the growth of bacteria. How do antibiotics kill bacteria without harming human cells? Most antibiotics work by disabling a necessary component of bacterial cells that is not found in human cells.



1,355×

One colony on the platecontains billions of individual bacterial cells.



A single SA cell

RIBOSOMES
Tetracycline interferes with bacterial ribosomes, cellular structures that make proteins. Your ribosomes are different enough to be unaffected.

CELL WALL
Penicillin disrupts the formation of bacterial cell walls, which your cells lack.

BACTERIAL CHROMOSOMES
Ciprofloxacin works by disrupting an enzyme that helps organize bacterial DNA. Your version of this enzyme is unaffected by the drug.

CYTOPLASMIC ENZYMES
Sulfa drugs inhibit the growth of bacteria by blocking an enzyme used to produce the nutrient folate. You can obtain folate from your diet and so do not need to synthesize it.

! Antibiotic-resistant bacteria infect more than 2 million people and cause 23,000 deaths in the United States each year.

8

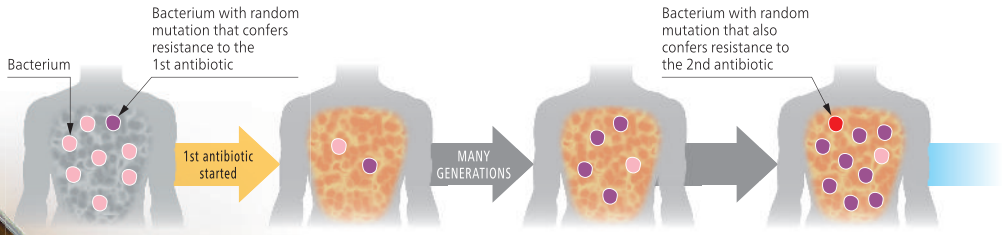
relevant and current high interest topics

CORE ISSUE 4

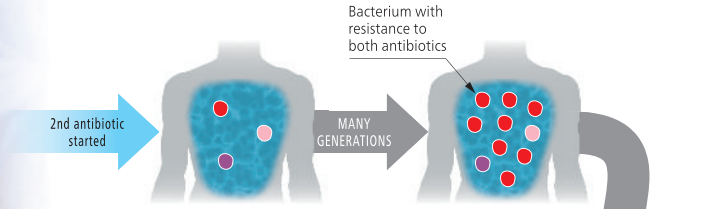
EVOLUTION OF ANTIBIOTIC RESISTANCE

7.2

Soon after their discovery, antibiotics were heralded as "wonder drugs" with the potential to wipe out infections altogether. This has not come to pass due to the evolution of antibiotic resistance. By the early 2000s, doctors began to document a formidable "superbug" known as **MRSA (multidrug-resistant *Staphylococcus aureus*)**. Bacteria can become resistant to multiple drugs in a stepwise fashion.



Exposed to an antibiotic, natural selection favors bacteria with random mutations that make them resistant to the drug. These bacteria will multiply, eventually evolving into a population that is resistant to that antibiotic.



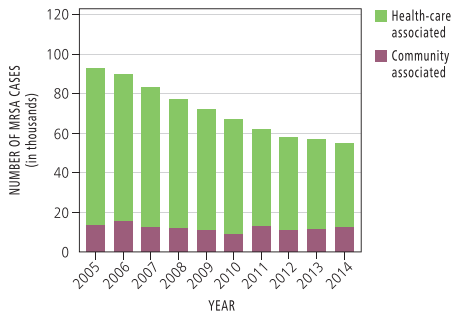
Since the first antibiotic is no longer effective, doctors switch to a second antibiotic. Natural selection may then favor a new strain that is resistant to both antibiotics.

Continued over time, the result can be multidrug-resistant bacteria like MRSA.

TRACKING MRSA

1.7

Staphylococcus aureus is common in health-care facilities, where the extensive use of antibiotics creates a selection pressure in favor of antibiotic resistance. It is not surprising, then, that MRSA was first found in hospital settings. The Centers for Disease Control and Prevention (CDC) has tracked MRSA cases for over a decade. As you can see from the bar graph, the number of cases occurring in health-care settings (green bars) has decreased over that time. This is due to increased awareness and education leading to better preventative measures. But MRSA outbreaks also occur in community settings such as athletic facilities, schools, and military barracks. The CDC data show that the number of these community-associated cases is holding steady (purple bars). These data point to the need for greater education, awareness, and prevention among the general public.



CORE IDEA

Antibiotics are drugs that inhibit or kill bacteria. Most work by disrupting cellular structures found in bacteria but not human cells. Evolution of antibiotic resistance can occur in a stepwise fashion to yield multidrug-resistant bacteria.

? Looking at the bar graph, what does it mean that the total height of the bars is lowering but the purple bars are relatively steady?

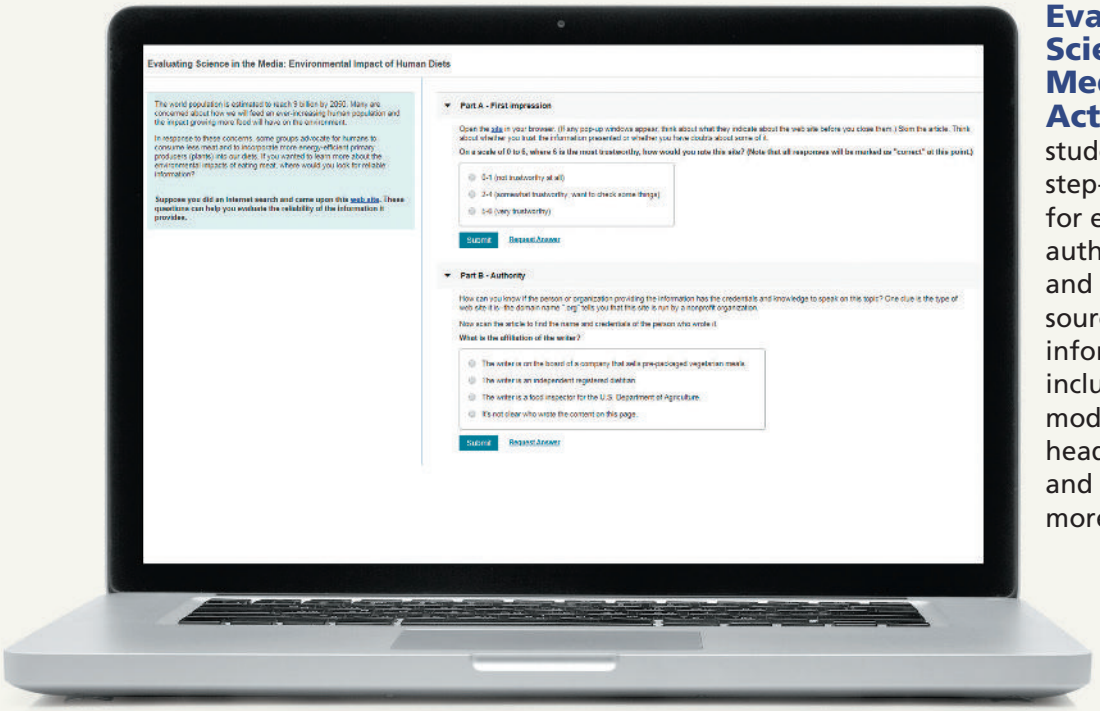
ANSWER: This shows that the number of community-based infections is holding steady even as the number of health-care-associated cases declines.

9

NEW! Core Issue Modules highlight relevant current issues like vaccinations, antibiotic resistance, cancer, and more. Each new module relates the core issue to biological concepts to help students see the relevancy of the course material, as well as connections across chapter concepts.

Each Core Issue Module is supported by a prebuilt assignment in Mastering Biology, while a Topic Guide and a Current Topic Lecture presentation in the Instructor Resources area of Mastering Biology helps instructors bring the issue into the classroom.

Develop students' scientific literacy skills



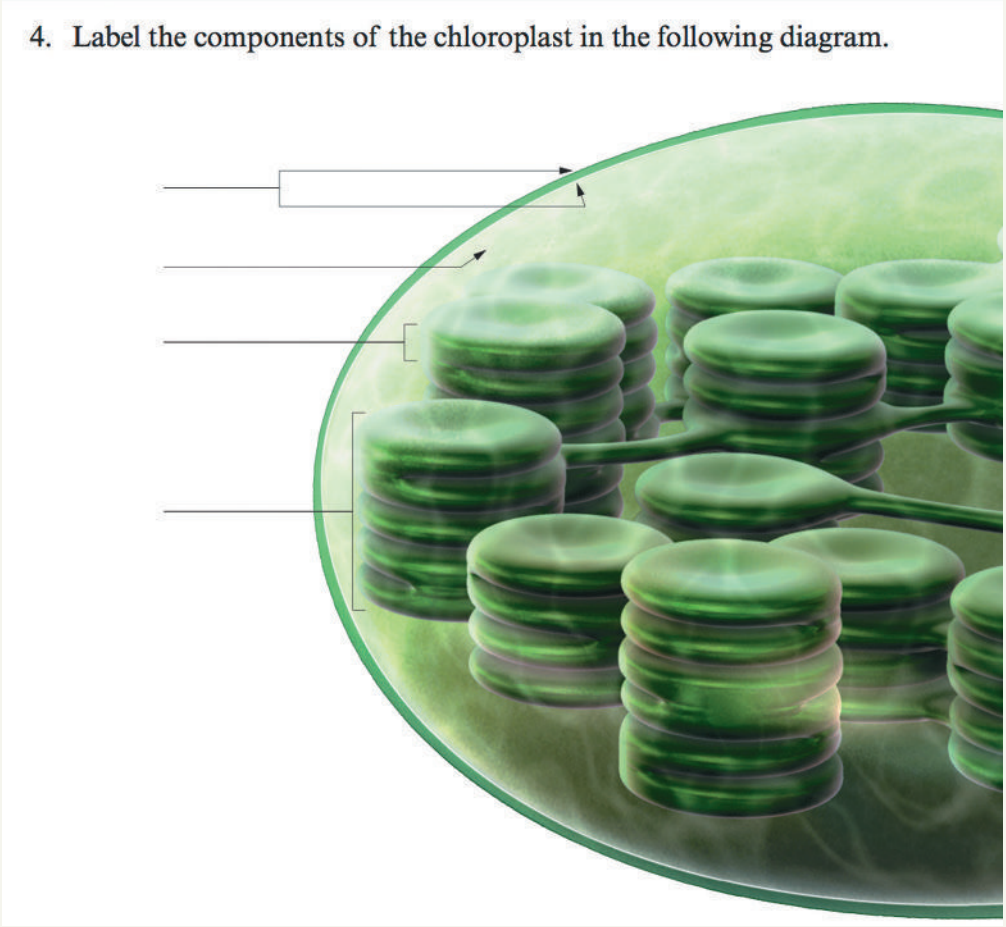
Evaluating Science in the Media Coaching Activities guide students through a step-by-step process for evaluating the authority, motivation, and reliability of online sources of scientific information. Topics include genetically modified organisms, head injuries, tanning and skin cancer, and more.

GraphIt! Coaching Activities help students read, interpret, and create graphs that explore real environmental issues using real data. All 10 activities explore current topics such as the carbon footprint of food, fresh water availability, and ocean acidification in an entirely new mobile experience with accessible design.

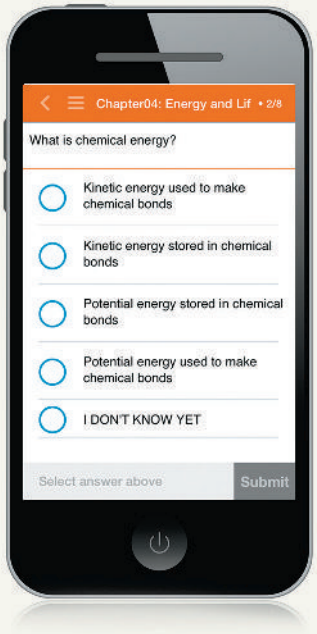
Engage students with active learning

NEW! Ready-to-Go Teaching Modules make use of teaching tools for before, during, and after class, including new ideas for in-class activities. Each of the 10 modules for ***The Core*** highlights a specific current issue and suggests how to incorporate Mastering Biology, active learning resources including Learning Catalytics, and instructor resources. These modules can be accessed through the Instructor Resources area of Mastering Biology.

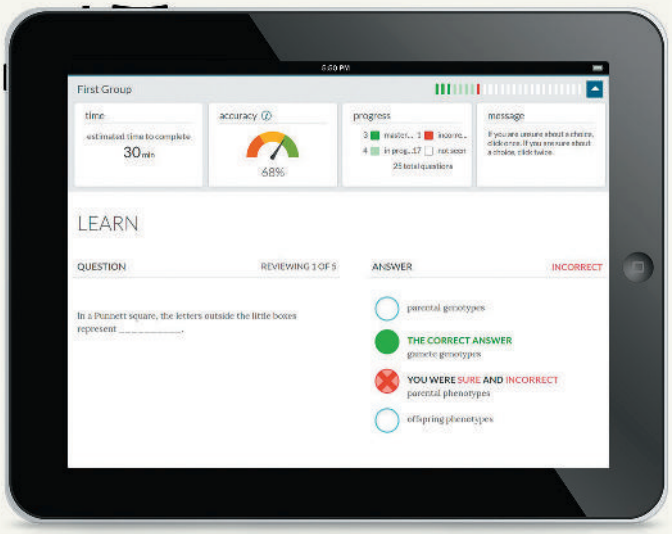
UPDATED! Guided Reading Activities are organized around each module and provide students with basic questions that guide them through the module, using an active reading approach. The worksheets offer an easy, low-tech way to assign work outside of or during class as a group work activity. These are available in the Mastering Biology Study Area, in the Instructor Resources, and in Pearson Collections.



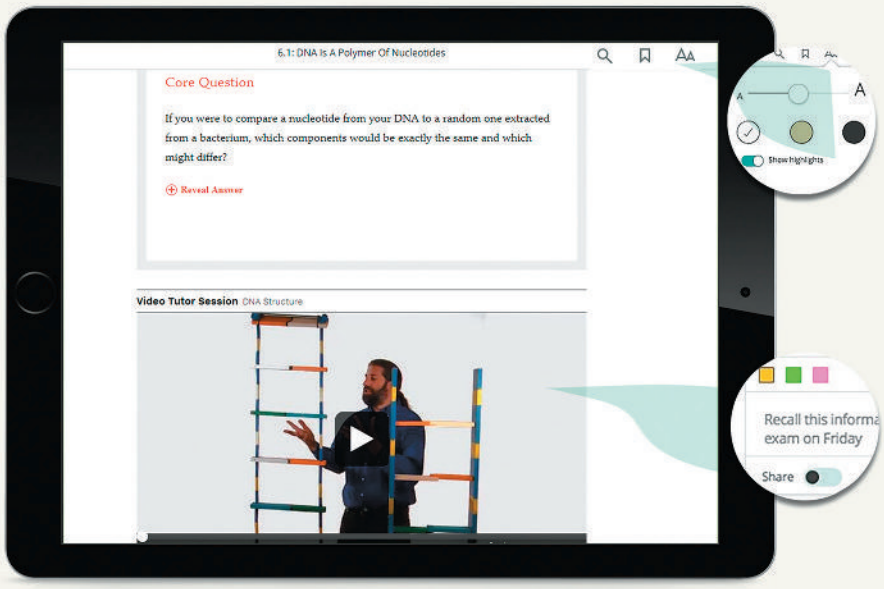
Reach every student with Pearson eText and Dynamic Study Modules



Dynamic Study Modules help students study effectively—and at their own pace. Each module poses a series of questions about a course topic, which adapt to each student's performance and offer personalized, targeted feedback to help them master key concepts.



Students can easily review their answers and monitor their own progress and understanding of key concepts as they move through each module.



Pearson eText is a simple-to-use, mobile optimized, personalized reading experience available within Mastering. It allows students to easily highlight, take notes, and review key vocabulary all in one place—even when offline. Integrated videos engage students and give them help when they need it. Pearson eText is available within Mastering Biology when it comes with a new book; students can also purchase Mastering with Pearson eText online. For instructors not using Mastering, Pearson eText can also be adopted on its own as the main course material.

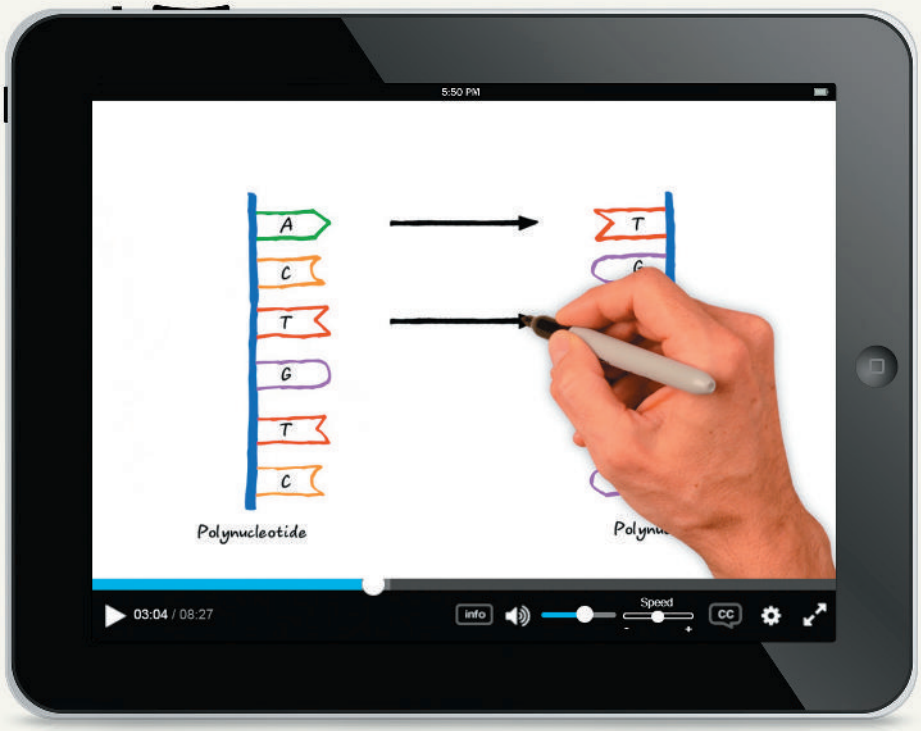
Deliver trusted content in Mastering Biology

NEW and UPDATED! Guided Video Tours, developed and narrated by author Eric Simon, present a brief "mini-lecture" that walks students through key concepts and module content presented in the text. All Guided Video Tours can be assigned as a coaching activity with personalized feedback in Mastering Biology, and are also embedded in the eText.

NEW! Topic Overview videos, created by the author, introduce key concepts and vocabulary. These brief, engaging videos introduce topics that will be explored in greater depth in class.

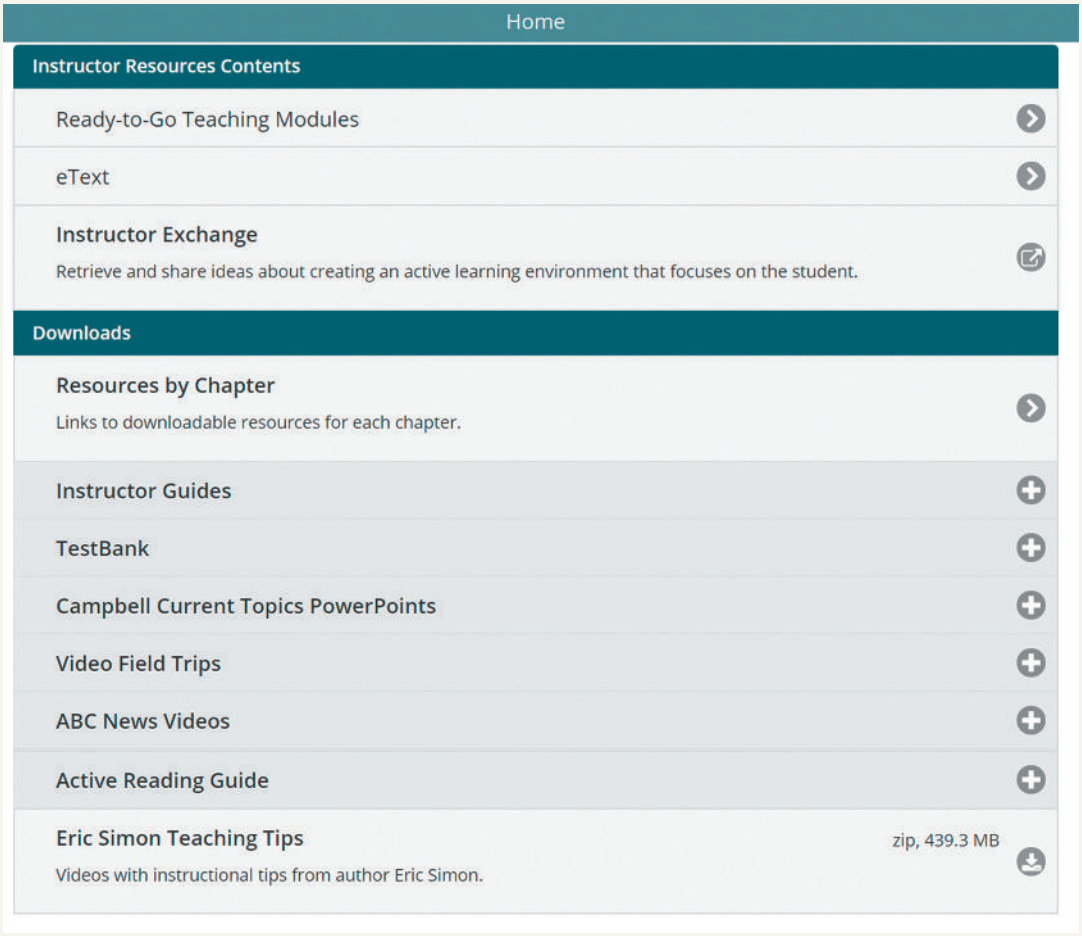
Topics include:

- Macromolecules
- Ecological Organization
- Mechanisms of Evolution
- An Introduction to Structure and Function
- Interactions Between the Respiratory and Circulatory Systems
- DNA Structure and Function
- And more!



Resources to help you build your class, your way

Biology: The Core includes a full suite of instructor support materials in the Instructor Resources area in Mastering Biology to help you build your course. Resources include Ready-to-Go Teaching Modules; current topic lecture slides and topic guides that help you integrate biology content with relevant current topics; an active learning resource guide; animations, videos, and lecture presentations to show in class; all images from the text; a testbank; and free access to our unique Instructor Exchange website, where you can share ideas with other non-majors biology faculty.



ACKNOWLEDGMENTS

There are many people to thank and acknowledge for their contributions to the Third Edition of *Biology: The Core*. One of the most gratifying aspects of writing a book is the opportunity to interact with so many skilled professionals at Pearson Education and so many talented biology colleagues from around the country. While any problems or mistakes within this book or any of the materials related to it are solely my responsibility, the successful aspects are due to the efforts of many people.

A few people deserve special mention for their deep contributions; these people form the core of *The Core*. Alison Rodal, as Courseware Portfolio Manager, worked with me and the rest of the team nearly every day, bringing a broad array of talents to bear on this project. Alison's consistently positive energy and her diplomatic skills were invaluable at several key junctures in the book's development. Alison reminds me every day that our overriding goal is to produce a book that will help students and teachers, and her guidance is invaluable. I will always owe a deep debt of gratitude to Beth Wilbur, Director of Portfolio Management, whose vision, understanding, and unwavering high standards have benefited every project since she brought me into the Pearson family over a decade ago. Courseware Editorial Assistants Sherry Wang, Summer Giles and Chelsea Noack were a continuous help in coordinating reviews and solving countless problems, always with a buoying positive energy. Ginnie Simione Jutson, Courseware Director of Content Development, provided her masterful oversight of all matters editorial and gave invaluable help when it was most needed.

I love my editors! All members of the Pearson editorial team bring decades of experience and talent to every project they take on. Senior Developmental Editor Evelyn Dahlgren has been my rock for this edition, building on the work and talents of Mary Ann Murray in the Second Edition. Evelyn's expertise with both words and art were of great help in preparing this edition. Hilair Chism used her keen sense of art development to design and improve many of the new features found in this edition. You can see Hilair's unique skills shine in Chapter 1 and in the Core Issue modules, both of which glimmer with her talent. Content Producer Ami Sampat proved to be a wise, capable, and gentle guide through the seemingly countless deadlines that comprise the writing of a new edition. Thank you to Indexer Robert Swanson for making the book much more user-friendly (see "Indexer, continued gratitude for"). Design Manager Mark Ong for his work on the Core Issue modules and designer Tani Hasegawa refreshed the design for this third edition and also designed the cover.

Once the text was written and the art developed, the production team took over, turning countless individual ideas into the reality of the book you see before you. For this, we thank Photo Researcher John Paul Belciña of Wanderlust Photos, Pearson Rights & Permissions Project Manager Matt Perry, Proofreaders Pete Shanks and Marleis Roberts, copyeditor Julie Kennedy, and Project Manager Margaret McConnell of Integra, which also provided expert composition services. Mark Mykytiuk and his team at Imagineering lent their talents to art development and art creation.

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After a book is written, the marketing team steps in to ensure that the complete story is told to all who might benefit. For this we thank Product Marketing Manager Alysun Burns and Field Marketing Manager Kelly Galli. Acting as the final facilitators of the long journey from author to student, I thank the entire Pearson Education sales team including all the sales managers, publisher's representatives, and technology specialists who work tirelessly every semester to help students learn and instructors teach.

In closing, I beg forgiveness from those who lent their unique talents to this book but who I failed to mention—I hope you will excuse my oversight and know that you have earned my gratitude.

With deepest, sincerest, and humblest thanks and respect to all who contributed their talents to *Biology: The Core*, Third Edition,

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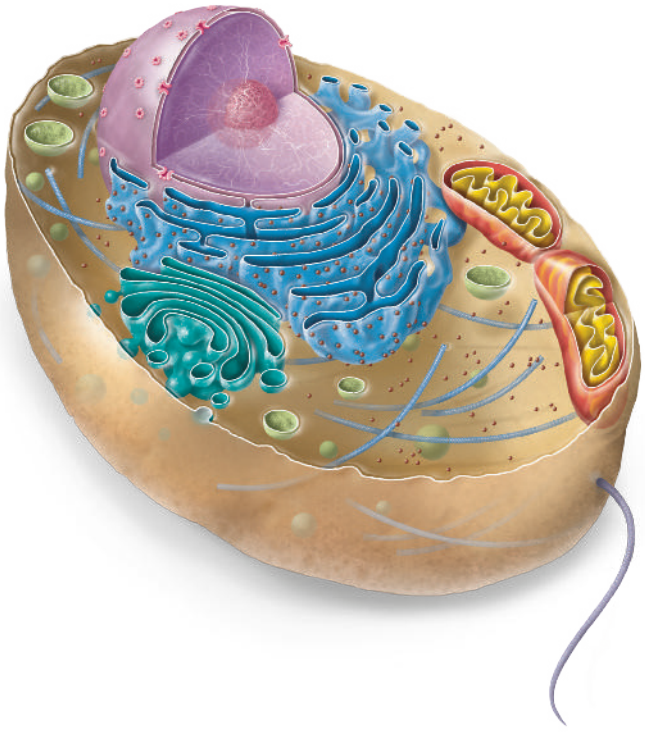
CI Core Issues

1 An Introduction to the Science of Life

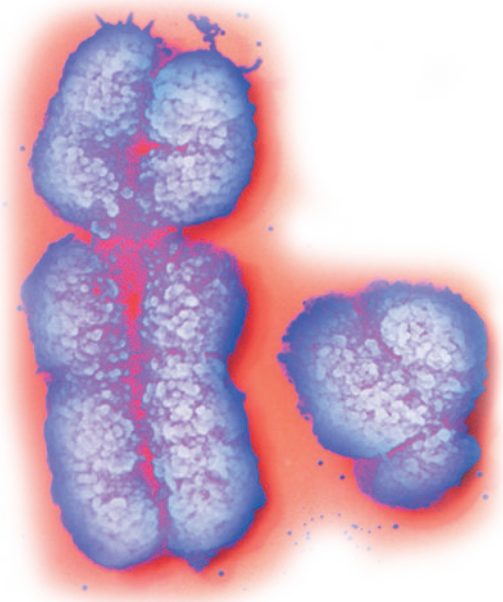
2 The Chemistry of Life

3 The Cell: The Fundamental Unit of Life



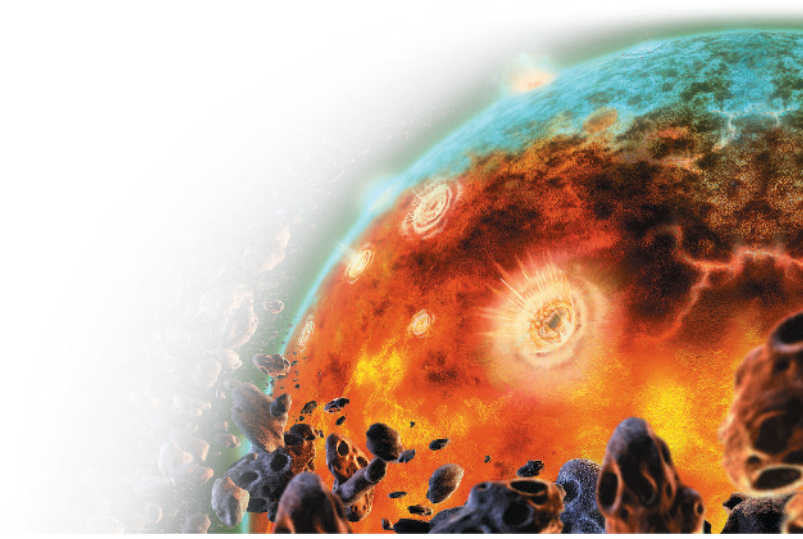
4 Energy and Life

5 Chromosomes and Inheritance



6 DNA: The Molecule of Life

7 Darwinian Evolution

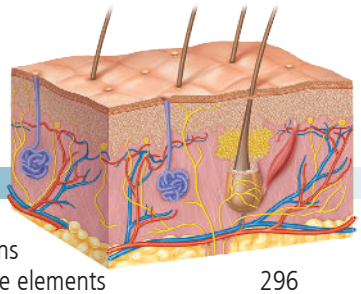


8 Biodiversity 1: Microscopic Organisms

9 Biodiversity 2: Fungi and Plants

10 Biodiversity 3: Animals

11 Human Body Systems



12 Ecology

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biology

THE CORE

3rd Edition

You can make informed decisions about your diet

In the biological sense, you are what you eat: Nearly all the molecules in your body are constructed using building blocks from your food. Proper nutrition provides fuel for cellular work, materials for constructing molecules, and essential nutrients for health. Improving your diet requires a basic understanding of several biological concepts.

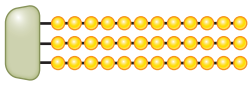
11.6 The U.S. Food and Drug Administration requires food labels to list the amounts of each nutrient per serving and as a percentage of a daily value based on a 2,000-Calorie diet. These values are therefore "one-size-fits-all" numbers that should be used as rough guidelines. Be sure to note the serving size and adjust the rest of the nutritional information accordingly. For example, if you consume two of the burgers listed here, double all values.

Nutrition Facts

Serving size	1 Double Cheeseburger Sandwich (155g)
Amount per serving	
Calories	**440**
	% Daily Value*
Total Fat 19g	**24%**
Saturated Fat 11g	**55%**
Trans Fat 1g	
Cholesterol 85mg	**28%**
Sodium 950mg	**41%**
Total Carbohydrate 35g	**13%**
Dietary Fiber 2g	**7%**
Total Sugars 6g	
Includes 0g Added Sugars	**0%**
Protein 25g	
Vitamin C 1mg	2%
Vitamin A 1020IU	20%
Iron 3.5mg	20%
Calcium 180mg	20%

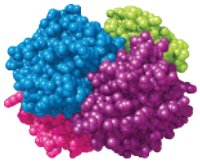
*The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

2.10 Dietary fat (found in the hamburger) comes in the form of molecules of triglyceride and is used by the body to store energy.

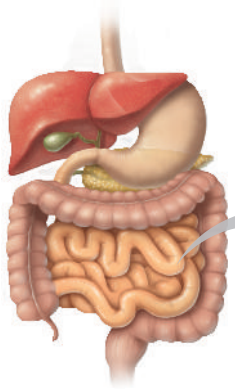


2.9 **Carbohydrates** such as sugars and starch (found in the bun) provide energy in the form of glucose molecules.

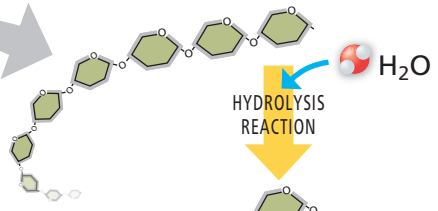
2.12 **Proteins** (found in the hamburger and cheese) provide amino acids that the body can use to rebuild a wide variety of its own molecules.

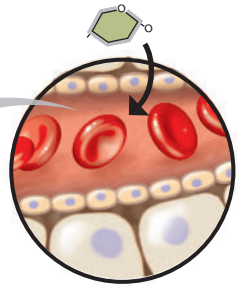


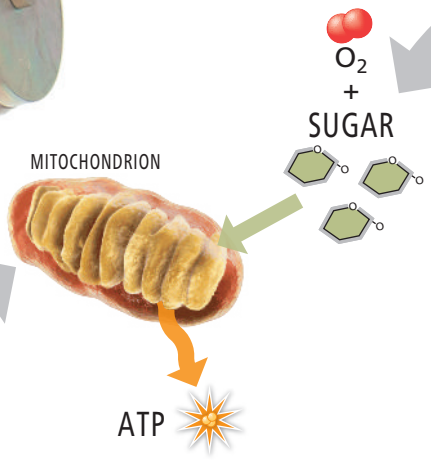
11.4 The four stages of food processing (ingestion, digestion, absorption, and elimination) take place in the **alimentary canal**, a long tube that is divided into specialized digestive organs (mouth, esophagus, stomach, etc.). Various **accessory organs** (such as your liver and pancreas) secrete digestive enzymes into the alimentary canal.



2.8 Within the digestive system, enzymes promote **hydrolysis reactions** that break larger polymers in food (such as carbohydrates) into the smaller monomers that make them up (such as glucose).







11.9 Within the **circulatory system**, blood carries small nutrient molecules (such as glucose) from the small intestine to the rest of the body. Capillaries surrounding all body cells allow nutrient molecules to flow from the bloodstream into cells.

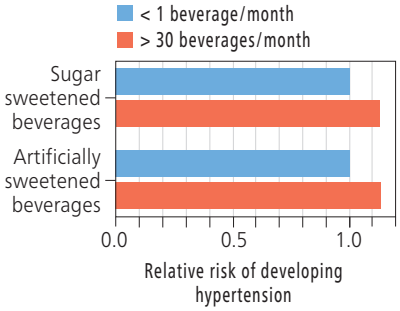
4.2 Within the mitochondria of body cells, the process of **cellular respiration** provides cellular energy. Glucose molecules from digested food and oxygen from the respiratory system are used to produce molecules of ATP, releasing CO_2 and water as waste products. The molecules of ATP produced by this process power all the body's activities.

! You'd have to walk about 9 miles to burn off the calories in a double cheeseburger.

TESTING THE EFFECTS OF SWEETENED BEVERAGES

1.8 Nutrition studies often look for connections between diet and specific health conditions. For example, a 2012 study looked for correlations between the number of sugared or artificially sweetened beverages consumed and hypertension (high blood pressure). The data show that participants who consumed at least one sweetened beverage per day were 13% more likely to develop hypertension than those who consumed none. Surprisingly, a nearly identical increased risk (14%) was seen in participants who consumed similar numbers of artificially sweetened beverages. This experiment is an **observational study**, one that seeks answers without manipulating test subjects (since it is very hard to control what people eat!). No conclusions can be drawn about the cause—for example, it could be carbonation, rather than sweetening, that accounts for the increased risk of hypertension. In other words, correlation does not imply causation.

CONSUMING SWEETENED BEVERAGES AND THE RISK OF DEVELOPING HYPERTENSION



Source: L. Cohen et al., *J Gen Intern Med*, v27(9):1127–34 (2012).

CORE IDEA

Reading food labels provides information about the nutrients found within food. These nutrients provide energy and building materials to your body through the action of the digestive system, the circulatory system, and cellular respiration.

? Do the data shown in the graph prove that sweetened beverages cause hypertension?

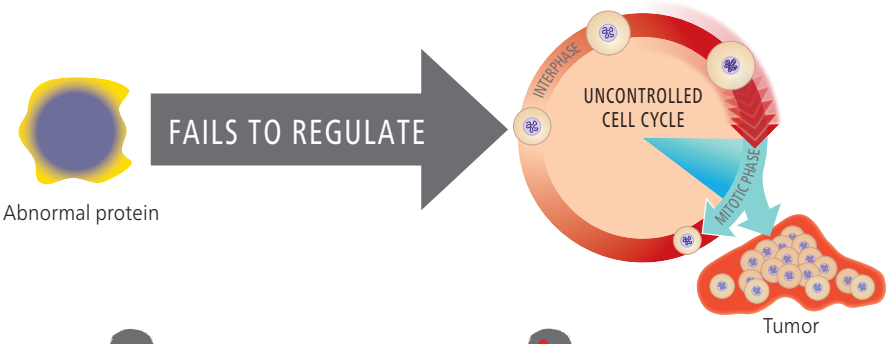
ANSWER: No. Just because two effects are correlated does not mean that one causes the other.

Understanding the biological basis of cancer can help with prevention, treatment, and survival

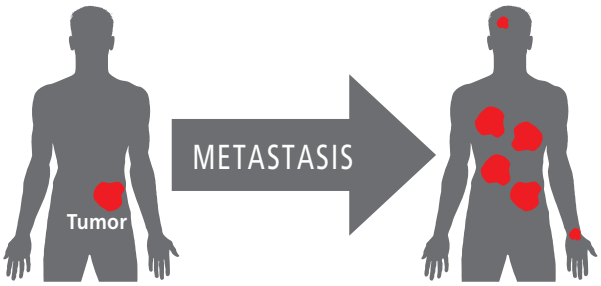
Nearly half of all Americans will be diagnosed with cancer, so chances are you or someone you love will be affected. Cancer is caused by your own body cells going awry. The normal mechanisms that regulate cell growth break down, leading to a runaway mass of body tissue called a tumor. Understanding the biological basis of cancer can increase your chances of living a cancer-free life.

5.3 All cells arise from preexisting cells following an ordered series of steps called the **cell cycle**. Proteins regulate the cell cycle, controlling when cells multiply and when they remain dormant.

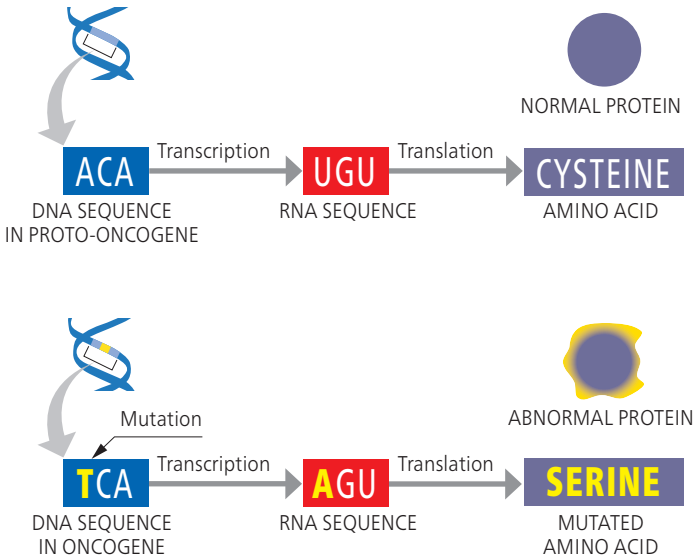
6.11 Proteins can speed up the cell cycle, slow it down, or turn it off altogether. If these proteins malfunction, control of the cell cycle is lost. Body cells will begin to grow continuously, forming a mass of cells called a **tumor**.

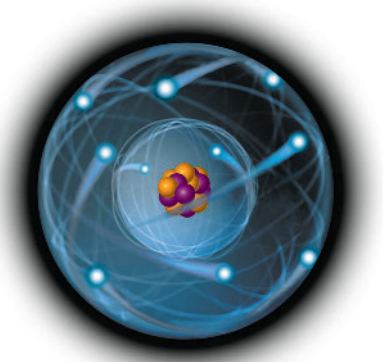


6.12 If a tumor cannot move beyond its original location, it is called a **benign tumor**. In contrast, a **malignant tumor** is one that can spread. During **metastasis**, cells from the initial tumor circulate through the body, forming new tumors in distant locations. A person with malignant tumors is said to have **cancer**.



6.10 All cases of cancer can be traced to one or more **mutations** in the person's DNA. **Proto-oncogenes** are genes that produce proteins that control the cell cycle. A mutation may change a proto-oncogene into an **oncogene**, a gene that promotes cancer by producing a faulty protein that fails to properly regulate the cell cycle.

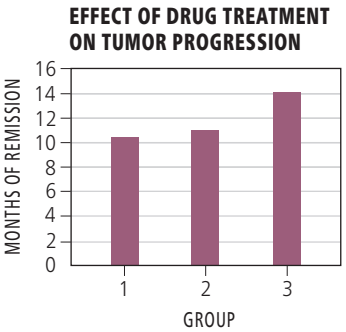




2.3 A radioactive **isotope** is a version of an atom with a nucleus that decays spontaneously, shedding particles and radiation. Some tumors can be treated with radioactive isotopes. For example, patients with thyroid tumors drink radioactive iodine, which accumulates in the thyroid gland, delivering radiation that can help destroy the tumor.

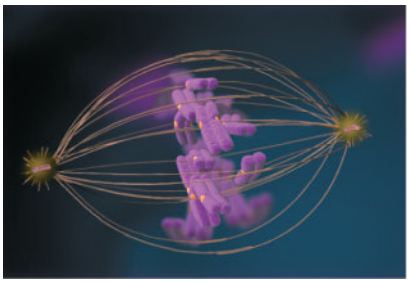
TESTING A NEW CANCER DRUG

1.6 Ideally, medical studies are conducted as a **double-blind experiment** with a **placebo** control. A 2011 study involved 1,873 women with advanced ovarian cancer. The study sought to determine whether adding a new chemotherapy drug to the standard treatment routine was beneficial. The women were randomly divided into three groups: (1) standard treatment plus a placebo (2) standard treatment plus the new drug for the first of three rounds followed by a placebo; (3) standard treatment plus the new drug for all rounds. The study was double-blind: Neither the patients nor the medical staff knew which patients received the drug and which received the placebo. As the graph shows, tumor remission (the average number of months before the cancer progressed) lengthened for patients receiving the drug. This suggests that adding the new drug is beneficial. The researchers could be confident of their conclusions because of the careful study design.

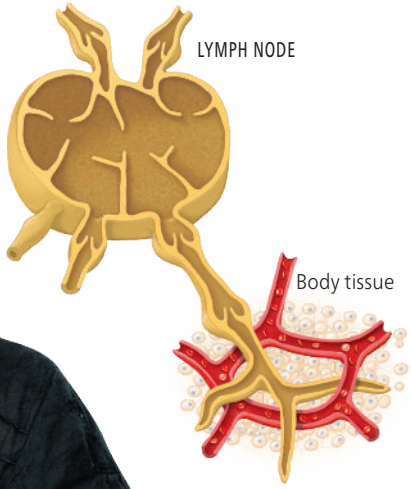


Source: Burger et al., *The New England Journal of Medicine*, v365:26 (2011).

5.4 Paclitaxel (sold under the brand name Taxol) is a drug used to treat breast, ovarian, and other types of cancer. The drug works by targeting the **mitotic spindle**, a set of protein tracks onto which chromosomes assemble during cell division. The drug disables cell division, preventing cancer cells from growing and spreading.



! Lung cancer alone accounts for about one-fourth of all deaths from cancer.



11.12 The **lymphatic system** is an important component of your body's defense against disease. But if tumor cells migrate into lymph nodes, they can quickly spread throughout the body. Thus, the involvement of lymph nodes (or not) is used to characterize the stage of a patient's cancer.

CORE IDEA

Cancer is caused by normal body cells losing the ability to regulate their own growth. This is due to mutations in genes that produce cell cycle control proteins.

? Name three good design features in the ovarian cancer study.

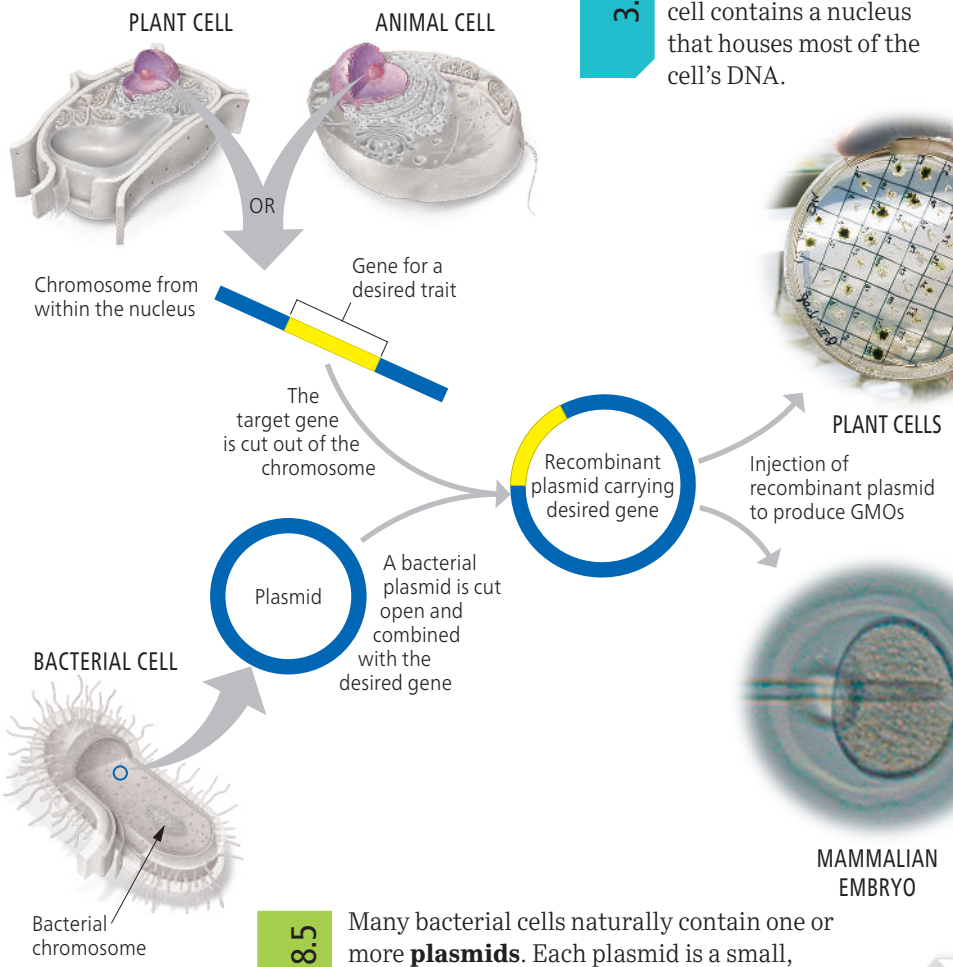
ANSWER: It involves a lot of patients, it has a control group, and it is double-blind.

Genetically modified organisms are created for a variety of uses

Genetically modified organisms (GMOs) are ones that have acquired one or more genes through genetic engineering. If the transferred gene is from another species (for example, a goat carrying a human gene), then the organism is called a **transgenic organism**. Genetic engineering of GMOs now routinely complements conventional animal and crop breeding programs that aim to increase the productivity of our food sources.

BUILDING A GMO

6.13 Because the hereditary information of all life is written in the identical chemical language of DNA, a gene from one species may be cut and pasted into the DNA of a different species. On this page, you can see how **gene cloning** can be used to place a desired gene into a bacterial plasmid, which can then be transferred into other species.



3.5 Every plant and animal cell contains a nucleus that houses most of the cell's DNA.

8.5 Many bacterial cells naturally contain one or more **plasmids**. Each plasmid is a small, circular DNA molecule. Like a miniature chromosome containing just a few genes, a plasmid resides in the cytoplasm of the bacterium and can be duplicated by the cell.

GM CROPS

Since ancient times, people have selectively bred crops to make them more useful. In modern times, DNA technology is replacing traditional breeding programs. In the United States today, a typical meal is likely to contain one or more genetically modified plant crops, although there is currently no way to tell from reading food labels.

GM ANIMALS

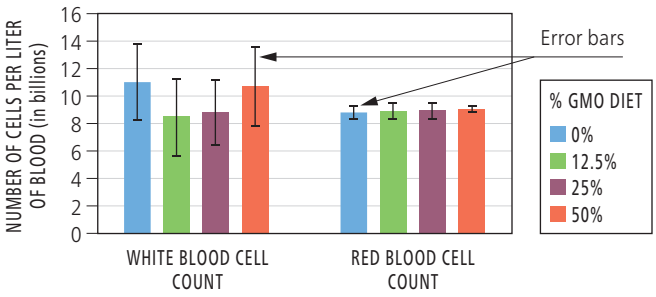
Transgenic animals have been made that produce useful human proteins and that provide improved yields. GM animals as food may be arriving to your supermarket soon.

! In 1980, the U.S. Supreme Court ruled that GMOs, unlike other forms of life, can be patented.

ARE GM FOODS SAFE?

1.9

Some people question the safety of GM foods. How can this issue be tested? Human health trials are impractical because it is very difficult to precisely measure what humans consume, so researchers often use animal studies instead. For example, a 2018 study tested a strain of GM corn containing a bacterial gene that rendered the corn resistant to some herbicides (making it cheaper to control weeds). A total of 140 rats were divided into groups and fed diets that contained 0%, 12.5%, 25%, or 50% GM corn for 90 days. After that time, there were no measurable differences in health between the groups of rats. Advocates of GMOs point to such studies as evidence of safety. Critics point out that the study did not involve humans (who may react differently to GMOs) and did not test for long-term effects. As with any scientific study, you should apply critical thinking skills when drawing conclusions.



These graphs show two standard health indicators: the number of white blood cells (left) and red blood cells (right) per liter of blood. Although the heights of the bars differ among the four groups (represented by four different colors), the error bars indicate that we cannot be confident that there are significant differences between the groups.

Source: Zou et al., *Regulatory Toxicology and Pharmacology,* v96 (2018).

Bt corn expresses a protein from the bacterium *Bacillus thuringiensis*. This protein acts as an insecticide, selectively killing caterpillars that attack the corn plant.

Golden Rice carries daffodil genes for beta-carotene, which our body uses to make vitamin A. This rice could help prevent debilitating vitamin A deficiency among people who eat rice as a staple food.

In Hawaii, the ring spot virus nearly wiped out the papaya industry until a GM papaya variety resistant to the virus was introduced in 1992.

These pigs have been genetically modified to lack one copy of a specific gene. That gene produces a protein that can trigger immune rejection in humans, making these pigs better suited for organ transplants.

This goat carries a gene for a human blood protein. The protein is harvested from the milk, purified, and used for medical treatments.

The Atlantic salmon shown in the background has been genetically modified to reach market size in 18 months rather than three years and to grow twice as large. The FDA has approved the sale of this GM salmon to U.S. consumers, declaring that it is as safe and nutritious as traditional salmon. This is the first GM animal approved for consumption.

CORE IDEA

Genetic engineers can use plasmids to create transgenic plants and animals. While GM plants currently make up a significant part of our food supply, GM animals do not. GM foods are considered safe to consume, although research continues.

? In the rat GMO study, does the control group have more white blood cells per liter of blood than the 12.5% GMO group?

ANSWER: No. Although the blue bar is taller than the green bar, the error bars show that the range of possible values overlap.

The evolution of antibiotic-resistant bacteria poses a significant health threat

Penicillin and other **antibiotics**—drugs that inhibit or kill bacteria—have saved countless lives. The discovery of penicillin in the 1940s prevented the deaths of millions of people with common infections. However, within a few decades, penicillin had become virtually useless in hospitals because of the evolution of penicillin-resistant bacteria. In response, new antibiotics were developed. By the 1990s, doctors began to discover bacteria that were resistant to many, even all, known antibiotics. Responding to the evolution of such multidrug-resistant strains is one of the most important health challenges facing our society.

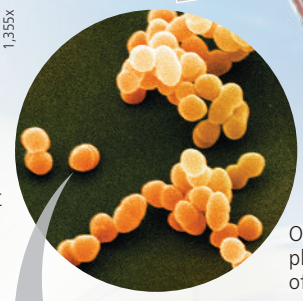
ANTIBIOTICS

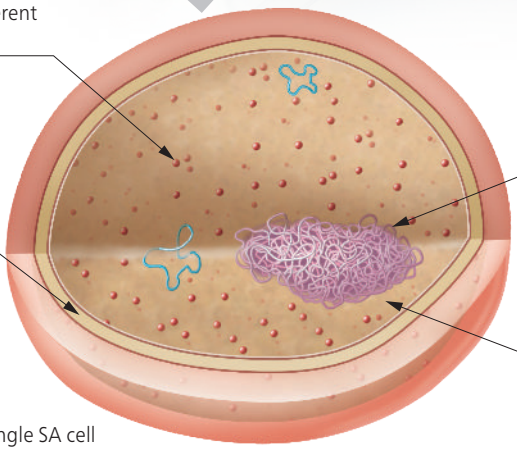
8.2 *Staphylococcus aureus* (SA, commonly called "staph") is a species of bacteria. Like SA, all bacteria are **prokaryotes**, single-celled organisms with relatively simple structures, lacking membrane-enclosed organelles. The genus *Staphylococcus* is named for its shape: irregular clusters (*staph-*) of spheres (*-coccus*, or plural *-cocci*).

8.4 *Staphylococcus aureus* is a member of your **normal flora**, microorganisms that commonly live on or in your body. SA is found on your skin and within your respiratory tract, but it does not normally cause disease. However, certain mutant strains of SA are **pathogens**, species that can cause serious illness. If untreated, a staph infection can be life-threatening.

3.1 An antibiotic is a drug that kills or inhibits the growth of bacteria. How do antibiotics kill bacteria without harming human cells? Most antibiotics work by disabling a necessary component of bacterial cells that is not found in human cells.

One colony on the plate contains billions of individual bacterial cells.





RIBOSOMES
Tetracycline interferes with bacterial ribosomes, cellular structures that make proteins. Your ribosomes are different enough to be unaffected.

CELL WALL
Penicillin disrupts the formation of bacterial cell walls, which your cells lack.

BACTERIAL CHROMOSOMES
Ciprofloxacin works by disrupting an enzyme that helps organize bacterial DNA. Your version of this enzyme is unaffected by the drug.

CYTOPLASMIC ENZYMES
Sulfa drugs inhibit the growth of bacteria by blocking an enzyme used to produce the nutrient folate. You can obtain folate from your diet and so do not need to synthesize it.

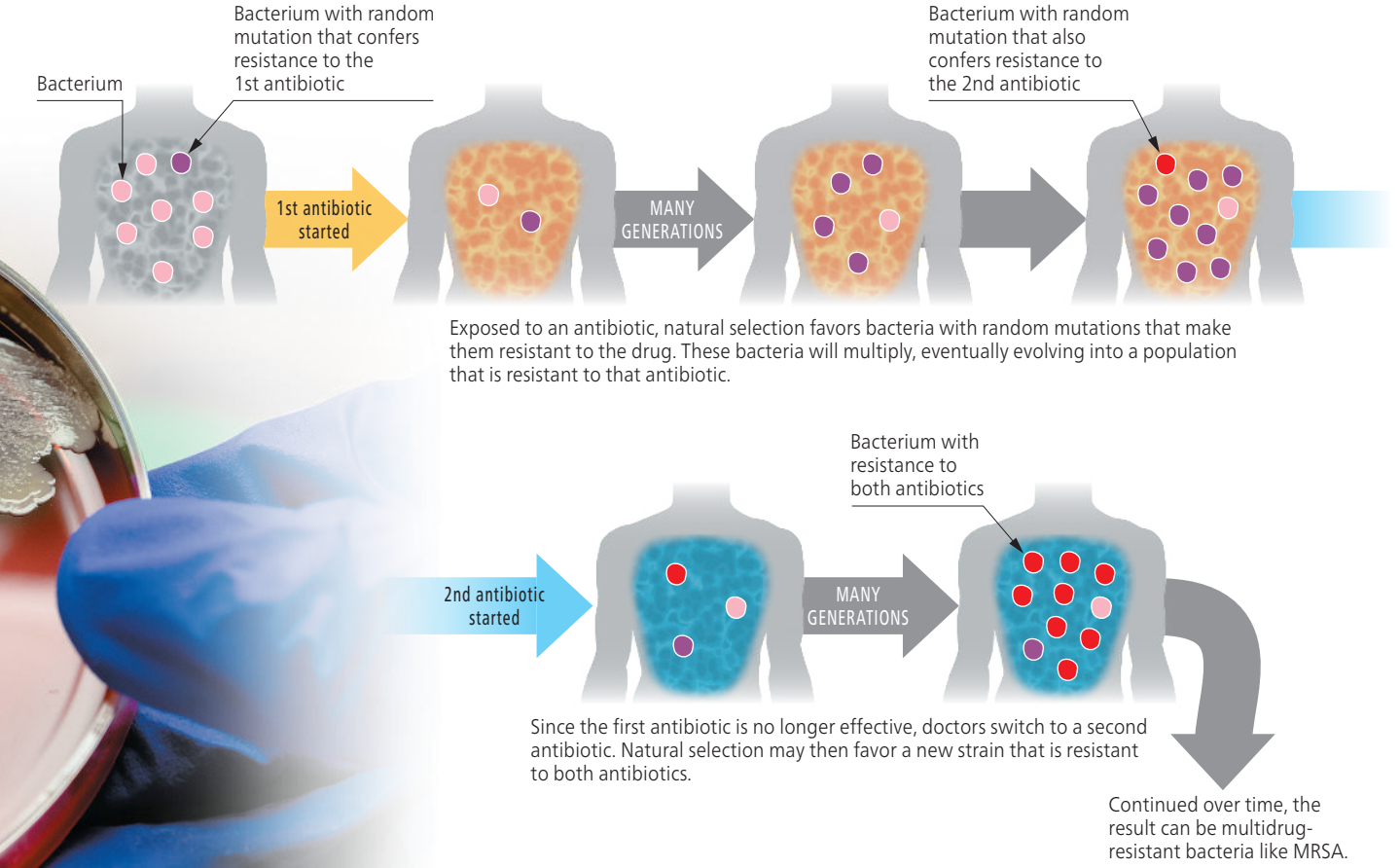
A single SA cell

! Antibiotic-resistant bacteria infect more than 2 million people and cause 23,000 deaths in the United States each year.

EVOLUTION OF ANTIBIOTIC RESISTANCE

7.2

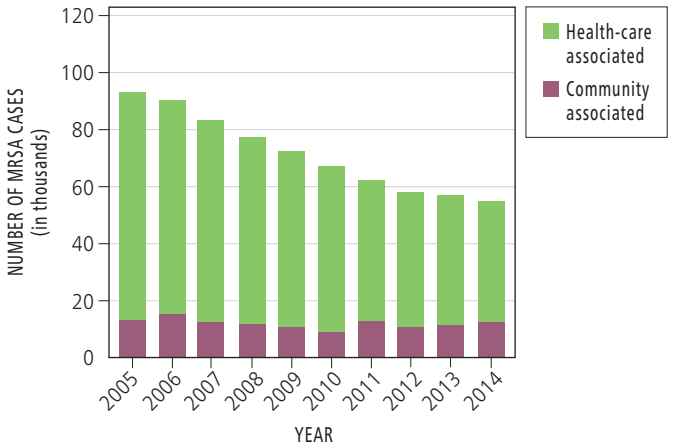
Soon after their discovery, antibiotics were heralded as "wonder drugs" with the potential to wipe out infections altogether. This has not come to pass due to the evolution of antibiotic resistance. By the early 2000s, doctors began to document a formidable "superbug" known as **MRSA (multidrug-resistant *Staphylococcus aureus*)**. Bacteria can become resistant to multiple drugs in a stepwise fashion.



TRACKING MRSA

1.7

Staphylococcus aureus is common in health-care facilities, where the extensive use of antibiotics creates a selection pressure in favor of antibiotic resistance. It is not surprising, then, that MRSA was first found in hospital settings. The Centers for Disease Control and Prevention (CDC) has tracked MRSA cases for over a decade. As you can see from the bar graph, the number of cases occurring in health-care settings (green bars) has decreased over that time. This is due to increased awareness and education leading to better preventative measures. But MRSA outbreaks also occur in community settings such as athletic facilities, schools, and military barracks. The CDC data show that the number of these community-associated cases is holding steady (purple bars). These data point to the need for greater education, awareness, and prevention among the general public.



Source: Centers for Disease Control and Prevention Emerging Infections Program Network (2018).

CORE IDEA

Antibiotics are drugs that inhibit or kill bacteria. Most work by disrupting cellular structures found in bacteria but not human cells. Evolution of antibiotic resistance can occur in a stepwise fashion to yield multidrug-resistant bacteria.

? Looking at the bar graph, what does it mean that the total height of the bars is lowering but the purple bars are relatively steady?

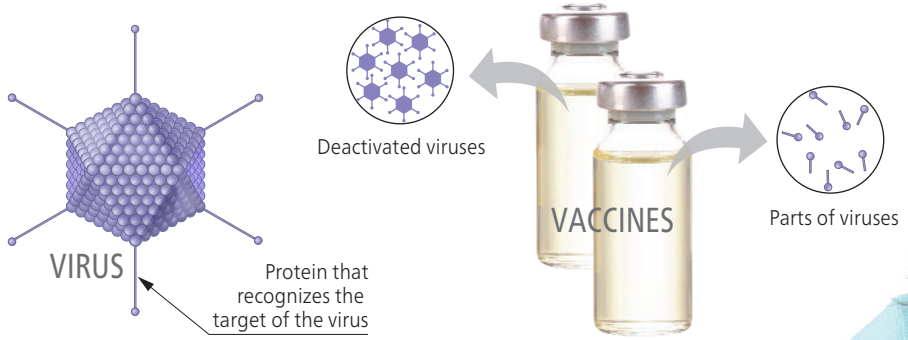
ANSWER: This shows that the number of community-based infections is holding steady even as the number of health-care-associated cases declines.

Vaccines enhance the body's natural protections

Vaccines are one of the great advances of modern medicine. Thanks to vaccination, diseases that once killed millions have now been largely or entirely wiped out. For example, polio and measles have been eliminated from much of the world, and smallpox (which infected 15 million people in 1967) has been entirely wiped out. A **vaccine** is a substance that resembles a disease-causing microorganism (usually a virus). Injecting the vaccine stimulates the immune system to recognize it, destroy it, and most importantly to remember it. Later exposure will result in rapid recognition and destruction of the invader.

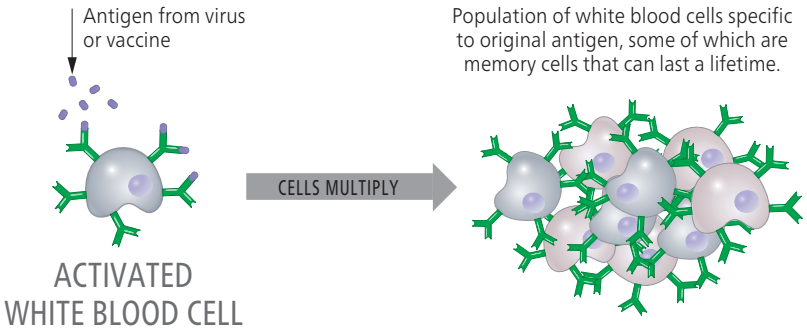
8.9

Vaccination is the only effective medical treatment against **viruses**, noncellular infectious particles that cause such diseases as measles, mumps, and chicken pox. Some vaccines contain dead or weakened viruses. Other vaccines contain pieces of viruses, such as the proteins that protrude from the virus surface.



11.12

Injecting a vaccine stimulates the body's natural protections, the **immune system**, to produce defenses against the virus from which the vaccine was derived. An **antigen** is a molecule that causes an immune response, such as a natural virus or an artificial vaccine. A particular antigen will activate some white blood cells. Once activated, those cells multiply, producing a large population that are all specific for that same invading antigen. Some of these cells, called **memory cells**, can be active for decades. If the same invader is encountered again, the memory cells will instigate a vigorous and rapid immune response that quickly neutralizes the invader. Thus, once exposed to an infectious disease, you may have lifetime immunity against it.



TESTING THE POLIO VACCINE

1.6

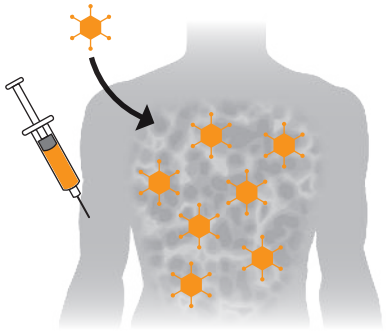
Polio is a contagious disease caused by a virus that attacks the nervous system, leading to paralysis. In 1952, over 50,000 cases of polio were reported in the United States. In 1953, Jonas Salk developed a vaccine containing a deactivated form of the polio virus. To test the effectiveness of the vaccine, Salk conducted a large-scale controlled experiment involving over 400,000 children. Each child was randomly assigned to either a control group or an experimental group. Children in the control group were injected with salt water (a placebo); children in the experimental group were injected with the polio vaccine. The experiment was double-blind, meaning that neither the participants nor the researchers knew to which group each child was assigned. Every test subject was followed for six months. The results, published in 1955, were clear: There were significantly fewer cases of polio in children who received the vaccine injection than in children who received the placebo. Within a few years, the number of polio cases in the United States dropped by 90%. By 1979, polio had been eradicated in the United States.

RESULTS FROM THE SALK POLIO VACCINE TRIALS OF 1954

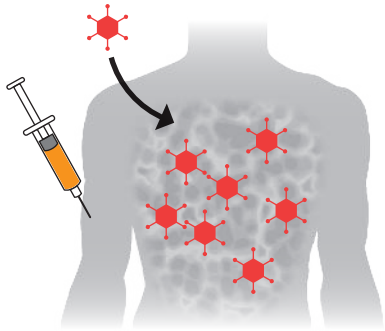
STUDY GROUP	NUMBER OF CHILDREN	NUMBER OF POLIO CASES
Control group (received placebo injection)	201,229	142
Experimental group (received polio vaccine)	200,745	57

Source: Francis et al., *American Journal of Public Health*, v45:5 (1955).

! The United Nations estimates that vaccinations save 2–3 million lives each year.



YEAR 1
Vaccine is effective.



YEAR 2
Vaccine against Year 1 virus may be ineffective.

7.2

Although viruses do not have all of the characteristics of life (they do not, for example, contain cells), populations of viruses can evolve. This is why we all need a new flu shot each year. Although last year's flu shot may be effective against last year's flu strains, chances are good that new strains of the influenza virus have evolved which could evade the old version of the vaccine. The yearly flu shot therefore represents an arms race between the evolving virus and our ability to produce new vaccines.

CORE IDEA

Vaccines stimulate the body's natural immune defense system to produce protection against a harmless version or piece of a virus. If the actual virus is ever encountered, it can be quickly destroyed.

? In the Salk study, why was the experimental group compared against a control group that also received injections? Why not just compare to children who received no injections?

ANSWER: Injecting salt water allowed the researchers to avoid the placebo effect. (See module 1.6.)

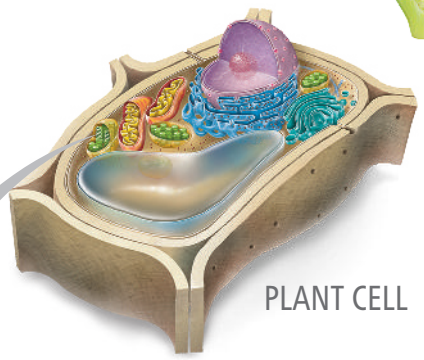
Scientific approaches have greatly improved agriculture

The development and progress of human civilization is closely tied to **agriculture**, the cultivation of plants and animals to provide food and other products (fiber, medicine, and building materials, for example). Around 10,000 years ago, humans began to develop agricultural crops, which allowed for the first cities, trade, and the advent of modern societies. As you can see here, modern agricultural practices depend on understanding the biology of plants.

THE BIOLOGICAL BASIS OF AGRICULTURE

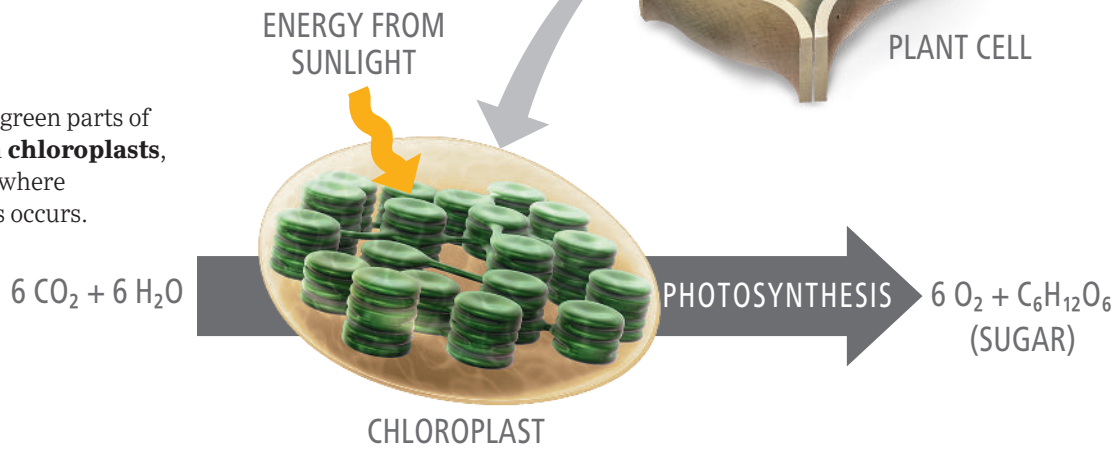
9.11 The vast majority of modern food crops are **angiosperms** (flowering plants). In fact, just 10 species of angiosperms account for over 90% of the total calories consumed by humans worldwide. Like all plants, angiosperms depend upon the process of photosynthesis to grow and thrive. An understanding of photosynthesis therefore underlies any study of agriculture.

3.2 Like all eukaryotic cells, plant cells contain several **organelles**, membrane-enclosed structures that perform specific functions.



PLANT CELL

4.3 The cells in all green parts of a plant contain **chloroplasts**, the organelles where photosynthesis occurs.



4.4 To perform **photosynthesis**, plants require carbon dioxide from the air, water via the roots, and energy from sunshine. These ingredients are used to produce sugars, releasing oxygen gas into the atmosphere. To grow successfully, crop plants must be provided with all the materials needed to promote photosynthesis.

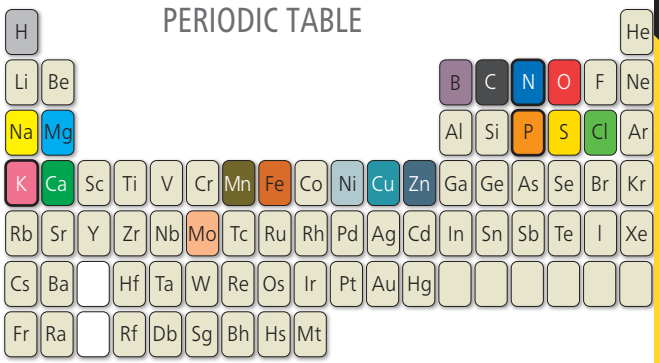
! The U.S. organic farming industry has grown 20% per year during the past decade, making it one of the fastest-growing segments of agriculture.

FERTILIZERS

2.2

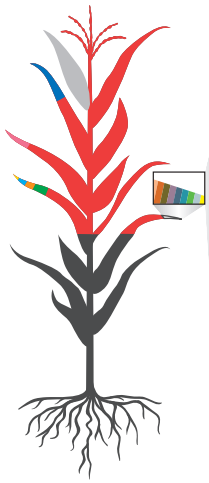
Fertilizers are compounds applied to the soil to promote plant growth. Fertilizers provide minerals (chemical elements) that the plant needs. Although plants need a total of 18 elements to grow, most fertilizers emphasize the "N-P-K" ratio: the relative amounts of the three nutrients most often deficient in depleted soils: nitrogen (N), phosphorus (P), and potassium (K).

PERIODIC TABLE



9 MACRONUTRIENTS
99.5% of plant weight (needed in relatively large amounts)

Carbon (C)	45.0%
Oxygen (O)	45.0%
Hydrogen (H)	6.0%
Nitrogen (N)	1.5%
Potassium (K)	1.0%
Calcium (Ca)	0.5%
Magnesium (Mg)	0.2%
Phosphorus (P)	0.2%
Sulfur (S)	0.1%

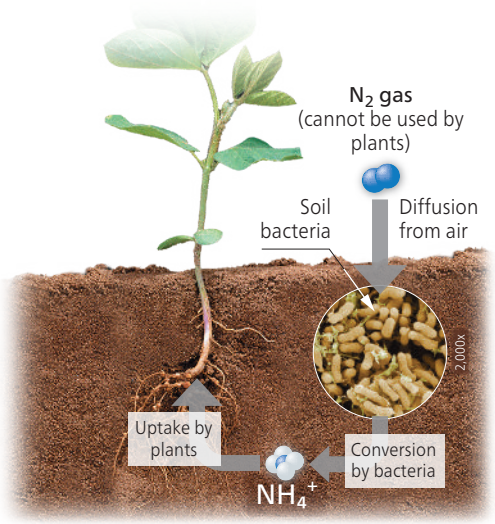


9 MICRONUTRIENTS
0.5% of plant weight (needed in only tiny amounts)

- Molybdenum (Mo)
- Iron (Fe)
- Manganese (Mn)
- Boron (B)
- Zinc (Zn)
- Copper (Cu)
- Chlorine (Cl)
- Nickel (Ni)
- Sodium (Na)

8.4

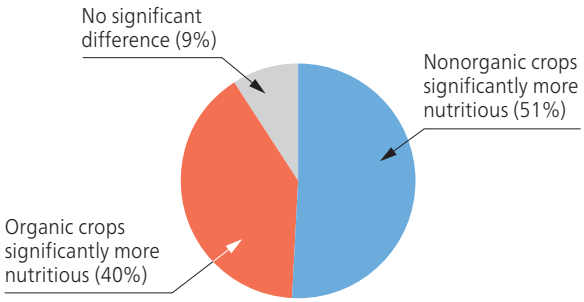
A form of natural fertilizer is provided when bacteria within the soil convert N_2 gas in the air into compounds the plants can use. Some plants (such as soybeans) house beneficial bacteria that add even more nitrogen to the soil. This is one reason why crop rotation—growing a series of different plants in the same plot—is beneficial.



TESTING BENEFITS OF ORGANIC PRODUCE

1.9

Organic farming is a series of agricultural practices that promote biological diversity by maintaining soil quality through natural methods such as rotating crops, planting cover crops, amending the soil with organic matter, providing habitat for predators of pests rather than relying mainly on synthetic pesticides, and avoiding genetically modified organisms. Organic farming aims to improve the health of the soil, the crops, and the humans that eat them. But do they? An important factor when evaluating scientific claims is reproducibility. One study may claim health benefits for organic produce (or not), but what about *all* such studies? In 2011, researchers surveyed over 900 independent studies of organic produce. As you can see in the pie chart, an organic label is no guarantee of improved nutrition: There is no scientific consensus on whether organically grown foods are more nutritious than conventionally grown foods.



Source: Hunter et al., *Critical Reviews in Food Science and Nutrition*, v51:6 (2011).

CORE IDEA

Humans take advantage of plants' natural photosynthesizing abilities to cultivate crops. We can improve the health of our plants by using fertilizer and organic farming techniques.

? If you read a study that demonstrates organic strawberries have fewer harmful pesticides than nonorganic strawberries, what is a logical next step?

ANSWER: You should seek out other studies to see if they agree.

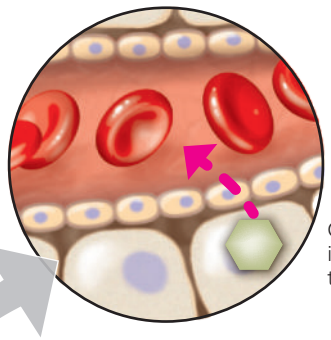
Diabetes is one of the most significant health issues facing our society

Diabetes mellitus is a serious disease that affects over 30 million Americans—that's nearly 10% of the population. In **diabetes**, body cells cannot obtain enough glucose from the bloodstream, even if there is plenty present. As a result, the glucose concentration in the blood can become dangerously high. Meanwhile, starved for fuel, cells are forced to burn the body's supply of fats and proteins. There are treatments for diabetes but no cure. Every year, at least 200,000 people in the United States die from the disease or its complications, making diabetes one of the most pressing health problems facing our society.

GLUCOSE FROM FOOD

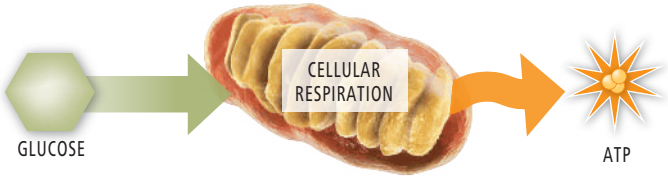
11.4

The **digestive system** breaks down food into small molecules, including glucose. From the small intestine, glucose enters the bloodstream, which carries it to every cell in the body.



Glucose moves from intestinal cells into the bloodstream.

! The CDC estimates that diabetes costs the U.S. economy over $300 billion annually.



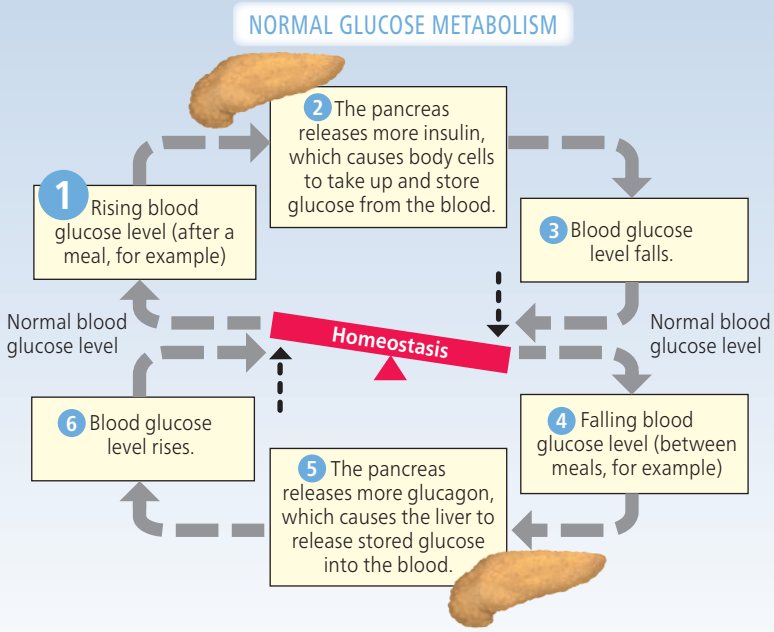
4.7

Within the mitochondria of every cell, the process of **cellular respiration** uses the energy within glucose to build ATP. Molecules of **ATP** provide the energy to drive all of life's processes.

GLUCOSE METABOLISM

11.3

The amount of glucose in the blood is regulated by two hormones produced by the pancreas. **Insulin** causes body cells to take up glucose, thereby lowering its level in the blood. In contrast, **glucagon** causes the liver to release glucose, thereby increasing its level in the blood. The pancreas maintains **homeostasis** (a steady state) of glucose in the blood by releasing different quantities of one or the other hormone. As a result, the glucose level in the blood continuously fluctuates around (but always near) the ideal value.

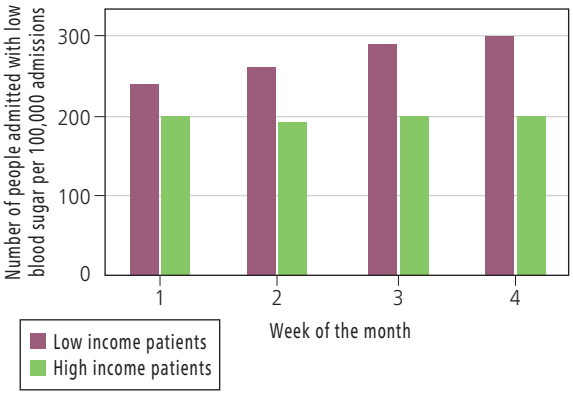


TYPES OF DIABETES			
TYPE	PERCENTAGE	CAUSE	TREATMENT
1 (insulin-dependent)	5% of American diabetes cases (1.25 million)	The pancreas does not produce insulin.	Regular injections of insulin
2 (non-insulin dependent)	95% of American diabetes cases (29 million)	Body cells do not properly respond to insulin.	Exercise; diet; medication
Gestational	9% of American pregnancies (368,000/year)	Development of diabetes during pregnancy; cause unknown	Monitoring mother and baby; diet; exercise; medication

DIABETES AND POVERTY

1.8

Understanding biology helps us better understand the society in which we live. For example, a 2014 study investigated the link between diabetes-related hospital visits and poverty in the United States. The researchers counted hospital admissions for low blood sugar in the state of California over an 8-year period. Patients were categorized by economic status as either "low income" or "high income." Many low-income people benefit from food assistance that arrives at the start of each month, making it more difficult to eat well as the month progresses. The researchers found a strong association between hospital admissions for low blood sugar and the week of the month for low-income patients, but not for high-income patients. The study does not prove that lack of access to proper nutrition caused the increased hospital visits, but it does highlight the intersection of biology and society.



Source: Seligman et al., Exhaustion of Food Budgets at Month's End and Hospital Admissions for Hypoglycemia, *Health Affairs*, v33:116–123 (2014).

DIABETIC GLUCOSE METABOLISM

In a diabetic person, glucose homeostasis fails. After a meal, glucose levels spike, and then fall slowly, often remaining dangerously high.

CORE IDEA

Diabetes is a common and dangerous disease caused by a breakdown in glucose metabolism. Understanding the biology of diabetes can help our society make important decisions regarding health care.

? According to the bar graph, which group(s) of people show a correlation between hospital admissions and week of the month?

ANSWER: There is such a correlation for the low-income group: Notice that the purple bars get successively taller. There is no correlation for the high-income group (green bars).

Athletes can improperly enhance performance in a variety of ways

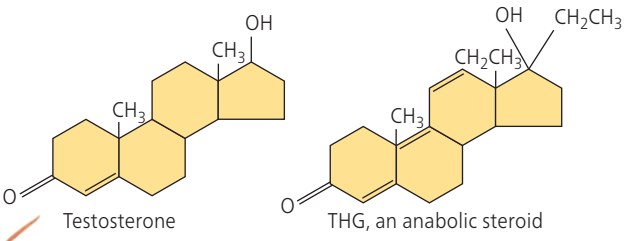
Athletic performance depends on cooperation between several bodily systems. Some athletes seek to boost their strength and endurance by artificially enhancing these systems. Here we survey some of the ways that athletes may seek to gain an unfair advantage.

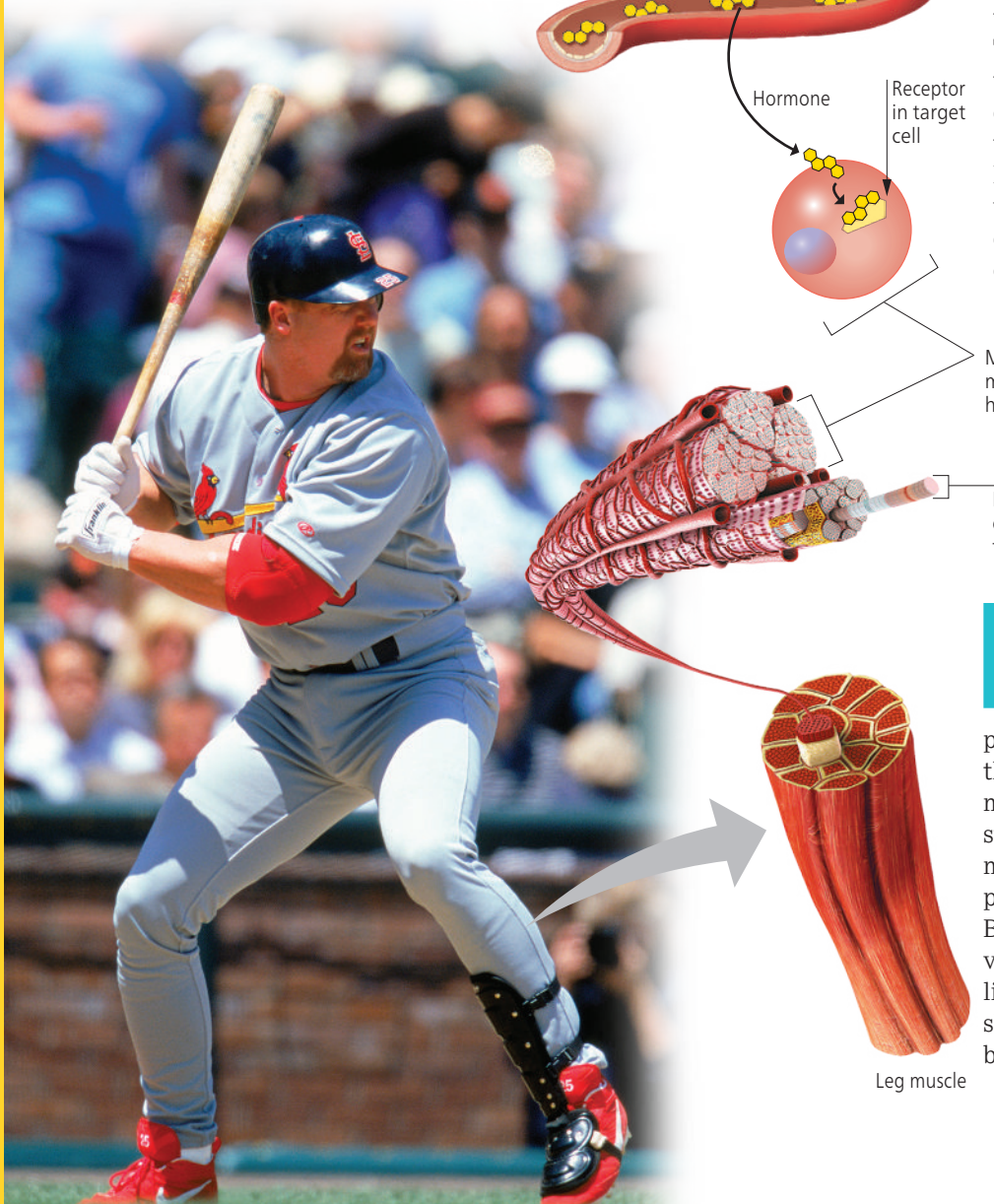
ANABOLIC STEROIDS

2.10

Hormones are natural chemical signals that help regulate body functions. The steroid (fat-based) hormone testosterone stimulates building of muscle and bone during puberty and controls sexual characteristics throughout life. **Anabolic steroids** are artificial chemicals that are very similar in structure to testosterone and mimic some of its effects.

! Eleven consecutive winners of the Tour de France bicycle race (1996–2006) were disqualified for using performance-enhancing drugs.





11.14

Cells within the testes (and, in smaller quantities, within the ovaries) secrete testosterone into the bloodstream. The hormone travels throughout the body, but only some cells, called target cells, respond to that specific hormone. Steroid hormones diffuse into target cells, where they bind to a receptor, causing specific genes to be turned on or off.

11.23

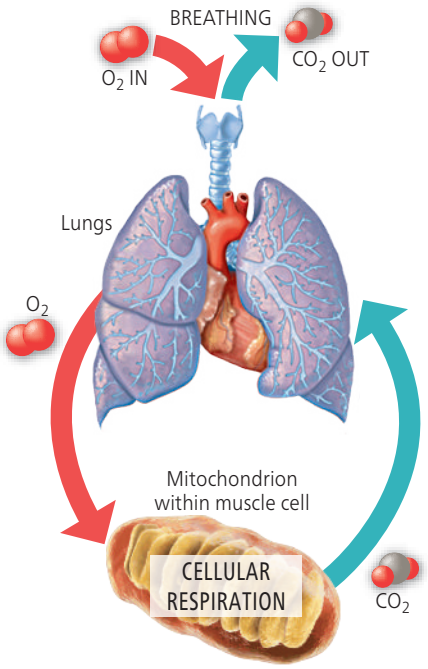
Natural testosterone and artificial anabolic steroids turn on genes that produce muscle fiber proteins. The result is thickening of the fibers, which increases muscle mass and strength. Anabolic steroids can therefore increase muscle mass beyond what is possible through training alone. But there are side effects, including violent mood swings ("'roid rage"), liver damage, high blood pressure, shrinking testicles, infertility, and breast enlargement.

BOOSTING ENDURANCE

4.7

Many sports require endurance, the ability to perform an activity over a long time. Endurance requires that a continuous supply of oxygen be delivered by red blood cells to contracting muscles. Muscle cells use this oxygen to obtain energy through the process of **cellular respiration**. Increasing the number of red blood cells therefore increases endurance. There are several ways that this can be accomplished:

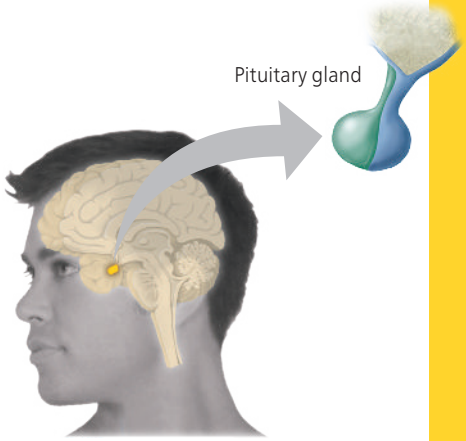
ALLOWED	NOT ALLOWED
• Learning proper breathing technique allows more oxygen to be delivered by the bloodstream.	• Blood doping involves transfusing extra blood cells into an athlete before an event.
• Living or training at high altitude boosts the production of red blood cells.	• Injections of the hormone erythropoietin (EPO) stimulates bone marrow to produce more red blood cells. EPO is naturally produced by the kidneys, but injecting it carries significant health risks.
• Sleeping in a low-oxygen environment (an "altitude tent") simulates living at high altitude.	



HUMAN GROWTH HORMONE

11.14

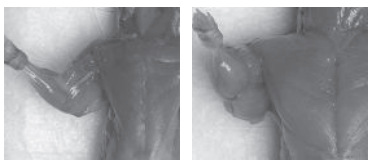
The **endocrine system** helps control whole-body activities, such as growth and metabolism, by secreting hormones from several glands. One of the most important of these is the **pituitary gland**, a pea-sized structure that hangs from the brain. The pituitary gland secretes **human growth hormone (HGH)**. HGH promotes the development and enlargement of all parts of the body from fetal development through adolescence. HGH is sometimes abused by athletes to quickly build muscle mass or to decrease recovery time after an injury. Abuse of HGH may lead to joint problems, diabetes, and heart complications.



GENE DOPING: THE FUTURE OF ATHLETIC CHEATING?

1.4

In order to treat genetic diseases, researchers have developed techniques that modify genes in living human cells. Such techniques could also be used for gene doping, the modification of genes to enhance athletic performance. For example, a gene called myostatin turns off muscle growth in many animals. A naturally occurring mutation that deactivates myostatin is associated with increased muscle mass in some breeds of cattle. Could this mutation have a similar effect in humans? Doctors examined a child with unusually big muscles and found that he was born with a nonfunctioning myostatin gene. Other researchers manipulated mice to turn off the myostatin gene, causing significantly bigger muscles. Taken together, this research suggests that human gene doping may be possible. The process of science always includes outcomes, both good and bad; it is up to our society to decide what role, if any, gene doping should play in the future of athletic competition.



Comparing a control mouse (left) with an experimental mouse carrying a change in the myostatin gene (right)
Source: McPherron et al., *Nature,* v387 (1997).

This 7-month-old baby carries mutations that make him unusually muscular.

Source: Scheulke et al., *The New England Journal of Medicine*, v350:26 (2004).

CORE IDEA

The action of hormones and the process of cellular respiration play a role in athletic performance. Athletes can enhance performance by taking anabolic steroids, boosting endurance through doping, or by taking human growth hormone. Some of these methods are acceptable; others are considered cheating.

? How can eliminating a gene cause muscles to grow bigger?

ANSWER: The myostatin gene naturally turns off muscle growth; eliminating this gene can cause muscles to continue to grow.

Biodiversity hot spots offer challenges and rewards for conservation

Biodiversity hot spots are relatively small areas with unusually high concentrations of endangered species, threatened species, and **endemic species** (ones that are found nowhere else). Although such hot spots account for less than 1.5% of Earth's surface, they are home to over 30% of all species of plants and vertebrates. When we think of preserving species, we tend to focus on large organisms that we can see, but hot spots help maintain diversity of all forms of life, including fungi and microscopic life. Identifying, studying, and protecting these species-rich zones can have an outsized impact on the overall biodiversity of our planet at a relatively low cost.

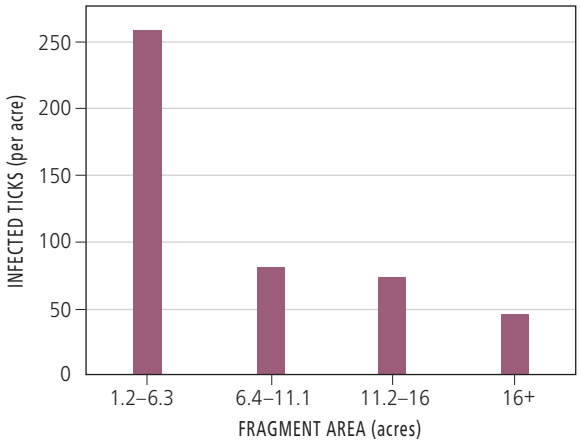
EARTH'S BIODIVERSITY HOT SPOTS

On this map, the green areas indicate hot spots.

10.1 Members of every major animal **phyla** can be found in coral reefs, such as this one in the Caribbean. If you look carefully, you can spot sponges, cnidarians (corals and anemones), and chordates (fishes).

BIODIVERSITY AND HUMAN HEALTH

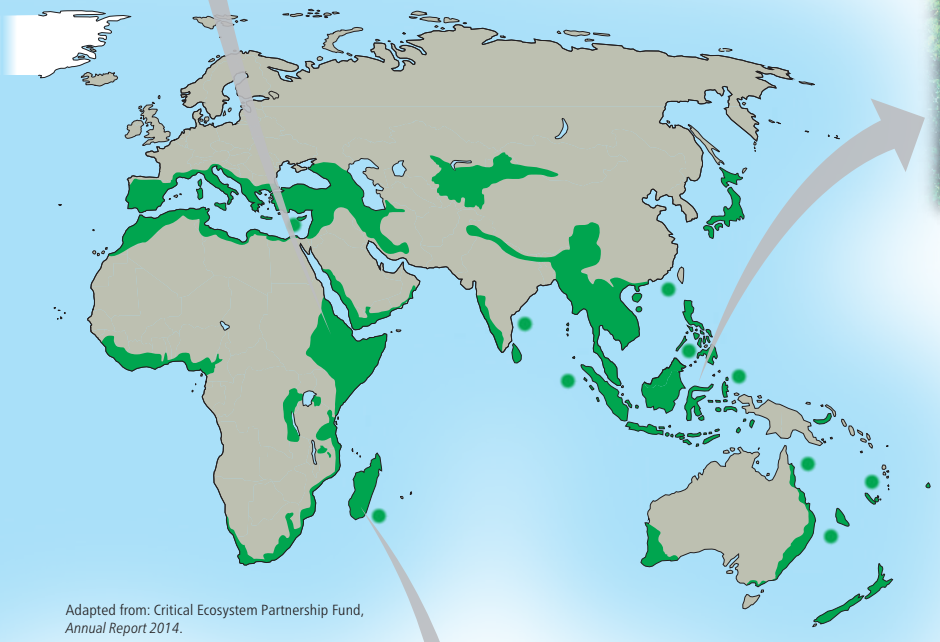
1.6 Human population growth threatens biodiversity when our living spaces subdivide large ecosystems into isolated fragments. The loss of biodiversity due to fragmentation can be seen in the northern forests of the United States. There, populations that thrive in small areas are exploding, while populations that require more living space are disappearing. A group of researchers studied the link between fragmentation and Lyme disease, a serious illness caused by bacteria that are carried by ticks. Many species of animals that thrive in fragmented areas are known to be carriers of the bacteria. The researchers studied 14 forest fragments of different sizes from an area in New York known to harbor Lyme disease. Researchers collected ticks from each fragment and tested them for the Lyme disease bacteria. As you can see in the graph, the smallest forest fragments had much higher densities of infected ticks, suggesting that habitat fragmentation may increase our exposure to Lyme disease. This study highlights the fact that biodiversity provides valuable services (both obvious and unseen) to our society.



Smaller forest fragments have a higher density of infected ticks.

Source: Allan, et al., *Conservation Biology*, v17:1 (2003).

12.12 When protecting biodiversity, the goal is not simply to preserve individual species but to sustain ecosystems, where natural selection can continue to act. Designated biodiversity hot spots can protect biomes, or specific habitats, such as the African **savanna**, where many species thrive.



Adapted from: Critical Ecosystem Partnership Fund, *Annual Report 2014.*

9.6 The warm, moist climate of tropical rain forests (such as this one in Indonesia) provides ideal growing conditions for three of the four major plant phyla: mosses, ferns, and angiosperms (flowering plants). In contrast, gymnosperms (cone-bearing plants) thrive in northern climates.

12.18 **Conservation biology** is an effort to investigate, halt, and eventually reverse the loss of biodiversity by sustaining natural ecosystems. Biodiversity hot spots provide an opportunity to protect many species in very limited areas, allowing conservationists to maximize the value of protected zones.

10.11 Although the exact number is a matter of debate, every one of the 100+ species of lemurs (a type of **primate**) is found in the wild only on Madagascar, a large island off the eastern coast of Africa. In fact, almost all of the mammals, reptiles, amphibians, and plants that inhabit Madagascar are endemic.

! The average height of adult lemurs (excluding the tail) ranges from 3.6 inches (Madame Berthe's mouse lemur) to 27 inches (the indri).

CORE IDEA

Biodiversity hot spots are relatively small areas that harbor an abundance of species. Protecting these areas can have an outsized impact on the health of our planet and our society.

? Why is the tick study characterized as an observational study rather than a controlled experiment?

ANSWER: The tick study is an observational study because it involves observing naturally occurring phenomena rather than purposefully manipulating test subjects.

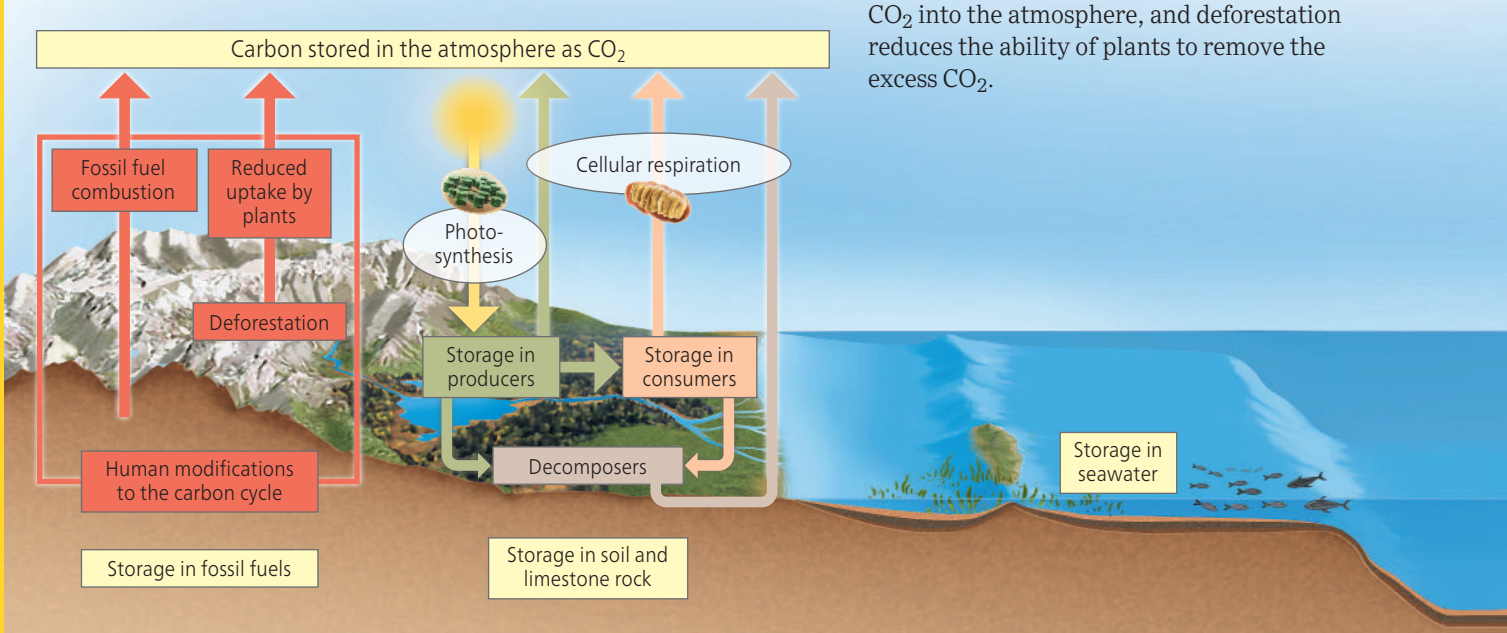
Rising levels of greenhouse gases are causing Earth's climate to change

Rising concentrations of carbon dioxide (CO_2) and other greenhouse gases in the atmosphere are changing global climate patterns. There is no debate among the vast majority of scientists: Global climate change is occurring. For example, the average temperature over the surface of the Earth has been rising since the late 1800s—including a rise of about 1°F in the past 30 years—a trend called **global warming**. Other effects include changes in rainfall patterns and the distribution of plants and animals. These changes affect all life on Earth, including our human society.

4.2 Plants and other producers take up CO_2 during photosynthesis. Both producers and consumers (such as animals) return CO_2 to the atmosphere during cellular respiration.

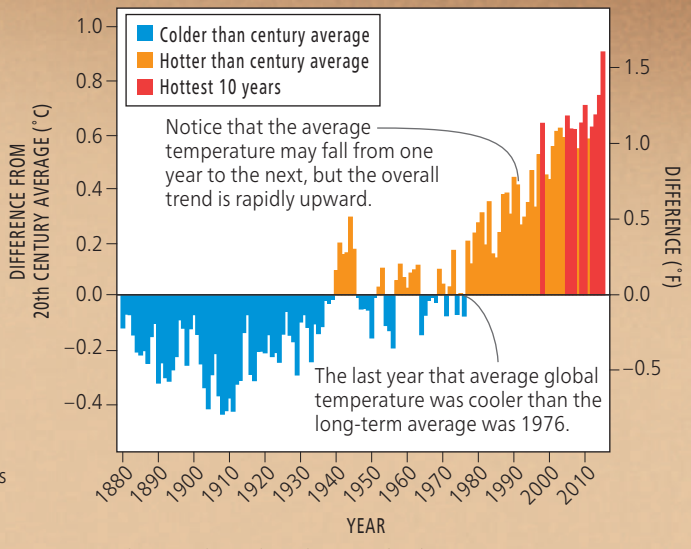
THE CARBON CYCLE

12.15 Carbon moves through the environment, cycling from living to non-living components. The oceans are Earth's primary reservoir of CO_2, followed by the atmosphere. The balance of CO_2 uptake and release is affected by human activities: Burning fossil fuels releases much CO_2 into the atmosphere, and deforestation reduces the ability of plants to remove the excess CO_2.



GLOBAL WARMING

12.19 The most obvious effect of increasing greenhouse gases is a steady increase in the average global temperature. The largest increases are in the northernmost regions of the Northern Hemisphere. In parts of Alaska and Canada, the average winter temperature has risen 3.4°C (more than 6°F) since 1961.



The temperature of the Earth's surface was measured at thousands of weather stations throughout the planet. These measurements were combined into an average annual global temperature for each year. This graph shows the difference between the annual average temperature compared to the average for the whole 20th century. Blue bars represent years that were colder than average; orange bars warmer; red bars represent the 10 warmest years ever measured.

Source: National Oceanic and Atmospheric Administration (2016).

EFFECTS OF GLOBAL CLIMATE CHANGE

Global climate change results in new patterns of temperature and rainfall. This is having a significant effect on the distribution of life. Melting permafrost is causing the boundary of tundra biomes to shift northward. Additionally, the borders of some deserts are expanding. Such changes affect food production and the availability of fresh drinking water. Make no mistake about it: We humans are susceptible to the effects of a changing climate.

! Due to warming temperatures, Montana's Glacier National Park has 27 glaciers today versus 150 in 1910.

HABITAT CHANGE

With rising temperatures, the ranges of many species are shifting toward the poles or to higher elevations. Ecologists have identified dozens of species of birds and butterflies that have migrated north or to higher altitudes in the last few decades.

FIRES

Earlier melting of snow has extended the dry season in much of western North America, creating conditions that promote widespread, devastating wildfires.

CORAL BLEACHING

Warming oceans cause coral to lose their symbiotic algae. When the algae are removed, the coral turns white, a phenomenon called coral bleaching. Coral cannot survive long this way, threatening entire reef ecosystems.

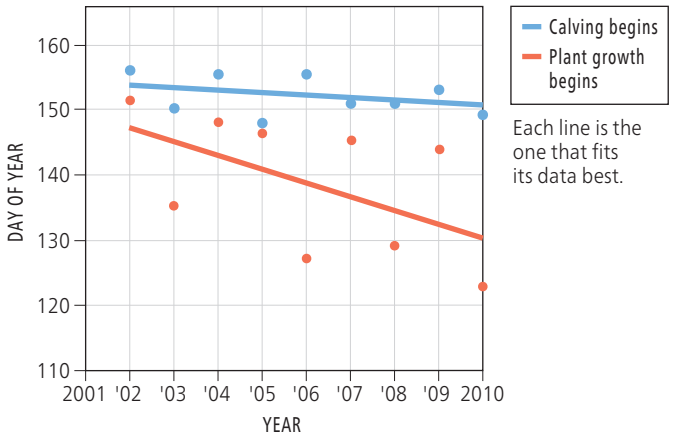
POLAR CLIMATES

As the globe warms, the ice-covered hunting grounds of the far northern Arctic polar bears (*Ursus maritimus*) are melting away. Similarly, the disappearance of southern sea ice is blamed for decreases in the populations of Antarctic penguins.

HOW ONE POPULATION IS RESPONDING TO CLIMATE CHANGE

1.7

As the global climate changes, some species have adjusted when they reproduce or migrate. But other species have not, causing their populations to face food shortages and declining numbers. In one example, researchers documented a link between rising temperatures and declining populations of caribou in the Arctic. The caribou largely depend on a flowering plant called alpine chickweed, which emerges during the rising temperatures of early spring. Over a 10-year period, global warming caused the chickweed to emerge about 18 days earlier. However, the timing of caribou births remained steady. As a result, the chickweed is less available by the time the baby caribou are ready to graze. This food shortage caused a significant drop in birth rates. This study shows how, in a relatively short span of time, global climate change can significantly affect a population.



Each line is the one that fits its data best.

Source: Post, E., *Ecology of Climate Change—The Importance of Biotic Interactions*, Princeton University Press: Princeton, NJ (2013).

CORE IDEA

Increasing concentrations of greenhouse gases in the atmosphere are causing rising temperatures and other changes. Global climate change has many far-reaching effects on ecosystems and the life within them, including human life.

? True or false: According to the graph on the left page, every year since 1990 has been hotter than the last.

ANSWER: False. Temperatures go up or down from one year to the next, but the overall trend is clearly upward.

All living organisms share certain properties

Biology is the scientific study of life. While the definition of biology is very straightforward, it does raise some important questions. Perhaps the most obvious is: What is life? How do we distinguish living organisms from nonliving matter? How do we know that an elephant is alive, but a boulder is not? The phenomenon of life defies a simple, one-sentence definition. That is, we recognize **life** by what living things do. Here, we highlight some of the properties and processes we associate with life. An object is alive if and only if it displays all of them simultaneously.

THE PROPERTIES OF LIFE

ORDER
Each living thing has complex but highly ordered structures, such as this elephant's eye.

ENERGY AND MATTER PROCESSING
Every organism takes in energy and matter, converts them to useful forms, and eventually expels energy and excess matter. This elephant is eating plant matter from which it extracts energy. This energy is used to move. Excess matter is released as waste back into the environment and energy is expelled in the form of heat.

REPRODUCTION
Like begets like; all organisms reproduce their own kind. Thus, elephants reproduce only elephants—never zebras or lions.

GROWTH AND DEVELOPMENT
Inherited information carried by genes controls the pattern of growth and development in all organisms. For example, all African elephants grow tusks as they age.

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ARE VIRUSES ALIVE?

Is a virus a living organism or is it nonliving matter? Viruses do display some of life's properties—each has a highly ordered structure, for example. Although viruses can infect a wide variety of organisms, they cannot reproduce or carry out many other of life's processes outside of a host cell. The idea is not settled, but many biologists agree that viruses are not alive, existing in a state between living organisms and nonliving chemicals.

RESPONSE TO THE ENVIRONMENT

All organisms respond to changes in the environment. Many of these responses help to keep an organism's internal environment within narrow limits even when the external environment changes a lot. This elephant is responding to the heat of the day by taking a bath, which helps keep its body temperature steady.

! The rover *Opportunity* is currently searching Mars for these same properties of life.

EVOLUTIONARY ADAPTATIONS

The broad thin ears of this elephant dissipate heat during hot African days. Such evolutionary adaptations evolve over countless generations by the reproductive success of those individuals with heritable traits that are best suited to their environments.

CORE IDEA

Biology is the scientific study of life. All living things display a shared set of properties. Nonliving matter never displays all of these properties of life simultaneously.

? Which properties of life does a car display? Which does it not?

ANSWER: A car processes energy and matter, is ordered, and responds to the environment. A car does not reproduce, grow, or develop, and a car does not display evolutionary adaptations shaped by the environment.

1.2

Life can be studied at many levels

The study of life encompasses a very broad range of scales, from the microscopic world of cells to the vast scope of Earth's ecosystems. This figure summarizes some of the levels at which biologists study life on Earth, starting at the upper end of the scale.

THE LEVELS OF BIOLOGICAL ORGANIZATION

BIOSPHERE
The **biosphere** consists of all life on Earth and all of the environments that support life, from the deepest oceans to high in the atmosphere.

ECOSYSTEM
An **ecosystem** includes all the living organisms in one particular area (such as this African savannah) as well as the nonliving components that affect life, such as soil, air, and sunlight.

COMMUNITY
A **community** consists of all the interacting populations of organisms occupying an ecosystem. This community includes plants, animals, and even microscopic organisms.

POPULATION
A **population** is a group of interacting individuals of one species living within a particular area, such as the African savannah elephants shown here.

ORGANISM
An **organism** is an individual living being, such as one African savannah elephant (*Loxodonta africana*).

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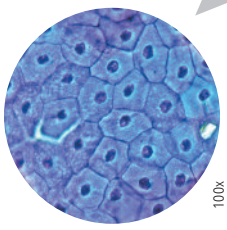
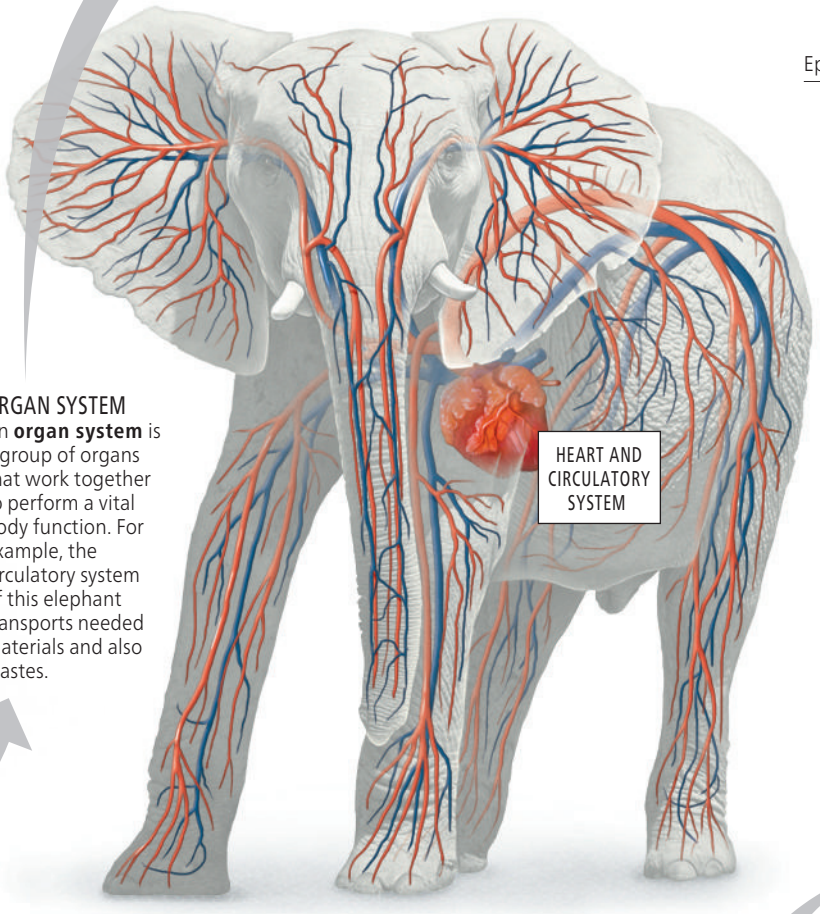
! An adult elephant's heart can weigh over 40 pounds.

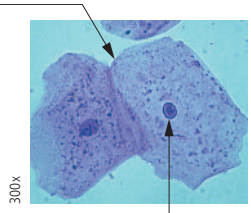
ORGAN
An **organ** consists of multiple tissues that cooperate to perform a specific task. The elephant's heart, for example, pumps blood through the circulatory system.



TISSUE
A **tissue** is an integrated group of similar cells that work together to perform a specific function. This microscopic image shows a section of cardiac epithelial tissue, which lines the heart, allowing blood to flow freely over the surface.

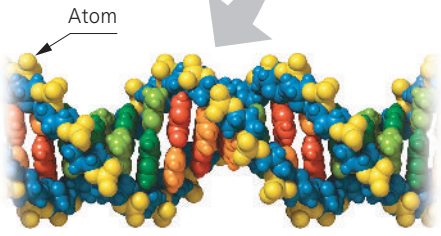


ORGAN SYSTEM
An **organ system** is a group of organs that work together to perform a vital body function. For example, the circulatory system of this elephant transports needed materials and also wastes.

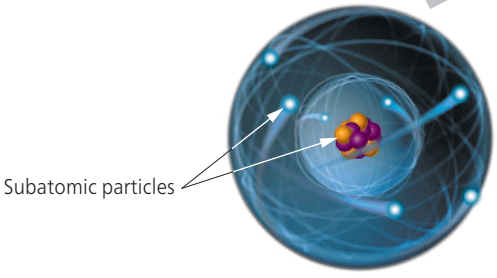


CELL
All living organisms consist of **cells**, the fundamental unit of life. Nothing smaller than a cell is capable of having all of life's properties. Some organisms (such as a bacterium) have just one cell; others (like an elephant) have trillions.

ORGANELLE
An **organelle** is a component of the cell that performs a specific function. An epithelial cell's nucleus, for example, houses the DNA.



MOLECULE
A **molecule** is a group of atoms bonded together. Here, you see a computer-generated image of DNA, a molecule essential to all life on Earth. In this image, each atom is represented as a ball.



ATOM
An **atom** is the fundamental unit of matter; it is the smallest unit of an element capable of displaying the properties of that element. Atoms themselves are made up of even smaller units called subatomic particles.

CORE IDEA

Life can be studied on a hierarchy of levels from the very large (such as whole ecosystems) to the very small (such as individual molecules). Biologists study life at all of these levels.

? Which level of life's organization is the smallest one that can be considered alive?

ANSWER: The cell is the smallest unit that is capable of displaying all of life's properties.