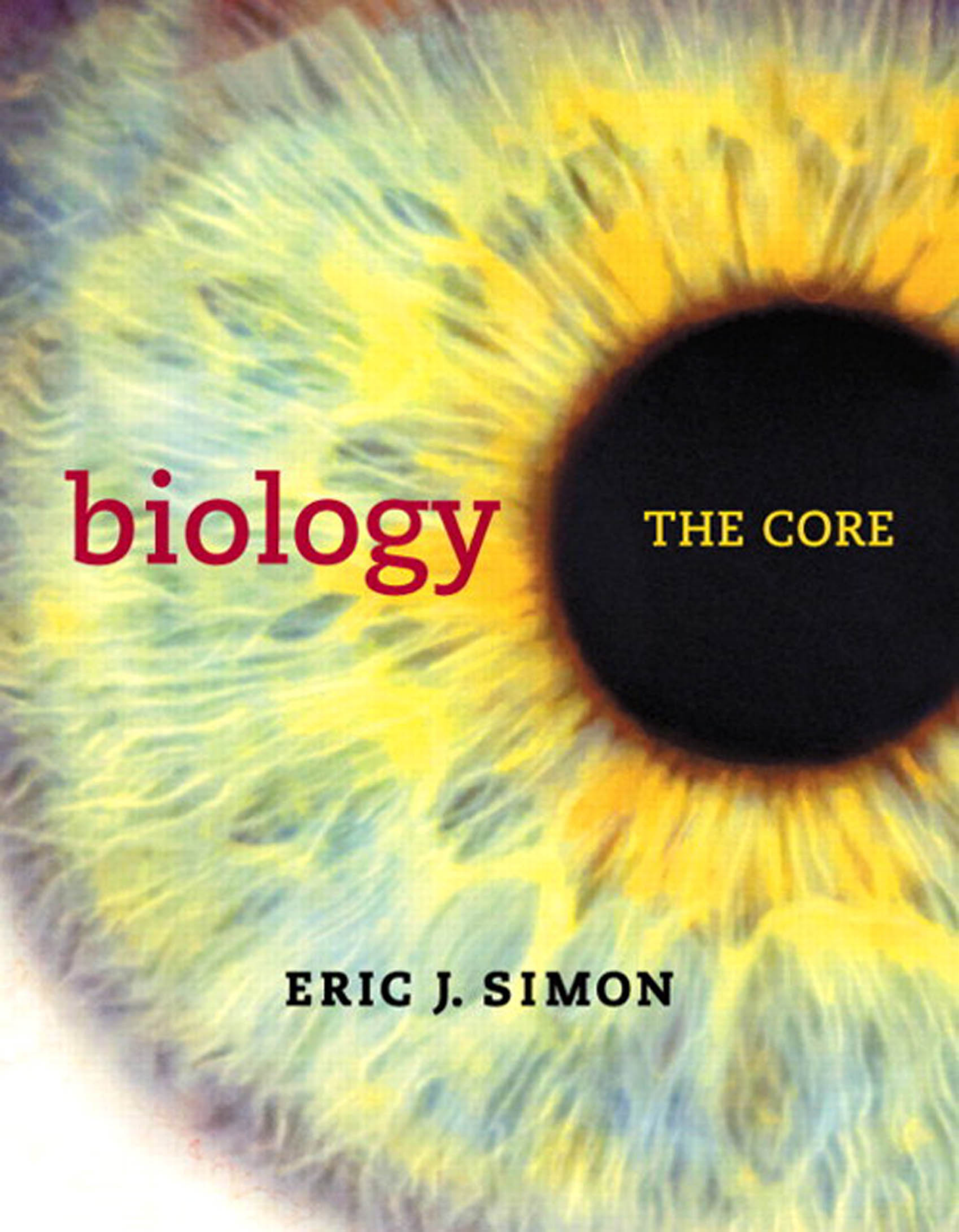
biology
THE CORE

ERIC J. SIMON



BRIEF CONTENTS

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ERIC J. SIMON
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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 to science majors and non-science majors, as well as upper-level courses in tropical marine biology and careers in science. 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 teaching and learning in the science classroom, particularly for non-science majors. He lives in rural New Hampshire with his wife, two boys, two Cavalier King Charles Spaniels, a few dozen chickens, a dwarf hamster, and a leopard gecko. Dr. Simon is the lead author of the introductory non-majors biology textbooks *Campbell Essential Biology* (5th ed.) and *Campbell Essential Biology with Physiology* (4th ed.), and a co-author of the introductory biology textbook *Campbell Biology: Concepts and Connections* (8th ed.), all published by Pearson Benjamin Cummings.

"I dedicate this book to those who form the core of my life: Amanda, a partner of unwavering patience and kindness, and my boys Reed and Forest."

Preface

To the Student,

Being a college student today means juggling many priorities: work, school, extracurricular activities, family. I imagine that, if you're reading this book, you are enrolled in your first college science course, and it may be the only one you'll ever take. When it seems like there are so many priorities all competing for your attention, you may be unsure about how to fit studying biology into your busy life. Good news: This book is written specifically for you!

Over the years, I've observed my own students strive to succeed in their biology course in as efficient a manner as possible. *Biology: The Core* has been designed from the ground up to help you study effectively and succeed. Only the most important and relevant information—the core of biology content—is included. Biological concepts are displayed in highly visual and approachable two-page modules that guide you along a clear learning path, allowing your study time to be as efficient and effective as possible.

You might also be wondering how this course—and biology generally—applies to your own life. Luckily, this is easy to address, since issues like nutrition, cancer, reproductive health, and exercise physiology directly affect you and those you love. *The Core* is paired with a robust online library, *MasteringBiology*, that contains videos, 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.

I hope that *Biology: The Core* meshes with your goals and your priorities, acting as a helpful guide for this course and addressing questions you run into in your broader life. Please feel free to drop me a line to tell me about your experience with *Biology: The Core* or to provide feedback 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 all 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, why write a new one? The answer is simple: 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 graduation—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 new 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 narrative and art into a single teaching tool. Each module is complete with a topic statement, introductory paragraph, all text and graphics needed to explain the topic, a summary, and a self-quiz. In addition to a consistent pedagogical structure, each module is designed to stand on its own. Modules can be read in any order, allowing you the flexibility to assign topics in whatever sequence best suits your course.

The printed text is paired with *MasteringBiology,* 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 *MasteringBiology* also offer you the flexibility to incorporate a wide variety of applications and current issues 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 from ABC News and the BBC, *New York Times* articles, and interactive tutorials—enables you to connect the core content to interesting, relevant, and timely applications and issues that are important to you and your students.

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 drop me a line to tell 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.
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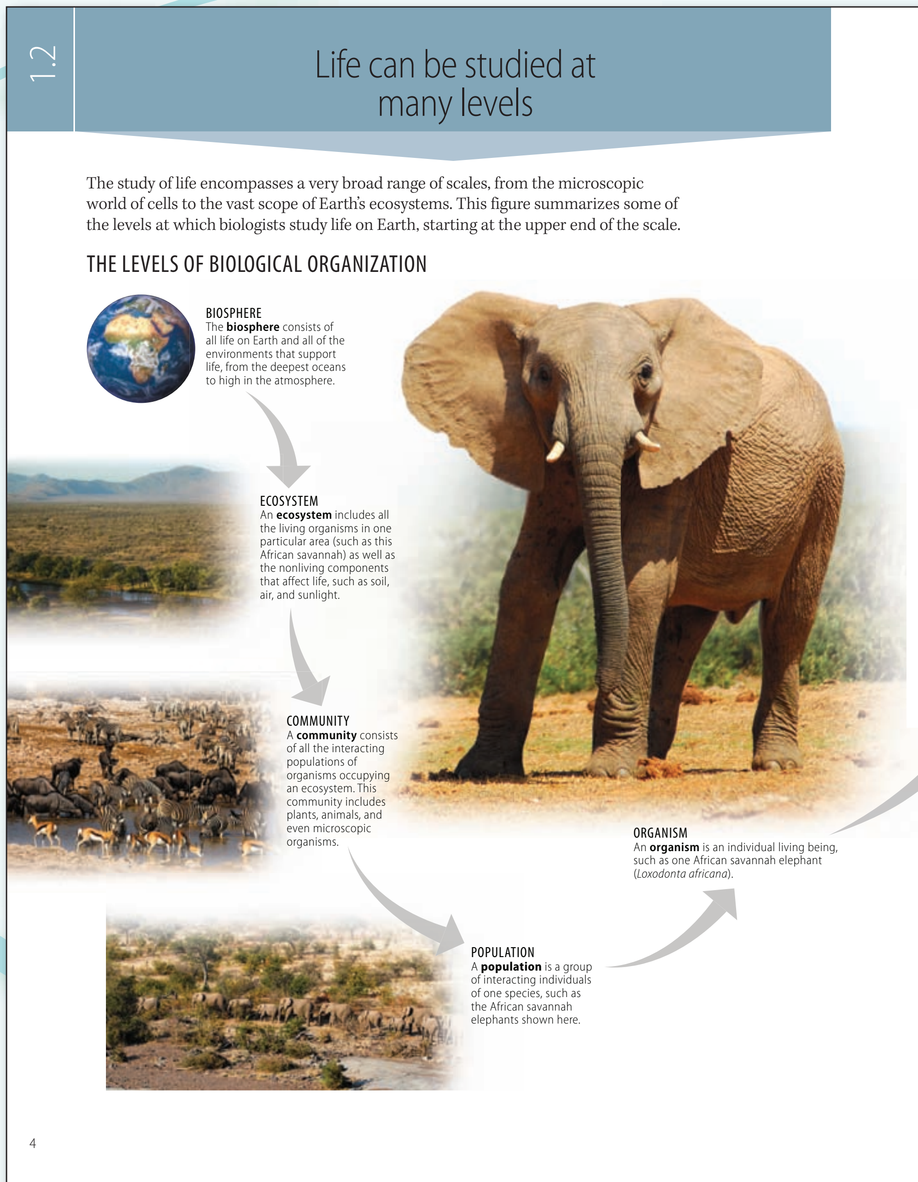
A New Biology Learning Program Built for Today's Students



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, 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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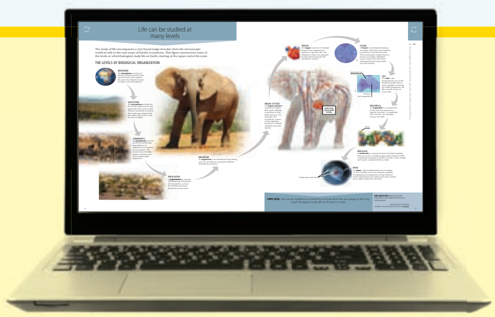
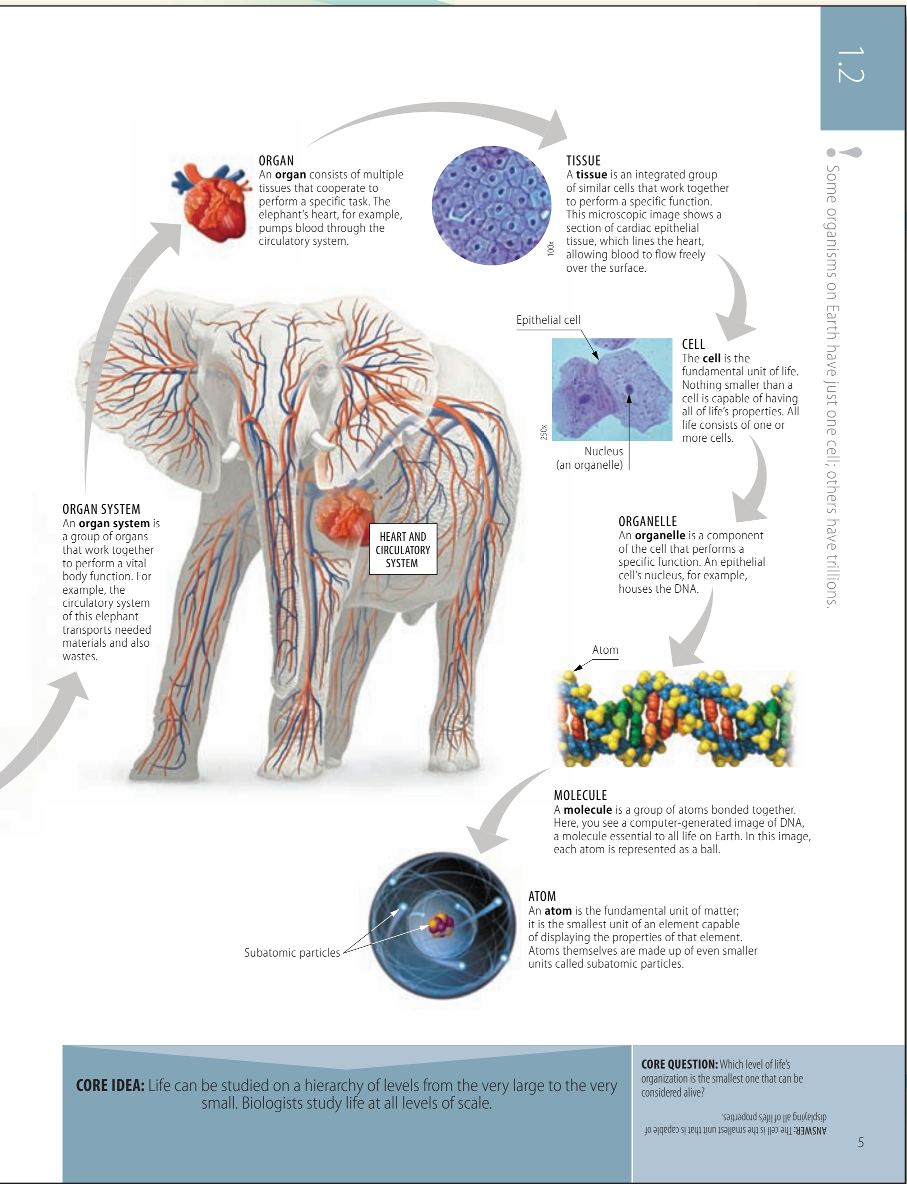
*A brief textbook focused on only the **core** content that students need to learn for a non-majors course.*

MasteringBiology®

is an online homework and tutoring system that delivers self-paced activities designed to help students arrive to class prepared. Instructors can efficiently maximize class time with easy-to-assign and automatically graded assessments.



A Modern Teaching Program Supports Innovation and Active Learning



A modular format and dynamic set of applications give instructors flexibility in teaching the course.

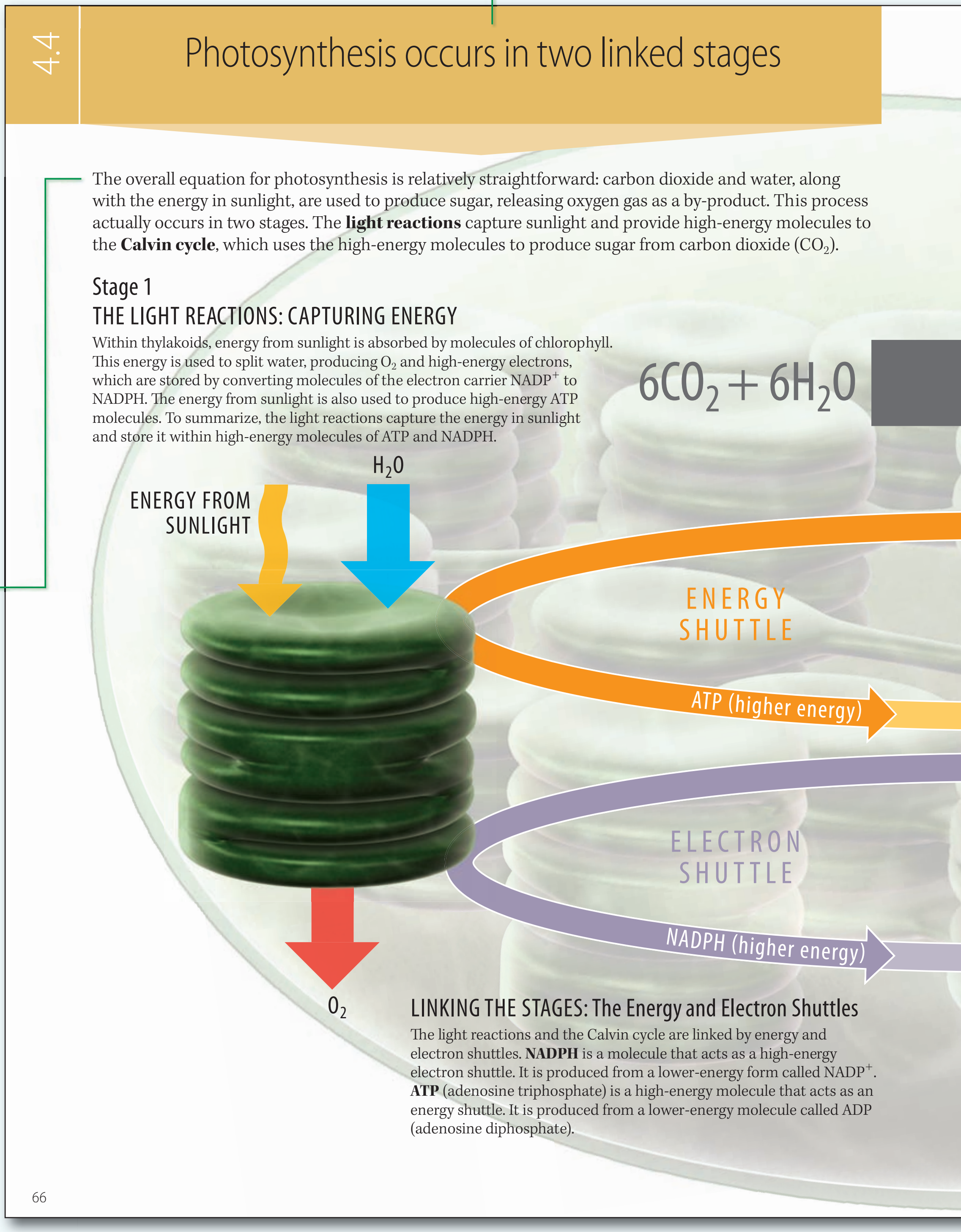
MasteringBiology® offers:

- **Interactive online activities** to help students apply and relate biological concepts to real life.
- **Unique teaching materials and resources** to assist instructors in preparing an innovative and effective course.

See the Big Picture

Biology: The Core is designed to help you efficiently learn the material and see the big picture. Begin studying each **concise module** by reading the **concept statement** which summarizes the key biological concept presented below.

▶ Next, the **narrative** introduces you to the key concept. The prose in each module is brief and works together with the illustrations to convey only the most core information so you never get lost in a sea of details.



4.4 Photosynthesis occurs in two linked stages

The overall equation for photosynthesis is relatively straightforward: carbon dioxide and water, along with the energy in sunlight, are used to produce sugar, releasing oxygen gas as a by-product. This process actually occurs in two stages. The **light reactions** capture sunlight and provide high-energy molecules to the **Calvin cycle**, which uses the high-energy molecules to produce sugar from carbon dioxide (CO_2).

Stage 1

THE LIGHT REACTIONS: CAPTURING ENERGY

Within thylakoids, energy from sunlight is absorbed by molecules of chlorophyll. This energy is used to split water, producing O_2 and high-energy electrons, which are stored by converting molecules of the electron carrier $NADP^+$ to NADPH. The energy from sunlight is also used to produce high-energy ATP molecules. To summarize, the light reactions capture the energy in sunlight and store it within high-energy molecules of ATP and NADPH.

LINKING THE STAGES: The Energy and Electron Shuttles

The light reactions and the Calvin cycle are linked by energy and electron shuttles. **NADPH** is a molecule that acts as a high-energy electron shuttle. It is produced from a lower-energy form called $NADP^+$. **ATP** (adenosine triphosphate) is a high-energy molecule that acts as an energy shuttle. It is produced from a lower-energy molecule called ADP (adenosine diphosphate).

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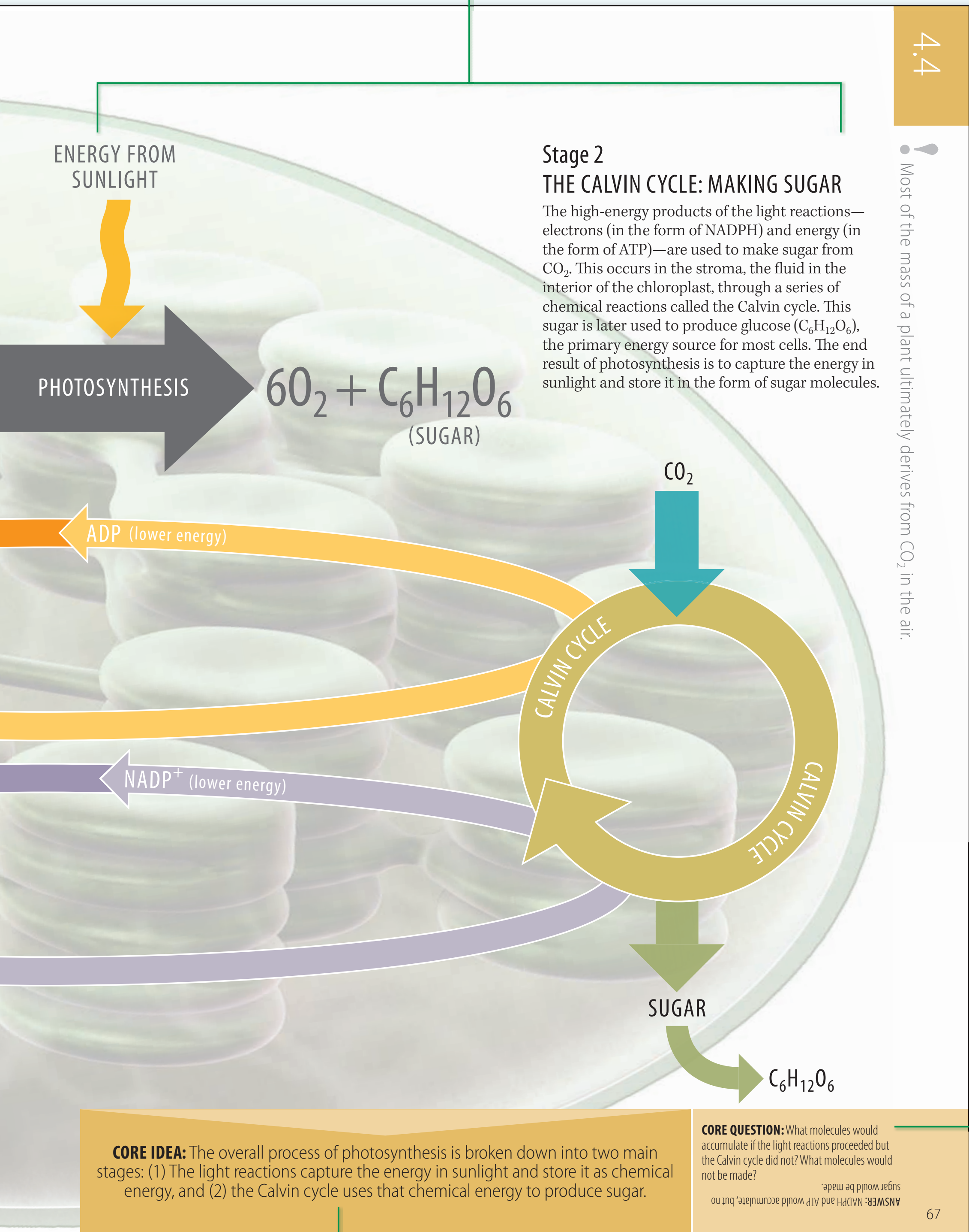
▼ Then, read through each module looking at both the text and the illustrations. **Figures and narrative work together** to convey concepts and help you understand the material. Everything you need to study a core concept is at your fingertips.

MasteringBiology®

Guided Video Tours walk you through key concepts in each module and let you check your understanding of the core ideas.

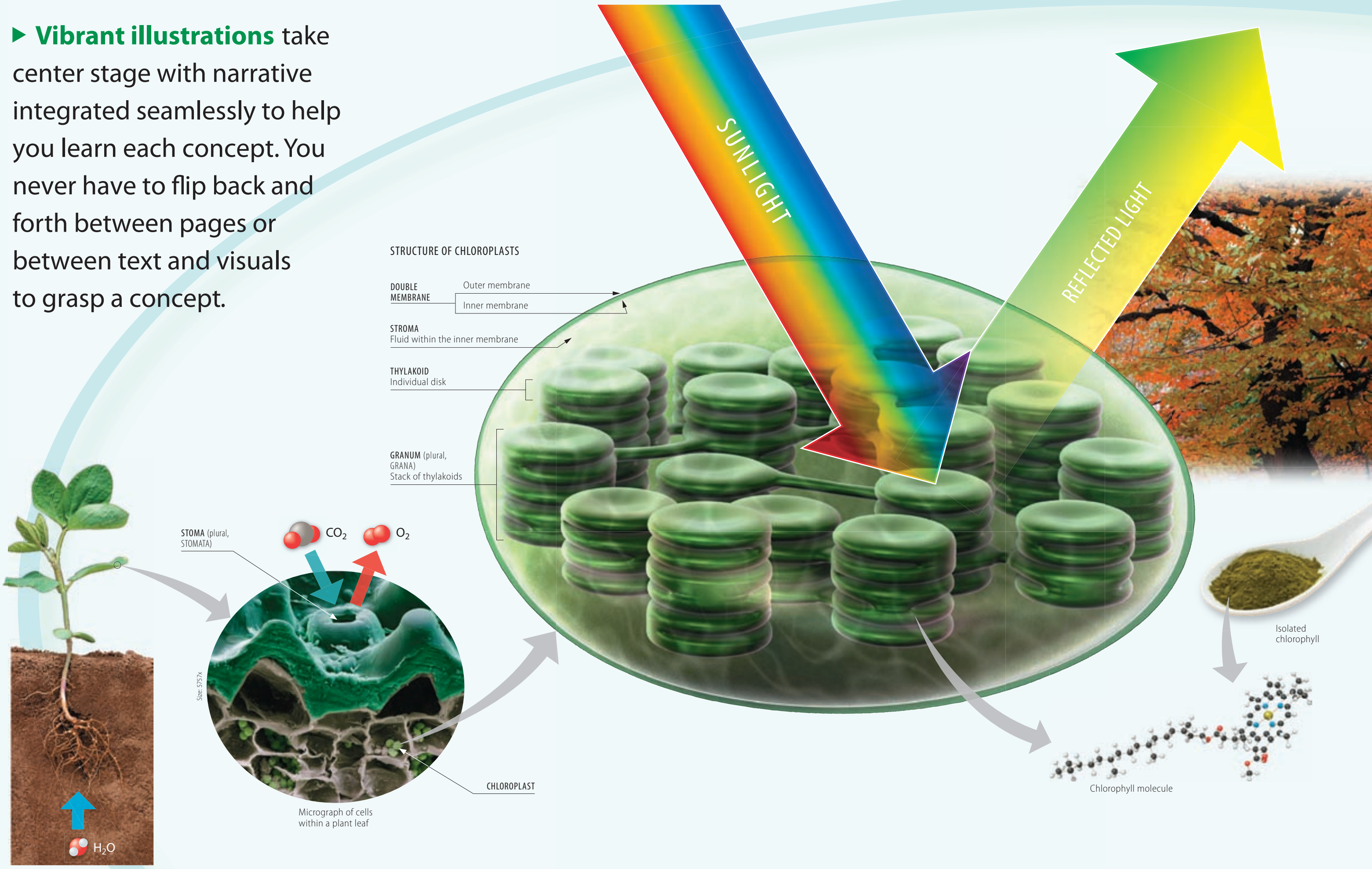


◀ After you have studied the entire module, the **Core Questions** allow you to apply your knowledge and check your understanding of the concepts.

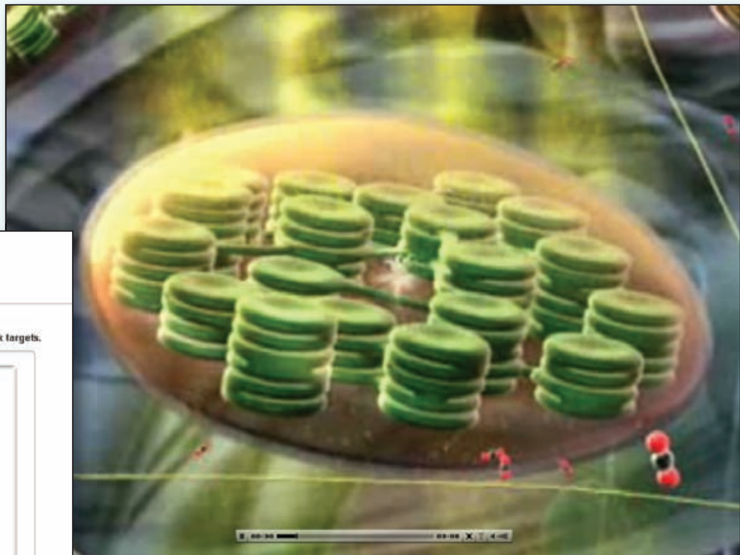
▲ Review the **core idea** with a summary of the module to reinforce what you just learned.

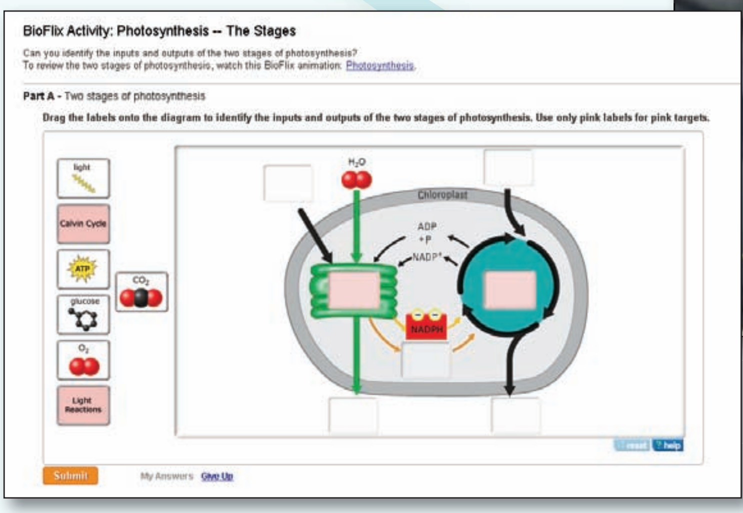
Dynamic Visuals Explain Each Concept

▶ **Vibrant illustrations** take center stage with narrative integrated seamlessly to help you learn each concept. You never have to flip back and forth between pages or between text and visuals to grasp a concept.



▶ **BioFlix Animations** are 3-D animations that help you visualize and learn the toughest topics in biology. Interactive activities provide coaching and feedback.




BioFlix Activity: Photosynthesis -- The Stages

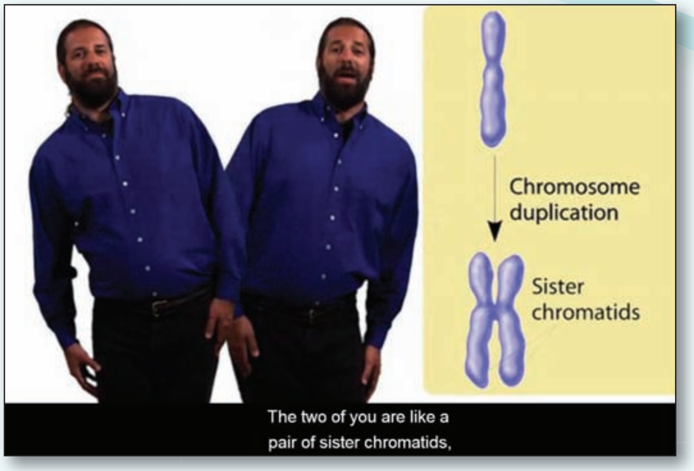
Can you identify the inputs and outputs of the two stages of photosynthesis?
To review the two stages of photosynthesis, watch this BioFlix animation: Photosynthesis.

Part A - Two stages of photosynthesis

Drag the labels onto the diagram to identify the inputs and outputs of the two stages of photosynthesis. Use only pink labels for pink targets.

MasteringBiology® Brings Concepts to Life

MasteringBiology® is designed to help you practice the course concepts and apply them to current topics. Interactive activities and individualized coaching help you arrive to class prepared and offer study tools for you to use wherever you are!

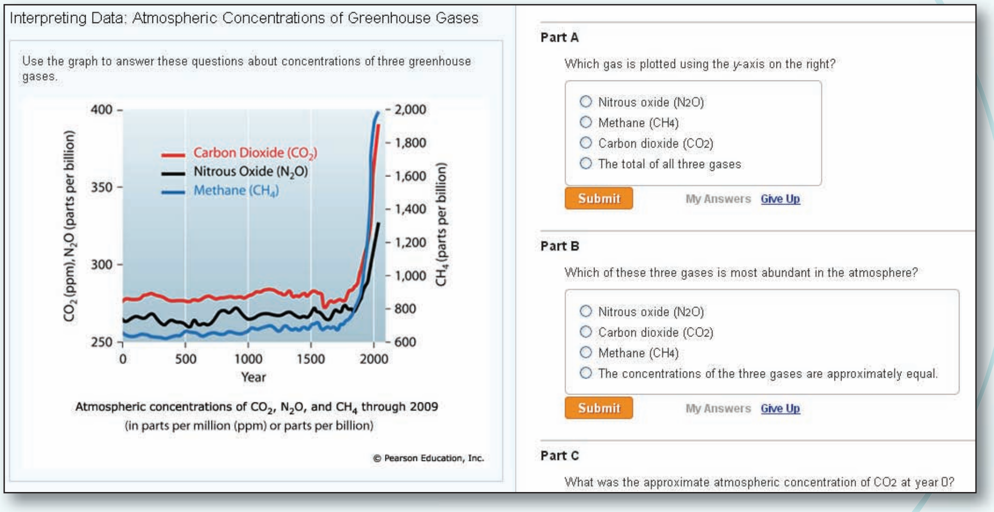


◀ **Video Tutor Sessions and MP3 Tutor Sessions.** Get help with key concepts with on-the-go tutorials hosted by author Eric Simon. Each video or audio session will help you build on the basic knowledge presented in your textbook.

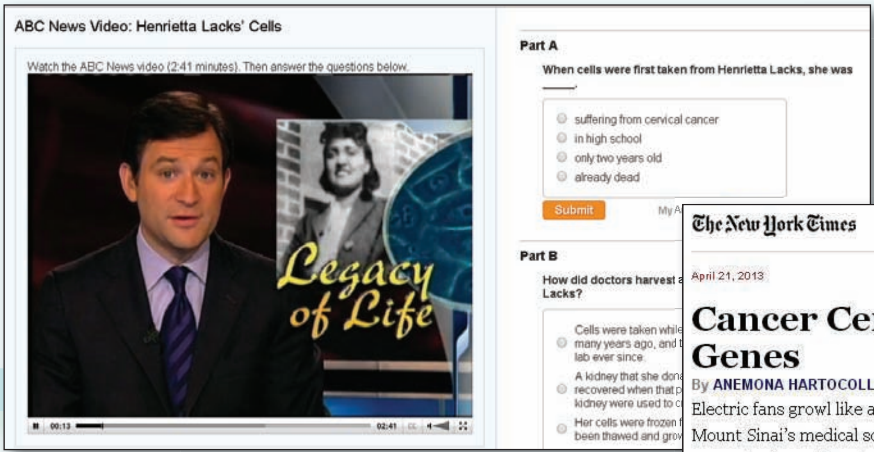
Eric Simon's Video Tutor Sessions include:

- DNA Profiling
- DNA Structure
- Mitosis vs. Meiosis
- Phylogenetic Trees
- Sex-Linked Pedigrees
- Survey of Biodiversity

▶ **Interpreting Data and You Decide activities.** Receive coaching on how to analyze data and graphs, and learn how you can use data to make informed decisions in everyday life.



◀ **ABC News videos** and **current events** from the ***New York Times*** cover a wide range of biological topics to show you how science connects to your everyday life.




The New York Times

April 21, 2013

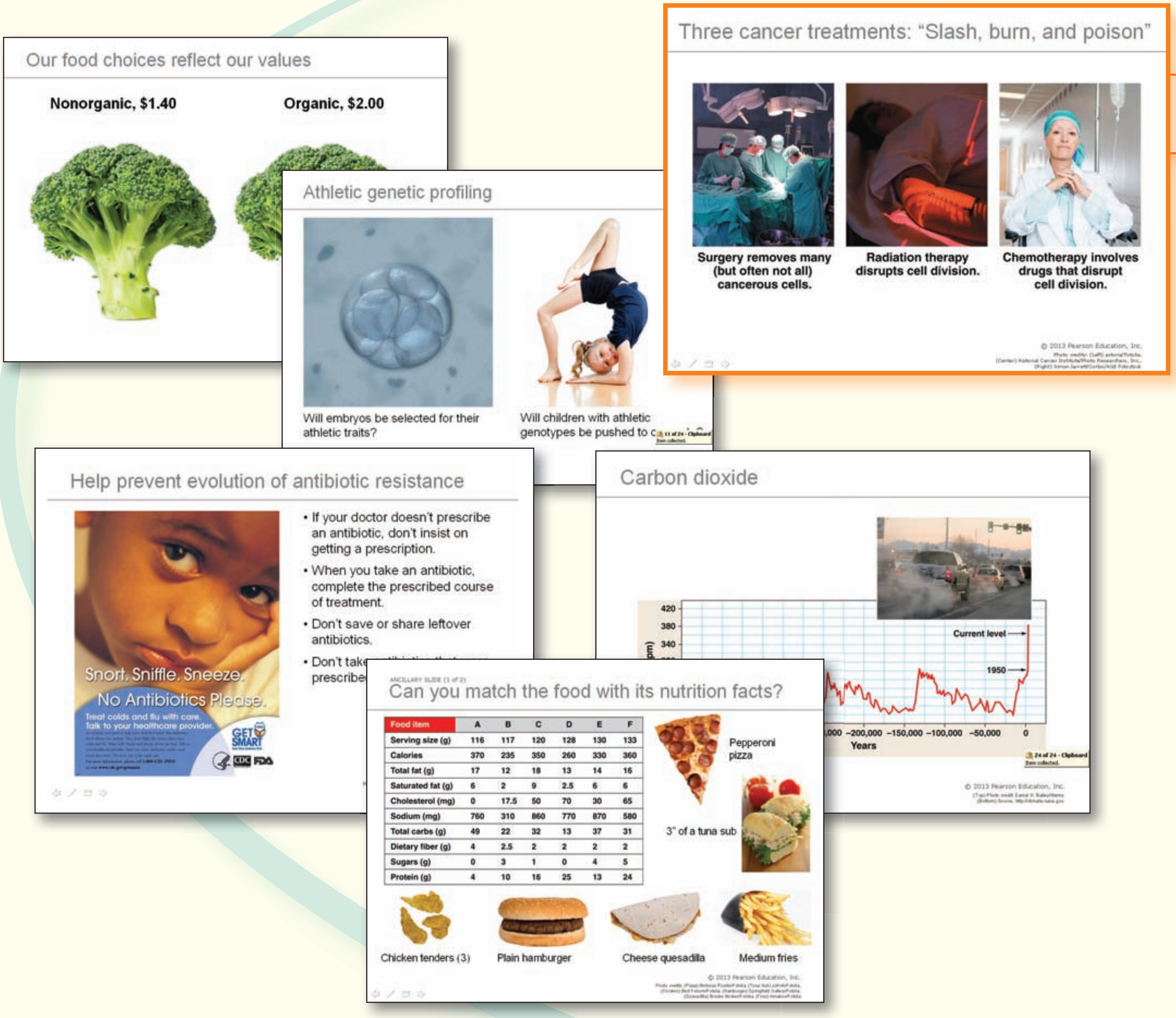
Cancer Centers Racing to Map Patients' Genes

By ANEMONA HARTOCOLLIS

Electric fans growl like airplanes taking off and banks of green lights wink in a basement at Mount Sinai's medical school, where a new $3 million supercomputer makes quick work of huge amounts of genetic and other biological information.

Teach the Course Your Way

Flexible and innovative instructor resources make it easy to prepare engaging classes that hook students into learning about biology-related topics such as agriculture, athletic cheating, cancer, food & nutrition, global climate change, evolution, and more.

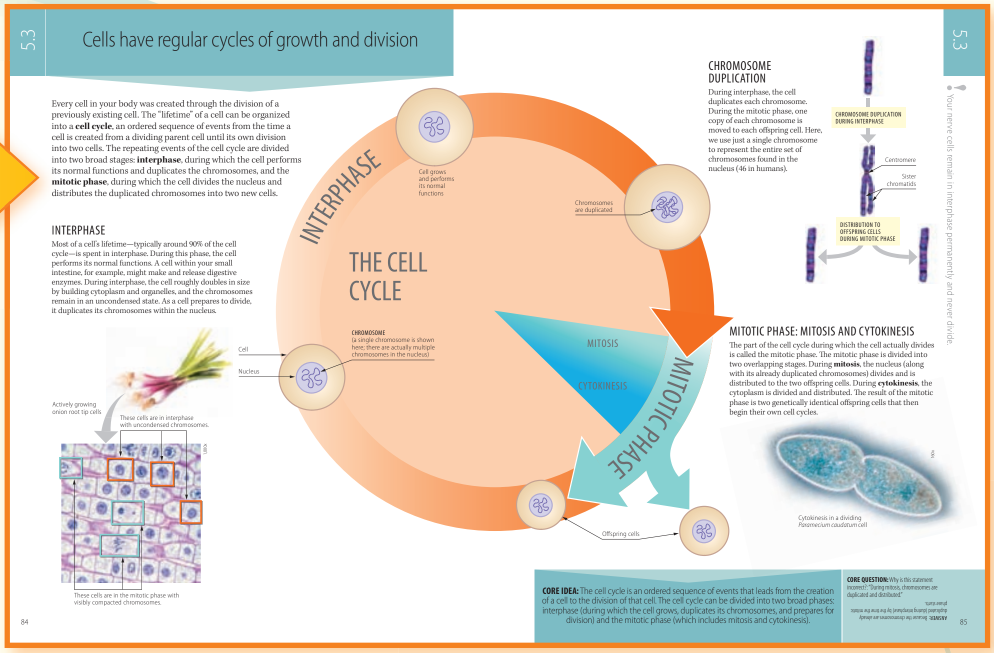


▶ Design high interest lectures and save time. Each application is assembled into a **learning unit** to support instructors with a detailed **topic guide** developed by author Eric Simon, along with a customizable **PowerPoint Lecture Presentation** and a related **MasteringBiology® Current Topic pre-built assignment**.

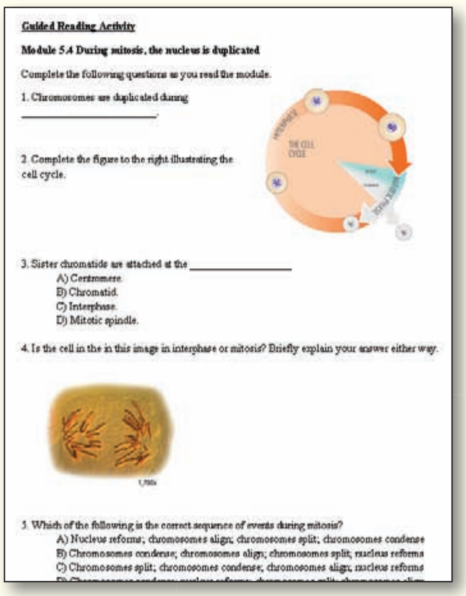
▶ Share ideas for easy to use in-class activities with **The Instructor Exchange**. This resource offers active lecture options for classes of any size and can be accessed through MasteringBiology®.

Flexible Resources Support Your Course Goals

Assign just the right amount of content with self-contained modules that cover only the core concepts you need to support your course syllabus and teaching goals.

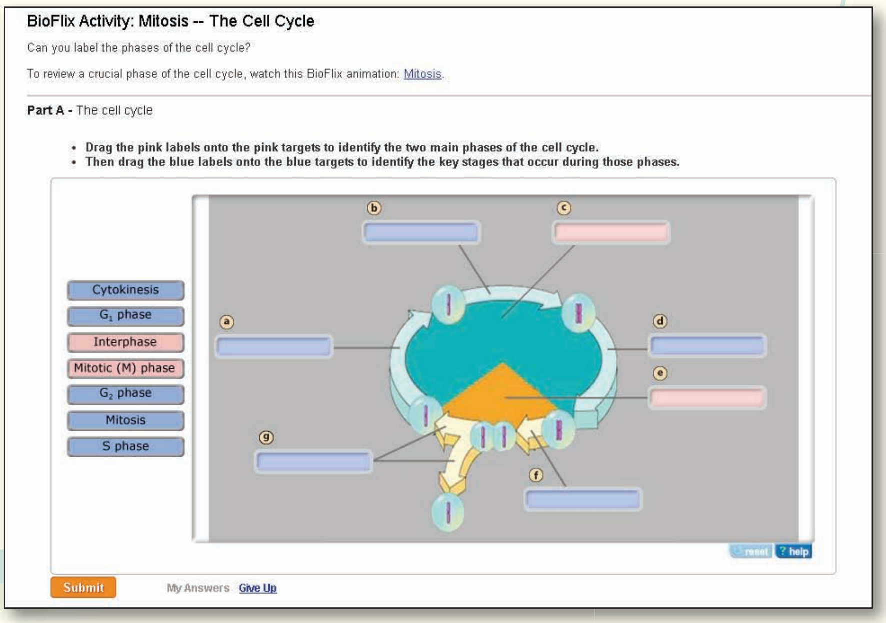


▶ Jump between topics with ease. **The modular organization** of the textbook gives you the freedom to teach concepts in your preferred order throughout the course and helps your students maximize their study time with modules that cover just what they need to know.



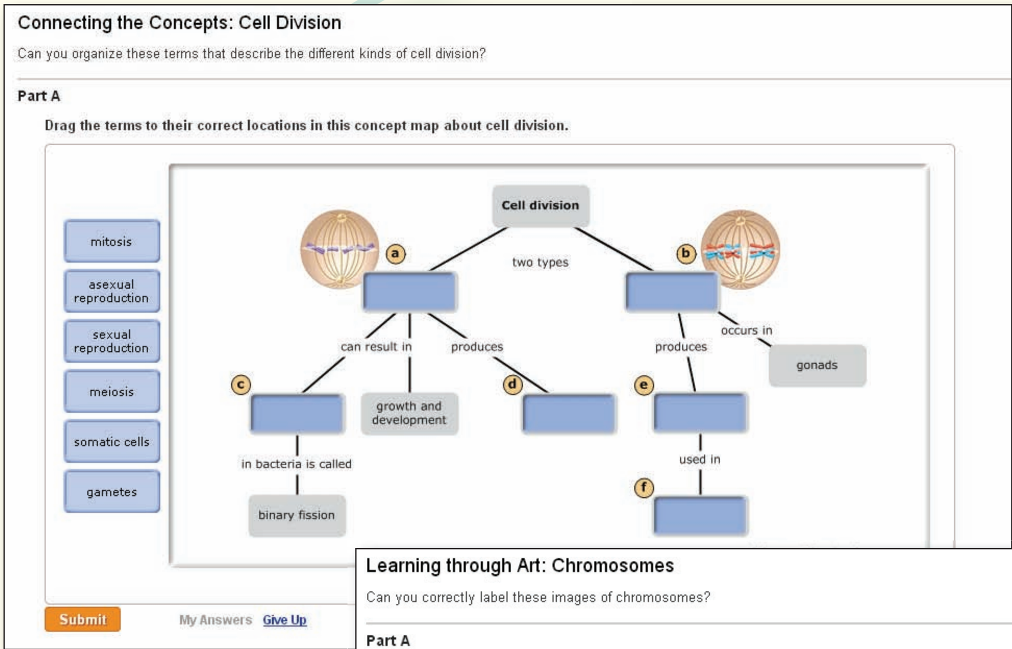
▲ Encourage Active Reading with **Guided reading activities** to help students navigate the text and allow them to practice their understanding of every module.

▼ Ensure your students arrive to class prepared. Assign automatically graded activities, animations, and reading quizzes in **MasteringBiology®** to encourage students to practice basic biological concepts outside of class.

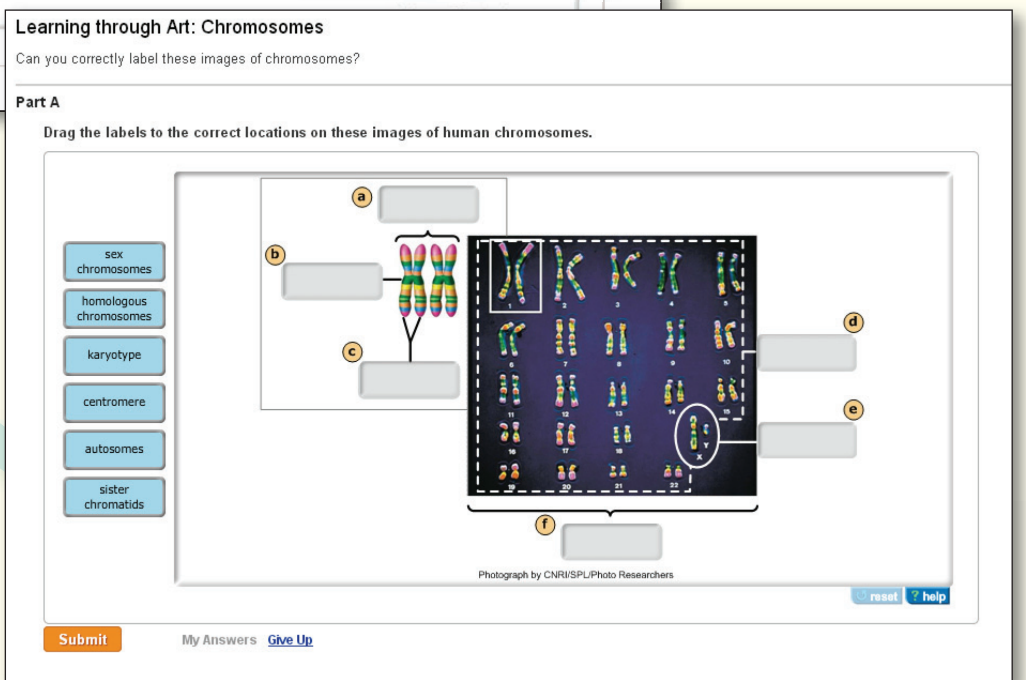


Evaluate Student Understanding and Boost Success

Help students practice foundational biology principles outside of class and ensure they arrive to lecture prepared. MasteringBiology® activities allow students to assess their understanding and receive personalized feedback designed to help them grasp key concepts.



◀ Challenge students to see how core concepts work together by assigning **Connecting the Concepts Activities**.



▶ Assign activities that reinforce the text's **visual approach** to learning core biology concepts.

▼ Provide students with **personalized wrong-answer feedback** by assigning coaching activities in MasteringBiology®.

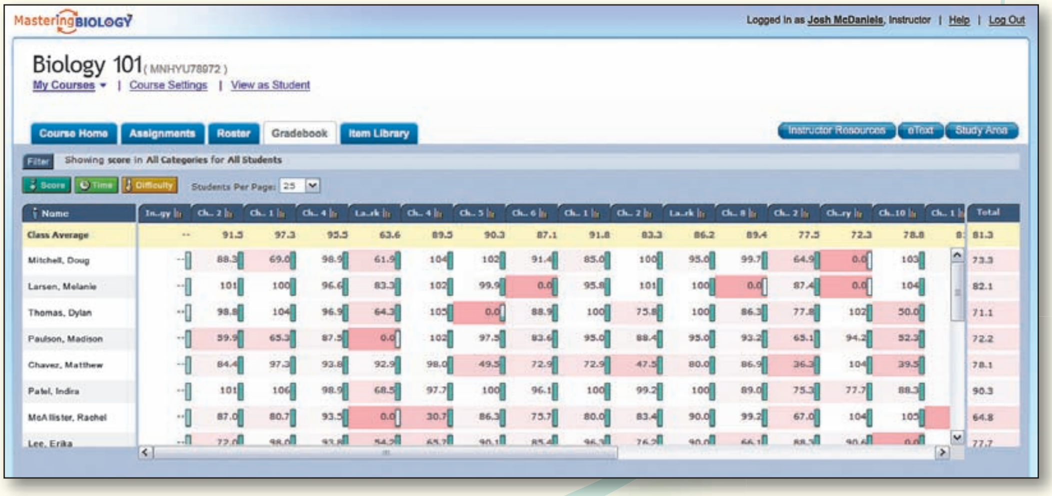
Try Again

You labeled 3 of 6 targets incorrectly. For target (f), what term describes this photographic inventory of a complete set of chromosomes from one cell? This one shows all 46 chromosomes in a human somatic cell.

▶ **Learning Catalytics** is a "bring your own device" student engagement and assessment educational tool, allowing you to actively engage each student during lecture and access rich data to assess student understanding. Students can use any web-enabled device and instructors can create their own assessment items or select from an existing set of items.

◀ Learn what your students do and don't understand before class using **one-click diagnostics**, so that you can make the most of valuable time in class.

▶ The **Mastering gradebook** provides easy-to-interpret insight into student performance. Every assignment is automatically graded and shades of red highlight challenging assignments.



Answer Stats:	Students	% Correct	% Unfinished	% Req'd Solution	Wrong/student	Hints/student
System Average	5548	98%	1.4%	0.6%	0.6	0
This Course (MBDEMOGRADES)	25	100%	0%	0%	0.5	0

◀ Learn which topics are challenging for your students and **compare your class data** to the national average.

Acknowledgments

After five years of working on *Biology: The Core*, there are many people to thank and acknowledge for their contributions. One of the most gratifying aspects of writing a book is the opportunity it presents 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 related to it are solely my responsibility, the successful aspects are due to the efforts of dozens of people.

A few people deserve special mention for their deep contributions; these people form the core of *The Core*. First and foremost is Nora Lally-Graves—Developmental Editor, Project Manager, and all-around problem-solver—whose passion for communicating undergraduate science can be seen on literally every page of this book. Chalon Bridges used her unbounded positivity, unbridled enthusiasm, and a deep empathy toward students and teachers to help launch this project, leaving strong echoes of her talents even after she moved on to pursue other opportunities. Alison Rodal, as Acquisitions Editor, worked with me and the rest of the team nearly every day, bringing a broad array of talents to bear on this project.

Rounding out the original Pearson team is Beth Wilbur, Editor-in-Chief, whose vision, understanding, and unwavering high standards have benefited every project since she brought me into the Pearson family over a decade ago. Editorial Assistants Rachel Brickner and Libby Reiser provided never-ending help coordinating reviews and supplements and solving countless problems, always with a buoying positive energy. Deborah Gale, Director of Development, provided her masterful oversight of all matters editorial and gave invaluable help when it was most needed. Thanks are also due to President of Science, Business and Technology Paul Corey and former President of Pearson Science and Math, Linda Davis, whose vision and insights were vital to launching this project.

I love my editors! All members of the Pearson editorial team bring decades of experience and talent to every project they take on. Developmental editors Mary Ann Murray and Evelyn Dahlgren provided eagle-eyed editorial help during the late stages of the book. For saving me from countless embarrassments large and small, I thank Copyeditor Lorretta Palagi and Editorial Proofreader Julie Lewis. Thank you to Indexer Robert Swanson for making the book much more user-friendly (see "Indexer, gratitude for"). Anna Amato, Program Manager, stepped in during the later stages of production to aid in ushering this text to publication.

If you like the look of this book—the layout, photographs, and graphics—then you can thank the amazing design team at DK Publishing (Dorling Kindersley). This team was a key part of *The Core* from literally the first day. Stuart Jackman and Sophie Mitchell helped manage the London-based crew and kindly turned their keen senses of style to this project. Anthony Limerick designed every spread in *The Core* and is therefore the one person most responsible for its beautiful look.

Once the text was written and the art developed, the production team took over, turning countless individual scraps of information into a coherent book. Led by Senior Project Manager Shannon Tozier, this group graciously implemented ideas, turning them into the reality of the book you see before you. For this we thank Production Project Manager Michael Penne, Managing Editor Michael Early, photo researcher Kristin Piljay of Wanderlust Photos, Pearson Image Lead Donna Kalal, and permissions specialist Michael Farmer. Thank you also to Amanda Waldo for her assistance in compiling the art manuscript and glossary. Jon Ballard began media production, and Daniel Ross capably continued that effort. I thank Yvo Riezebos for his design of the book cover, and Design Manager Marilyn Perry for her help in producing it. Roxanne Klaas at S4Carlisle provided expert composition, and Kristina Seymour, Heidi Richter, Megan Stewart, and Jan Troutt of Precision Graphics lent their talents to art development and art creation. Some of the truly special three-dimensional art in the book was developed by Martin Hale, Terri Hamer, and Craig Vrankovich of Animated Biomedical Productions Studio—thank you all for your special artistic contributions!

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Of equal importance to the book itself are the many multimedia supplements that accompany it. Many teaching colleagues provided help with writing supplements for *The Core*. In particular, I thank test bank author Brandon Foster of Wake Tech Community College, instructor's guide author Brenda Leady of University of Toledo, PowerPoint presentation author Wendy Kuntz of Kapiolani Community College, active learning question author Heather Miller of Front Range Community College and Kaplan University, and Active Reading Guide author Dana Kurpius of Elgin Community College. Special thanks go to Cindy Klevickis of James Madison University for writing the reading questions that supplement the book in *MasteringBiology*. It is especially gratifying to thank Mackie Glashow (a former student of mine at New England College) for her contributions to *The Core* multimedia. I'd like to extend particular thanks to the many instructors and students who class-tested *The Core* prior to publication, helping to ensure its usefulness and effectiveness.

Many people at Pearson also helped produce the media that accompanies this text. In particular, Director of *MasteringBiology* Editorial Content Tania Mlawer and *MasteringBiology* Developmental Editor Juliana Tringali provided much assistance in preparing this vital part of the program. From the engineering side of *MasteringBiology*, I thank Katie Foley, Caroline Ross, and Taylor Merck. I also thank Senior Supplements Project Manager Susan Berge and Supplements Project Manager Kim Wimpsett.

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 Executive Marketing Manager Amee Mosley, Market Development Manager Michelle Cadden, and Market Development Coordinator Kait Nagi. 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 and publisher's representatives 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 forgive 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*,

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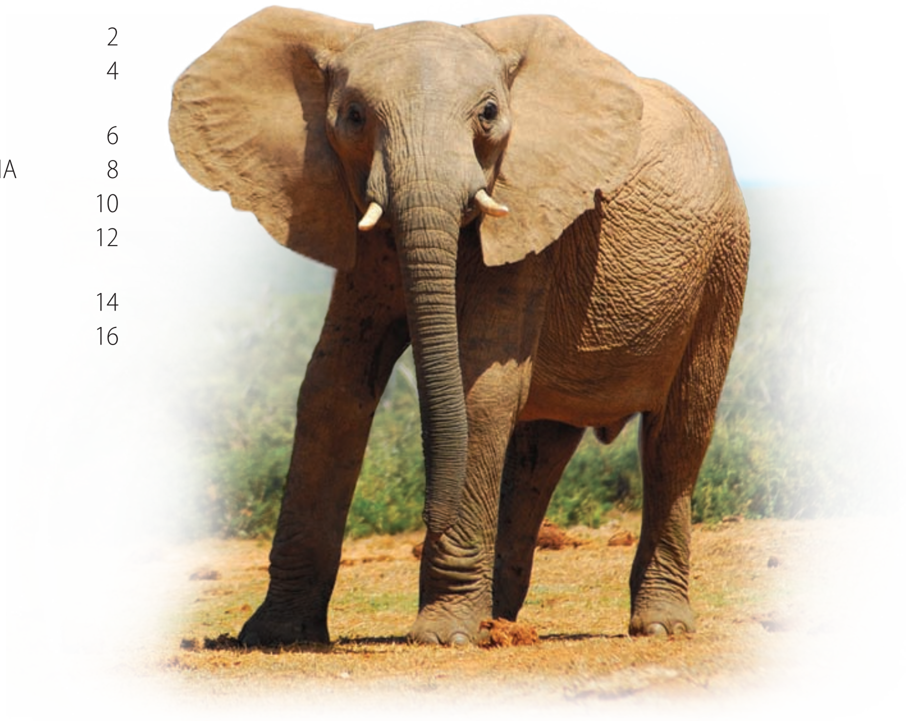

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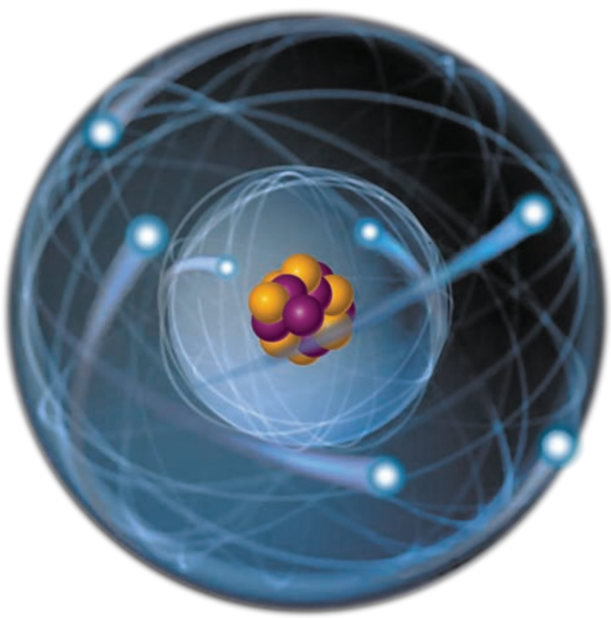

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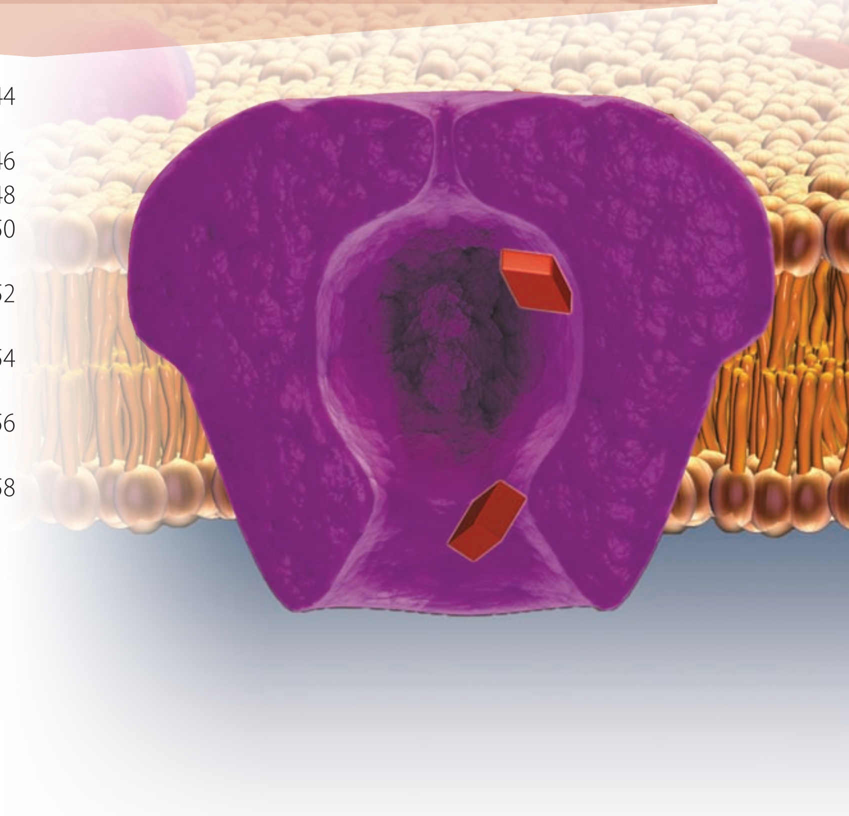

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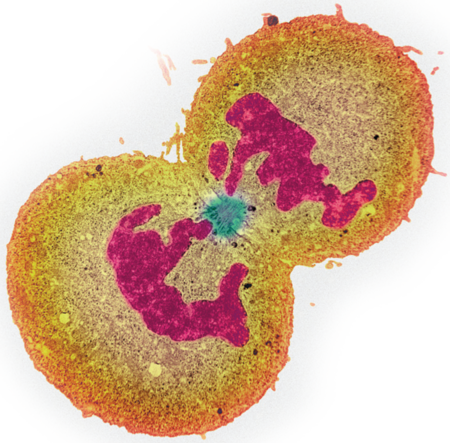

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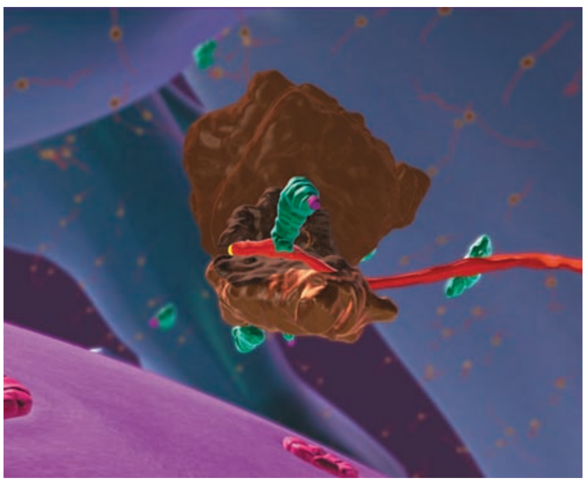

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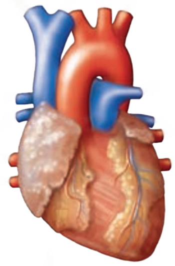

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biology THE CORE

All living organisms share certain properties

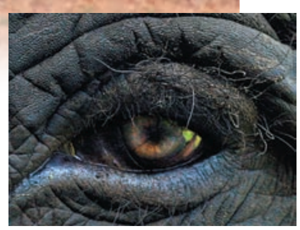
Biology is the scientific study of life. While the definition of biology is very straightforward, it does raise some important questions. Perhaps the most obvious is: What is life? How do we distinguish living organisms from nonliving matter? How do we know that an elephant is alive, but a boulder is not? Biologists recognize **life** through a series of characteristics shared by all living things. We define life through the properties that living things display. An object is alive if and only if it displays all of these properties simultaneously.

THE PROPERTIES OF LIFE

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

GROWTH AND DEVELOPMENT
Information carried by genes controls the pattern of growth in all organisms. For example, male elephants grow tusks as they age.

ENERGY USE
Every organism takes in energy, converts it to useful forms, and expels energy. This elephant is taking in energy by eating a plant. It can use that energy to move. It also releases energy as heat.



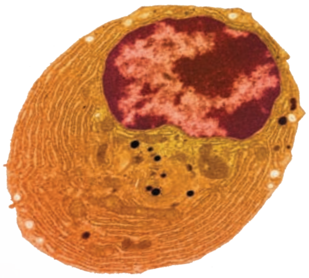
ORDER
Each living thing has a complex but well-ordered structure, as seen in the elephant's eye.

Life first appeared on Earth around 3.5 billion years ago.

A VIRUS IS NOT ALIVE

We know that a virus is not alive because it does not display all of the properties of life. For example, a virus is not composed of cells, and it cannot reproduce on its own. While nonliving matter may display some of life's properties (a virus has order, for example), it never displays all of life's properties simultaneously.

200,000x



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CELLS

All living organisms consist of cells. Some living organisms have just one cell, but others (such as an elephant) have trillions.

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.

EVOLUTION

Individuals with traits that help them survive and reproduce pass the genes for those traits to offspring. Over many generations, such adaptations drive the evolution of populations. For example, modern elephants and woolly mammoths evolved from a common ancestor species that lived until about 5 million years ago.

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

CORE QUESTION: Which properties of life does a car display? Which does it not?

ANSWER: A car uses energy, is ordered, and responds to the environment. A car does not reproduce, grow or develop, or evolve, and a car is not made of cells.

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.

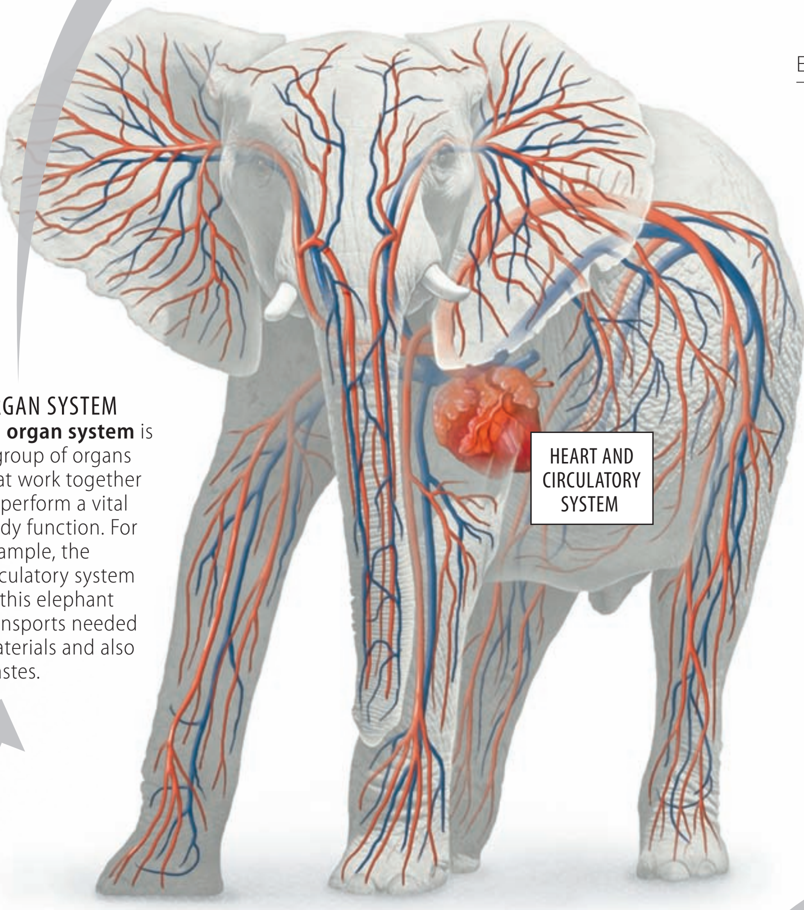
ECOSYSTEM
An **ecosystem** includes all the living organisms in one particular area (such as this African savannah) as well as the nonliving components that affect life, such as soil, air, and sunlight.

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, such as the African savannah elephants shown here.

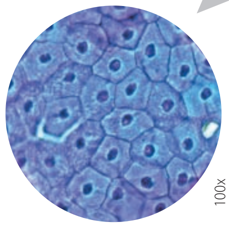
ORGANISM
An **organism** is an individual living being, such as one African savannah elephant (*Loxodonta africana*).

Some organisms on Earth have just one cell; others have trillions.

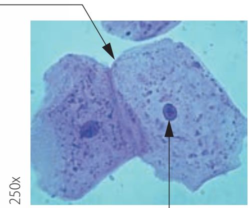


ORGAN SYSTEM
An **organ system** is a group of organs that work together to perform a vital body function. For example, the circulatory system of this elephant transports needed materials and also wastes.

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.

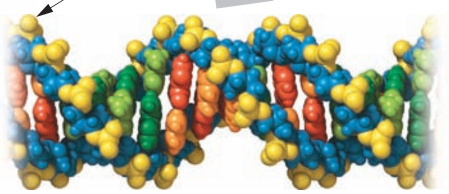


TISSUE
A **tissue** is an integrated group of similar cells that work together to perform a specific function. This microscopic image shows a section of cardiac epithelial tissue, which lines the heart, allowing blood to flow freely over the surface.

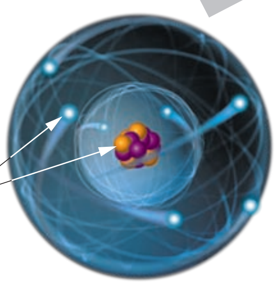


CELL
The **cell** is the fundamental unit of life. Nothing smaller than a cell is capable of having all of life's properties. All life consists of one or more cells.

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 to the very small. Biologists study life at all levels of scale.

CORE QUESTION: 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.

1.3

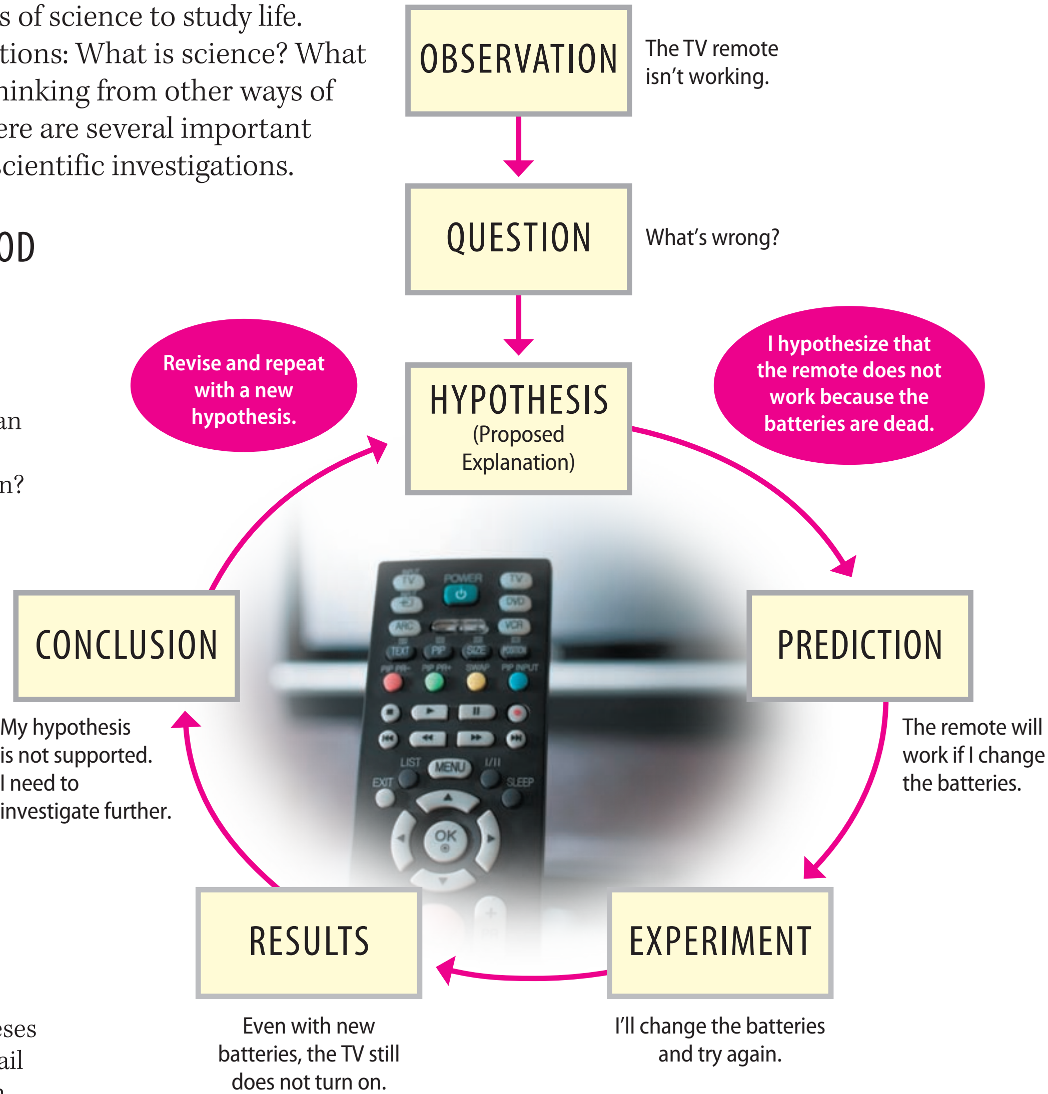
Scientists use well-established methods to investigate the natural world

Biologists use the process of science to study life. That raises obvious questions: What is science? What distinguishes scientific thinking from other ways of investigating nature? There are several important principles that underlie scientific investigations.

THE SCIENTIFIC METHOD

Science always begins by observing the world. Such observations inevitably lead to questions about why the world is the way it is. How can you uncover an explanation for an observed phenomenon? The **scientific method** is a rough "recipe" for discovery, a series of steps that, if followed, may help a scientist understand an observation. The scientific method is simply a way of formalizing how we usually try to solve problems.

Scientists use the scientific method as a guideline, but it need not be followed rigidly. During a particular investigation, for example, a scientist might investigate multiple hypotheses simultaneously, or perhaps fail to make a specific prediction.



DISCOVERY SCIENCE

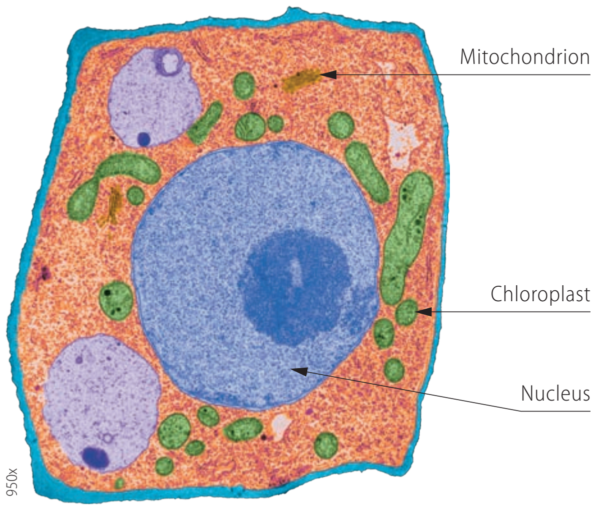
When scientists make verifiable observations, take careful measurements, and gather data—even in the absence of a hypothesis—they are performing **discovery science**. Discovery science provides data that can be used to describe the natural world. The researcher shown here, for example, is gathering information on the insect community living in a rainforest canopy. The data gathered via discovery science can prompt questions and guide the scientific method. For example, Charles Darwin's careful descriptions of the plants and animals he observed during his journeys led to hypotheses about how organisms evolve. Both methods of investigation—hypothesis-driven science and discovery science—allow scientists to investigate the natural world.

HYPOTHESES AND THEORIES

When discussing scientific ideas, it is important to distinguish between hypotheses and theories. Notice that a scientist uses the word "theory" differently than we tend to use it in everyday speech. In common usage, the word "theory" often means "a guess," which is not how scientists use the word.

HYPOTHESIS

The scientific method depends on the development of hypotheses. A **hypothesis** is a proposed explanation for an observation. A valid hypothesis must be testable, and the results of such tests will either support or refute the hypothesis. For example, the endosymbiotic hypothesis proposes that some cellular components (such as the chloroplast and mitochondrion visible in the cell here) were once free-living organisms that were long ago incorporated into a larger cell.



THEORY

A **theory** is much broader in scope than a hypothesis. It is much more comprehensive, it has not been shown false, and it already explains a great many observations. Theories are supported by a large and growing body of evidence. For example, the Cell Theory states that every living organism consists of cells that arose from preexisting cells. Theories can be used to devise specific hypotheses to be tested.

The word "science" is derived from the Latin verb "scire," which means "to know."

CONTROLLED EXPERIMENTS

To investigate a hypothesis, a scientist may choose to perform a **controlled experiment** in which a test is run multiple times with one variable changing—and, ideally, all other variables held constant. The use of a controlled experiment allows a scientist to draw conclusions about the effect of the one variable that did change. The photos shown here represent a controlled experiment on the effect of using cake flour versus all-purpose flour on the thickness of chocolate chip cookies.

This batch of cookies was baked using cake flour.

This batch of cookies was baked using all-purpose flour. Other than the kind of flour, the recipe was exactly the same. This controlled experiment supports the hypothesis that cake flour increases the height of these chocolate chip cookies.

CORE IDEA: Scientific investigations may be hypothesis-driven (using the scientific method) or discovery-based. Careful observations and controlled experiments allow scientists to investigate hypotheses and develop theories.

CORE QUESTION: If you observe squirrels, come up with a tentative explanation for their behavior, and then test your idea, what method of inquiry are you performing?

ANSWER: The scientific method.

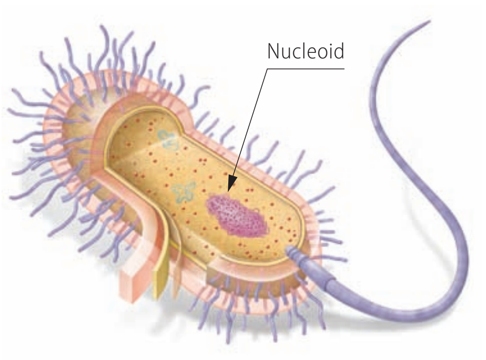
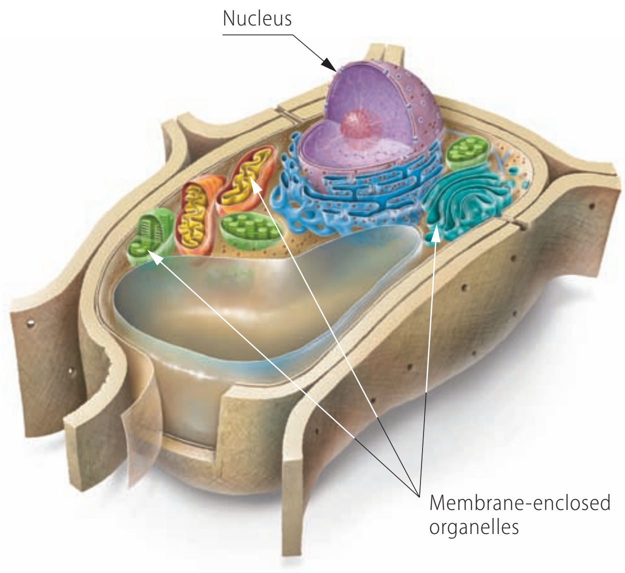
1.4

Cells, the fundamental units of life, contain DNA

The cell is the fundamental unit of life: Every living organism is composed of one or more cells, and nothing smaller is capable of performing all of the activities required for life. Some living creatures (such as microscopic bacteria) are unicellular, composed of just a single cell. Others (such as you) are composed of trillions of cells. Within each cell, one or more molecules of DNA act as the hereditary material.

TWO KINDS OF CELLS

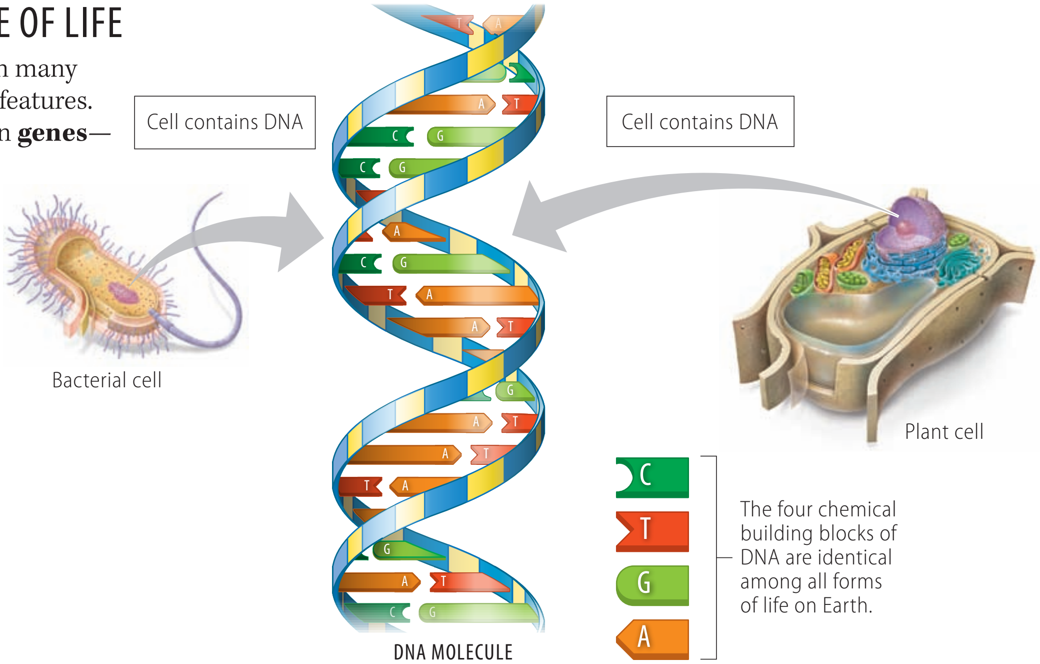
All life on Earth is composed of one of two types of cells: prokaryotic or eukaryotic. These two types of cells have many similarities but also some fundamental differences.

	PROKARYOTIC CELL	EUKARYOTIC CELL
	 A typical prokaryotic bacterial cell	 A typical eukaryotic plant cell
Size	Smaller	Typically 10–100× larger
Complexity	Simpler	More structurally complex
Organelles	No membrane-enclosed organelles	Has membrane-enclosed organelles
Evolution	First appeared approximately 3.5 billion years ago	Evolved from prokaryotes approximately 2.1 billion years ago
DNA	Not contained within any cellular structure	Housed in membrane-enclosed nucleus
Number of cells	Unicellular	Unicellular or multicellular
Examples	Bacteria and archaea	Plants, animals, fungi, and protists

Your body contains approximately 200 trillion cells.

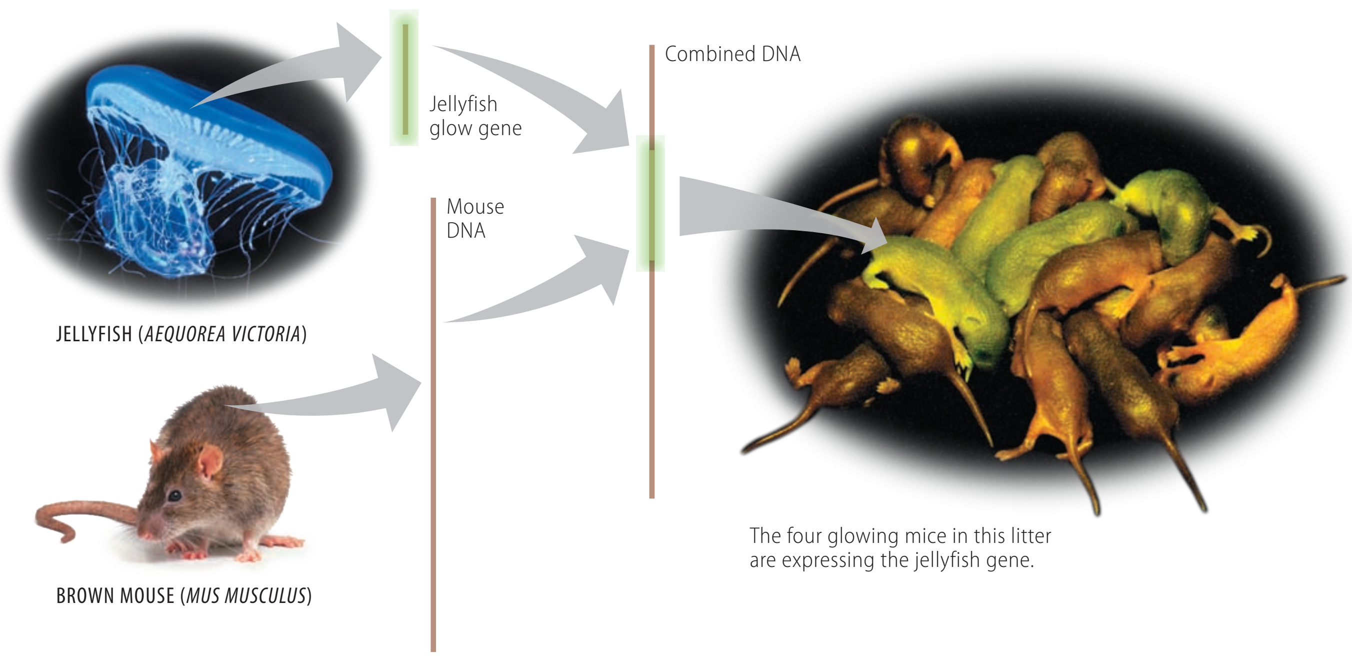
DNA IS THE MOLECULE OF LIFE

Although cells vary widely in many respects, they share certain features. For example, all cells contain **genes**—units of hereditary information—made from the same molecule: DNA. Although different organisms may have different genes, the genes of all organisms are coded by DNA molecules that contain the same four building blocks, abbreviated A, T, C, and G.



DNA CAN BE MIXED AND MATCHED

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. Genetic engineers have produced many such organisms. For example, biologists have made mice (as well as fish, cats, and monkeys) that contain a glow gene from a jellyfish, and many of our food crops are genetically modified to contain genes from other organisms.



The four glowing mice in this litter are expressing the jellyfish gene.

CORE IDEA: All life on Earth is composed of either small, simple prokaryotic cells, or larger, complex, organelle-containing eukaryotic cells. All cells contain genes made from the same four building blocks of DNA.

CORE QUESTION: Both eukaryotic and prokaryotic cells contain DNA. How do they differ in terms of where the DNA is stored?

ANSWER: In eukaryotic cells, the DNA is stored within a membrane-enclosed nucleus. In prokaryotic cells, the DNA is not enclosed.