



biology

THE CORE

ERIC J. SIMON

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biology

THE CORE

ERIC J. SIMON

New England College

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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.

SimonBiology@gmail.com

A New Biology Learning Program Built for Today's Students

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

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 savanna) 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.

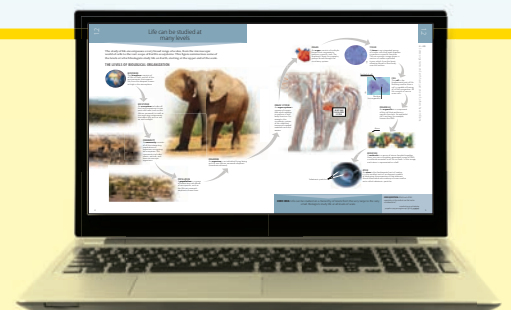
POPULATION
A **population** is a group of interacting individuals of one species, such as the African savanna elephants shown here.

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

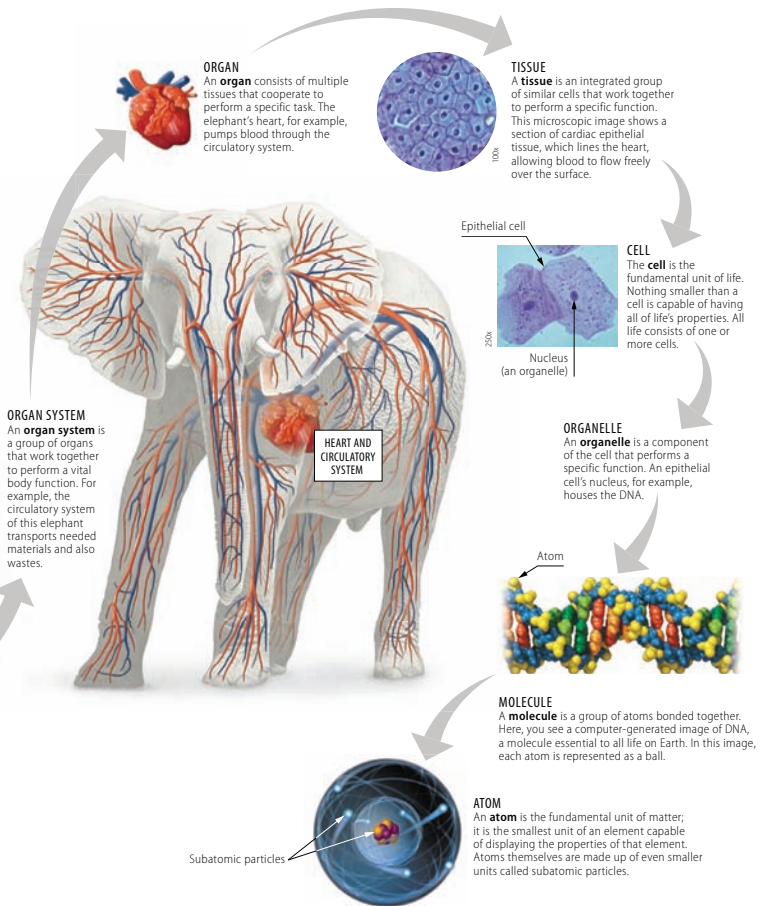
4

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



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.

5

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

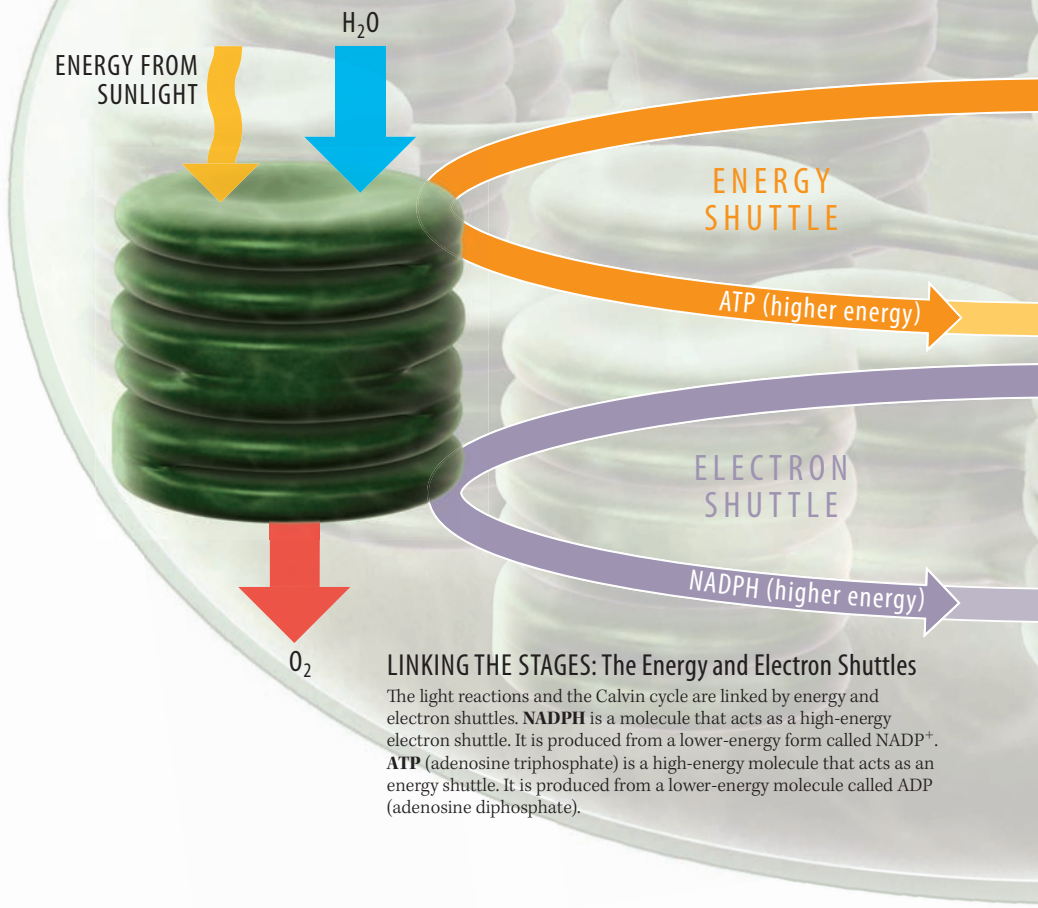
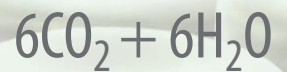
Photosynthesis occurs in two linked stages

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 .

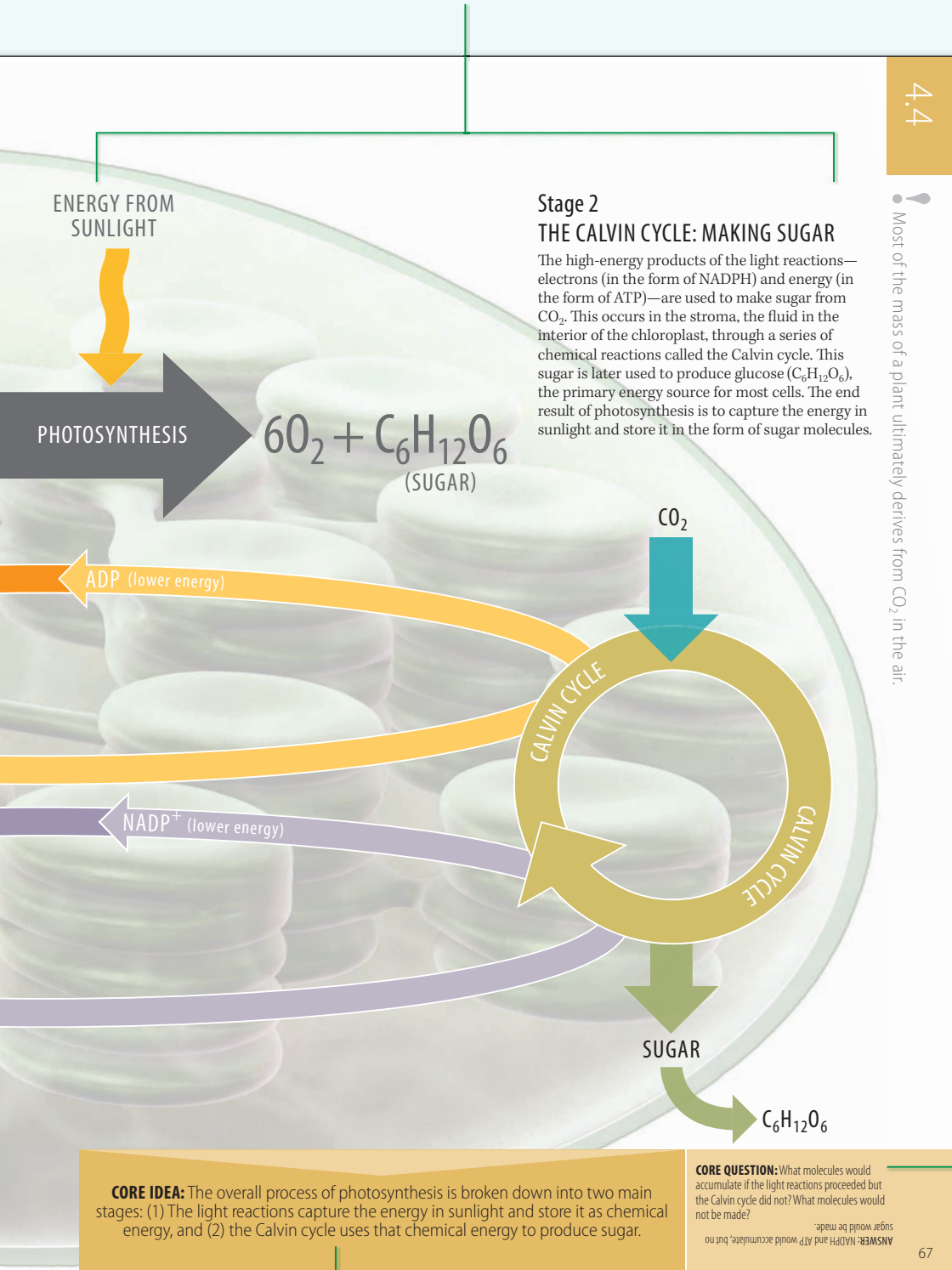


LINKING THE STAGES: The Energy and Electron Shuttles

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).

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

▼ 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.

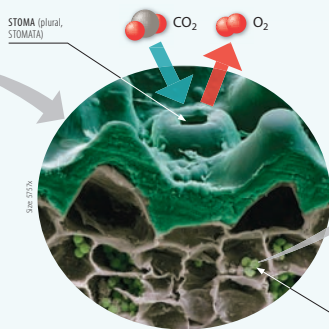


◀ After you have studied the entire module, the **Core Questions** allow you to apply your knowledge and check your understanding of the concepts.

▲ 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.



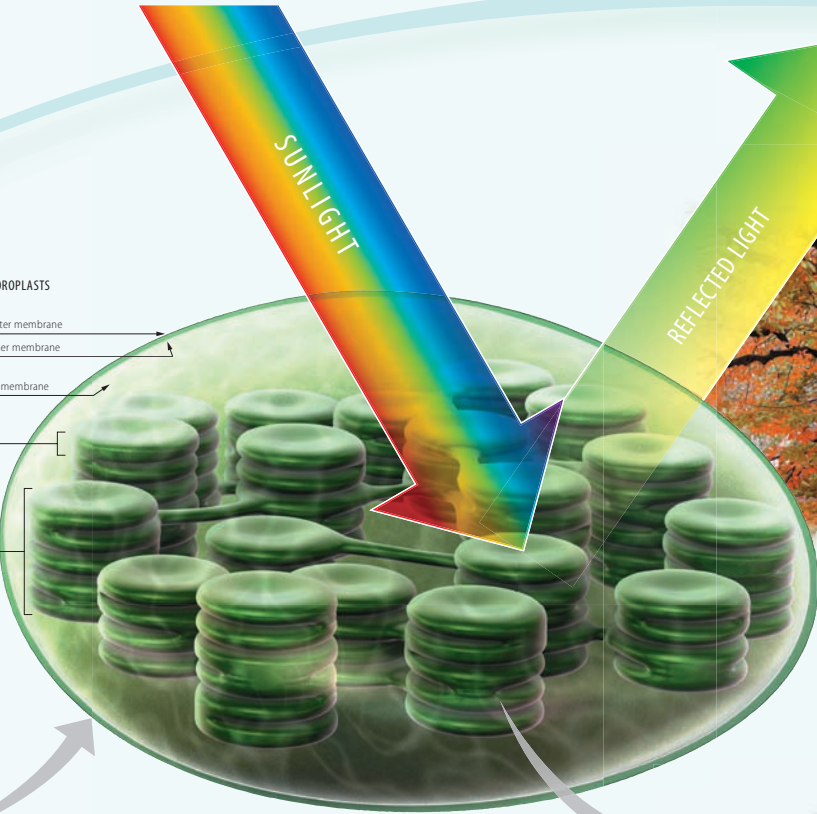
STRUCTURE OF CHLOROPLASTS

DOUBLE MEMBRANE Outer membrane Inner membrane

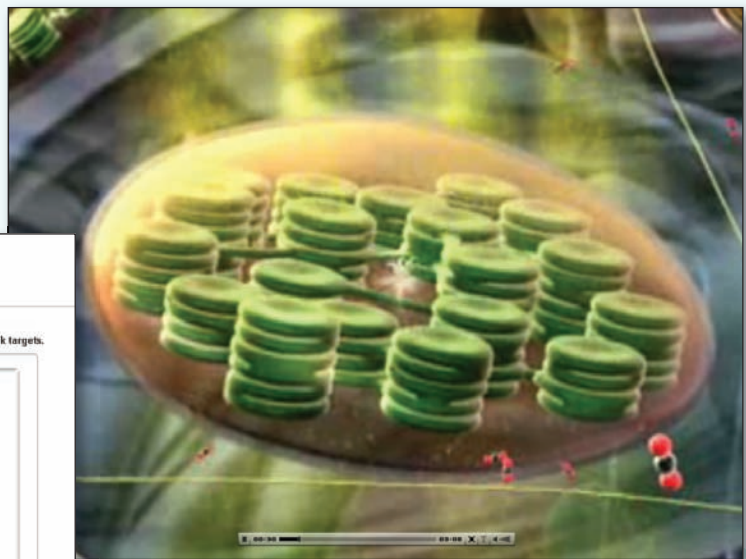
STROMA Fluid within the inner membrane

THYLAKOID Individual disk

GRANUM (plural, GRANA) Stack of thylakoids



▶ **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.

light

Calvin Cycle

ATP

glucose

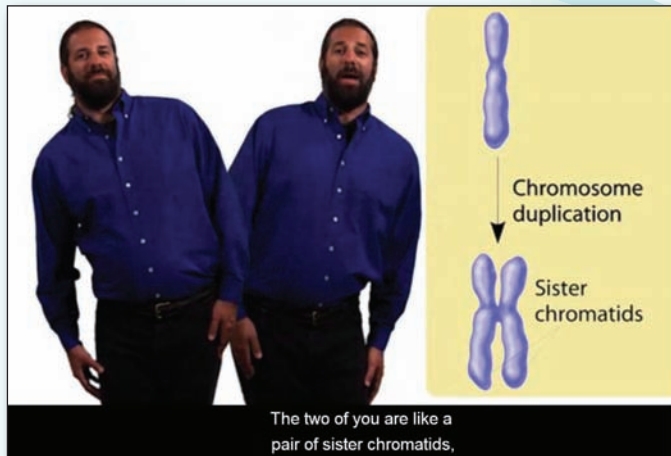
O₂

Light Reactors

Submit My Answers Get Help

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.

Interpreting Data: Atmospheric Concentrations of Greenhouse Gases

Use the graph to answer these questions about concentrations of three greenhouse gases.

Atmospheric concentrations of CO₂, N₂O, and CH₄ through 2009 (in parts per million (ppm) or parts per billion)

© Pearson Education, Inc.

Part A

Which gas is plotted using the y-axis on the right?

Nitrous oxide (N₂O)

Methane (CH₄)

Carbon dioxide (CO₂)

The total of all three gases.

[Submit](#) [My Answers](#) [Give Up](#)

Part B

Which of these three gases is most abundant in the atmosphere?

Nitrous oxide (N₂O)

Carbon dioxide (CO₂)

Methane (CH₄)

The concentrations of the three gases are approximately equal.

[Submit](#) [My Answers](#) [Give Up](#)

Part C

What was the approximate atmospheric concentration of CO₂ at year 0?

ABC News Video: Henrietta Lacks' Cells

Watch the ABC News video (2:41 minutes). Then answer the questions below.

Part A

When cells were first taken from Henrietta Lacks, she was _____

suffering from cervical cancer

in high school

only two years old

already dead

[Submit](#) [My Answers](#)

Part B

How did doctors harvest Henrietta Lacks' cells?

Cells were taken while she was in the lab ever since.

A kidney that she donated was recovered when that kidney was used to transplant another person.

Her cells were frozen and then thawed and grown in a lab.

◀ 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 HARTO COLLIS

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.

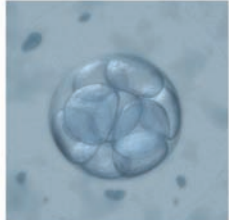
Teach the Course Your Way

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.


Our food choices reflect our values

Nonorganic, \$1.40	Organic, \$2.00
	

Athletic genetic profiling



Will embryos be selected for their athletic traits?



Will children with athletic genotypes be pushed to...?

Three cancer treatments: "Slash, burn, and poison"



Surgery removes many (but often not all) cancerous cells.



Radiation therapy disrupts cell division.



Chemotherapy involves drugs that disrupt cell division.


Help prevent evolution of antibiotic resistance



Short. Sniffle. Sneeze. No Antibiotics Please.

- If your doctor doesn't prescribe an antibiotic, don't insist on getting a prescription.
- When you take an antibiotic, complete the prescribed course of treatment.
- Don't save or share leftover antibiotics.
- Don't take a prescription...

Carbon dioxide




Current level


1950

Can you match the food with its nutrition facts?


Food item	A	B	C	D	E	F
Serving size (g)	116	117	120	128	130	133
Calories	370	235	350	260	330	360
Total fat (g)	17	12	18	13	14	16
Saturated fat (g)	6	2	9	2.5	6	6
Cholesterol (mg)	0	17.5	50	70	30	65
Sodium (mg)	760	310	860	770	870	580
Total carbs (g)	49	22	32	13	37	31
Dietary fiber (g)	4	2.5	2	2	2	2
Sugars (g)	0	3	1	0	4	5
Protein (g)	4	10	16	25	13	24




Chicken tenders (3)



Plain hamburger



Cheese quesadilla



Medium fries

► 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.

Cells have regular cycles of growth and division

Every cell in your body was created through the division of a previously existing cell. The "lifetime" of a cell can be organized into a **cell cycle**, an ordered sequence of events from the time a cell is created from a dividing parent cell until its own division into two cells. The repeating events of the cell cycle are divided into two broad stages: **interphase**, during which the cell performs its normal functions and duplicates the chromosomes, and the **mitotic phase**, during which the cell divides the nucleus and distributes the duplicated chromosomes into two new cells.

INTERPHASE
Most of a cell's lifetime—typically around 90% of the cell cycle—is spent in interphase. During this phase, the cell performs its normal functions. A cell within your small intestine, for example, might make and release digestive enzymes. During interphase, the cell roughly doubles in size by building cytoplasm and organelles, and the chromosome remains in an uncondensed state. As a cell prepares to divide, it duplicates its chromosomes within the nucleus.

CHROMOSOME DUPLICATION
During interphase, the cell duplicates each chromosome. During the mitotic phase, one copy of each chromosome is moved to each offspring cell. Here, we use just a single chromosome to represent the entire set of chromosomes found in the nucleus (46 in humans).

MITOTIC PHASE: MITOSIS AND CYTOKINESIS
The part of the cell cycle during which the cell actually divides is called the mitotic phase. The mitotic phase is divided into two overlapping stages. During **mitosis**, the nucleus (along with its already duplicated chromosomes) divides and is distributed to the two offspring cells. During **cytokinesis**, the cytoplasm is divided and distributed. The result of the mitotic phase is two genetically identical offspring cells that then begin their own cell cycles.

CORE IDEA: The cell cycle is an ordered sequence of events that leads from the creation of a cell to the division of that cell. The cell cycle can be divided into two broad phases: interphase (during which the cell grows, duplicates its chromosomes, and prepares for division) and the mitotic phase (which includes mitosis and cytokinesis).

CORE QUESTION: Why is this statement incorrect: "During mitosis, chromosomes are duplicated and distributed?"

Guided Reading Activity

Module 5.4 During mitosis, the nucleus is duplicated

Complete the following questions as you read the module.

- Chromosomes are duplicated during _____.
- Complete the figure to the right illustrating the cell cycle.
- Sister chromatids are attached at the _____.
 - Chromatid
 - Centriole
 - Interphase
 - Mitotic spindle
- Is the cell in the image in interphase or mitosis? Briefly explain your answer either way.

5. Which of the following is the correct sequence of events during mitosis?
 A) Nucleus reforms; chromosomes align; chromosomes split; chromosomes condense
 B) Chromosomes condense; chromosomes align; chromosomes split; nucleus reforms
 C) Chromosomes split; chromosomes condense; chromosomes align; nucleus reforms
 D) Chromosomes condense; nucleus reforms; chromosomes split; chromosomes align

▲ 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.

BioFlix Activity: Mitosis -- The Cell Cycle

Can you label the phases of the cell cycle?

To review a crucial phase of the cell cycle, watch this BioFlix animation: [Mitosis](#).

Part A - The cell cycle

- Drag the pink labels onto the pink targets to identify the two main phases of the cell cycle.
- Then drag the blue labels onto the blue targets to identify the key stages that occur during those phases.

Submit My Answers Give Up

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.

Connecting the Concepts: Cell Division

Can you organize these terms that describe the different kinds of cell division?

Part A

Drag the terms to their correct locations in this concept map about cell division.

Terms to be placed in the map:

- mitosis
- asexual reproduction
- sexual reproduction
- meiosis
- somatic cells
- gametes

Submit My Answers Give Up

◀ 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.

Learning through Art: Chromosomes

Can you correctly label these images of chromosomes?

Part A

Drag the labels to the correct locations on these images of human chromosomes.

Terms to be placed in the images:

- sex chromosomes
- homologous chromosomes
- karyotype
- centromere
- autosomes
- sister chromatids

Submit My Answers Give Up

▼ 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.

Name	Intro	Ch. 2	Ch. 1	Ch. 4	Lab 4	Ch. 4	Ch. 3	Ch. 0	Ch. 2	Lab 3	Ch. 2	Ch. 9	Ch. 10	Ch. 1	Total	
Class Average	--	91.3	97.3	95.5	63.6	89.5	90.3	87.1	91.8	83.3	86.2	89.4	77.5	72.3	78.8	81.3
Mitchell, Doug	--	88.3	69.0	98.0	61.9	104	100	91.4	85.0	100	95.0	99.7	64.5	0.0	100	73.3
Larsen, Melanie	--	101	100	96.0	83.3	105	99.0	0.0	95.8	101	100	0.0	87.4	0.0	104	82.1
Thomas, Dylan	--	98.8	104	96.9	64.3	105	0.0	88.9	100	75.8	100	86.3	77.4	102	50.0	71.1
Paulson, Madison	--	59.5	65.2	87.2	0.0	102	97.2	83.4	95.0	88.4	95.0	93.2	65.1	94.2	52.2	72.2
Chavez, Matthew	--	84.4	97.3	93.8	92.9	98.0	49.5	72.9	72.9	47.5	80.0	86.9	36.3	104	39.5	78.1
Patel, Indra	--	101	106	98.0	68.5	97.7	100	96.1	100	99.2	100	89.0	75.2	77.7	88.3	90.3
McAllister, Rachel	--	87.0	80.7	93.2	0.0	30.7	86.2	73.7	80.0	83.4	90.0	39.2	67.0	104	100	64.8
Lee, Erika	--	77.0	88.0	91.8	84.2	65.7	90.1	85.4	96.3	76.2	90.0	64.1	88.3	90.4	60.0	77.7

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.

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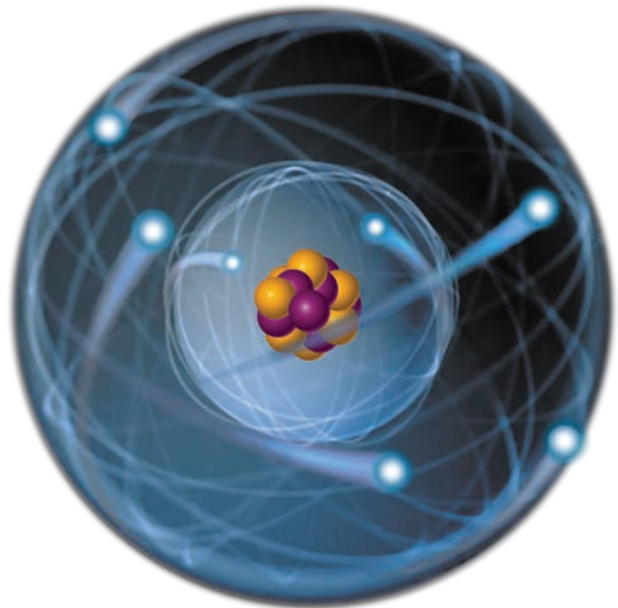


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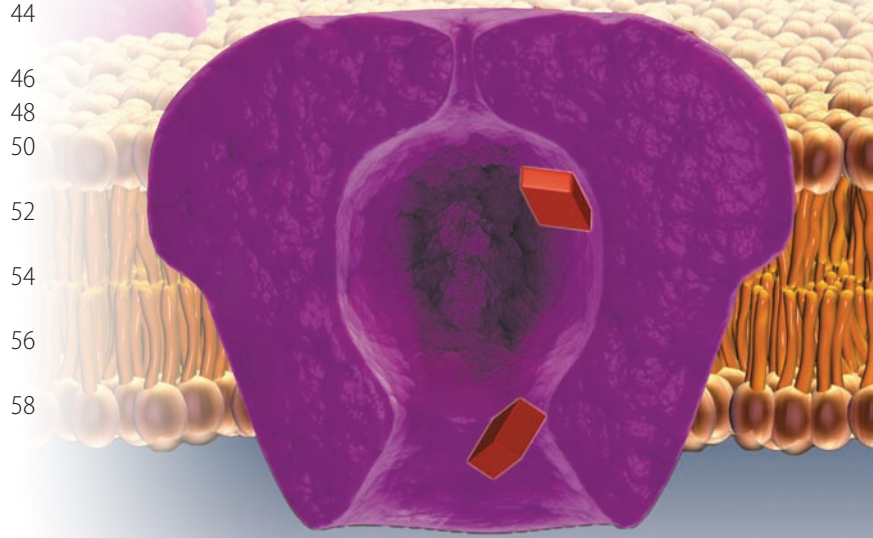


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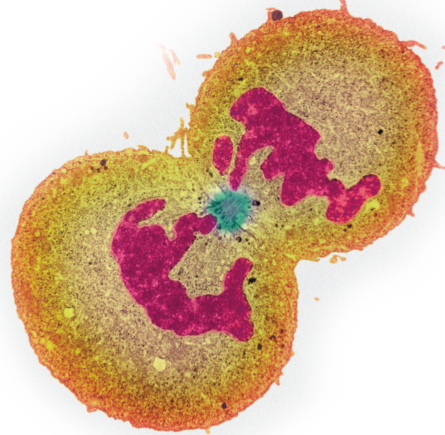


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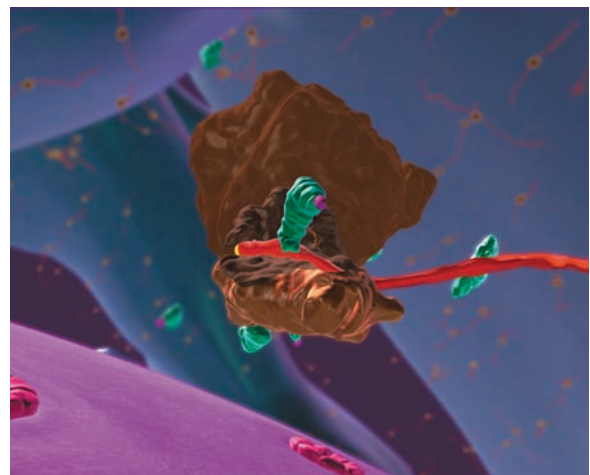


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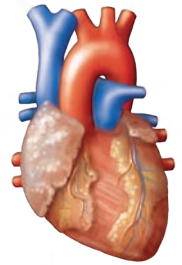
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biology

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.

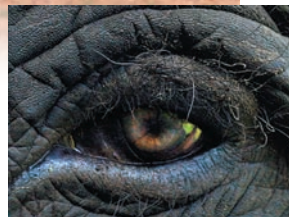
GROWTH AND DEVELOPMENT

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.

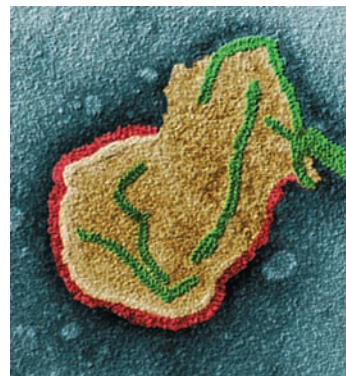


ORDER

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

A VIRUS IS NOT ALIVE

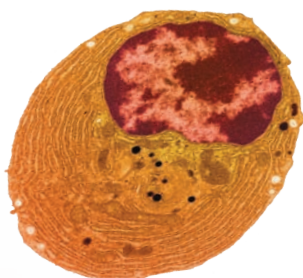
We know that a virus is not alive because it does not display all of the properties of life. For example, a virus is not composed of cells, and it cannot reproduce on its own. While nonliving matter may display some of life's properties (a virus has order, for example), it never displays all of life's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



200,000x

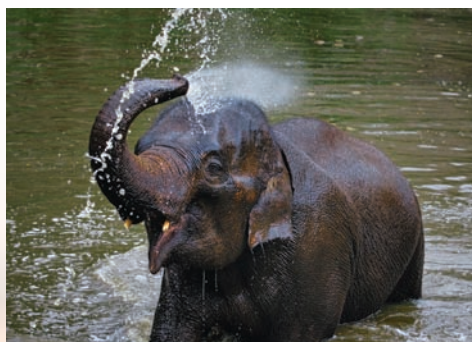


13,500x



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.

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

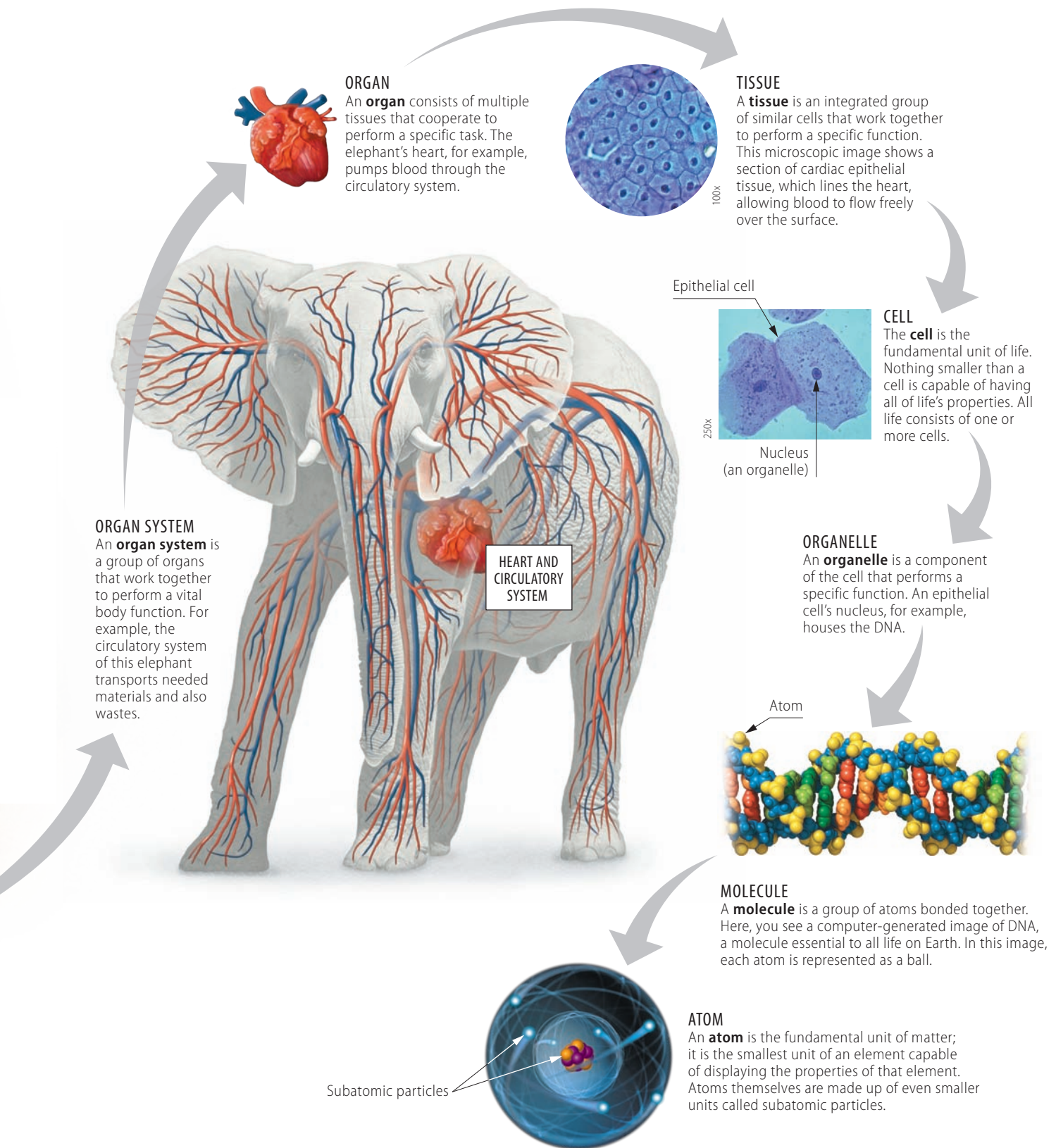
A **population** is a group of interacting individuals of one species, such as the African savannah elephants shown here.

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.



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.

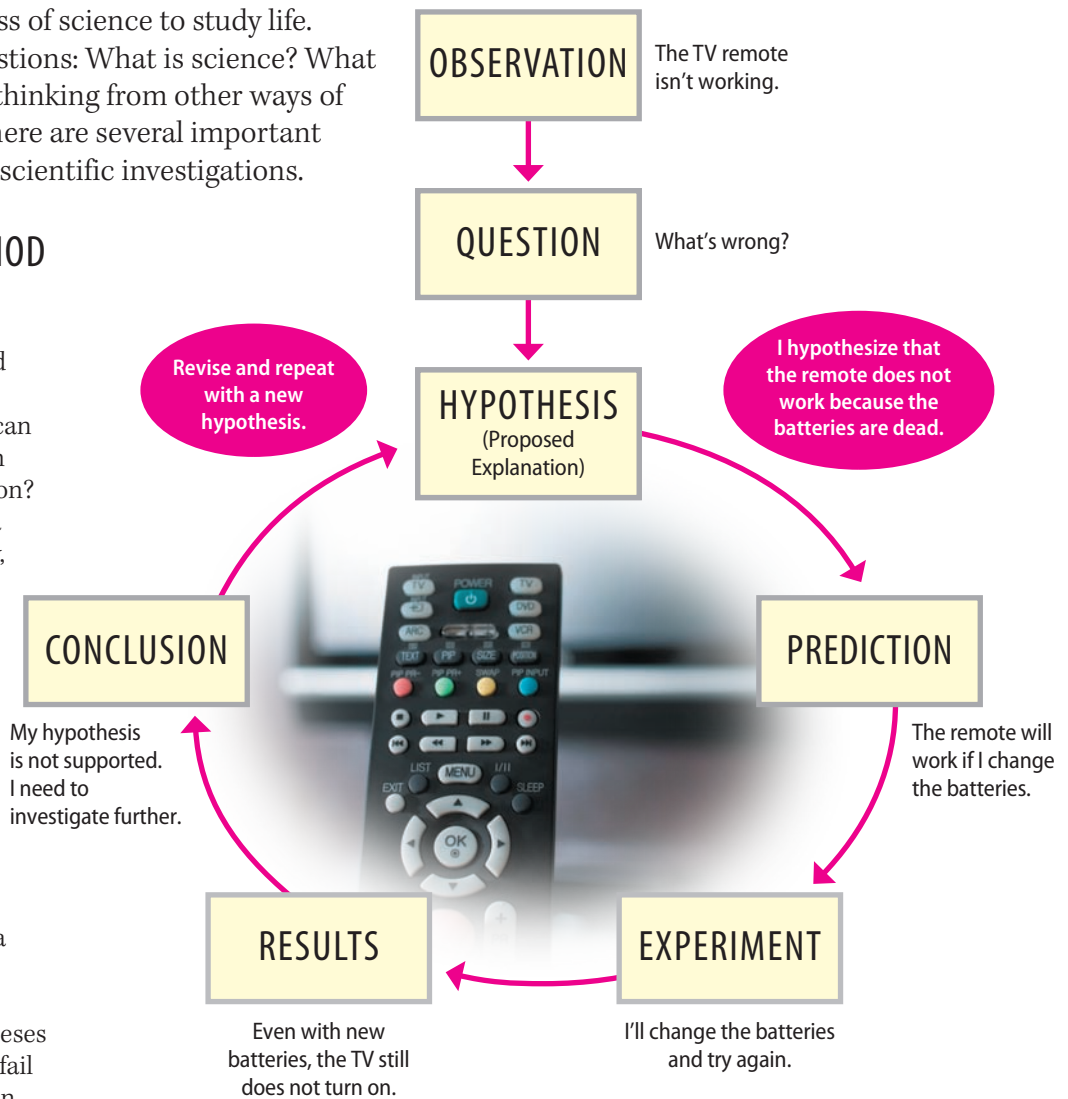
Scientists use well-established methods to investigate the natural world

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.



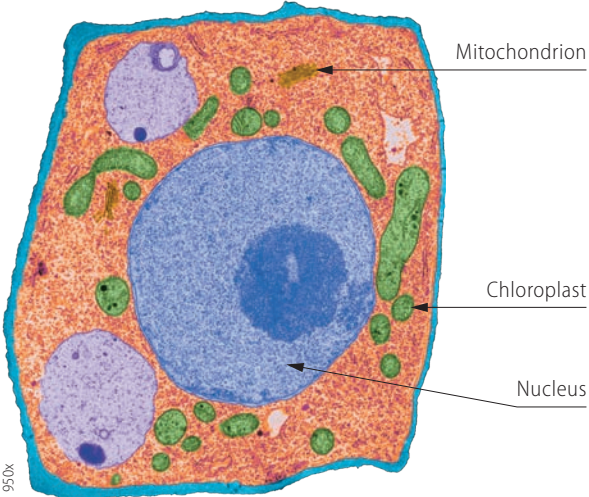

DISCOVERY SCIENCE

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	THEORY
<p>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.</p>  <p>Mitochondrion</p> <p>Chloroplast</p> <p>Nucleus</p> <p>950x</p>	<p>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.</p>  <p>400x</p>

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?

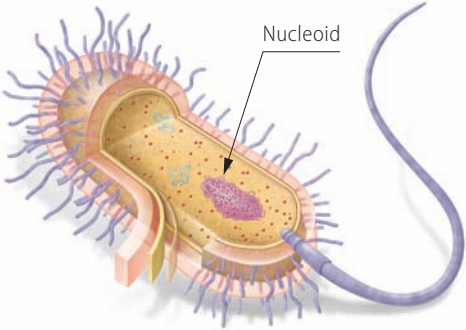
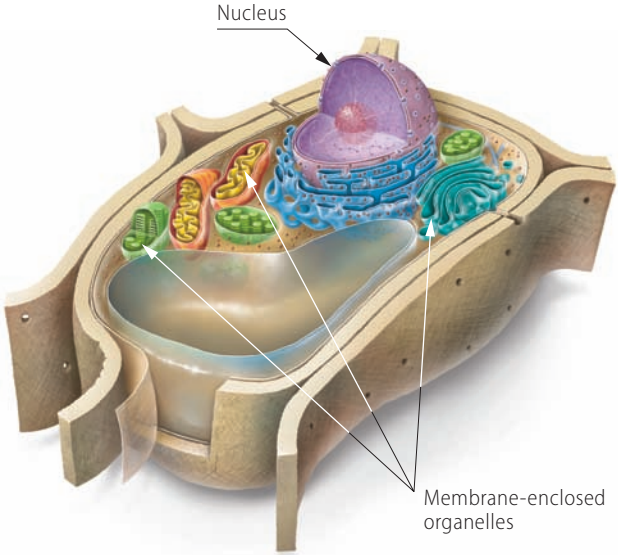
ANSWER: The scientific method.

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

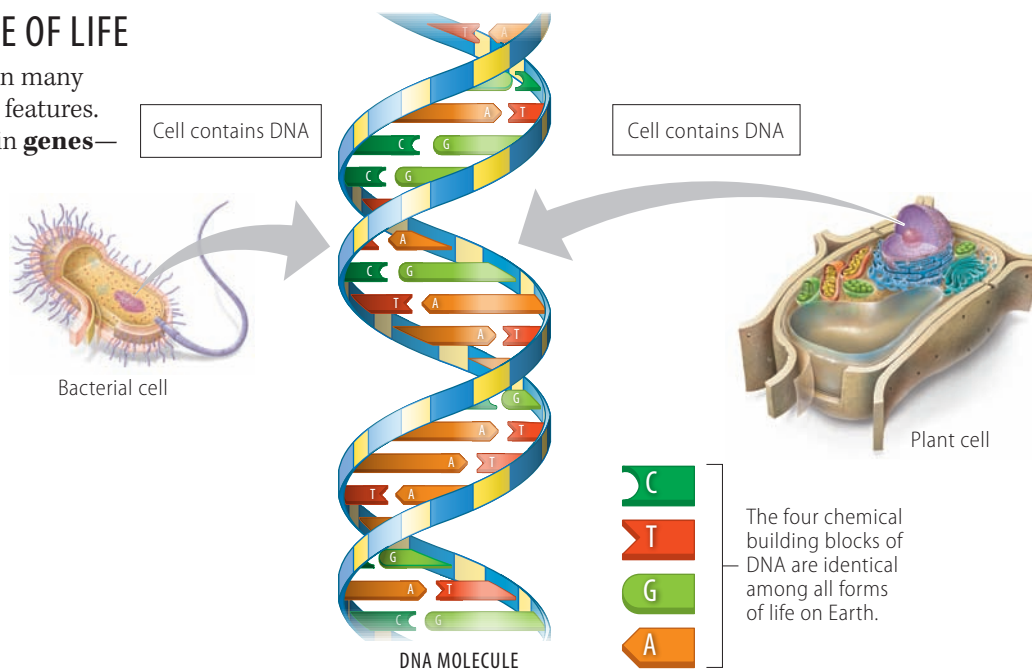
All life on Earth is composed of one of two types of cells: prokaryotic or eukaryotic. These two types of cells have many similarities but also some fundamental differences.

	PROKARYOTIC CELL	EUKARYOTIC CELL
	 <p>A typical prokaryotic bacterial cell</p>	 <p>A typical eukaryotic plant cell</p>
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.

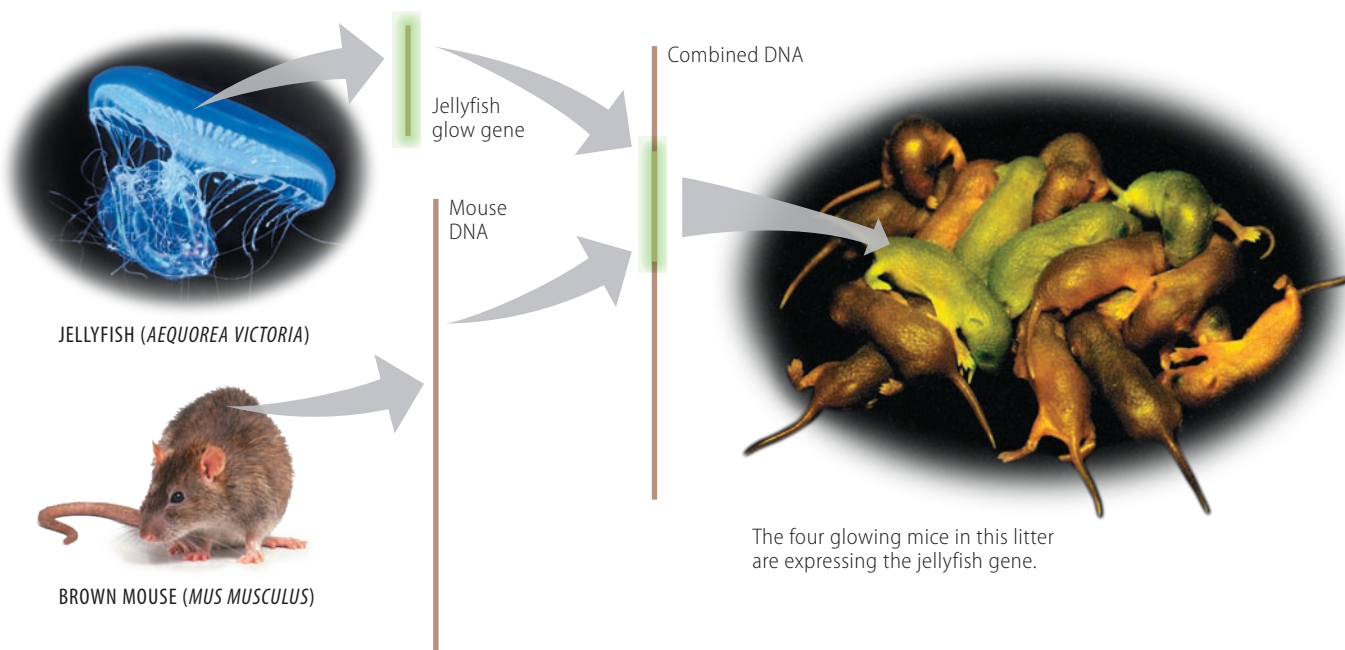
DNA IS THE MOLECULE OF LIFE

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.



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.