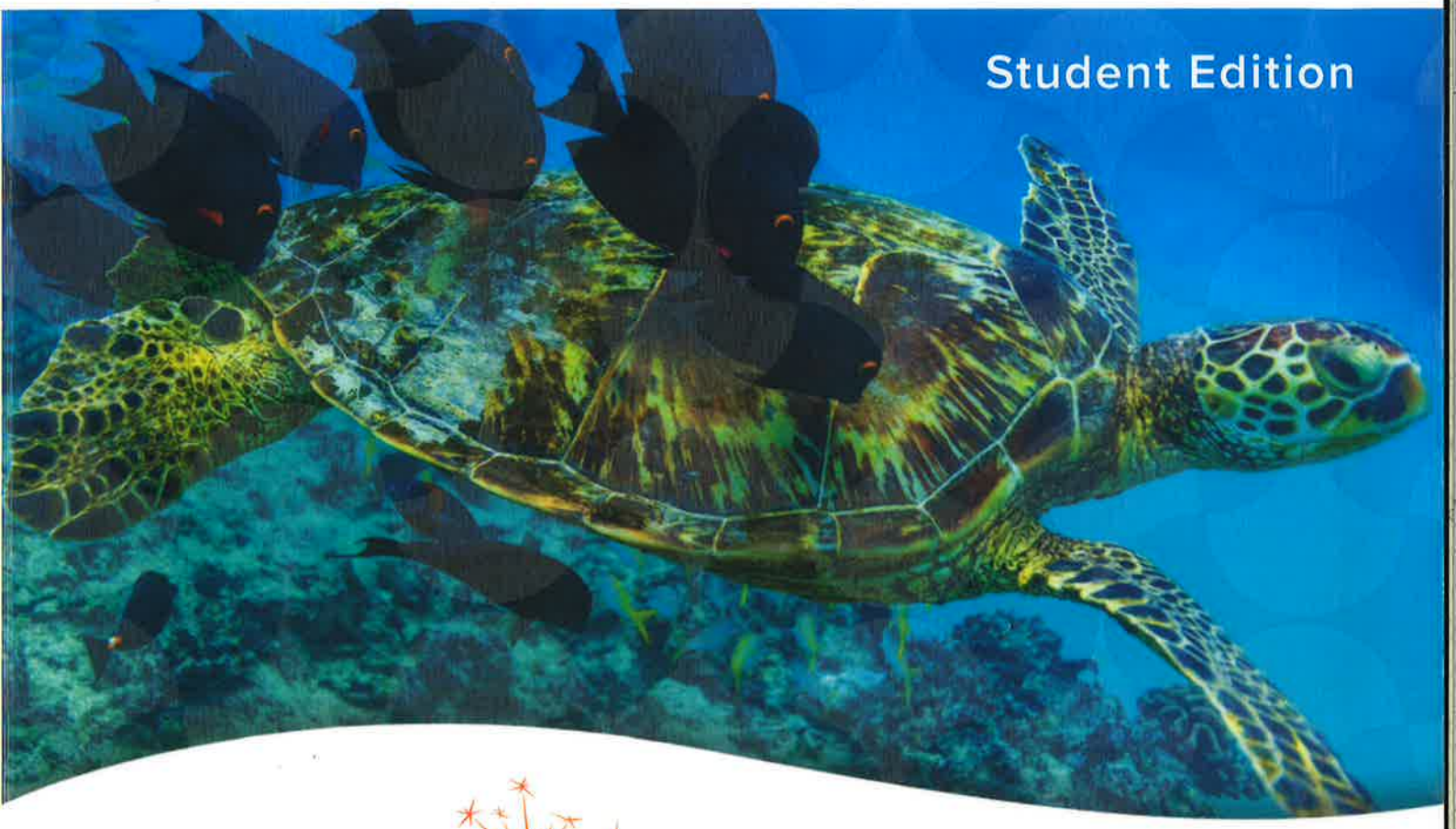
UNITED ARAB EMIRATES
MINISTRY OF EDUCATION

المدرسة الإماراتية



Student Edition

Inspire Science

Life

UAE Edition
Grade 6 ASP
2022-2023

Mc Graw Hill

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UAE Edition Grade 6 ASP 2022-2023

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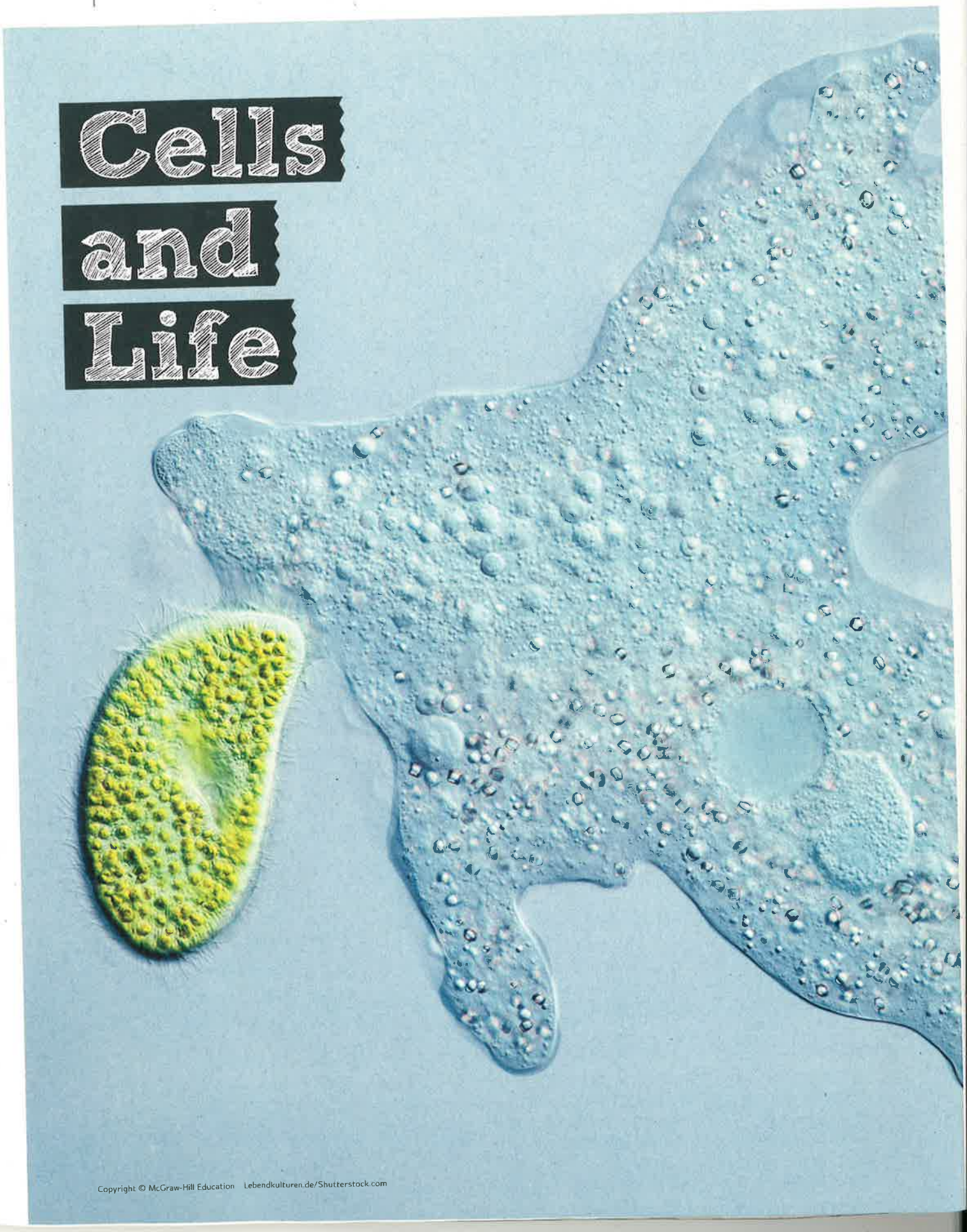
Contents

Cells and Life



ENCOUNTER
THE PHENOMENON

How does this microscopic amoeba perform all the same functions that you do to stay alive?

GO ONLINE
Watch the video *What's for Lunch?* to see this phenomenon in action.

Collaborate With a partner, discuss the functions that both you and the amoeba in the photo need to perform in order to stay alive. How do you think those functions are carried out? Record or illustrate your thoughts in your Science Notebook.

STEM Project

The concepts you learn throughout this module will help you plan and complete the STEM Project. Go online to read more about the project and launch the science challenge!

STEM Project
Science Challenge

IT'S ALIVE! Or is it?

You have been invited by scientists to work on a special project involving the possibility of life on another planet. Your job is to help decide whether or not life has been found in outer space.

Astronauts were able to travel to a nearby planet and gather samples. Some of the samples appear to be living, but the scientists don't know for sure.

Your goal is to determine whether or not the samples are living by conducting an investigation to show what living things are made of, and developing and using a model of the building blocks of a living thing to show how all living things, from yourself to the microscopic amoeba at the beginning of the project, perform functions to stay alive. You will present your investigation and model to a panel of scientists.

After You Read *Exploring Life*

In your Science Notebook, list the steps in your investigation to show whether the samples are living or nonliving.

How will scientists conclude whether the samples from the other planet are living or nonliving?

After You Read *Cell Structure and Function*

Answer the following questions in your Science Notebook.

What will be the parts in your model, and how will you show what each part represents?

How will your model show the function of the system as a whole and the ways each part contributes to the function as a whole?

How will your model help the scientists determine whether the samples are living or nonliving?

Look at the planning you did after each lesson. Use that information to complete the plan for your investigation in your Science Notebook, and build your model.

STEM Project
Science Challenge

Explain Your Investigation and Use Your Model

Now that you've planned your investigation and developed your model, copy and complete the tables below in your Science Notebook.

Investigation	
Purpose What is the phenomenon under investigation?	
Evidence What data will be collected to address the purpose of the investigation?	
Planning Explain the methods and tools to be used in the investigation. Keep in mind the size and scale of cells.	

Model	
Components What are the different parts of my model?	
Relationships How do the components of my model interact?	
Connections How does my model help me understand the phenomenon?	

STEM Project
Science Challenge

Give Your Presentation

Analyze and evaluate your plan and model before you make your presentation for the panel of scientists.

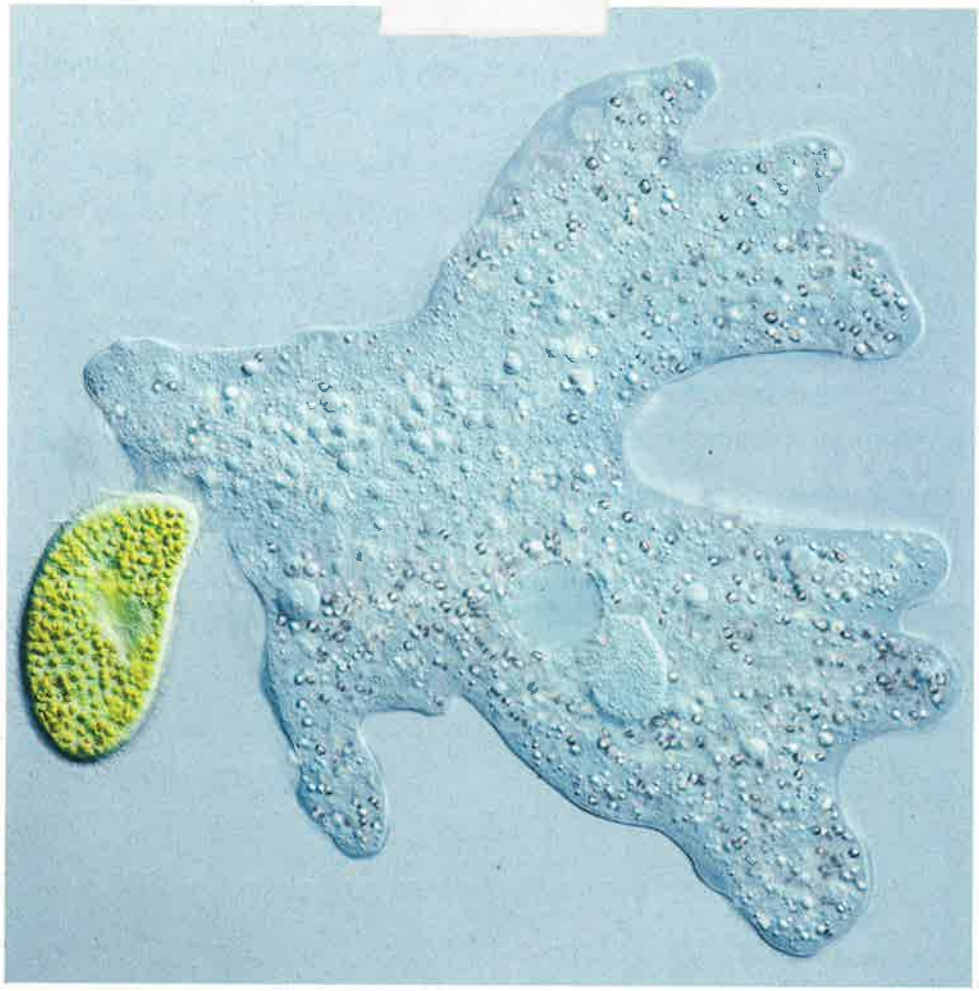
How do your investigation and model help you better understand how the amoeba at the beginning of the project is a living thing that performs the same functions that you do in order to stay alive?

Congratulations! You've completed the Science Challenge requirements.

Wrap-Up

REVISIT THE PHENOMENON

Using the concepts you have learned throughout this module, explain how the amoeba shown at the beginning of the module performs all the same functions that you do to stay alive.



OPEN INQUIRY

What are one or two questions you still have about the phenomenon?

Choose the question that interests you the most. Plan and conduct an investigation to answer this question.

LESSON

Exploring Life

SCIENCE PROBES

Are seeds alive?

Four friends were planting flowers in the school garden. They began to question whether or not seeds are alive. Here are their thoughts:

Eli: I don't think seeds are alive until they are watered.

Tory: I think seeds are always alive.

Kelly: I don't think seeds are alive.

DeAndre: I don't think seeds are alive until they sprout.

Name the friend you most agree with. Explain why you agree with that person. You will revisit your response to the Science Probe at the end of the lesson.

ENCOUNTER
THE PHENOMENON

How can you tell whether or not this campfire is alive?

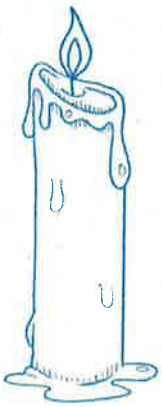
All living things share the same basic characteristics that make them different from nonliving things. Brainstorm what characteristics all living things might have and make a list in your Science Notebook.

Observe the lit candles. Record your observations. Are there any of the characteristics that you listed above that you also observe in the flames?

What characteristics do the flames share with living things? What characteristics of living things do the flames lack? Record your thoughts.

EXPLAIN
THE PHENOMENON

You observed flames and compared them to living things. Did you notice that all living things must have some characteristics in common that make them different from nonliving things? Now make a claim about characteristics that all living things share. Use the outline below to help organize your thinking.



Claim

All living things...

Evidence

A. What evidence have you discovered to explain what living things are made of that differentiates them from nonliving things, such as a flame?

B. What evidence have you discovered to explain the characteristics of life that differentiate living things from nonliving things, such as a flame?

Revise Claim

All living things...

Reasoning

The evidence I collected supports my claim because...

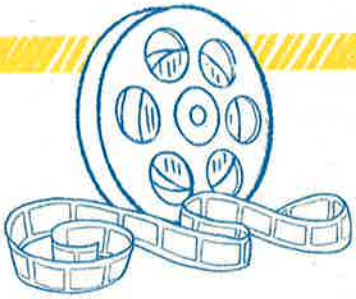
GO ONLINE
Watch the video *Dancing Flames* to see this phenomenon in action.

What are living things?

How can you tell if something is living or nonliving? What is the difference between living things and nonliving things?

INVESTIGATION

Living v. Nonliving



GO ONLINE Watch the video *Is it alive?*

Copy the table below in your Science Notebook and record which things are living and which are not. Explain your reasoning for each.

	Living	Nonliving	Reasoning
Kit fox	✓		
Volcano	✓		
Grapes	✓		
Sand/water		✓	
Sponge		✓	
Robot		✓	
Chrysalis	✓		
Eggs	✓		
Moon/clouds		✓	
Sea anemone	✓		
Light rays		✓	
Bacteria	✓		

Building Blocks of Life All living things share seven characteristics of life. The first characteristic that living things have in common is what they are made of. Let's take a closer look at the building blocks of life.

Want more information?
Go online to read more about the characteristics of living things.

FOLDABLES
Go to the Foldables® library to make a Foldable® that will help you take notes while reading this lesson.

LAB A Closer Look at Life

Safety

Materials

microscope

prepared slides of human cheek sample, onion, pond water, salt

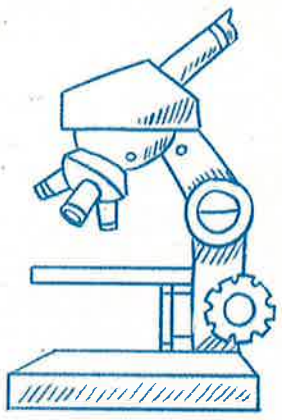
Procedure

1. Read and complete a lab safety form.
2. Observe each slide under the microscope. What do you see? Illustrate and record your observations in your Science Notebook.
3. Follow your teacher's instructions for proper cleanup.

Analyze and Conclude

4. What similarities did you notice between the slides?
5. What differences did you notice between the slides?
6. Make a claim about the differences between the living samples and the nonliving samples.
7. What evidence from the investigation supports your claim?

Technology Leads to Discovery You just used a microscope to observe what living things are made of—**cells.** Have you ever looked up at the night sky and tried to find other planets in our solar system? It is hard to see them without using a telescope because other planets are millions of kilometers away. Just like we can use telescopes to see other planets, we can use microscopes to see cells. But people didn't always know about cells. Because cells are so small, early scientists had no tools to study them. It took hundreds of years for scientists to learn about cells.



Have you ever used a magnifying lens to see details of an object? If so, then you have used a tool similar to the first microscope. The invention of microscopes enabled people to see details of living things that they could not see with the unaided eye. The microscope was an advance in engineering that enabled people to make important discoveries about living things.

For centuries, people have been looking for ways to see objects in greater detail. Can you find a way to do this using only the simple materials in the lab below?

ENGINEERING

LAB Magnify It

Safety

Materials

newspaper	plastic 2-liter bottle	water	scissors
dropper	plastic wrap	glass jar	

Procedure

1. Read and complete a lab safety form.
2. Before you begin exploring the materials, define the problem.
3. What are the criteria and constraints for your exploration? Record them in your Science Notebook in an organizer like the one shown below.

Criteria:	Constraints: Time: Materials:

4. With your group, brainstorm how you could use the given materials to magnify objects. Record your ideas.
5. Test your ideas and collect data. What worked and didn't work? Record your observations.
6. Follow your teacher's instructions for proper cleanup.

Analyze and Conclude

7. Evaluate each of your design solutions by looking at your data and thinking about what worked best. Record your best solution or combine aspects of different solutions to propose your best solution.

Read a Scientific Text

HISTORY Connection More than 300 years ago, an English scientist named Robert Hooke built a microscope. He used that microscope to discover cells. How did he do it, and what conclusions did he come to? Read his original writings on observations of his discovery below.

Take a look at this photo of one of Robert Hooke's drawings!

CLOSE READING

Inspect

Read the passage *Observation XVIII of the Texture of Cork.*

Find Evidence

Reread the passage. Locate words and phrases in which Hooke describes the cells of the cork.

Make Connections

Talk About It With your partner, discuss how the microscope led to the discovery of cells.

PRIMARY SOURCE

Observation XVIII of the Texture of Cork
Robert Hooke, 1665

I took a good clear piece of Cork, and with a Pen-knife sharpen'd as keen as a Razor, I cut a piece of it off, and thereby left the surface of it exceeding smooth, then examining it very diligently with a Microscope, me thought I could perceive it to appear a little porous; but I could not so plainly distinguish them, as to be sure that they were pores, much less what Figure they were of: But judging from the lightness and yielding quality of the Cork, that certainly the texture could not be so curious, but that possibly, if I could use some further diligence, I might find it to be discernable with a Microscope, I with the same sharp Penknife, cut off from the former smooth surface an exceeding thin piece of it, and placing it on a black object Plate, because it was itself a white body, and casting the light on it with a deep plano-convex Glass, I could exceeding plainly perceive it to be all perforated and porous, much like a Honey-comb, but that the pores of it were not regular; yet it was not unlike a Honey-comb in these particulars.

First, in that it had a very little solid substance, in comparison of the empty cavity that was contain'd between [...]

Next, in that these pores, or cells, were not very deep, but consisted of a great many little Boxes [...]

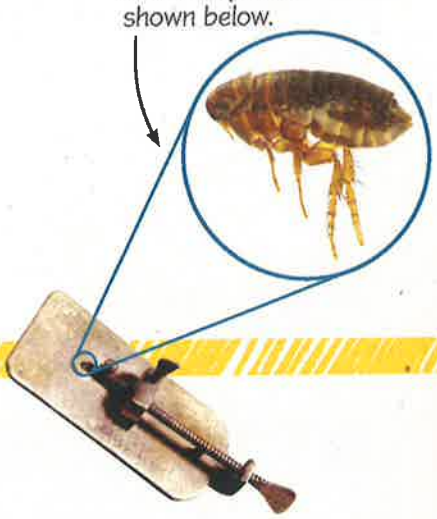
Source: Project Gutenberg

ENGINEERING Connection How have microscopes helped people learn about living things on a different scale?

HISTORY Connection In the late 1600s, the Dutch merchant Anton van Leeuwenhoek (LAY vun hook) made improvements to the first microscopes. His microscope, similar to the one shown in the image, had one lens and could magnify an image about 270 times its original size. This made it easier to view organisms.

After Hooke's discovery, other scientists began making better microscopes and looking for cells in many other places, such as pond water and blood. The newer microscopes enabled scientists to see different structures inside cells. Three important observations about cells made by three different scientists were combined into one theory called the **cell theory.**

Anton van Leeuwenhoek observed pond water and insects using a microscope like the one shown below.



INVESTIGATION

Discovering the Cell Theory

GO ONLINE Watch the animation *The Cell Theory.*

Draw a table like the one below in your Science Notebook. As you watch the animation, fill in the table to describe the three principles of the cell theory.

The Cell Theory	
Principle	Example

Principles of the Cell Theory You might recall that all matter is made of atoms and that atoms combine and form molecules. Molecules make up cells. All living things are made up of cells, which are the smallest unit of life. Cells perform different functions to keep organisms alive. All cells come from preexisting cells through the process of cell division.

COLLECT EVIDENCE

What are living things made of that differentiates them from nonliving things, such as a flame? Record your evidence (A) in your Science Notebook.

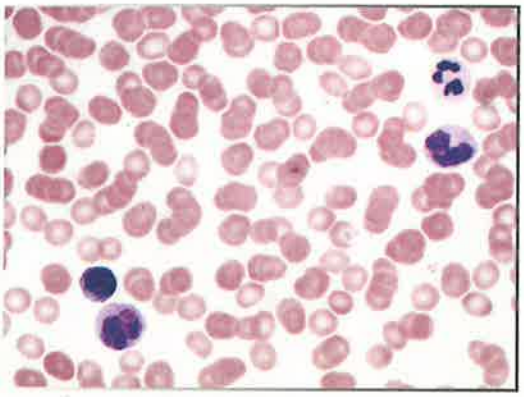
ENGINEERING Connection Since the development of the cell theory in the 1830s, microscopes have continued to become more advanced. If you have used a microscope in school, then you have probably used a light microscope. **Light microscopes** use light and lenses to enlarge an image of an object. Light microscopes can enlarge images up to 1,500 times their original size. In some cases the object, such as the blood cells in the photo on the right, must be stained with a dye in order to see any details.

You might know that electrons are tiny particles inside atoms. **Electron microscopes** use a magnetic field to focus a beam of electrons through an object or onto an object's surface. An electron microscope can magnify an image 100,000 times or more. The two main types of electron microscopes are transmission electron microscopes (TEMs) and scanning electron microscopes (SEMs).

TEMs are usually used to study extremely small things such as cell structures. In a TEM, electrons pass through the object and a computer produces an image of the object. A TEM image of an intestinal microvilli is shown on the right.

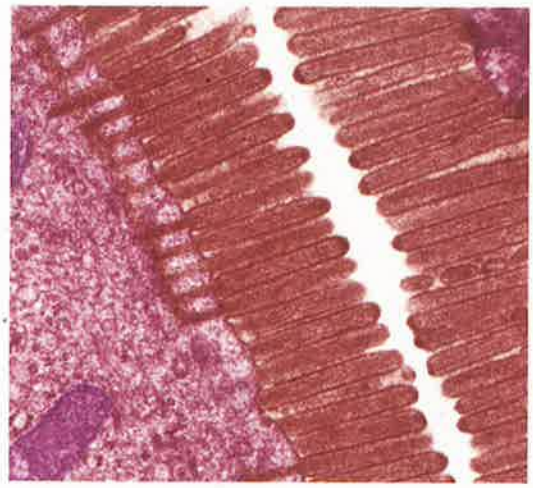
SEMs are usually used to study an object's surface. In an SEM, electrons bounce off the object and a computer produces a three-dimensional image of the object. An image of blood cells from an SEM is shown. Note the difference in detail in this image compared to the image of blood cells from a light microscope.

Light Microscope



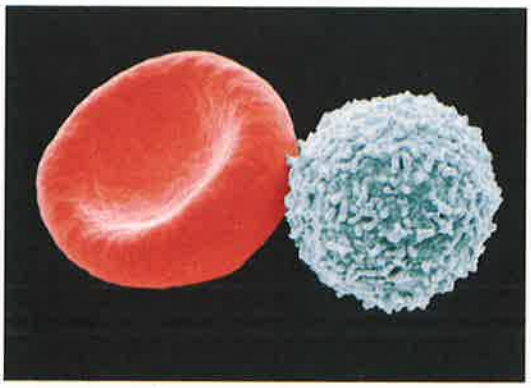
Stained LM Magnification: 640×

Transmission Electron Microscope



Color-Enhanced TEM Magnification: 8,900×

Scanning Electron Microscope



Color-Enhanced SEM Magnification: 8,500×

STEM Careers

A Day in the Life of a Microbiologist

Microbiologists study living things that are too small to be seen with the unaided eye, such as bacteria, algae, and fungi. Some microbiologists also study viruses. Without microscopes, the field of microbiology and the industries it supports, such as the food and medical industries, would not be the same today.

A typical day in the life of a microbiologist depends on what specific field of microbiology he or she works in. Some microbiologists focus solely on certain organisms, such as bacteria; some focus on the ways in which microorganisms interact with the environment; and some focus on ways to detect, treat, and prevent diseases caused by microorganisms.

Microbiologists spend much of their time preparing the samples that they study, conducting experiments, and writing reports on their findings. Since their specimens cannot be seen with the unaided eye, microbiologists use microscopes, along with many other technologies, in their work.

It's Your Turn

WRITING Connection Suppose that you are planning on getting a college degree in microbiology. Which area of microbiology would you like to focus on? Research the different fields and specialties of microbiology, and then choose the one that interests you the most. Write a paragraph explaining the field of microbiology that you have selected and why that field interests you.

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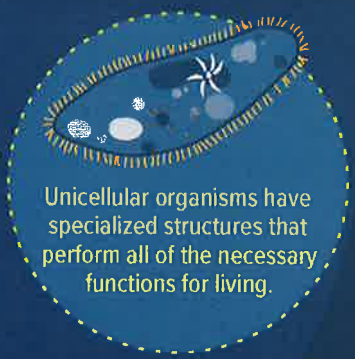
isms are organized in different ways. Living things that are made of only one cell alled **unicellular organisms**. Living things that are made of two or more cells are l multicellular organisms.

Unicellular organisms are made of one cell.

Paramecium

Amoeba



Unicellular organisms have specialized structures that perform all of the necessary functions for living.

Multicellular organisms are made of two or more cells.

.2 llion Mouse

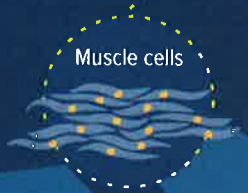
7.2 illion Human

.00 adrillion Blue whale

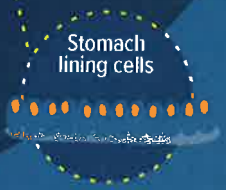
In multicellular organisms the cells are organized into groups that have specialized functions, such as:

Movement

Digestion



Muscle cells



Stomach lining cells

THREE-DIMENSIONAL THINKING

What do you notice about scale, proportion, and quantity of cells in unicellular versus multicellular organisms? Record your response in your Science Notebook.

STEM Careers

A Day in the Life of a Microbiologist

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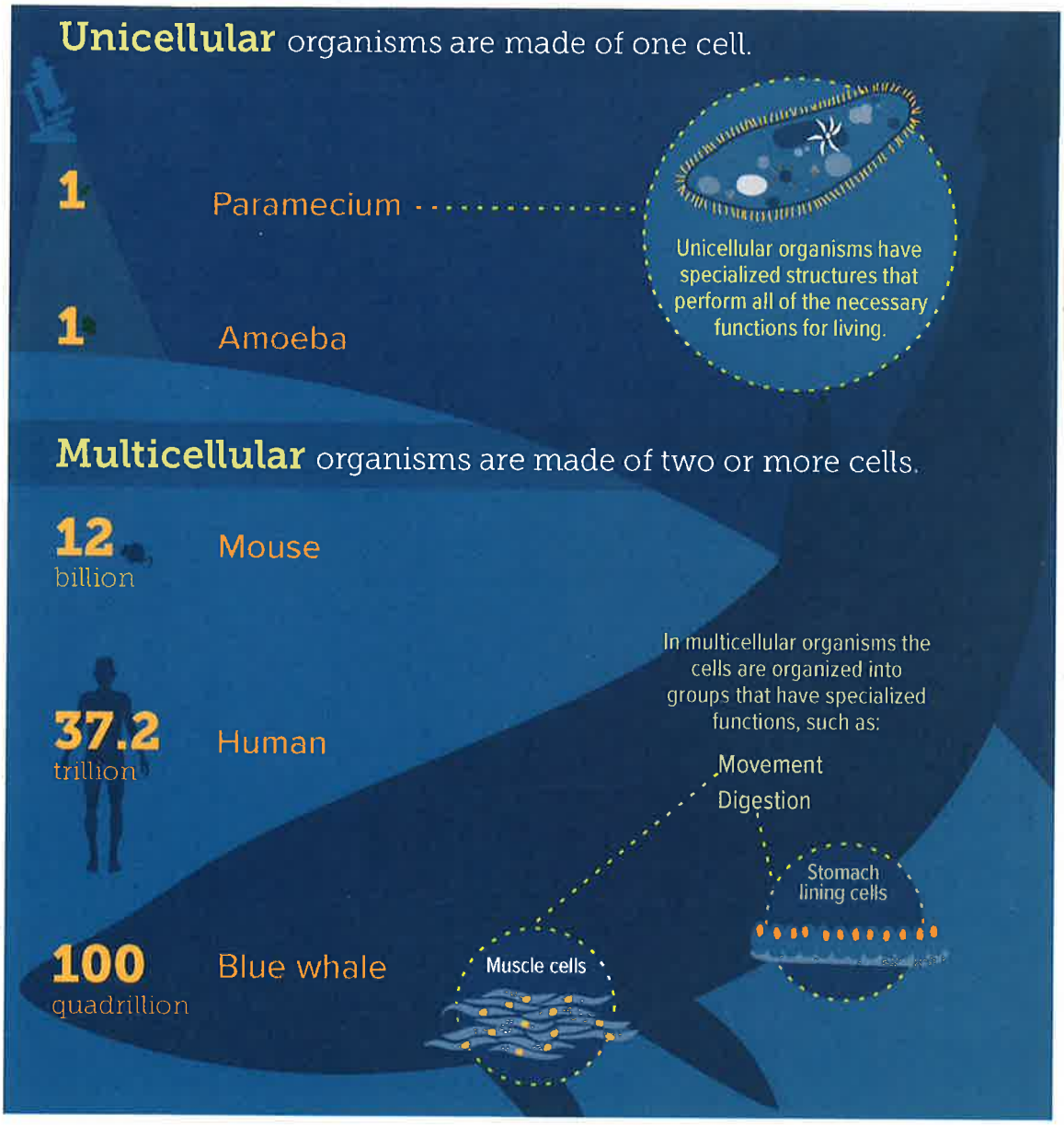
How many cells do living things have?

Organisms are organized in different ways. Living things that are made of only one cell are called **unicellular organisms**. Living things that are made of two or more cells are called multicellular organisms.



THREE-DIMENSIONAL THINKING

What do you notice about scale, proportion, and quantity of cells in unicellular versus multicellular organisms? Record your response in your Science Notebook.

Common Characteristics You now know that all living things are made of cells. What are the other six characteristics that all living things have in common? These include organization, growth and development, reproduction, response to stimuli, maintaining internal conditions, and using energy.

INVESTIGATION

Characteristics of Life

WRITING Connection Your teacher will assign one of the characteristics of life for you to research with your group. Create graphic organizers like the ones below in your Science Notebook. Use the graphic organizer for your characteristic to help guide your research. Your group will create a visual for your assigned characteristic and present it to the class. Fill in the graphic organizers for the rest of the characteristics as the other groups present.

1. Organization

Living things are organized by...

organisms are less complex.

organisms are more complex.

2. Growth and development

Growth is...

Development is...

3. Reproduction

Reproduction is...

Types of reproduction:

4. Response to stimuli

Internal stimuli are...

Examples:

External stimuli are...

Examples:

5. Maintaining internal conditions

Maintaining internal conditions is called

Examples of how organisms maintain internal conditions:

6. Use of energy

Most organisms get their energy from _____.

_____ use energy from the Sun to make food.

Other organisms obtain energy by _____ _____.

Characteristics of Life All living things are organized according to different structures that perform different functions. Living things grow and develop meaning they increase in size and go through changes during their lifespans. Living things create new living things through the process of **reproduction.** They also respond to changes in their environments called stimuli. Another characteristic of organisms is that they maintain **homeostasis**, the ability to keep steady internal conditions when outside conditions change. All organisms require energy for everything they do. If something doesn't display each of these characteristics, it is not a living thing.

COLLECT EVIDENCE

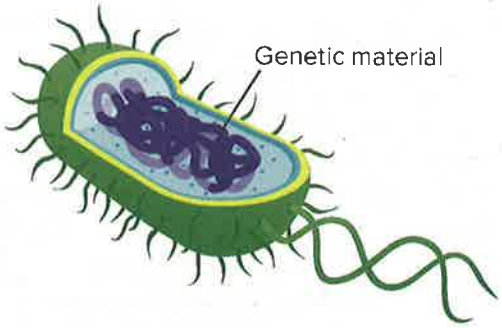
What are the characteristics of living things that differentiate them from nonliving things, such as a flame? Record your evidence (B) in your Science Notebook.

What are the different types of cells?

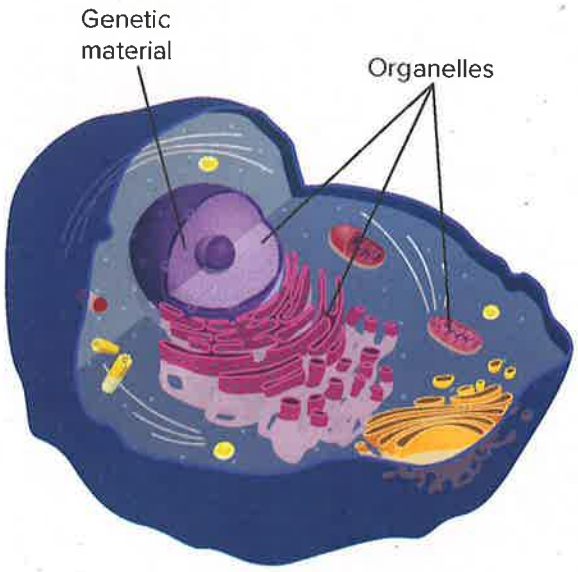
Recall that the use of microscopes enabled scientists to discover cells. With more advanced microscopes, scientists discovered that all cells can be grouped into two categories—prokaryotic (proh ka ree AH tihk) cells and eukaryotic (yew ker ee AH tihk) cells.

All cells contain genetic material—the means by which information is transmitted from one generation to the next. In some cells this genetic material is surrounded by a lining. In **prokaryotic** cells, the genetic material is not surrounded by a lining. This is the most important feature of a prokaryotic cell. In general, prokaryotic cells are smaller than eukaryotic cells and have fewer parts to their cells. Most prokaryotic cells are unicellular organisms and are called prokaryotes. Some prokaryotes live in small groups called colonies. Some can also live in extreme environments.

Plants, animals, fungi, and organisms called protists are all made of eukaryotic cells and are called eukaryotes. With few exceptions, each **eukaryotic** cell has genetic material that is surrounded by a lining. Every eukaryotic cell also has other structures called **organelles** which have specialized functions. Most organelles are surrounded by linings. Eukaryotic cells are usually larger than prokaryotic cells. About ten prokaryotic cells would fit inside one eukaryotic cell.



Prokaryotic cell



Eukaryotic cell

Compare and contrast prokaryotic cells and eukaryotic cells by completing a Venn diagram in your Science Notebook.

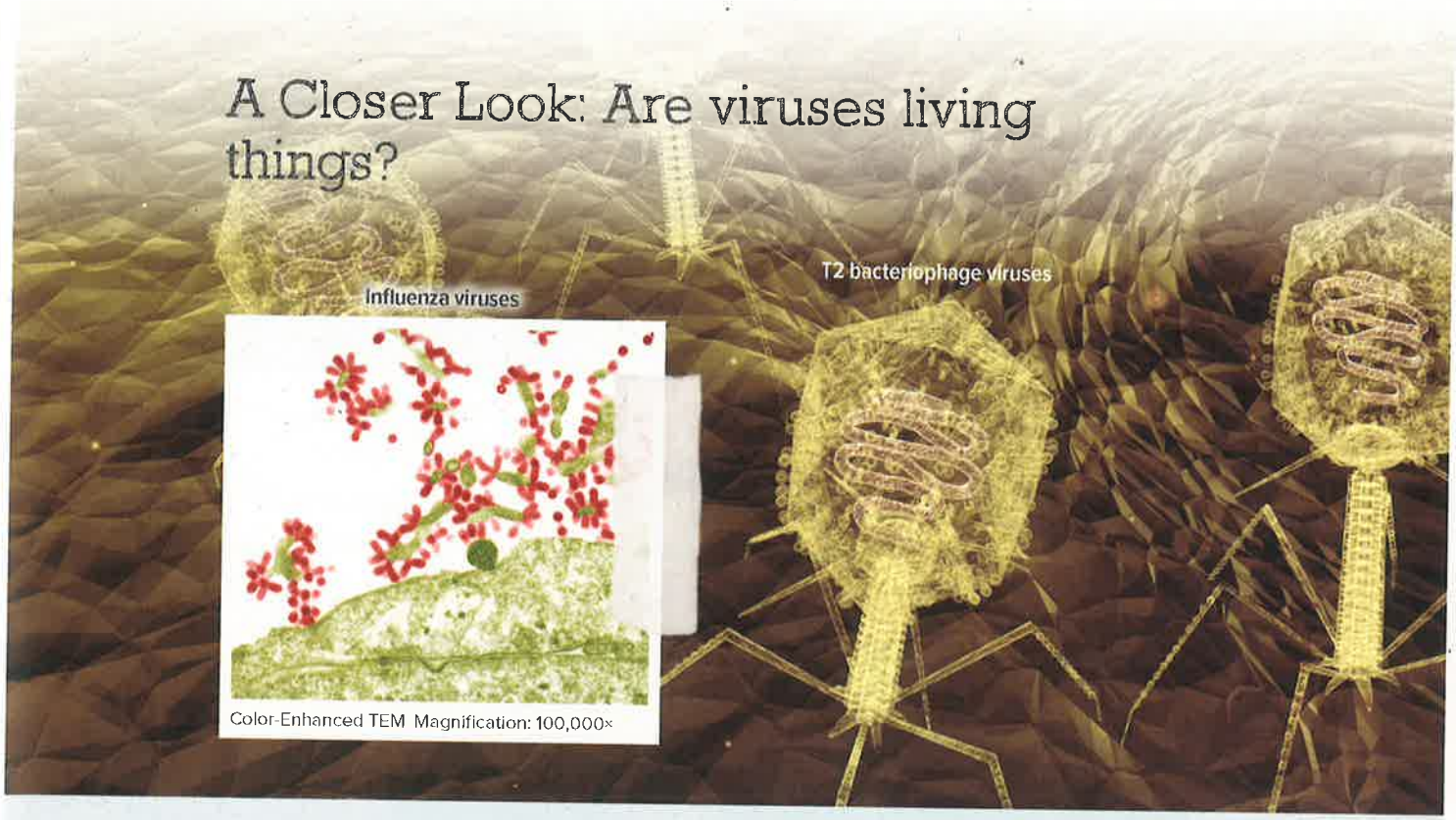
Classification Organisms are classified according to their cell type, prokaryotic or eukaryotic, as well as other characteristics. All organisms are classified into one of three domains—Bacteria, Archaea, or Eukarya (yew KER ee uh)—and then into one of six kingdoms. Organisms in the Bacteria and Archaea domains are unicellular prokaryotes, while organisms in the Eukarya domain are eukaryotes. The classification system of living things is still changing. The current classification method uses all the evidence that is known about organisms to classify them. This evidence includes an organism's cell type, habitat, the way it obtains food and energy, the structure and function of its features, and its common ancestry.

What about viruses? Where do they fit into this classification system? Are they living things?

Domains and Kingdoms

Domain	Bacteria	Archaea	Eukarya			
Kingdom	**Bacteria**	**Archaea**	**Protista**	**Fungi**	**Plantae**	**Animalia**
Example						
Characteristics	Bacteria are simple unicellular organisms.	Archaea are simple unicellular organisms that often live in extreme environments.	Protists are unicellular or multicellular and are more complex than bacteria and archaea.	Fungi are unicellular or multicellular and absorb food.	Plants are multicellular and make their own food.	Animals are multicellular and take in their food.

A Closer Look: Are viruses living things?



Color-Enhanced TEM Magnification: 100,000×

Color-Enhanced TEM Magnification: 64,000×

Have you ever had a cold, the chicken pox, or the flu? If so, then you have been infected by a virus. Are viruses alive? Let's see if viruses have all the characteristics of life to find out more.

Like living things, viruses also have structure and are organized. Viruses don't grow or develop like living things do. Viruses do reproduce and make more viruses, but in order to do so they need to enter and take over living cells. While viruses don't respond to light or sound the way that animals do, we still cannot say for sure that viruses don't respond to anything in their environment. It takes a lot of energy for viruses to replicate, but the energy that viruses use comes from the host. Viruses are not made up of cells like living things are, so they do not have the parts of cells required to maintain certain internal conditions.

Most scientists agree that since viruses aren't made out of cells, don't grow, use energy only from a host, and don't maintain homeostasis, they are not living things.

Ebola virus particles

Color-Enhanced SEM Magnification: Unavailable

It's Your Turn

WRITING Connection What questions do you still have about viruses? Research one question, gathering information from several sources, and write a paragraph on your findings. Record other questions that come up as your conduct your research.

Summarize It!

1. **Organize** In your Science Notebook, create an infographic that shows what you know about living things. Include illustrations, key terms, and examples in your infographic. Make sure to show all that you know!

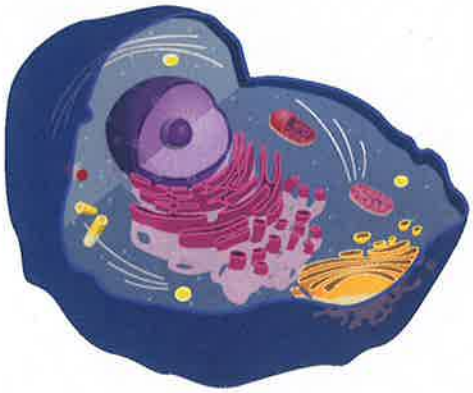
REVISIT SCIENCE PROBES Do you still agree with the friend you chose at the beginning of the lesson? Return to the Science Probe at the beginning of the lesson. Explain why you agree or disagree with that person now.

EXPLAIN THE PHENOMENON

Revisit your claim about characteristics of living things. Review the evidence you collected. Explain how your evidence supports your claim.

Three-Dimensional Thinking

2. If a living organism contains a cell with the structures seen in the diagram, which of the following can you conclude about the organism?



   A The organism is a eukaryote.

   B The organism is unicellular.

   C The organism's cells do not contain organelles.

   D The organism's cells do not contain genetic information.

3. If you were to conduct an investigation to determine if an organism is a plant or an animal, which characteristic could be used to distinguish between the two?

   A whether the organism is unicellular or multicellular

   B whether or not the organism is made of cells

   C whether or not the organism responds to its environment

   D whether the organism makes its own food or takes in food

4. Which should NOT be included in a model developed to show differences between unicellular and multicellular organisms?

   A Unicellular organisms have fewer cells than multicellular organisms.

   B Unicellular organisms are larger than multicellular organisms.

   C Unicellular organisms are organized differently than multicellular organisms.

   D Unicellular organisms are smaller than multicellular organisms.

Real-World Connection

5. **Construct an Argument** Your friend thinks that studying cells is a waste of time. He says, "Cells are so small, most of them can't even be seen without a microscope. So why waste your time focusing on researching things you can't even see?!" Construct an argument detailing the importance of studying cells and how it can affect your friend's life.

6. ENGINEERING Connection Using what you've learned in this lesson, explain how science is dependent on advances in engineering and technology.

LESSON

Cell Structure and Function

PAGE KEELEY SCIENCE PROBES

The Basic Unit of Life

The cell is called the basic unit of life. What do you think that means? Choose the answer that best matches your thinking.

A. I think it means the cell is the smallest part of matter.
B. I think it means the cell is the smallest part of mass.
C. I think it means the cell is the smallest part of volume.
D. I think it means the cell is the smallest part of mass and volume.
E. I think it means the cell is the smallest part of energy.
F. I think it means the cell is the smallest part of structure.
G. I think it means the cell is the smallest part of structure and function.
H. I think it means the cell is the smallest part of matter, structure, and function.
I. I think it means the cell is the smallest part of matter, energy, and structure.

Explain your answer. Describe your thinking about the cell as a basic unit of life. You will revisit your response to the Science Probe at the end of the lesson.

Color-Enhanced SEM Magnification: Unavailable

ENCOUNTER
THE PHENOMENON

How do the parts of an ostrich egg–the largest cell on the planet–work together in order for it to function?

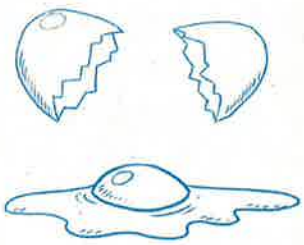
Bird eggs have different structures, such as a shell, a membrane, and a yolk. Each structure has a different function that assists in development of the baby bird. Place an uncooked egg in a bowl. Feel the shell and record your observations in your Science Notebook. Crack open the egg. Pour the contents into the bowl. Observe the inside of the shell and the contents of the egg. Record your observations. What do you think is the role of the eggshell? What does the structure of the eggshell tell you about its function?

EXPLAIN
THE PHENOMENON

You observed an egg and inferred the function of its shell. Like the egg, other cells also have separate parts with particular functions. Use your observations about the phenomenon to make a claim about how different parts of a cell work together in order for a whole cell to function. Use the outline below to guide your thinking.

Claim

Parts of a cell work together...



Evidence

A. What evidence have you discovered to explain what structures surround a cell, such as the ostrich egg, and how these structures help a cell function?

B. What evidence have you discovered to explain what powers a cell?

C. What evidence have you discovered to explain what controls a cell?

Revise Claim

Parts of a cell work together...

Reasoning

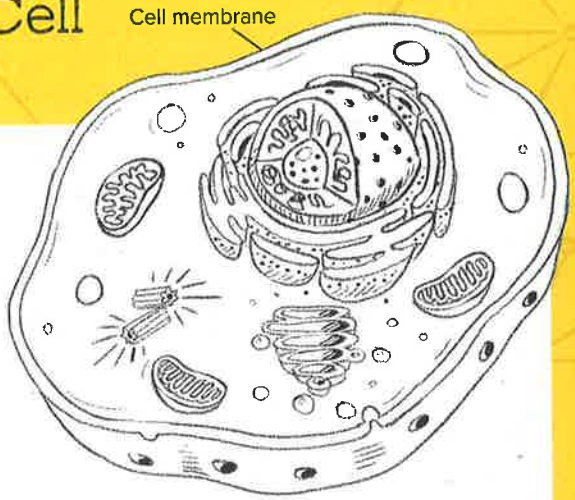
The evidence I collected supports my claim because...

GO ONLINE
Watch the video *Eggcellent Science* to see this phenomenon in action.

What surrounds a cell?

Although different types of cells perform different functions, all cells have some structures in common. Every cell is surrounded by a protective boundary called a membrane. The **cell membrane** is a flexible covering that protects the inside of a cell from the environment outside a cell. What else does the cell membrane do? Let's investigate!

LAB Investigating Cell Membranes



Safety

Materials

piece of wire mesh
600-mL beaker
birdseed

Procedure

1. Read and complete a lab safety form.
2. Place a square of wire mesh on top of a beaker.
3. Pour a small amount of birdseed on top of the wire mesh. Record your observations in your Science Notebook.
4. Follow your teacher's instructions for proper cleanup.

Analyze and Conclude

5. If the wire mesh in this model represents the cell membrane, how do you think the cell membrane controls what materials enter and leave a cell?

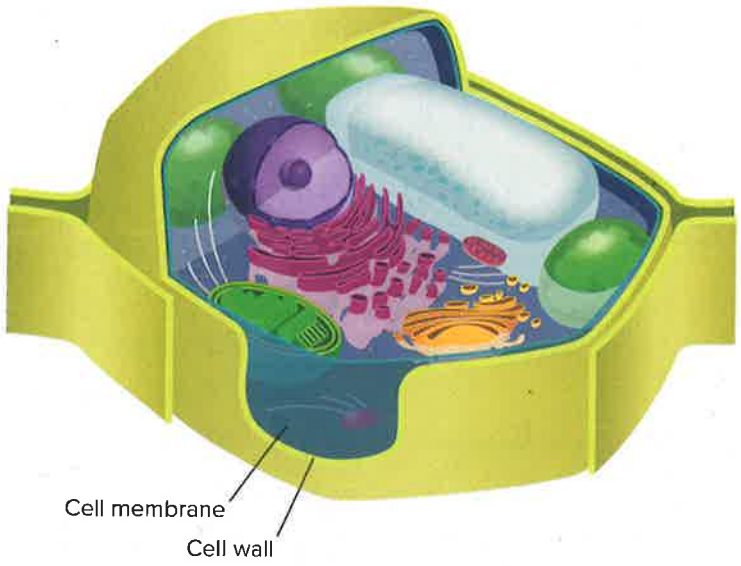
Want more information?
Go online to read more about cell structure and function.

FOLDABLES
Go to the Foldables® library to make a Foldable® that will help you take notes while reading this lesson.

Cell Membrane The cell membrane surrounds the cytoplasm. The **cytoplasm** is a fluid inside a cell that contains salts and other molecules. However, as you just observed, another important role of cell membranes is to control the movement of substances into and out of cells. A cell membrane is semipermeable. This means it allows only certain substances, like nutrients and wastes, to enter or leave a cell.

Cell Wall Every cell has a cell membrane, but some cells are also surrounded by a structure called the cell wall. Plant cells, fungal cells, bacteria, and some types of protists have cell walls. Take a look at the image of the plant cell below and compare it to the image of the cell on the previous page.

A **cell wall** is a stiff structure outside the cell membrane. A cell wall protects a cell from attack by viruses and other harmful organisms. In some plant cells and fungal cells, a cell wall helps maintain the cell's shape and gives structural support.



COLLECT EVIDENCE

What structures surround a cell, and how do these structures help a cell function? Record your evidence (A) in your Science Notebook.

GO ONLINE for additional opportunities to explore!

Investigate cell membranes by performing one of the following activities.

Discover the function of a cell membrane in the **Lab** *How is a balloon like a cell membrane?*

OR

Explore more about the cell membrane in the **PhET Interactive Simulation** *Membrane Channels.*

How does cell size affect the transport of materials?

Nutrients, oxygen, and other materials enter and leave a cell through the cell membrane. Does the size of a cell affect the transport of these materials throughout the cell? Let's investigate!

Surface Area and Volume The movement of nutrients, waste material, and other substances into and out of a cell is important for survival. For this movement to happen, the area of the cell membrane must be large compared to its volume. The area of the cell membrane is the cell's surface area. The volume is the amount of space inside the cell. As a cell grows, both its volume and its surface area increase. The volume of a cell increases faster than its surface area. If a cell were to keep growing, it would need large amounts of nutrients and would produce large amounts of waste material. However, the surface area of the cell's membrane would be too small to move enough nutrients and wastes through it for the cell to survive.

INVESTIGATION

Cell Size and Transport of Materials

Watch the demonstration.

1. Use colored pencils to illustrate the two samples you observed in the demonstration.
2. How does the depth of the color compare on the two cubes?

MATH Connection A ratio is a comparison of two numbers, such as surface area and volume. If a cell were cube-shaped, you would calculate surface area by multiplying its length (ℓ) by its width (w) by the number of sides (6).

You would calculate the volume of the cell by multiplying its length (ℓ) by its width (w) by its height (h). To find the surface-area-to-volume ratio of the cell, divide its surface area by its volume.

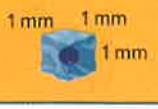
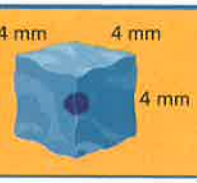
$$\text{Surface area} = \ell \times w \times 6$$

$$\text{Volume} = \ell \times w \times h$$

$$\frac{\text{Surface area}}{\text{Volume}}$$

In the table on the next page, surface-area-to-volume ratios are calculated for cells that are 1 mm and 4 mm per side. Notice how the ratios change as the cell's size increases.

3. Create a table like the one shown below in your Science Notebook. Fill in the missing parts of the table.

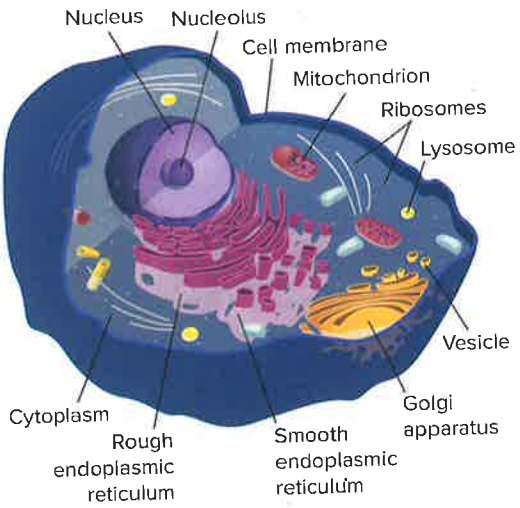
		
Length	1 mm	4 mm
Width	1 mm	4 mm
Height	1 mm	4 mm
Number of Sides	6	?
Surface Area ($\ell \times w \times$ no. of sides)	1 mm × 1 mm × 6 = ? mm^2	4 mm × 4 mm × 6 = 96 mm^2
Volume ($\ell \times w \times h$)	1 mm × 1 mm × 1 mm = 1 mm^3	4 mm × 4 mm × 4 mm = ? mm^3
Surface-area-to-volume ratio	$\frac{6\ mm^2}{1\ mm^3} = \frac{6}{1}$ or ? :1	$\frac{96\ mm^2}{64\ mm^3} = \frac{1.5}{1}$ or 1.5:1

4. Would a cell with a small surface-area-to-volume ratio be able to transport nutrients and waste through the cell as efficiently as a cell with a large surface-area-to-volume ratio? Explain why or why not.

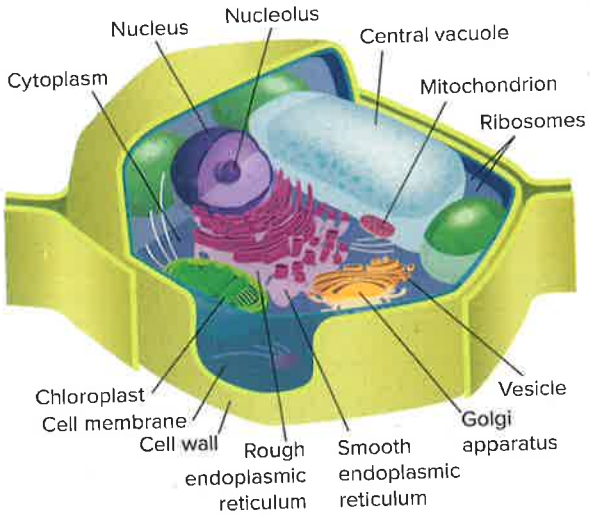
What organelles are involved in the transport of materials?

As you just discovered, the cell membrane enables materials to enter and leave the cell. There are several other organelles related to the transport of materials as well.

Ribosomes Amino acid molecules made up of carbon, hydrogen, oxygen, nitrogen, and sometimes sulfur, join together to form long chains called **proteins**. Some proteins help cells communicate with each other while others transport substances inside cells. Proteins are made on small structures called ribosomes. Unlike other cell organelles, a ribosome is not surrounded by a membrane.



Animal Cell



Plant Cell

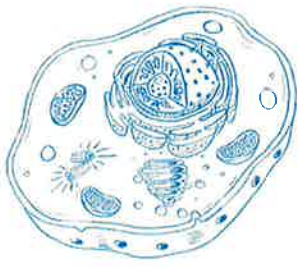
Endoplasmic Reticulum Ribosomes can be attached to a weblike organelle called the endoplasmic reticulum (en duh PLAZ mihk • rih TIHK yuh lum), or ER. The ER spreads from the nucleus throughout most of the cytoplasm. Endoplasmic reticulum with ribosomes on its surface is called rough endoplasmic reticulum. Rough ER is the site of protein production. ER without ribosomes is called smooth ER. Smooth ER is helps remove harmful substances from a cell.

Vacuoles Some cells also have saclike structures called vacuoles. Vacuoles are organelles that store food, water, and waste material. A typical plant cell usually has one large vacuole. Some animal cells have many small vacuoles. A plant cell's vacuole may take up half of the cell's size. This vacuole not only stores water and other substances, but also enables the plant to stay rigid and supported when filled with water.

The Golgi Apparatus Proteins are prepared for their specific jobs or functions by an organelle called the Golgi apparatus. Then the Golgi apparatus packages the proteins into tiny, membrane-bound, ball-like structures called vesicles. Vesicles are organelles that transport substances from one area of a cell to another area of a cell. Some vesicles in an animal cell are called lysosomes. Lysosomes contain substances that help break down and recycle cellular components.

THREE-DIMENSIONAL THINKING

In your Science Notebook, create a graphic organizer that explains how the various **structures,** or organelles, you just learned about help a cell **function** as a whole.



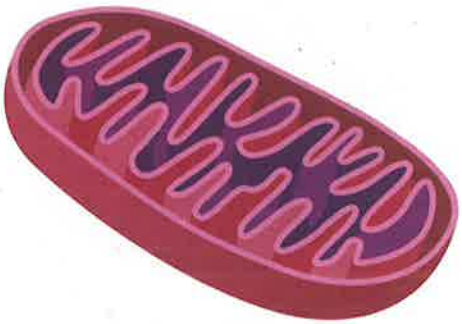
What powers cellular activity?

You learned about how cells transport materials across the cell membrane. How does the cell power such complex activity?

INVESTIGATION

Powering a Cell

What do you notice about the two organelles? What are their differences, and what are their similarities? Can you infer what their functions are? Summarize your thoughts in your Science Notebook.



Mitochondria The bean-shaped organelle on the left is called a mitochondrion, and it powers the cell through chemical reactions. Mitochondria are found in both plant and animal cells. It has two membranes to increase the surface area for these reactions to occur. Mitochondria are a vital part of cellular respiration. **Cellular respiration** is a series of chemical reactions that convert the energy in food molecules into a usable form of energy called ATP.

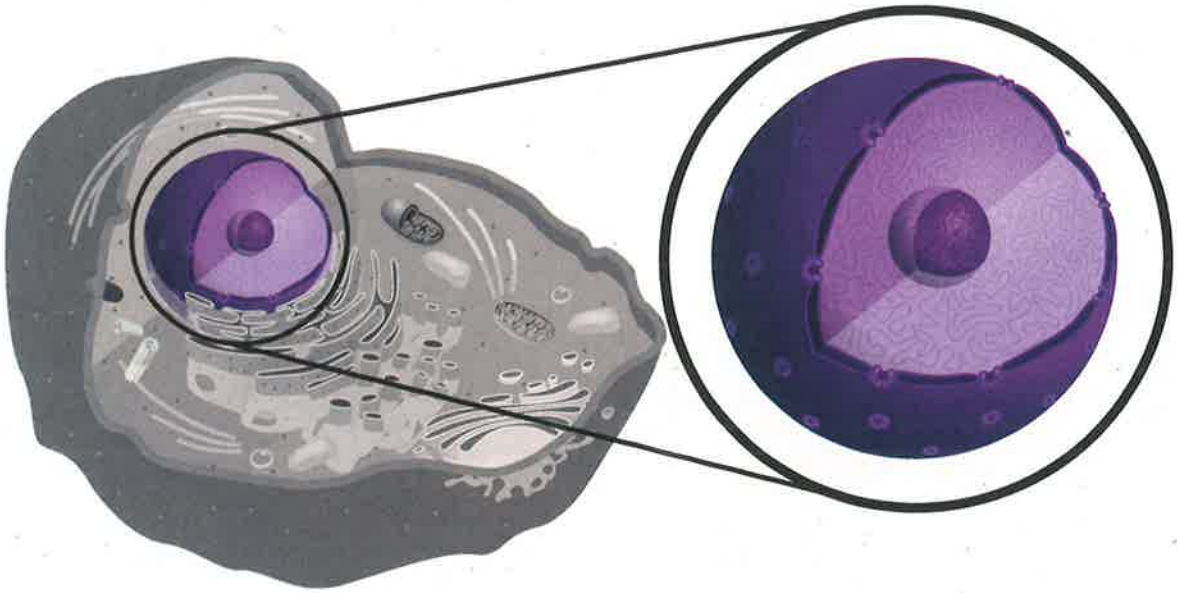
Powering Plant Cells In addition to mitochondria, plant cells contain organelles called chloroplasts (KLOR uh plasts). **Chloroplasts** are organelles that use light energy and make food—a sugar called glucose—from water and carbon dioxide.

COLLECT EVIDENCE

How is a plant or animal cell powered? Record your evidence (B) in your Science Notebook.

What controls all of this activity?

The largest organelle inside most eukaryotic cells is the nucleus. The **nucleus** is the part of a eukaryotic cell that directs cell activities and contains important cellular information stored in DNA. DNA is organized into structures called chromosomes. The DNA of each cell carries information that provides instructions for making all the proteins a cell requires.



In addition to chromosomes, the nucleus contains proteins and an organelle called the nucleolus (new KLEE uh lus). The nucleolus makes ribosomes, organelles that are involved in the production of proteins. The nucleus controls all cell activity by directing protein synthesis. Proteins are needed for almost every function in the body.

THREE-DIMENSIONAL THINKING

Can you think of some analogies for the nucleus? In your Science Notebook, make a drawing, diagram, or other illustration to help you understand the structure and function of the nucleus.

COLLECT EVIDENCE

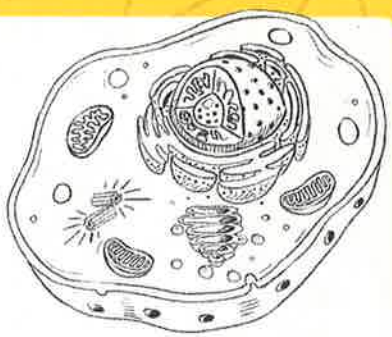
What controls a cell? Record your evidence (C) in your Science Notebook.

What is the difference between plant and animal cells?

You've learned that plants and animal cells differ in that plant cells have cell walls, but animal cells don't. How else are plant and animal cells different?

LAB Plant and Animal Cells

Safety



Materials

microscope	microscope slide and coverslip
forceps	dropper
Elodea plant	prepared slide of human cheek cells

Procedure

1. Read and complete a lab safety form.
2. Using forceps, make a wet mount slide of a young leaf from the tip of an *Elodea* plant.
3. Use a microscope to observe the leaf on low power. Focus on the top layer of cells.
4. Switch to high power and focus on one cell. Moving around the central vacuole are green, disk-shaped objects called chloroplasts. Try to find the nucleus. It looks like a clear ball.
5. Draw a diagram of an *Elodea* cell in your Science Notebook. Label the cell wall, chloroplasts, cytoplasm, and nucleus. Return to low power and remove the slide. Properly dispose of the slide.
6. Observe the prepared slide of cheek cells under low power.
7. Switch to high power and focus on one cell. Draw a diagram of one cheek cell in your Science Notebook. Label the cell membrane, cytoplasm, and nucleus. Return to low power and remove the slide.
8. Follow your teacher's instructions for proper cleanup.

Analyze and Conclude

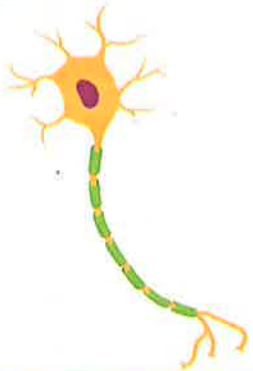
9. Based on your diagrams, how do the shapes of the *Elodea* cell and cheek cell compare?
10. Compare and contrast the cell structures in your two diagrams. Which structures did you observe in both cells? Which structures did you observe in only one of the cells?

What can different cells do?

You might recall that all living things are made up of one or more cells. Multicellular organisms have different types of cells with different functions that enable the survival of the entire organism. Cells come in many shapes and sizes. Explore how the structure of a cell relates to what it does.

THREE-DIMENSIONAL THINKING

The **structure** of a cell relates to its job, or **function.** Create a table like the one below in your Science Notebook. Infer each cell's function based on its shape.



Types of Cells and Structures Cells in the body can be incredibly diverse, as you just saw. Red blood cells are disk-shaped, which helps them move through blood vessels so that they can carry oxygen throughout the body. Xylem cells are tubelike cells that transport water from the roots to the leaves of plants. The neuron is a cell found in many animals that transmits impulses from different parts of the body. Each cell is unique but works with other cells as body functions are carried out.

A Closer Look: Vivacious *Vorticella*

Color-Enhanced SEM
Magnification: 1,300×

The organism you see isn't an alien but a unicellular organism called a *Vorticella*! The *Vorticella* is a protozoan found in freshwater ponds and lakes. The *Vorticella* may be small, but it has everything it needs to survive. The opening of the cell may look like it is full of hair, but the structures are actually appendages that help it gather food. The hairlike appendages are called cilia, and they create small water currents that bring food toward the cell. And that spiral appendage isn't a tail; it's a stalk that allows the cell to latch onto surfaces.

LM Magnification: 430×

HISTORY Connection *Vorticella* was first discovered by a Dutch scientist named Anton van Leeuwenhoek who thought its mouth parts were horns. Since then, scientists studying the organism have discovered its possibilities as a pest controller. *Vorticella* is able to bind to mosquito larvae and prevent them from reaching maturity. Mosquitos are known to carry pathogens that are dangerous to humans.

Vorticella may be small, but it has everything it needs to survive and thrive.

It's Your Turn

READING Connection With a partner, choose another unicellular organism to research. Create a presentation with a visual aid that details how the organism's structures relate to functions that ensure its survival.

LESSON
Review

Summarize It!

1. **Classify** information about organelles and cell structures. Draw a table like the one below in your Science Notebook. In the center column, describe the function of each. In the right-hand column, indicate whether the organelle is in a plant cell, an animal cell, or both.

Organelle	Function	Plant, animal, or both?
Nucleus		
Mitochondria		
Chloroplasts		
Cell Wall		
Cell Membrane		

REVISIT PAGE KEELEY SCIENCE PROBES

Do you still agree with the answer you chose at the beginning of the lesson? Return to the Science Probe at the beginning of the lesson. Explain why you agree or disagree with that answer now.

EXPLAIN
THE PHENOMENON

Revisit your claim about how the parts of a cell contribute to the function as a whole. Review the evidence you collected. Explain how your evidence supports your claim.

Three-Dimensional Thinking

2. Rosa is planning an investigation using a microscope to try to identify a group of cells. She sees that the cells are joined together, so she knows that they are from one organism. If she also sees that all of the cells have cells walls, Rosa can conclude that she could be looking at

A bacterial cells.

B human cells.

C mouse cells.

D plant cells.

3. Mitochondria function as subsystems within the larger system of the cell as a whole. Which explains why a mitochondrion, shown on the right, is known as the "power house" of a cell?

A It converts energy in food to ATP.

B It helps the cell gather sunlight.

C The cell eats it as food.

D It has two membranes.

4. MATH Connection Which statement could you use to construct an explanation for why it is important for a cell's surface-area-to-volume ratio to not be too small?

A Wastes and nutrients need to move through the membrane.

B If a cell's surface-area-to-volume ratio was too small, the cell would starve.

C If a cell's surface-area-to-volume ratio was too small, the cell would not produce enough waste material.

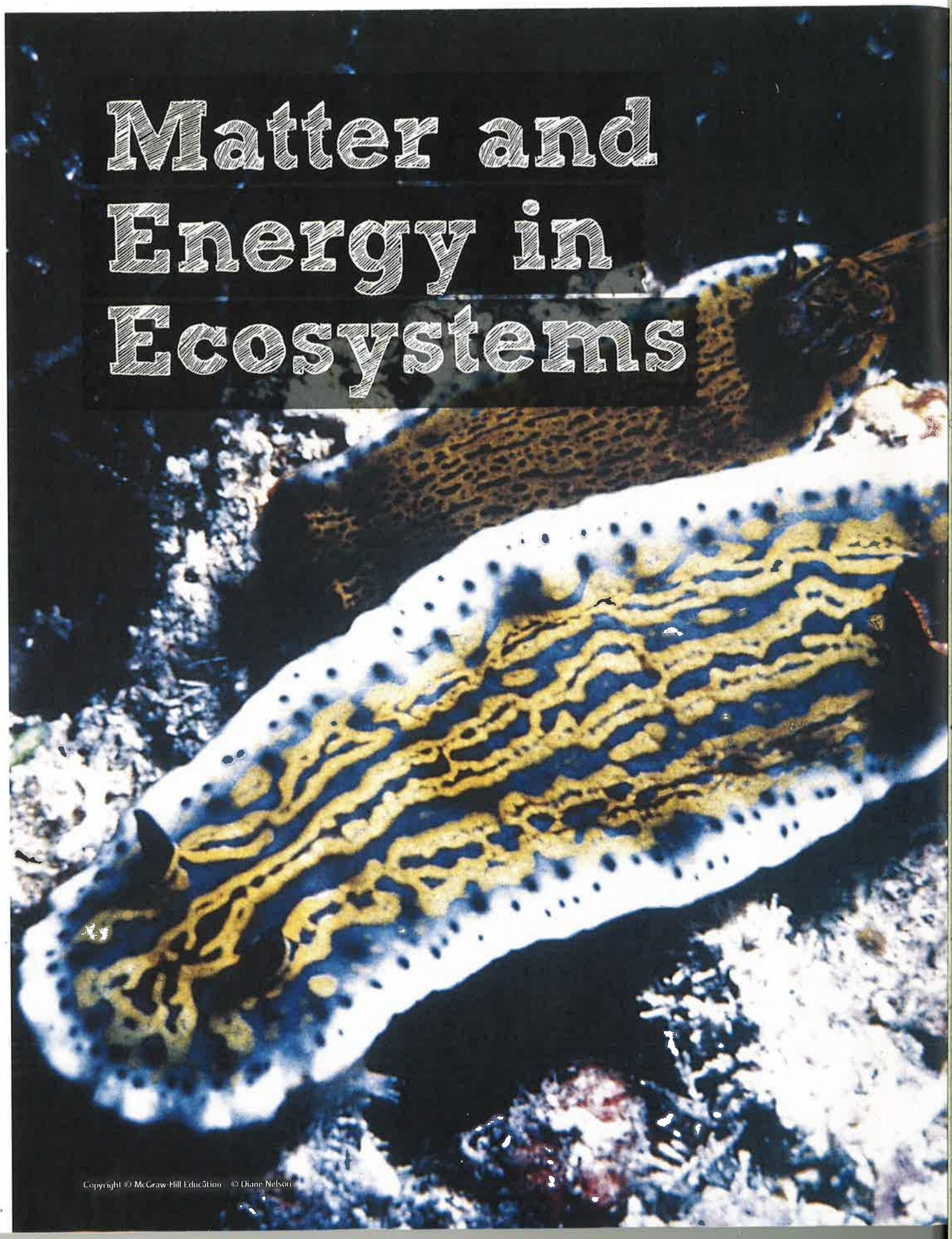
D If a cell's surface-area-to-volume ratio was too small, the organelles would grow too large to fit within the cell.

Real-World Connection

5. Infer Suppose that you are a scientist and you have been given a sample of unknown cells. By looking at the cells under a microscope, what would you be able to determine about the organisms the cells came from? Explain your reasoning.

6. Explain Your friend is making a model of a cell and wants to use metal to represent the cell membrane because metal is solid and would allow nothing to enter or leave the cell. Explain why you agree or disagree with his reasoning.

Matter and Energy in Ecosystems



ENCOUNTER
THE PHENOMENON

How does this sea slug get energy from the Sun?

GO ONLINE
Check out *Powered by the Sun* to see this phenomenon in action.

Communicate Think about the sea slug in the photo. Record your ideas in your Science Notebook for how it could obtain energy from the Sun. Discuss your ideas with three different partners. Revise or update your ideas, if necessary, after the discussions with your classmates.

STEM Project

The concepts you learn throughout this module will help you plan and complete the STEM Project. Go online to read more about the project and launch the science challenge!

STEM Project
Science Challenge

Sun Block

Suppose a volcanic eruption is occurring in a neighboring state. As a result, volcanic ash is predicted to partially block sunlight over your state for the next three months.

Your school's news team is preparing a report that explains how your area will be affected. The report will air on your local public television station. Your class will develop an explanation and model to show how local food webs and cycles of matter could be affected by an extended period of reduced sunlight.

After You Read *Photosynthesis and Cellular Respiration*

Model photosynthesis in your Science Notebook. Illustrate the changes that would occur if volcanic ash blocked the sun. Consider using colors, labels, and other methods to help you show information clearly. You will show this model in your news report, so be sure it is accurate and visually interesting.

After You Read *Flow of Energy*

Your news report will feature a local food web. In your Science Notebook, make a model of the local food web that you have researched. Label the producers, consumers, and decomposers. Think about how the transfer of energy can be tracked. You will need to be able to discuss this food web on air during your report, so be sure you can explain energy transfer between organisms as well as how food is rearranged through the chemical reactions in cellular respiration to form new molecules and release energy.

In your Science Notebook, write the opening statement for your news report. It should grab viewers' attention and answer the following question: What would happen to the flow of energy among the living parts of an ecosystem if there was less sunlight for three months?

STEM Project
Science Challenge

After You Read *Cycling of Matter*

In preparation for your report, construct an explanation in your Science Notebook for how cycles of matter will also be affected by the volcanic eruption. Use the carbon cycle as your example. Underline the portions of your explanation that you feel will be most helpful to include in your news report.

Make a diagram, or model, that shows the information you provided in your explanation. Be sure your model can be used to explain to a television audience that matter is conserved as it transfers between the living and nonliving parts of an ecosystem. Make notes in your Science Notebook detailing how you will explain this concept to an audience that does not have a background in science.

Evaluate

Look back at the planning you did after each lesson. Decide which information will be most important to share with the television audience. Make a bulleted list of the main points you want to include in your report. Under each bulleted main point, list several details related to the main point. Arrange the points in a logical order.

Review all of the information you have compiled and the models you have made. Look through the bulleted list of topics you want to include. Use the following questions to help you construct your explanation.

What evidence do you have for the roles of photosynthesis and cellular respiration in the flow of energy in ecosystems?

What evidence do you have for the roles of photosynthesis and cellular respiration in the cycling of matter in ecosystems?

What evidence supports your explanation of how a volcanic eruption will affect the flow of energy and cycling of matter in ecosystems?

Use the information from all of the lessons and your data analysis to construct your explanations for your summary statement in your Science Notebook. Be sure to consider your audience.

STEM Project
Science Challenge

Create Your Presentation

Analyze and evaluate your models before you make your report on your local news station.

Construct your summary statement in your Science Notebook. Be sure to consider your audience.

Think about the sea slug you read about at the beginning of the project. How would this slug and other organisms in its ecosystem be affected by a volcanic eruption?

Do your explanation and model work together to present information to an audience that may not have a clear understanding of scientific concepts and vocabulary? How?

Rehearse your presentation with your classmates. Give your report to another class in your school.

Congratulations! You've completed the Science Challenge requirements!

Wrap-Up

REVISIT THE PHENOMENON

Using the concepts you have learned throughout this module, how do you think this sea slug can get energy from sunlight?

OPEN INQUIRY

If you had to ask one question about what you studied, what would it be?

Plan and conduct an investigation to answer this question.

LESSON

Photosynthesis and Cellular Respiration

SCIENCE PROBES

Plant Procedures

Four friends were walking on a nature trail in their local park. They began to question whether or not the trees need to breathe, or need food like humans do. Here are their thoughts:

Katie: I think that plants need to eat but don't need to breathe.

Hugo: I think that plants need to eat and need to breathe.

Danielle: I think that plants need to breathe but don't need to eat.

Liam: I don't think plants need to eat or breathe.

Which friend do you agree with most? Explain why you agree with that friend. You will revisit your response to the Science Probe at the end of the lesson.

ENCOUNTER
THE PHENOMENON

How does this plant get the energy it needs to survive?

GO ONLINE
Watch the video *Sun-sational* to see this phenomenon in action.

Watch the video. What do you notice? Record your observations in your Science Notebook. Why do you think this phenomenon is occurring?

EXPLAIN
THE PHENOMENON

You have just observed plants following light. Are you starting to get some ideas about how plants obtain and process energy? Do you think animals obtain and process energy in the same way? Use your observations about the phenomenon to make a claim about how plants and animals obtain and process energy. Use the outline below to guide your thinking.

Claim

Plants, such as sunflowers, and animals obtain and process energy...

Evidence

A. What evidence have you discovered to explain how plants, such as sunflowers, use sunlight to produce energy?

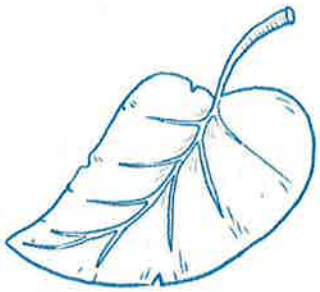
B. What evidence have you discovered to explain how plants, such as sunflowers, and animals process energy?

Revise claim

Plants, such as sunflowers, and animals obtain and process energy...

Reasoning

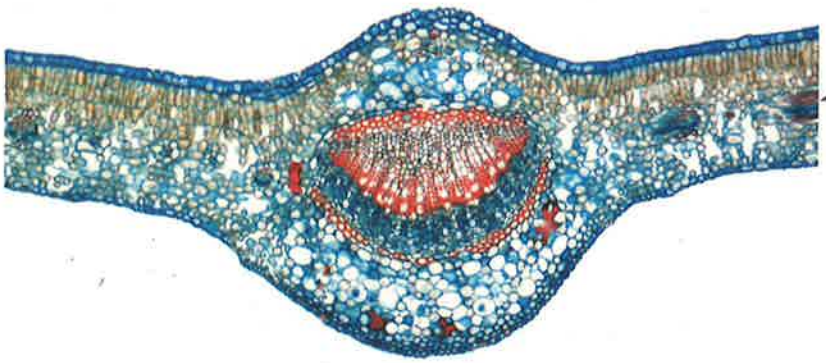
The evidence I collected supports my claim because...



Why do plants need sunlight?

Plants need food, but they cannot eat as people do. They make their own food, and leaves are the major food-producing organs of plants. To make their food source, leaves must capture energy from sunlight. This is why you may often see plants on windowsills with their leaves turned toward the Sun.

Photosynthesis Leaves are the sites of photosynthesis in plants. Plants and some unicellular organisms such as algae, phytoplankton, and other microorganisms obtain energy from light through the process of photosynthesis. **Photosynthesis** (foh toh SIHN thuh sus) is a series of chemical reactions that convert light energy, water, and carbon dioxide into the food-energy molecule glucose, and give off oxygen. The sugars produced in photosynthesis can be used immediately or stored for growth or later use.



Check out this cross section of a leaf!

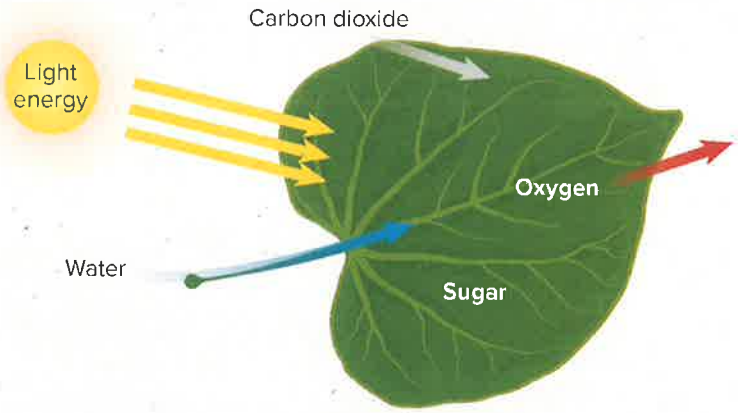
Want more information?
Go online to read more about photosynthesis and cellular respiration.

FOLDABLES
Go to the Foldables® library to make a Foldable® that will help you take notes while reading this lesson.

Leaves have many types of cells. Did you notice that? The cells that make up the top and bottom layers of a leaf are flat, irregularly shaped cells called epidermal (eh puh DUR mul) cells. On the bottom epidermal layer of most leaves are small openings called stomata (STOH muh tuh). Carbon dioxide, water vapor, and oxygen pass through stomata. Epidermal cells can produce a waxy covering called the cuticle.

Most photosynthesis occurs in two types of mesophyll (ME zuh fil) cells inside a leaf. These cells contain chloroplasts, the organelle where photosynthesis occurs. Near the top surface of the leaf are palisade mesophyll cells. They are packed together. This arrangement exposes the most cells to light. Spongy mesophyll cells have open spaces between them. Gases needed for photosynthesis flow through the spaces between the cells. You can see many of these structures in the cross section.

Capturing Light Energy In the first step of photosynthesis, plants capture the energy in light. This occurs in chloroplasts, which contain plant pigments. Pigments are chemicals that can absorb and reflect light. Most plants appear green because chlorophyll reflects green light and absorbs other colors of light. During photosynthesis, water molecules are split apart. This releases oxygen into the atmosphere.



Photosynthesis

Carbon dioxide + Water → Sugar + Oxygen

Light energy

$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

Making Sugars Sugars are made in the second step of photosynthesis, which can occur without light. In chloroplasts, carbon dioxide from the air is converted into sugars by using the energy stored and trapped by chlorophyll. Carbon dioxide combines with hydrogen atoms from the splitting of water molecules and forms sugar molecules. Plants can use this sugar as an immediate energy source or can store it for later use. Potatoes and carrots are examples of structures where sugar is stored.

PHYSICAL SCIENCE Connection Photosynthesis, like most chemical reactions, requires an input of energy. In this case light energy is absorbed by chlorophyll. When the light energy is absorbed, it is used to split water molecules. This results in oxygen, which is released from the leaves of the plant, and hydrogen, which is used to make glucose. In the chemical reaction for photosynthesis the reactants, carbon dioxide (CO_2) and water (H_2O), use energy from light to form glucose ($C_6H_{12}O_6$) and oxygen (O_2).

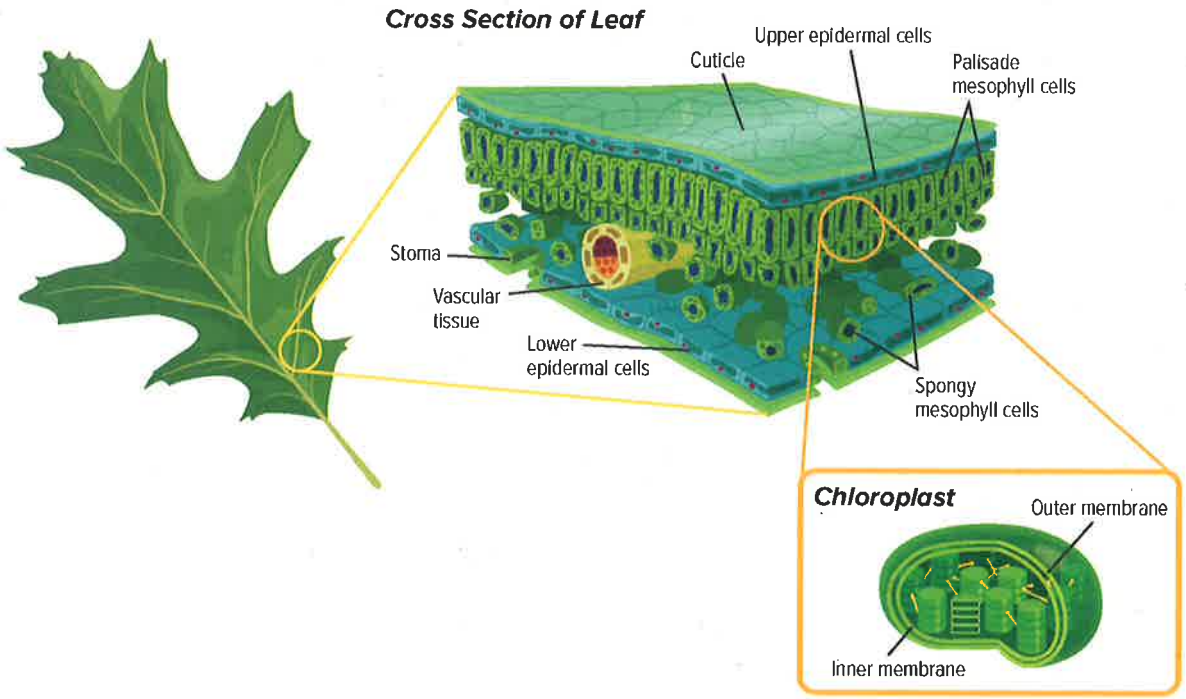
COLLECT EVIDENCE

How do plants, such as sunflowers, use sunlight to produce food? Record your evidence (A) in your Science Notebook.

INVESTIGATION

Plant Structure

Examine the leaf cross section below. How do you think sunlight is absorbed by a leaf? How are other materials necessary for survival, such as carbon dioxide, oxygen, water, and other nutrients, moved through a leaf? Record your ideas in your Science Notebook.



Read a Scientific Text

Plants and other photosynthetic organisms absorb carbon dioxide and produce oxygen, making them a necessary part of any ecosystem. An **ecosystem** is all the living and nonliving things in a given area. During the process of photosynthesis, trees absorb carbon dioxide and transfer carbon into their limbs and roots. What is the effect of carbon storage on forest ecosystems?

CLOSE READING

Inspect

Read the passage *Forests and Carbon Storage.*

Find Evidence

Locate information that describes how carbon is stored in trees. Identify information that describes carbon being released from trees back into the environment.

Make Connections

Communicate With your partner, summarize the central idea of the text distinct from prior knowledge or opinions.

PRIMARY SOURCE

Forests and Carbon Storage

Climate change increases the uncertainty of U.S. forests' ability to serve as a "sink" for carbon storage, but management options exist that could buffer the impacts of climate change on forests, and even lead to increased forest carbon storage potential.

Trees take up carbon dioxide (CO_2) and release oxygen (O_2) through photosynthesis, transferring the carbon (C) to their trunks, limbs, roots, and leaves as they grow. When leaves or branches fall and decompose, or trees die, the stored C will be released by respiration and/or combustion back to the atmosphere or transferred to the soil. Because of these processes, forests and forested landscapes can store considerable carbon and their growth can provide a carbon sink; landscapes that have been recently converted or reconverted to forests (from another land cover) can provide a carbon sink that is considerably larger than other land cover types.

[...]

While much about the forest carbon cycle is well understood, several key unknowns remain. The scientific community, including foresters, understands the carbon value of keeping forests as forests, planting forests where none existed historically (afforestation), replanting forests where they were located historically (reforestation), using forest biomass as fuel in place of fossil fuel, and storing carbon in long-lived products (which may continue to store carbon for years or decades). However, further research on several topics could improve our ability to design good forest management practices with respect to carbon.

Source: United States Department of Agriculture

THREE-DIMENSIONAL THINKING

ENVIRONMENTAL Connection Based on the scientific text, what would be the **effect** of increasing forest area? **Construct an explanation** to support your prediction. Write your answer in your Science Notebook.

LAB Photosynthesis and Light

It might help to think of photosynthesis as a process of give and take. Plant cells take in water and carbon dioxide, and, powered by light energy, make their own food. Plants give off oxygen as a waste product during photosynthesis. Can you determine how the intensity of light affects the rate of photosynthesis?

Safety

Materials

test tube	lamp	*Elodea*
watch or clock	colored pencils	scissors
beaker	thermometer	water

Procedure

1. Read and complete a lab safety form.
2. Cut the bottom end of an *Elodea* stem at an angle, and lightly crush the cut end. Place the *Elodea* in a test tube with the cut side at the top.
3. Fill the test tube with water. Stand the test tube and a thermometer in a beaker filled with water. (The water in the beaker keeps the water in the test tube from getting too warm under the lamp.) The bottom of the thermometer should not touch the bottom of the beaker. You may need a ring stand for this.
4. Place the beaker containing your test tube on a sheet of paper under a lamp. Measure the temperature of the water in the beaker. Record the temperature and initial observations in your Science Notebook.
5. In your Science Notebook, draw a data table like the one shown on the next page. When bubbles of oxygen begin to rise from the plant, start counting the number of bubbles per minute. Continue to record this data for 10 minutes. Record your data in the *Control* column of your data table.
6. Record the temperature of the water in the beaker at the end of the test.
7. Calculate the average number of bubbles produced per minute by your plant.
8. Repeat the experiment, changing the light variable so that you are observing your plant's reaction to getting either more or less light. Record *More* or *Less* in your data table to indicate your choice. An increase or decrease in water temperature will indicate a change in the amount of light. Keep all other conditions the same.

9. Compare your data with your classmates' data.

10. Follow your teacher's instructions for proper cleanup.

Data and Observations

Number of Bubbles per Minute		
Time (minutes)	Control	More/Less Light
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Analyze and Conclude

11. Use your data to form a hypothesis relating the amount of light to the rate of photosynthesis.

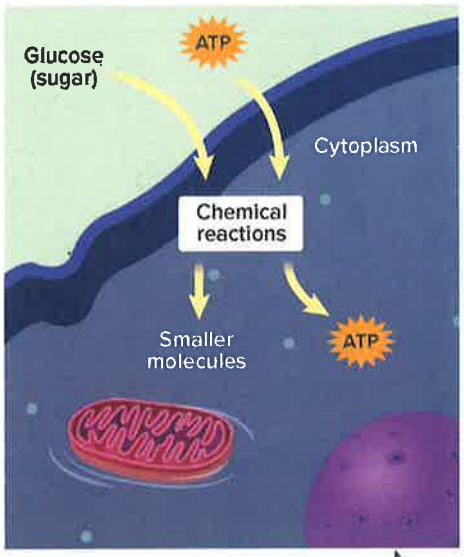
12. Draw a vertical and horizontal axis to create a graph. Plot the amount of bubbles on the vertical axis and time on the horizontal axis. Label the axes and add a title to your plot. Use a different color pencil for each set of data.

13. How does the amount of light affect photosynthesis? Explain your evidence.

14. How do plant cells make food? What do they take in and what do they give off? What source of energy do they use? Explain.

How does the energy in food molecules become usable?

All organisms require energy to survive. Energy is in the chemical bonds of food molecules. How does energy in food molecules become energy organisms can use for life processes? Let's investigate!



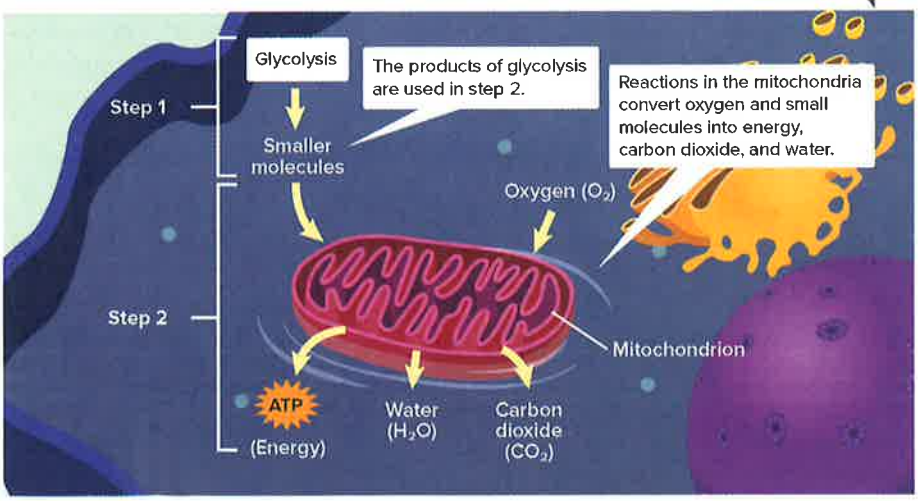
Step 1

Cellular Respiration When you breathe out, you breathe out carbon dioxide. Where did the carbon come from? It is a waste product from a process that releases energy from molecules. **Cellular respiration** is a series of chemical reactions that convert the energy in food molecules into a usable form of energy called ATP. Cellular respiration occurs in two parts of a cell—the cytoplasm and the mitochondria.

The first step of cellular respiration, called glycolysis, occurs in the cytoplasm of all cells. **Glycolysis** is a process by which glucose, a sugar, is broken down into smaller molecules. Glycolysis produces some ATP, an energy storage molecule. This process also uses energy from other ATP molecules.

The second step of cellular respiration occurs in the mitochondria of eukaryotic cells. This step requires oxygen. The smaller molecules made from glucose during glycolysis are broken down. Large amounts of ATP—usable energy—are produced. Cells use ATP to power all cellular processes. Two waste products—water and carbon dioxide (CO_2)—are given off during this step. The CO_2 released by cells as a waste product is used by plants and some unicellular organisms during photosynthesis.

Step 2

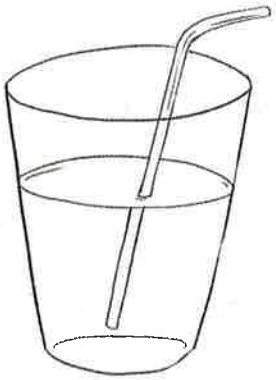


COLLECT EVIDENCE

How do plants and animals process energy from food? Record your evidence (B) in your Science Notebook.

LAB Breathe In, Breathe Out

Does the air you breathe in differ from the air you breathe out?



Safety

Materials

wrapped straw
small clear plastic cup
bromothymol blue solution

Procedure

1. Read and complete a lab safety form.
2. Unwrap a straw. Use the straw to slowly blow into a small cup of bromothymol blue. Do not splash the liquid out of the cup.
3. Record any changes or observations in your Science Notebook.
4. Follow your teacher's instructions for proper cleanup.

Analyze and Conclude

5. What changes did you observe in the solution?
6. What do you think caused the changes in the solution?
7. Why do you think the air you inhale differs from the air you exhale?
8. Imagine sitting at your desk. Now think about jogging. During which activity do you breathe more often? What is the relationship among the rate of breathing, oxygen, and the body's need for energy?

How are photosynthesis and cellular respiration related?

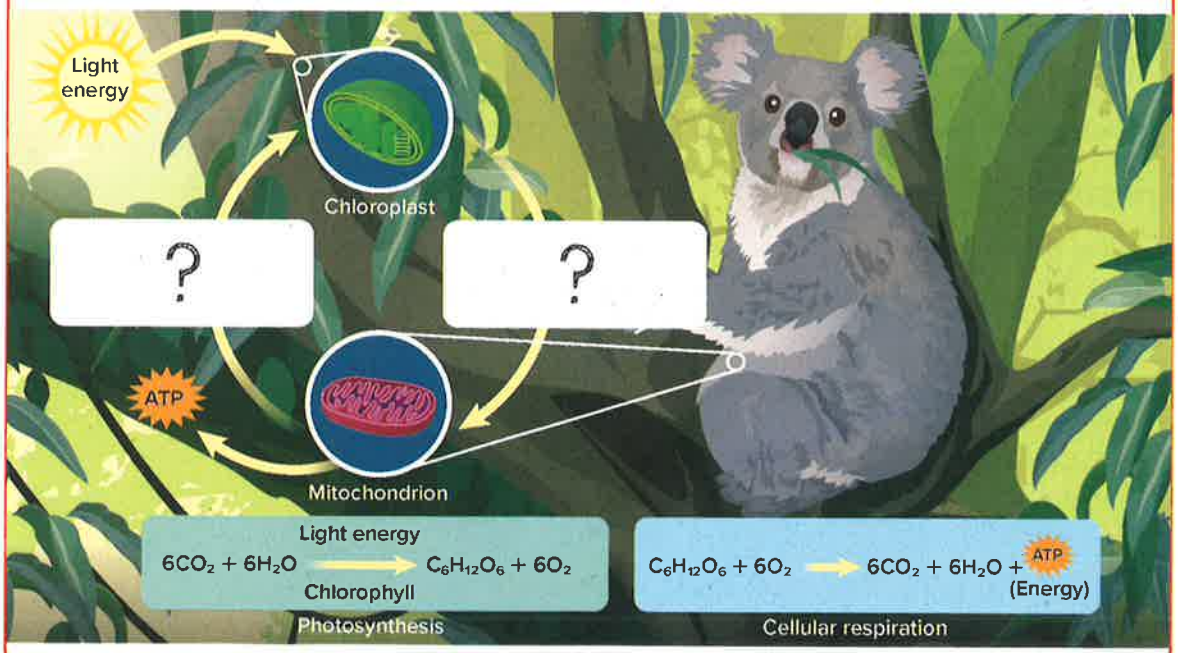
While animals only perform cellular respiration, plants conduct both cellular respiration and photosynthesis. How do the processes compare?

Comparing Photosynthesis and Cellular Respiration Photosynthesis requires the reactants carbon dioxide and water. Oxygen and glucose are the products. Most plants, some protists, and some bacteria are photosynthetic. Photosynthesis is important because plants help maintain the atmosphere you breathe. Photosynthesis produces most of the oxygen in the atmosphere.

Cellular respiration requires the reactants glucose and oxygen, produces carbon dioxide and water, and releases energy. Most organisms perform cellular respiration. Cellular respiration is important because if your body did not break down and rearrange the food you eat, you would not have energy to do anything. Plants produce their own sugar, but without cellular respiration, plants could not grow, reproduce, or repair tissues.

THREE-DIMENSIONAL THINKING

Think about how you would label the image of the system below to track the energy transfer in photosynthesis and cellular respiration. Write the labels in your Science Notebook.



GREEN SCIENCE

The Benefits of Algae

Big Benefits from Tiny Organisms

▲ Processing plants, such as this one, are a major source of algae oil.

Algae are protists that can do more than just cover a pond as slimy scum. They release oxygen through photosynthesis. In fact, most of the oxygen in Earth's atmosphere comes from photosynthesis that occurs in algae, plants, and some bacteria. Algae are also food for many organisms, including humans. But algae can provide something else very valuable—oil.

A microalga is another type of protist that is very small and reproduces quickly. The total mass of some microalgae can double several times a day. More than half of their mass is fats, also called lipids, that store energy. One type of lipid, triglycerides, can be turned into diesel oil, gasoline, and jet fuel.

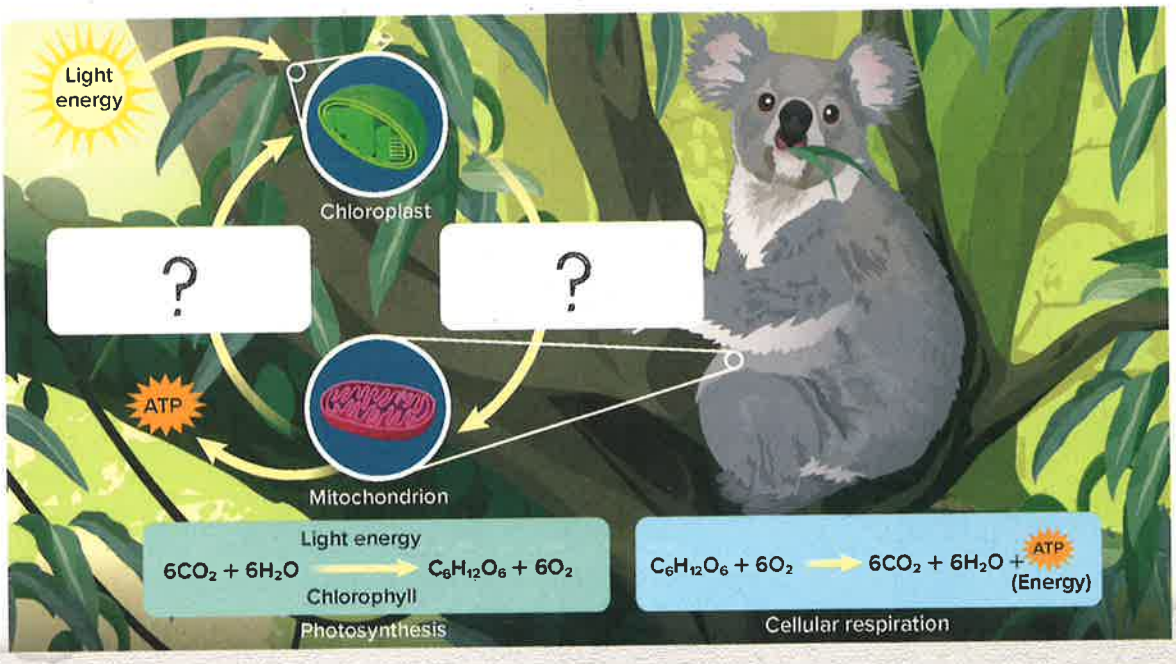
Microalgae can grow outdoors in ponds and produce 100 times more oil per acre than any other crop. They also can grow indoors under lights in photobioreactors. A photobioreactor is a tank filled with water and nutrients. Photosynthesis requires carbon dioxide. Instead of releasing carbon dioxide gas into the atmosphere, power plants can pump it into photobioreactors for microalgae to use. Also, microalgae can grow in water that is unsafe to drink. Using this technology, microalgae can grow in areas, such as deserts, where it is not ordinarily possible to grow other crops.

It's Your Turn

READING Connection Research how photobioreactors produce usable oil, then write an informative and explanatory text for a Web site detailing the process.

Summarize It!

1. **Explain** the transfer of energy and cycling of matter by modeling the chemical reactions of photosynthesis and cellular respiration in your Science Notebook. Use arrows to show movement in your model. Include yourself and the *Elodea* plant from the *Photosynthesis and Light* lab in the model.



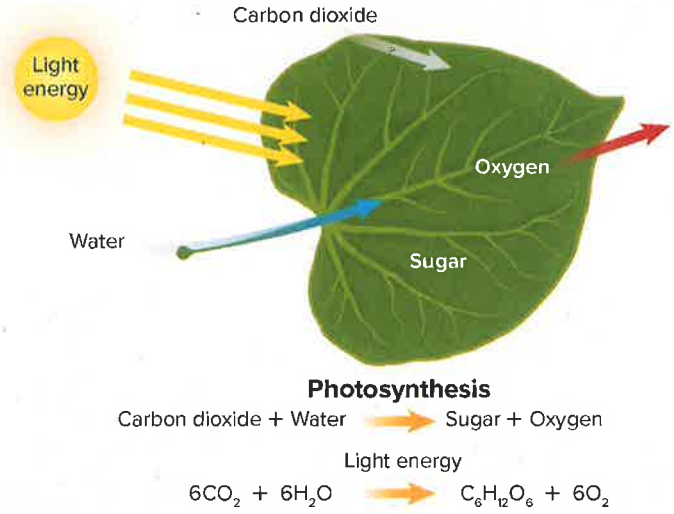
REVISIT SCIENCE PROBES Do you still agree with the friend you chose at the beginning of the lesson? Return to the Science Probe at the beginning of the lesson. Explain why you agree or disagree with that person now.

EXPLAIN THE PHENOMENON

Revisit your claim about how plants and animals obtain and process energy. Review the evidence you collected. Explain how your evidence supports your claim.

Three-Dimensional Thinking

Use the model to answer question 2.



2. Which is the best explanation of the change in energy shown in the model?

- **A** New energy is produced by plants during photosynthesis.
- **B** Large amounts of energy are released into the environment during photosynthesis.
- **C** Energy from sunlight is destroyed as it powers photosynthesis
- **D** Energy input from the environment is stored in food molecules during photosynthesis.

3. **EARTH SCIENCE Connection** In recent decades, average global temperatures have increased significantly. Scientists agree that the widespread destruction of the Amazon rain forest contributes to climate change. Which mechanism might be cited to support that hypothesis?

- **A** Deforestation causes water on the ground to reflect sunlight.
- **B** Deforestation reduces the number of plants able to absorb carbon dioxide.
- **C** Photosynthesis produces energy, which gives off heat.
- **D** Plants use up energy during cellular respiration.

Real-World Connection

4. **Construct an Explanation** A disease that destroys all the chloroplasts in a plant has been found in a plant population near your school. Using what you have learned from the text, what would be the effect of this disease?

5. **Summarize** how your body performs cellular respiration and how it relates to playing in gym class.

LESSON

Flow of Energy

SCIENCE PROBES

Exploring Energy

Four friends were playing on the playground. They began to question where all organisms get energy from. Here are their thoughts:

Brock: I think that the main source of energy for most life is food.

Malik: I think that the main source of energy for most life is water.

Kira: I think that the main source of energy for most life is the Sun.

Sydney: I think that most organisms make their own energy.

Which friend do you agree with most? Explain why you agree with that friend. You will revisit your response to the Science Probe at the end of the lesson.

ENCOUNTER
THE PHENOMENON

How do these bears and this fish get energy from the environment?

This bear about to eat a fish is just one example of the many feeding relationships between organisms. Examine the materials provided by your teacher. How do you think these things are related? In your Science Notebook, draw a diagram to show how you think the images could connect with one another. Include words in your diagram so the relationships between the images are clear.

EXPLAIN
THE PHENOMENON

Did you see how the images are related to each other, like the bear and the fish in the photo are related to each other? Use your observations about the phenomenon to make a claim about how energy moves through the environment. Use the outline below to guide your thinking.

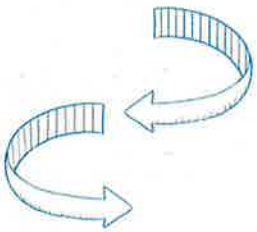
Claim

Organisms obtain energy from the environment by...

Evidence

A. What evidence have you discovered to explain how producers, decomposers, and consumers, such as the bears, obtain energy?

B. What evidence have you discovered to explain how energy moves through the environment?



Revise claim

Organisms obtain energy from the environment by...

Reasoning

The evidence I collected supports my claim because...

GO ONLINE
Watch the video *Grizzly Bears Catching Salmon* to see this phenomenon in action.

How do different organisms get energy?

The main source of energy for most life on Earth is the Sun. Unlike matter, energy does not cycle through ecosystems, instead it flows in one direction. In most cases, energy flow begins with the Sun, and moves from one organism to another. Many organisms get energy by eating other organisms.

Which organism gets its energy from the Sun, and which organism gets its energy by eating other organisms?

PHYSICAL SCIENCE Connection Not all the energy an organism gets is used for life processes. Some is released to the environment as thermal energy. You might have read that energy cannot be created or destroyed, but it can change form. This idea is called the law of conservation of energy.

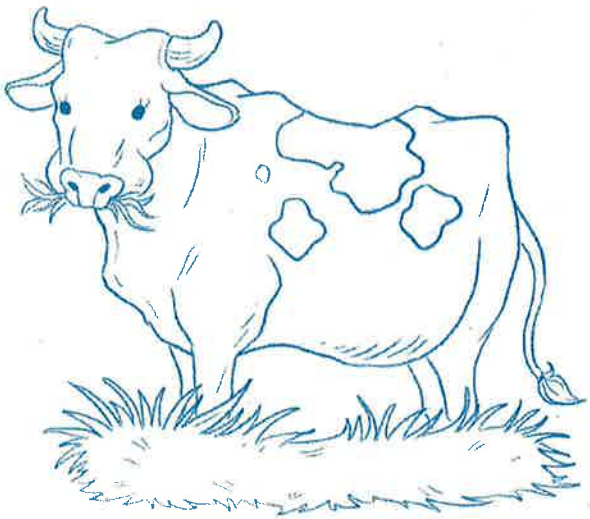
Producers Living things that make their own food are called **producers.** Producers make their food from materials found in their environments. Most producers are photosynthetic, such as plants. Other producers, including some bacteria, are chemosynthetic. Chemosynthesis is the process during which producers use chemical energy in matter rather than light energy to make food.

INVESTIGATION

Classifying Organisms

Most organisms get their energy from the Sun or by consuming other organisms. In this activity you will use photographs to classify organisms based on their feeding relationships.

1. Examine the images of ecosystems provided by your teacher.
2. Identify the organisms. Include a description of their environment in your Science Notebook.
3. How do you think these organisms get energy? Use details from the photograph to support your answer.



Consumers Unlike producers, **consumers** do not produce their own energy-rich food. Instead, they get the energy they need to survive by consuming other organisms. Consumers can be classified by the type of food that they eat. Herbivores feed on only producers. Carnivores eat other animals. Omnivores eat both producers and other consumers.

◀ This caterpillar is an herbivore and eats only plants.

This shark is a ▶ carnivore and eats other animals.

◀ These girls are omnivores and eat both producers and other consumers.

Want more information?
Go online to read more about the flow of energy in ecosystems.

FOLDABLES
Go to the Foldables® library to make a Foldable® that will help you take notes while reading this lesson.

Detritivores Another group of consumers are detritivores (dih TRI tuh vorz). **Detritivores** get their energy by eating the remains of other organisms. Some detritivores, such as bacteria and mushrooms, feed on dead organisms and help break down or decompose them. For this reason, these organisms often are called decomposers. During decomposition, decomposers produce carbon dioxide that enters the atmosphere. Some of the decayed matter enters the soil or water. In this way, decomposers help recycle nutrients through ecosystems. They also help keep ecosystems clean. Without decomposers, dead organisms would pile up in an ecosystem.

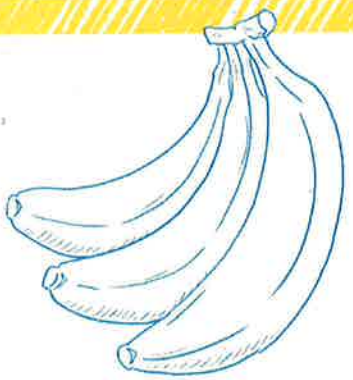
These mushrooms are decomposers!

COLLECT EVIDENCE

How do producers and consumers obtain energy? Record your evidence (A) in your Science Notebook.

INVESTIGATION

Go Bananas



Yeast is a common unicellular fungus. Watch what happens when yeast is added to a banana.

1. Observe the demonstration. Record your observations in your Science Notebook.
2. What did you notice about the bananas? Why do you think this happened?

A Closer Look: Composting

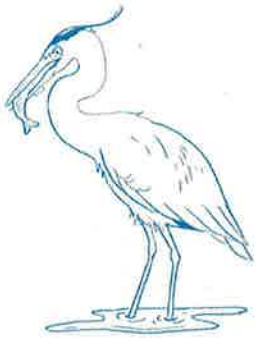
Every year humans generate millions of tons of waste. You probably have a place where you take your trash. You might even recycle, but have you ever heard of composting? Compost is decayed organic matter that can be used as fertilizer. Many people collect their food scraps to create fertilizer and reduce waste. This is done by collecting food waste in your yard or a designated bin. Yard waste and food scraps make up 20 to 30 percent of the trash we throw away. These materials can be composted instead of being put in a landfill, where they take up space and release methane, which is a greenhouse gas.

Composting is possible because microorganisms such as bacteria will break down the scraps, turning them into nutrient-rich organic matter. You can even add earthworms and other detritivores to your compost to speed up the process.

It's Your Turn

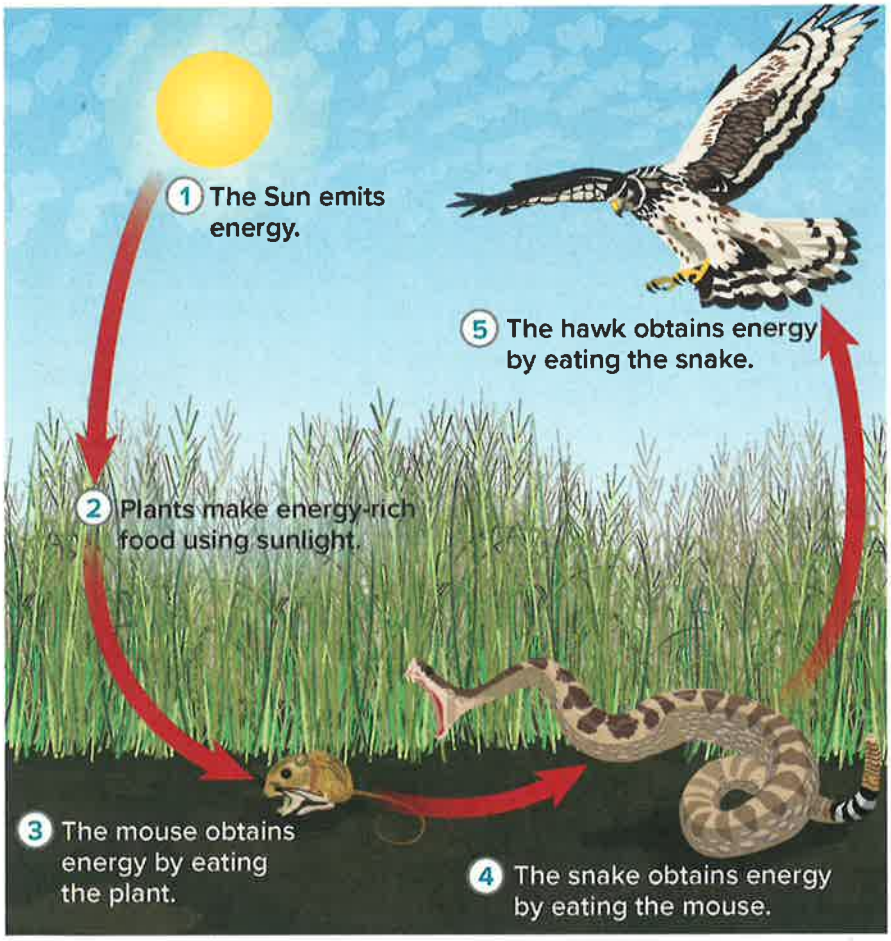
ENVIRONMENTAL Connection Research more information on composting using multiple sources. Then write a public service announcement to convince your friends and family to start a compost pile. Be prepared to use multimedia and visual displays to present your public service announcement to your class.

How does energy move through an environment?



In an ecosystem, food energy is transferred from one organism to another through feeding relationships. The transfer of energy drives the movement of matter. How can these relationships be modeled? Let's find out!

A **food chain,** such as the one shown below, is a simple model that shows how energy moves from the Sun, to a producer, to one or more consumers through feeding relationships. In a food chain, arrows show the transfer of energy. The amount of available energy decreases every time it is transferred from one organism to another. A food chain is helpful when studying certain parts of an ecosystem, but it does not show the whole picture.



LAB Modeling Energy Flow

Safety

Materials

I.D. card yarn

Procedure

1. Read and complete a lab safety form.
2. Display your I.D. card on your head, arm, or shirt. Take your assigned game position.
3. If your card represents an organism, use a piece of yarn to link up with another person who represents where you get the energy that you need to survive.
4. Continue making connections, forming a single chain beginning with the Sun. Your chain should include 3–5 people.
5. React to scenarios announced by your teacher. What would happen to your chain?
6. Follow your teacher's instructions for proper cleanup.

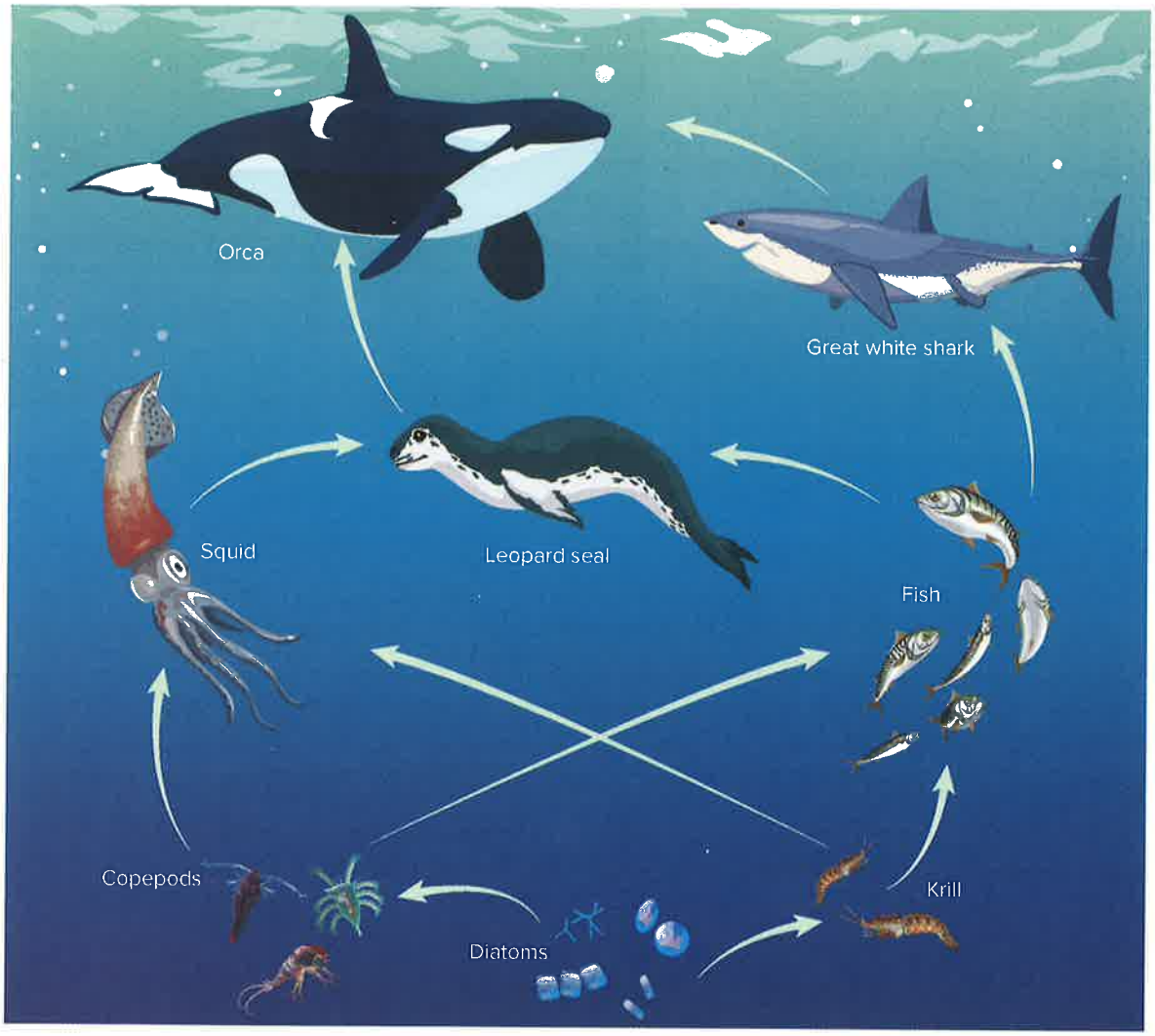
Analyze and Conclude

7. Describe the links that you made. Explain why each link formed in your Science Notebook.
8. Explain how your chain reacted to one of the scenarios.

THREE-DIMENSIONAL THINKING

In your Science Notebook, draw a **model** of the food chain that you created in the lab. Use arrows to **model** the flow of energy. Label each organism as a producer or consumer, and label each type of consumer.

Scientists use a model of energy transfer called a **food web,** such as the one shown below, to show how food chains in a community are interconnected. You can think of a food web as many overlapping food chains. Like in a food chain, arrows show how energy flows in a food web. Some organisms in the food web might be part of more than one food chain in that web.



LAB Web of Life

Safety

Materials

scissors
glue
yarn
construction paper

Procedure

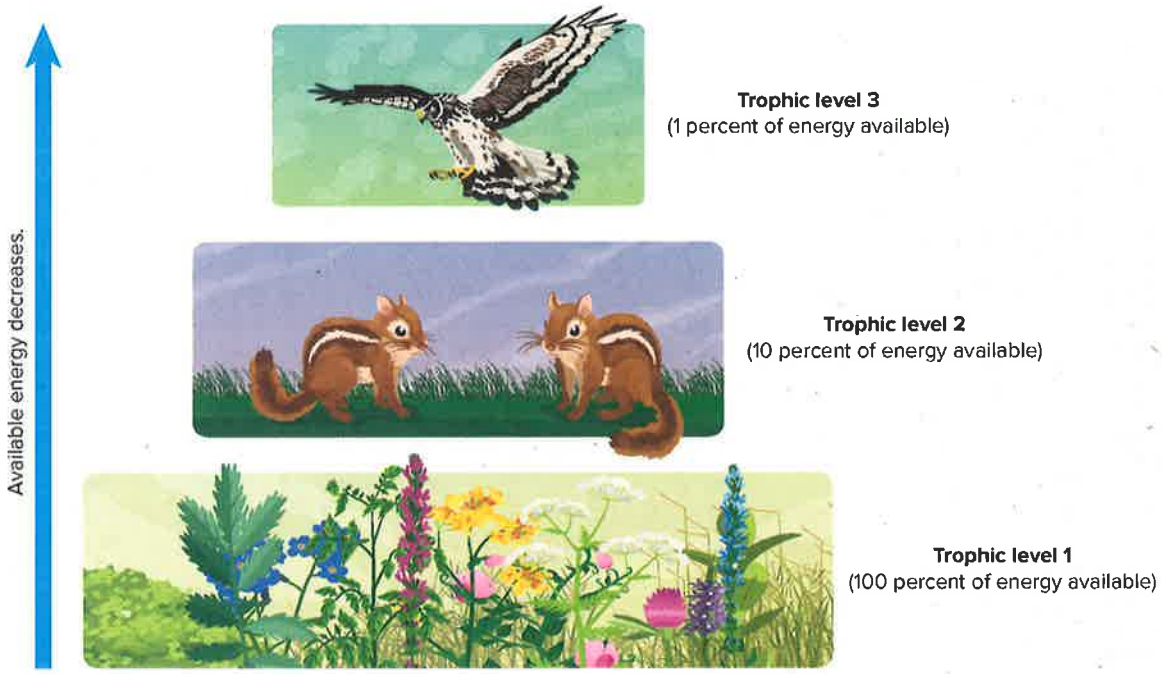
1. Read and complete a lab safety form.
2. On a sheet of paper, make a list of all of the organisms from the previous lab. Note that all of the organisms live in the same community, and there is a variety of producers and consumers.
3. Use scissors to cut out the name of each organism on your list.
4. Glue the names onto a piece of construction paper.
5. Use yarn and glue to connect organisms that have feeding relationships. For example, a piece of yarn would connect a rabbit and grass.
6. Follow your teacher's instructions for proper cleanup.

Analyze and Conclude

7. Add the label *Sun* to your model. Which organisms would be connected to the Sun? Why?
8. Which organisms in your model interact through feeding relationships?
9. Imagine that you removed three organisms from your food web. How would this affect the community?

Energy Pyramid Food chains and food webs show how energy moves in an ecosystem. However, they do not show how the amount of energy in an ecosystem changes. Scientists use a model called an **energy pyramid,** to show the amount of energy available in each step of a food chain. The steps of an energy pyramid are also called trophic levels.

Producers make up the trophic level at the bottom of the pyramid. Consumers that eat producers make up the next trophic level. Consumers that eat other consumers make up the highest trophic level. Less energy is available for consumers at each higher trophic level. Only about 10 percent of the energy available at one trophic level transfers on to the next trophic level.



COLLECT EVIDENCE

How does energy move through an environment? Record your evidence (B) in your Science Notebook.

GO ONLINE for additional opportunities to explore!

Investigate energy transfer in food chains and food webs by performing one of the following activities.

Model energy transfer in a food chain in the **Lab** *How is energy transferred in a food chain?*

OR

Observe energy movement though food webs in the **Animation** *Food Webs.*

EXPLAIN/EXPLORE Lesson: Flow of Energy

STEM Careers

A Day in the Life of a Wildlife Ecologist

Wildlife ecology is the study of animal and other wildlife populations with the focus on understanding their interactions with their ecosystem. Wildlife ecologists study wildlife, game and nongame species, and endangered species. They study physical characteristics of animals and animal behaviors, as well as how humans impact ecosystems and the wildlife that live in those ecosystems.

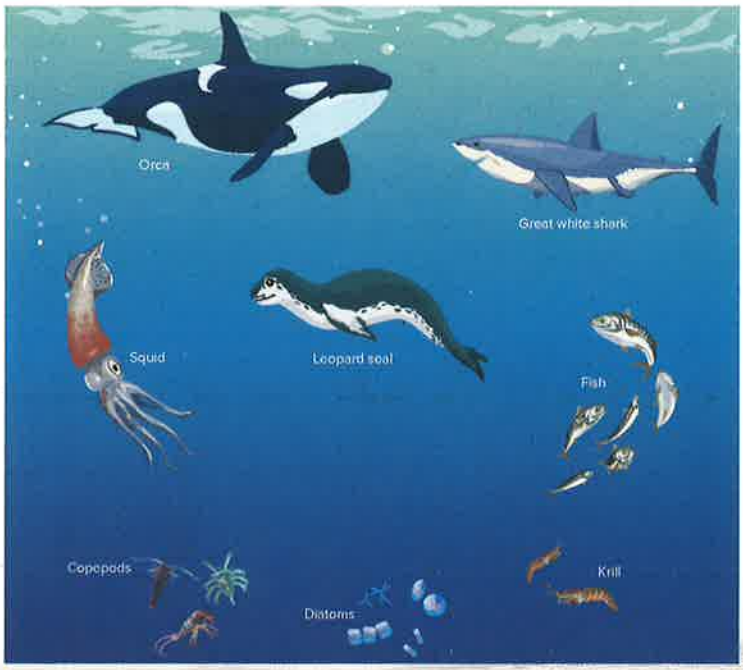
Wildlife ecology is a career that will best fit people who desire to aid wildlife populations and feel a responsibility towards wildlife resources. Wildlife ecologists spend a good deal of time outdoors, observing animals in their natural habitats and collecting data. To become a wildlife ecologist, you will need a bachelor's degree and possibly a master's degree in zoology, ecology, or a related field. After completing your education, you will be able to conduct research, work for resource management agencies or educational institutions, and much more!

It's Your Turn

WRITING Connection Write a paragraph in your Science Notebook explaining why you would or would not like to be a wildlife ecologist. Find a partner who had a different response than you and discuss your answers.

Summarize It!

1. In your Science Notebook, **model** a food web of your choice. Draw arrows to show the transfer of energy among the organisms you select.



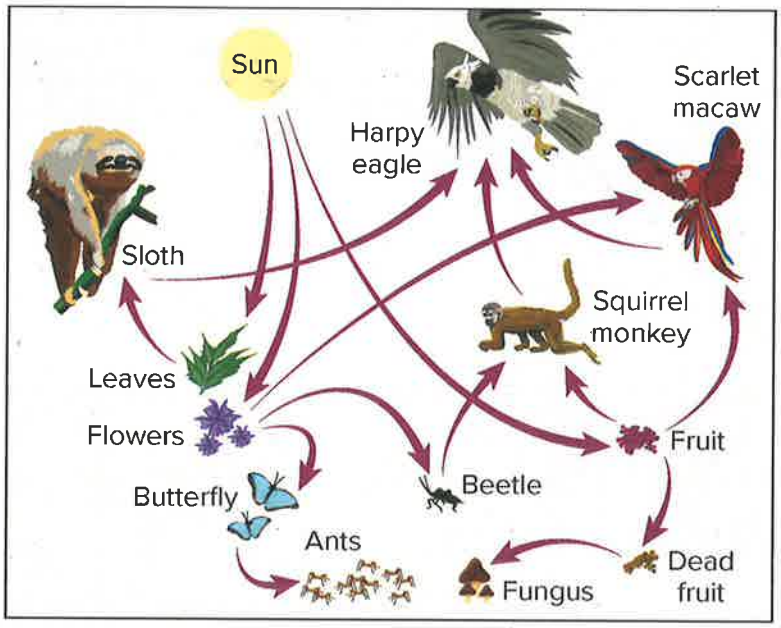
REVISIT SCIENCE PROBES Do you still agree with the friend you chose at the beginning of the lesson? Return to the Science Probe at the beginning of the lesson. Explain why you agree or disagree with that person now.

EXPLAIN THE PHENOMENON

Revisit your claim about how energy from a fish moves through the environment. Review the evidence you collected. Explain how your evidence supports your claim.

Three-Dimensional Thinking

2. Analyze the food web. Which statement is correct?



A The model tracks the transfer of energy as energy flows in this ecosystem.

B The transfer of matter back into the environment occurs only at the detritivore level.

C The model shows the transfer of matter only.

D The decomposers in the model use matter but not energy for their life processes.

3. In an energy pyramid, approximately 10 percent of the energy available in one trophic level is transferred to the next level. Which statement helps explain why this occurs?

A Consumers eat both producers and other consumers.

B Organisms use most of the available energy to fuel their own life processes.

C Predators eat more organisms in their own level than organisms in other levels.

D Producers exist in only the lowest level of the pyramid.

Real-World Connection

4. **Predict** what the effect would be if all great white sharks were removed from an aquatic ecosystem. Write a short radio ad explaining why sharks should be protected.

LESSON

Cycling of Matter

PAGE KEELEY SCIENCE PROBES

Cycling of Matter

Three friends were talking about carbon dioxide and oxygen in the ecosystem. They each had different ideas. This is what they said:

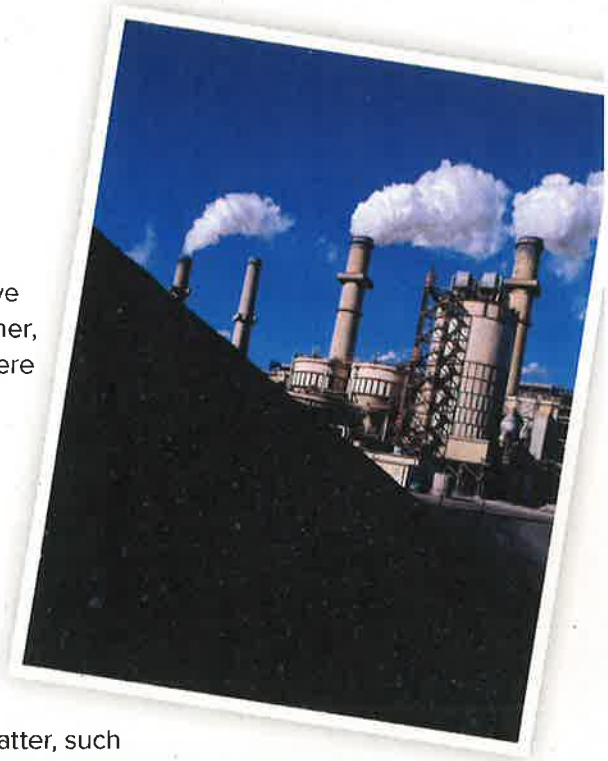
Flynn: I think animals take in oxygen and breathe out carbon dioxide. Plants then take in the carbon dioxide and release oxygen, and the cycle continues.

Jervis: I think both plants and animals take in oxygen and release carbon dioxide; but only the plants take in the carbon dioxide and release oxygen, and the cycle continues.

Melody: I think both plants and animals take in oxygen and release carbon dioxide. The oxygen is used up and carbon dioxide is not cycled again by living things.

Which friend do you agree with the most? Explain why you agree. You will revisit your response to the Science Probe at the end of the lesson.

ENCOUNTER
THE PHENOMENON



How does the carbon in this coal move through the environment?

In this activity, you will act like a carbon atom and move from one location to another as directed by your teacher, taking notes in your Science Notebook on how you were able to travel. Then, draw a map of the multiple paths you took.

EXPLAIN
THE PHENOMENON

Are you starting to get some ideas about how matter moves through ecosystems? Use your observations about the phenomenon to make a claim about how matter, such as carbon, moves through an environment. Use the outline below to guide your thinking.

Claim

Matter, such as carbon, moves through the environment...

Evidence

A. What evidence have you discovered to explain how carbon moves through an environment?

B. What evidence have you discovered to explain how water moves through an environment?

C. What evidence have you discovered to explain how nitrogen moves through an environment?

D. What evidence have you discovered to explain how oxygen moves through an environment?

Revise Claim

Matter, such as carbon, moves through the environment...

Reasoning

The evidence I collected supports my claim because...

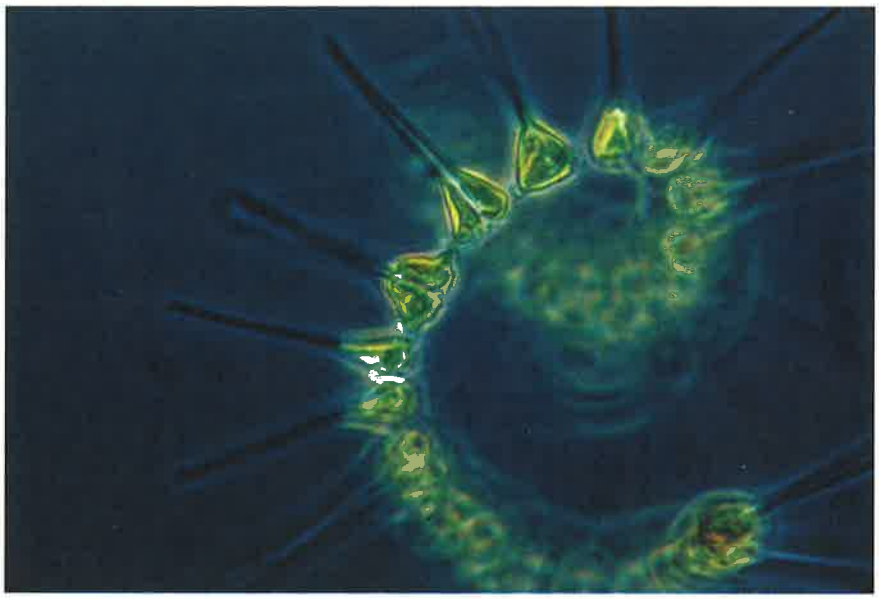
GO ONLINE
Watch the video *Coal Course* to see this phenomenon in action.

How does matter cycle through an environment?

In the previous lesson, you learned about how energy flows through an environment. Matter also moves through the environment, but instead of flowing through the environment like energy does, matter moves in cycles.

PHYSICAL SCIENCE Connection Matter moves continuously through ecosystems. It changes form, but is not created or destroyed. This idea is called the law of conservation of mass.

Carbon in Nature In the lab, you will observe carbon moving from a balloon into the water. In a natural setting you can observe carbon move through systems as well. Tiny ocean organisms called phytoplankton (fi toh PLANK tuhn) take in carbon dioxide gas from the air. An example of phytoplankton is shown in the photo below. In some types of phytoplankton, the carbon dioxide gas is converted to calcium carbonate, which the phytoplankton use to build their skeletons. When phytoplankton die, many of them sink to the bottom of the ocean, where their skeletons become fossilized. Over time, these fossilized skeletons build up and turn into chalk. When this chalk is weathered by rain and waves, it releases carbon dioxide gas into the air. This gas can then be taken in by phytoplankton again.



Want more information?
Go online to read more about cycles of matter.

FOLDABLES
Go to the Foldables® library to make a Foldable® that will help you take notes while reading this lesson.

LAB Movin' Matter

Matter is constantly cycling through ecosystems, even if you cannot always see it. How does this happen?

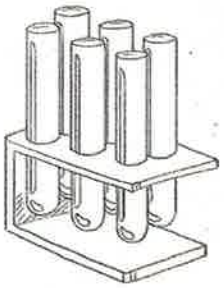
Safety

Materials

bromothymol blue
vinegar
balloon
powdered calcium carbonate or crushed natural chalk
20-mL test tube
250-mL Erlenmeyer flask
filter paper

Procedure

1. Read and complete a lab safety form.
2. Measure 15 g of calcium carbonate powder onto filter paper.
3. Pour the calcium carbonate powder into a 250-mL Erlenmeyer flask.
4. Add 50 mL of vinegar to the flask.
5. Quickly stretch the mouth of the balloon over the opening of the flask. Record your observations in your Science Notebook.
6. Fill the test tube almost to the top with water. Add 15 drops of bromothymol blue, a chemical indicator that turns yellow when exposed to carbon dioxide. Observe the color of the liquid in the test tube.
7. Pinch the neck of your balloon and remove it from the flask. Place the neck of the balloon over the mouth of the test tube, and then release the neck, allowing the gas to enter the test tube. Record your observations in your Science Notebook.
8. Follow your teacher's instructions for proper cleanup.

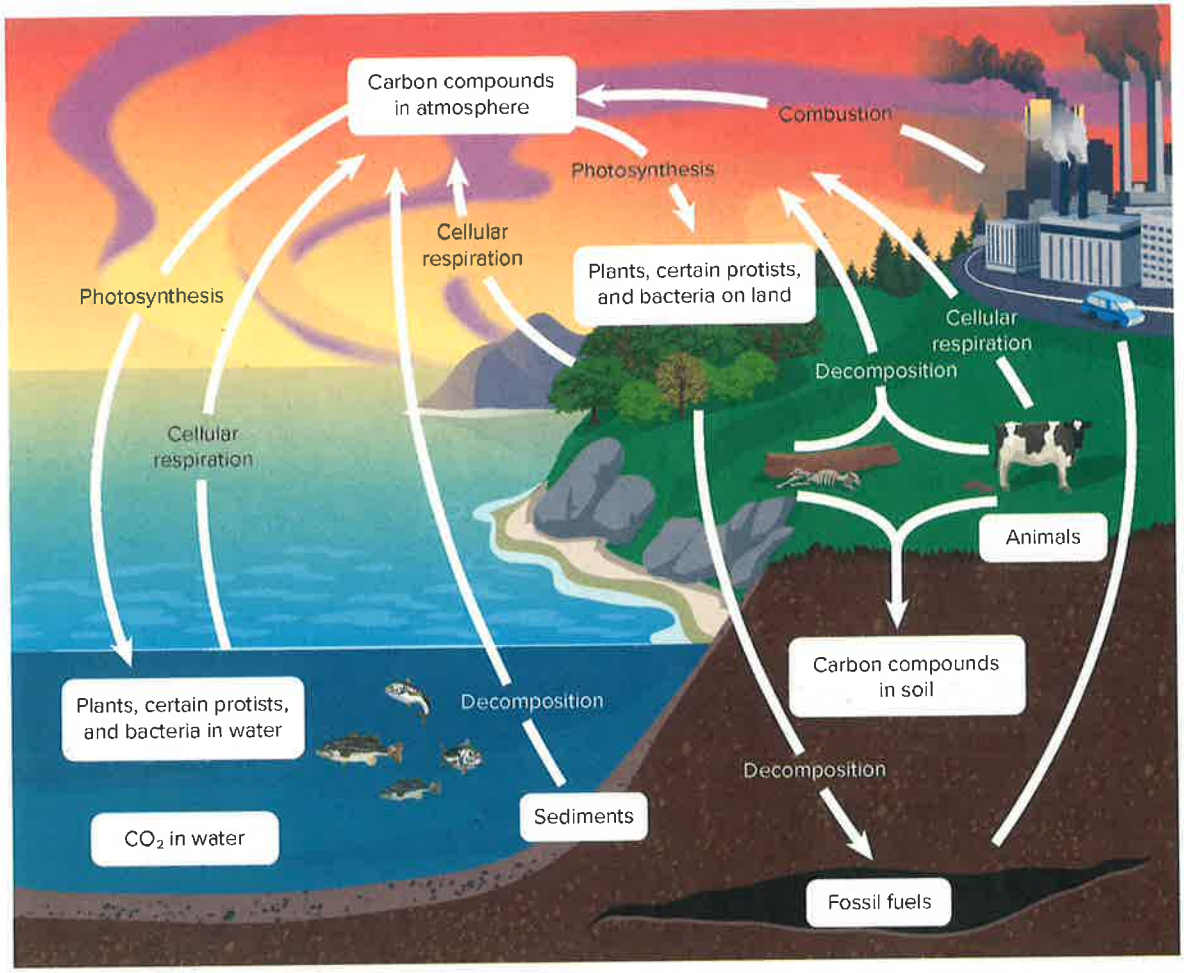


Analyze and Conclude

9. Interpret the data you collected. Determine what happened to the color of the liquid in the test tube. What caused the effect to occur?
10. Where do you think the gas in the balloon came from?

THREE-DIMENSIONAL THINKING

In your Science Notebook, **construct an explanation** for how the Lab *Movin' Matter* models the movement of carbon in fossilized phytoplankton skeletons.



The Carbon Cycle All organisms contain carbon. Some organisms, including humans, get carbon from food. Other organisms, such as plants, get carbon from the atmosphere or bodies of water.

Carbon can enter the environment when organisms die and decompose. This returns carbon compounds to the soil and releases carbon dioxide (CO_2) into the atmosphere for use by other organisms. Carbon is also found in fossil fuels, which formed when decomposing organisms were exposed to pressure, high temperatures, and bacteria over hundreds of millions of years.

Recall that carbon is found in the atmosphere as carbon dioxide. Plants and other photosynthetic organisms take in carbon dioxide and water to produce energy-rich sugars. These sugars are a source of carbon and energy for organisms that eat photosynthetic organisms.

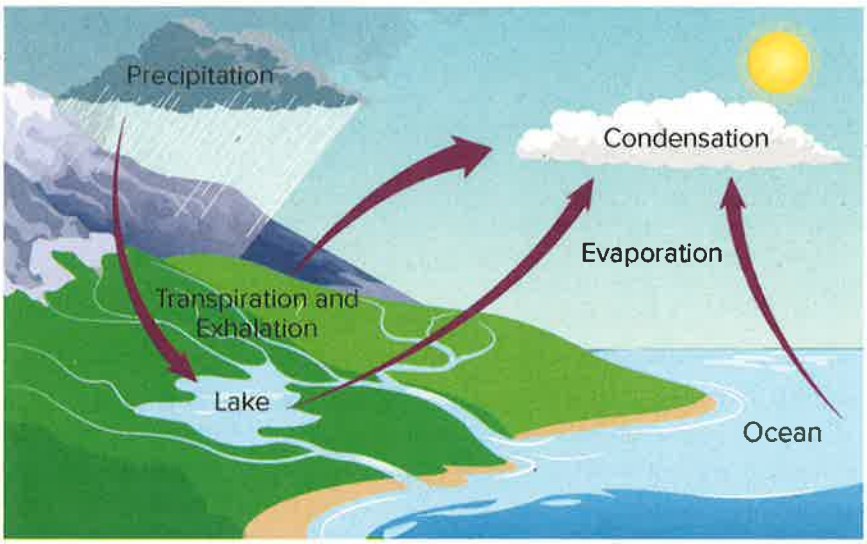
COLLECT EVIDENCE

How does carbon move through the environment? Record your evidence (A) in your Science Notebook.

What other important materials cycle through the environment?

Water covers about 70 percent of Earth's surface! Most of Earth's water—about 97 percent—is in oceans. Water is also in rivers and streams, lakes, and underground reservoirs. In addition, water is in the atmosphere, the ground, and living things. Water in a body may later end up at the top of a snow-capped mountain. How is this possible?

The Water Cycle Water continually cycles from Earth to its atmosphere and back again. This movement of water is called the water cycle. It involves three main processes: evaporation, condensation, and precipitation.



Evaporation is the process during which liquid water changes into a gas called water vapor. This water vapor rises into the atmosphere. Water vapor also enters the atmosphere when animals exhale and through transpiration, which occurs when plants release moisture.

The higher in the atmosphere you are, the cooler the temperature. As water vapor rises, it cools and condensation occurs. **Condensation** is the process during which water vapor changes into liquid water.

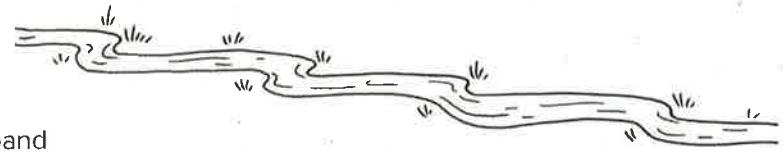
Water that falls from clouds to Earth's surface is called **precipitation.** It enters bodies of water or soaks into soil. Precipitation can be rain, snow, sleet, or hail.

COLLECT EVIDENCE

How does water move through the environment? Record your evidence (B) in your Science Notebook.

LAB Rain Check

Safety



Materials

plastic cup
warm water
plastic wrap
rubber band
ice cube

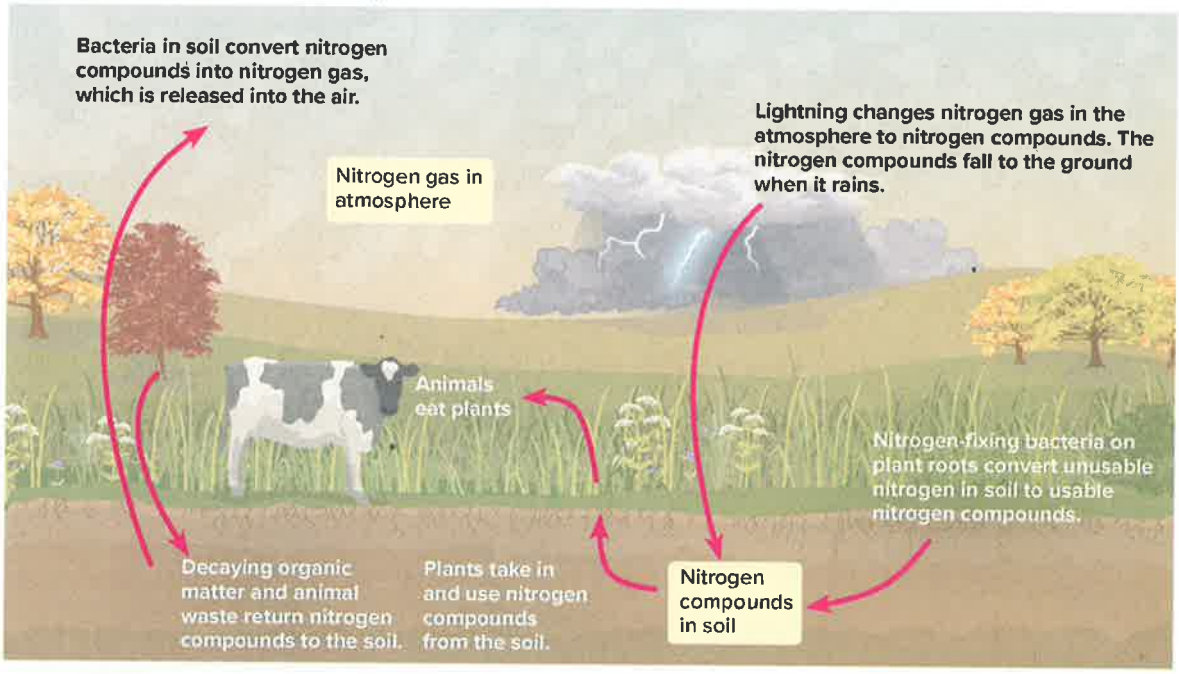
Procedure

1. Read and complete a lab safety form.
2. Half-fill a plastic cup with warm water.
3. Cover the cup with plastic wrap. Secure the plastic wrap with a rubber band.
4. Place an ice cube on the plastic wrap. Observe the cup for several minutes. Record your observations in your Science Notebook.
5. Follow your teacher's instructions for proper cleanup.

Analyze and Conclude

6. What did you observe on the underside of the plastic wrap? Why do you think this happened?
7. How might this activity model the formation of raindrops?

The Nitrogen Cycle Just as water is necessary for life on Earth, so is the element nitrogen. It is an essential part of proteins, which all organisms need to stay alive. Nitrogen, like water, cycles between Earth and its atmosphere and back again. Examine the figure and follow with your finger the path nitrogen takes according to descriptions.



Recall that the atmosphere is mostly nitrogen. However, this nitrogen is in a form that plants and animals cannot use. The process that changes atmospheric nitrogen into nitrogen compounds that are usable by living things is called **nitrogen fixation** (NI truh jun • fihk SAY shun). Plants and some other organisms take in this changed nitrogen from the soil and water. Then, animals take in nitrogen when they eat the plants or other organisms.

As you learned in the previous lesson, decomposers can break down the tissues of dead organisms. When organisms die, bacteria help return the nitrogen in the tissues of dead organisms to the environment. Nitrogen also returns to the environment in the waste products of organisms. Farmers often spread animal wastes, called manure, on their fields during the growing season. The manure provides nitrogen to plants for better growth.

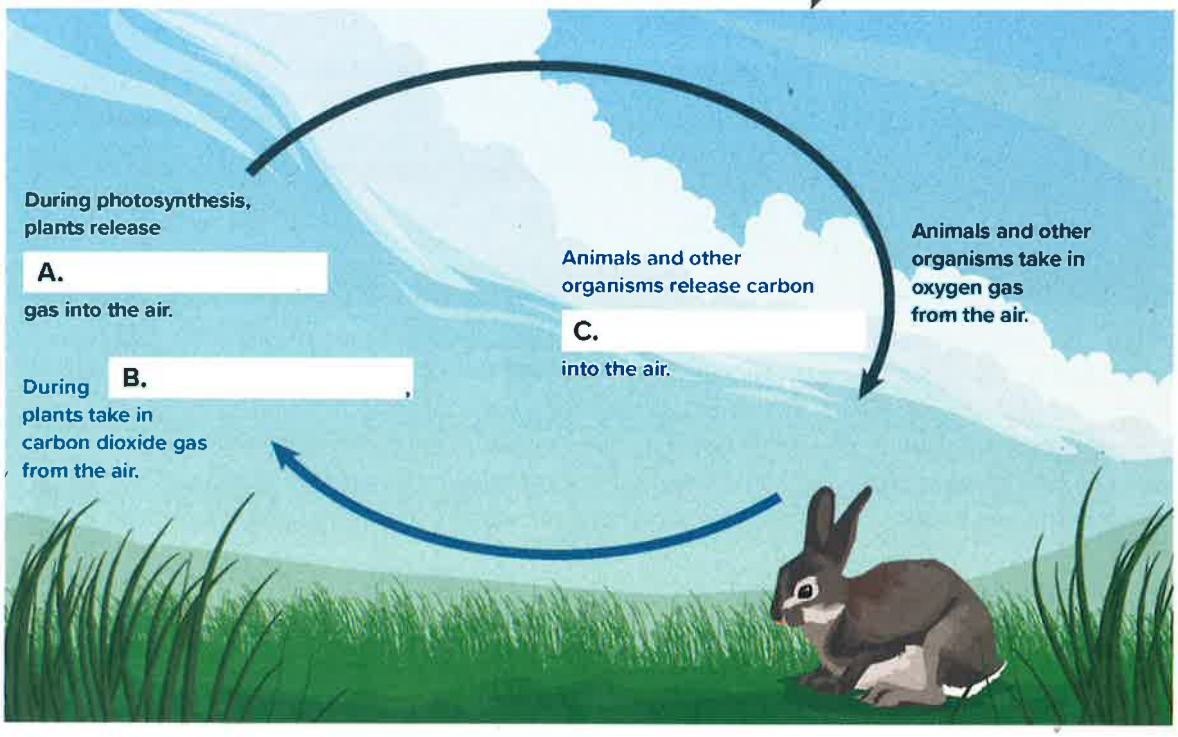
COLLECT EVIDENCE

How does nitrogen move through the environment? Record your evidence (C) in your Science Notebook.

The Oxygen Cycle Oxygen is another element that cycles through ecosystems. Recall that oxygen is necessary for cellular respiration. Oxygen is also part of many substances that are important to life, such as carbon dioxide and water.

Earth's early atmosphere probably did not contain oxygen gas. Oxygen might have entered the atmosphere when certain bacteria evolved that could carry out the process of photosynthesis and make their own food. A by-product of photosynthesis is oxygen. Over time, other photosynthetic organisms evolved and the amount of oxygen in Earth's atmosphere increased. Today, photosynthesis is the primary source of oxygen in Earth's atmosphere. Some scientists estimate that unicellular organisms in water, called phytoplankton, release more than 50 percent of the oxygen in Earth's atmosphere.

Record the correct terms in your Science Notebook.

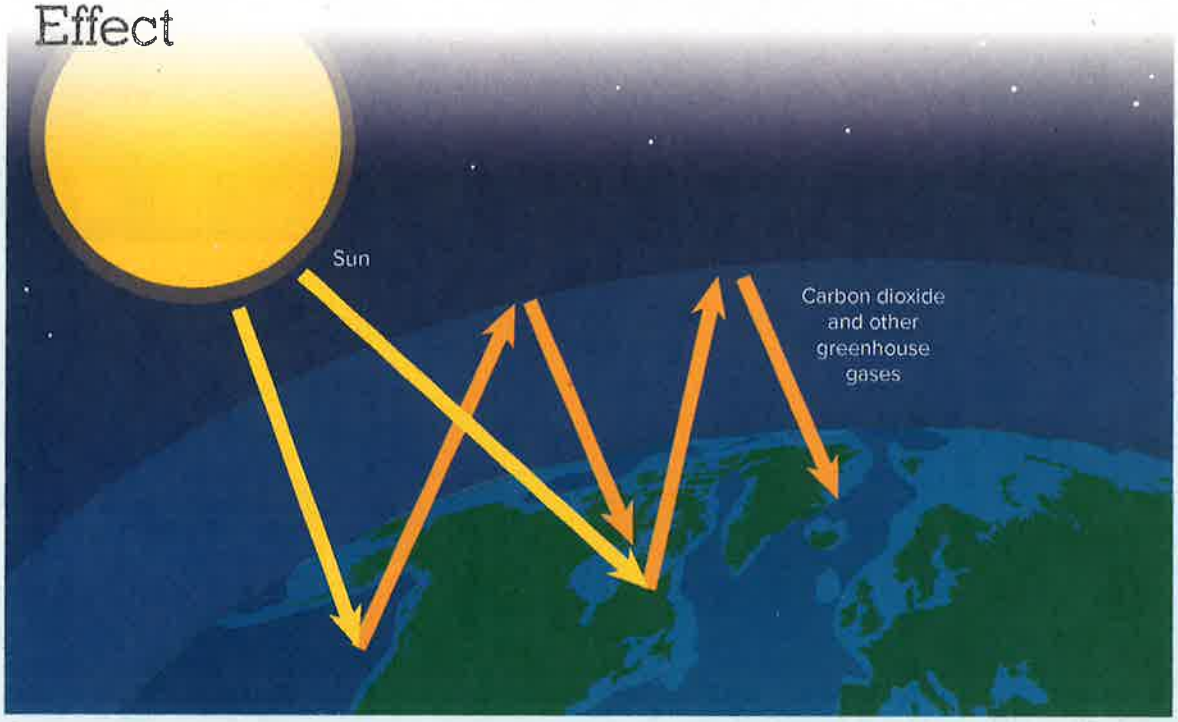


Many living things, including humans, take in oxygen and release carbon dioxide. The interaction of the carbon and oxygen cycles is one example of a relationship between different types of matter in ecosystems. As the matter cycles through an ecosystem, both the carbon and the oxygen take different forms and play a role in the other element's cycle.

COLLECT EVIDENCE

How does oxygen move through the environment? Record your evidence (D) in your Science Notebook.

A Closer Look: The Greenhouse Effect



A greenhouse is a structure many people use to enable them to grow plants in variable climates. In a greenhouse, sunlight passes through the glass and warms the plants inside, then the thermal energy is trapped inside.

Earth experiences a similar phenomenon called the greenhouse effect. The Sun produces solar radiation. Some of this energy is reflected back into space, and some passes through Earth's atmosphere. Greenhouse gases in Earth's atmosphere absorb thermal energy that reflects off Earth's surface. The more greenhouse gases released, the greater the gas layer becomes and the more thermal energy is absorbed. These gases are one factor that keeps Earth from becoming too hot or too cold.

While the greenhouse effect is essential for life, a steady increase in greenhouse gases can harm ecosystems. For example, carbon is stored in fossil fuels such as coal, oil, and natural gas. When people burn fossil fuels to heat homes, for transportation, or to provide electricity, carbon dioxide gas is released into the atmosphere. The amount of carbon dioxide in the air has increased due to both natural and human activities.

It's Your Turn

Create Work in groups to create a short skit to teach elementary students about the greenhouse effect. Be sure to integrate visual displays to emphasize the main points.

LESSON

Review

Summarize It!

1. **Model** the carbon, nitrogen, oxygen, or water cycle in your Science Notebook. Use arrows to show movement. Include inputs and outputs from one of the other cycles.

REVISIT PAGE KEELEY SCIENCE PROBES

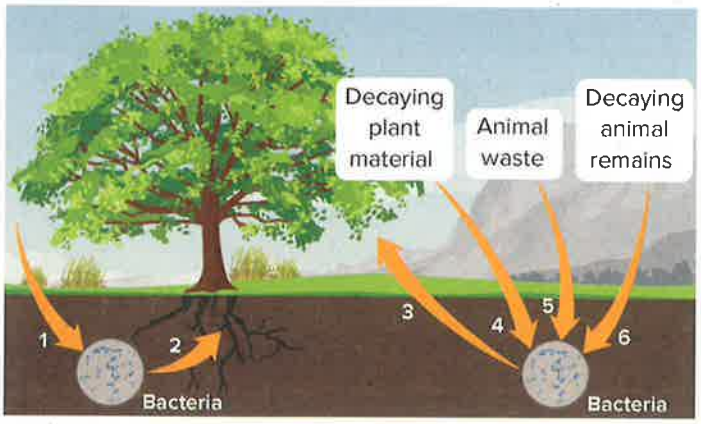
Do you still agree with the friend you chose at the beginning of the lesson? Return to the Science Probe at the beginning of the lesson. Explain why you agree or disagree with that person now.

EXPLAIN THE PHENOMENON

Revisit your claim about how matter moves through the environment. Review the evidence you collected. Explain how your evidence supports your claim.

Three-Dimensional Thinking

Keisha and her classmates created a model of the nitrogen cycle. Their diagram is shown below.



2. What is the function of the bacteria shown in the model?

- **A** They prevent the nitrogen from harming the plants.
- **B** They remove the nitrogen from the soil.
- **C** They remove the oxygen from the soil.
- **D** They return the nitrogen to the system.

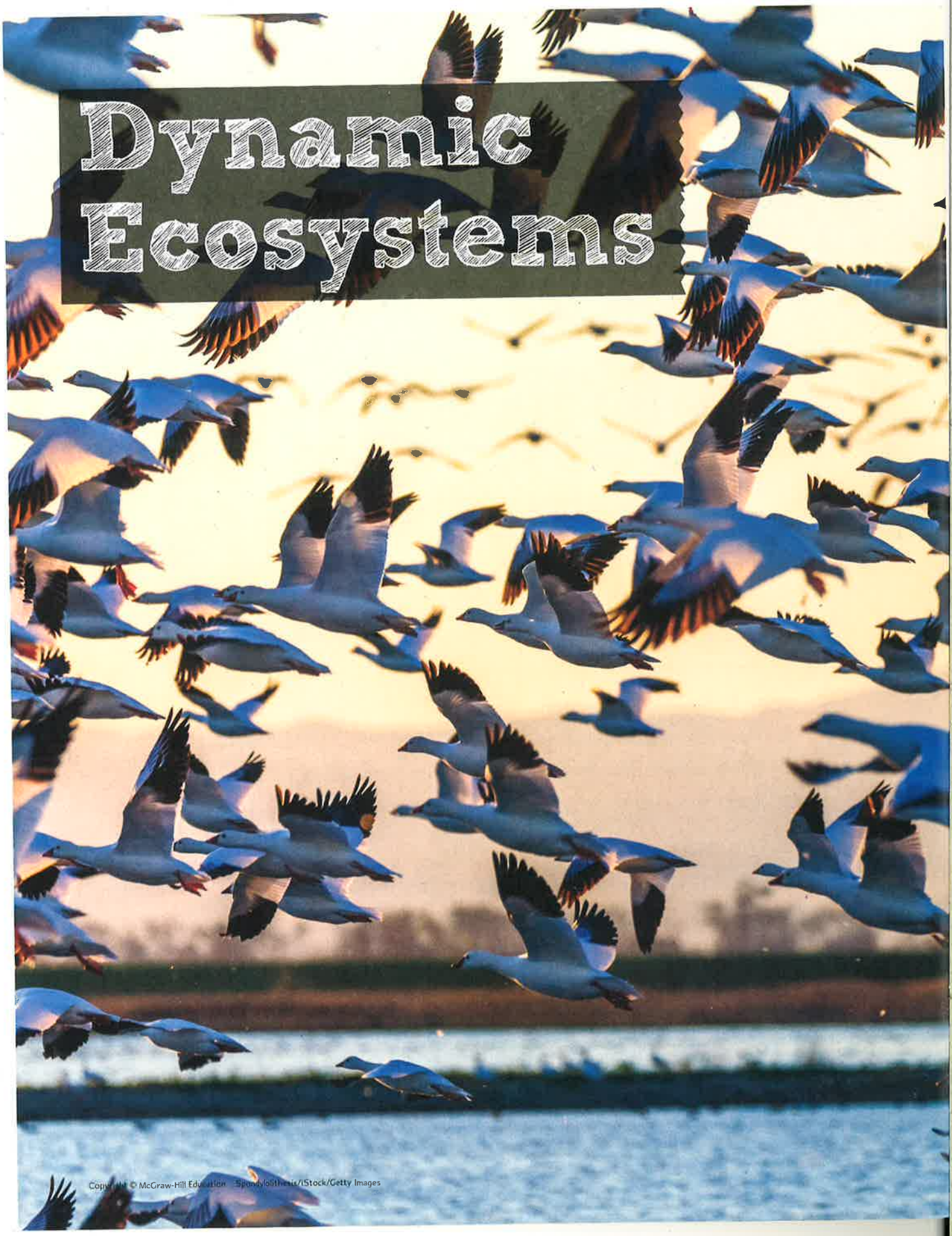
3. Which of the following is NOT true about systems that cycle matter?

- **A** Living things play a role in the cycling of matter.
- **B** Matter changes form as it cycles.
- **C** Some matter is destroyed as it cycles through the environment.
- **D** Matter is constantly cycling thought the environment.

Real-World Connection

4. **Explain** the role of living things, such as yourself, in the nitrogen cycle.

5. **Describe** how you are involved in both the carbon and oxygen cycles.



Dynamic Ecosystems

ENCOUNTER
THE PHENOMENON

How do these snow geese respond to the ecosystem around them?

GO ONLINE
Watch the video *Birds of a Feather* to see this phenomenon in action.

Collaborate With a partner, discuss why the snow geese in the photo are flying together. Where do you think they are flying? Record or illustrate your thoughts in your Science Notebook.

STEM Project

The concepts you learn throughout this module will help you plan and complete the STEM Project. Go online to read more about the project and launch the science challenge!

STEM Project
Science Challenge

The Fox and the Hare

You are volunteering at an arctic research site in Alaska helping a scientist study the relationship between arctic foxes and arctic hares in the tundra ecosystem.

The scientist is using the results of a 10-year study to look for evidence that populations are affected by the availability of resources in their ecosystem. Your team's job is to analyze and interpret a set of data from the study.

Your team will then prepare a summary statement for the scientist. Your statement should include explanations of the interactions between organisms and an argument that changes to the ecosystem affect populations, such as the population of snow geese.

After You Read *Resources in Ecosystems*

Decide what kind of graph would be most useful to analyze and interpret the data in Table 1.

Table 1 Number of Arctic Hares and Arctic Foxes in a Tundra Ecosystem, 2000-2010

Year	Number of Hares	Number of Foxes
2000	1,000	200
2001	1,500	250
2002	2,000	325
2003	2,100	500
2004	1,900	600
2005	500	650
2006	600	675
2007	800	200
2008	1,000	275
2009	1,200	325
2010	800	350

Create your graph in your Science Notebook. Analyze the data, and identify and discuss trends in the data. Refer to this table and your graph as you answer the questions after each lesson.

STEM Project
Science Challenge

After You Read *Resources in Ecosystems*, continued

List some resources individual organisms need to grow and survive. What resources might the foxes and the hares need to survive?

Describe how the growth and survival of individual organisms could be affected by decreased or increased resource availability. How would this affect the rate of reproduction for the population?

Can you use your graph as evidence to make a statement about the relationship between the size of the arctic fox population and the availability of resources (arctic hares) in the ecosystem? Explain your answer.

Explain how competition among arctic foxes and between arctic foxes and other populations is affected by the number of arctic hares in the tundra ecosystem.

After You Read *Interactions Within Ecosystems*

Arctic foxes eat arctic hares to get the energy they need to grow and survive. Classify the type of relationship these two populations have. In your Science Notebook, explain how the study data supports your classification.

Review the data table and the graph you made. Describe a pattern, or trend, in the sizes of the populations as these populations interact. Can you identify what changes were the cause and which were the effect?

Do you predict that interactions among organisms in all ecosystems depend on resource availability? Explain why or why not. Include predatory, competitive, and mutually beneficial interactions in your explanation.

After You Read *Changing Ecosystems*

Construct an explanation about how changes in the tundra ecosystem might affect the populations of arctic hares or arctic foxes.

Could the data from the study be used to make predictions about the effects of future changes in resource availability, growth of individual organisms, and population sizes? Explain why or why not.

STEM Project Science Challenge

Construct Your Explanation

Copy and complete a table like the one below in your Science Notebook.

Explanation Elements	Descriptions
Components (What evidence is used to develop the explanation?)	
Relationships (How are the different types of evidence related?)	
Connections (How does my explanation connect with what I have learned about ecosystems?)	

Write Your Summary Statement

In your Science Notebook, write the summary statement you will present to the scientist. Be sure to include:

- evidence for the effects of resource availability on the arctic fox population (evidence should be obtained by analyzing and interpreting the study data, you can also use other valid and reliable sources of evidence)
- an explanation of the pattern of interaction between the arctic foxes and arctic hares and a prediction of how this pattern of interaction among populations is similar in other ecosystems
- a description of one other way the evidence could be interpreted, and a description of why the evidence supports your claim
- an argument (based on evidence) that small changes in the tundra ecosystem could cause large changes in the populations of arctic hares and arctic foxes, and an explanation of how this cause-and-effect relationship also applies to other ecosystems

Review and Present

How might your analysis be different if your had data from 3 years instead of from 10 years? How might it be different if you had data from 20 years?

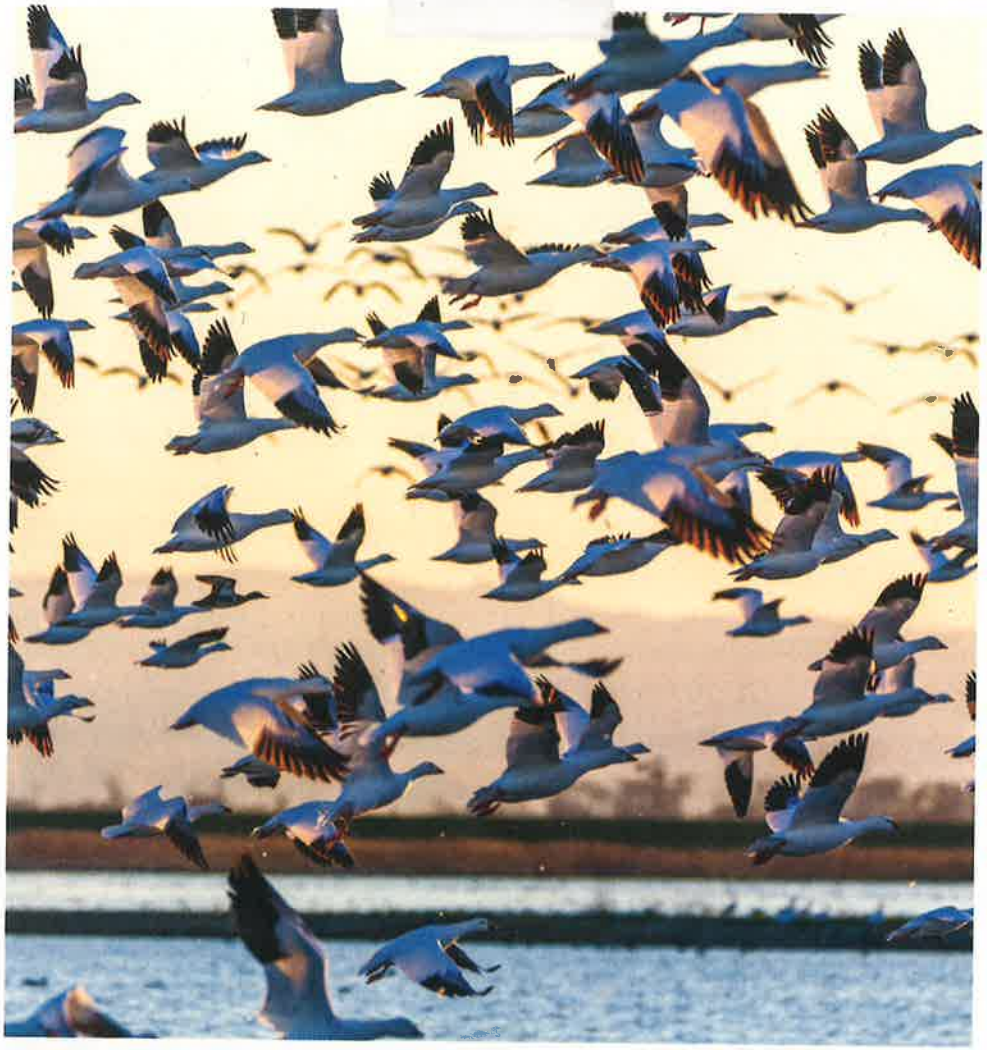
Present your summary statement to the class. How did your summary statement compare to other groups' statements?

How did your analysis of populations in a tundra ecosystem help you understand how migratory birds respond to changes in their ecosystems?

Wrap-Up

REVISIT
THE PHENOMENON

Using the concepts you learned throughout this module, explain why the snow geese responded to a change in their ecosystem and what their response was.



OPEN INQUIRY

What are one or two questions that you still have about the phenomenon?

Choose the question that interests you the most. Plan and conduct an investigation to answer this question.

LESSON

Resources in Ecosystems

PAGE KEELEY SCIENCE PROBES

Populations and Communities

Scientists use the words *population* and *community* when they study ecosystems. Which best describes how scientists use these words?

A. *Population* is used to describe the number of organisms in an area; *community* describes the place where organisms live.

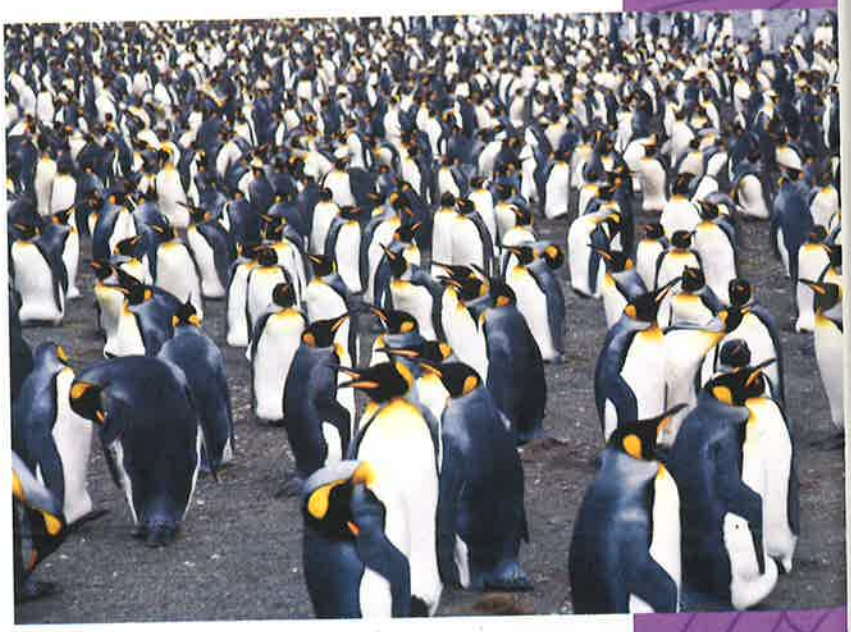
B. *Population* is used to describe all the different species living together in an area; *community* describes all the nonliving features of the area species live in.

C. *Population* describes all the organisms of the same species living in the same area at the same time; *community* describes all the populations living together in the same area at the same time.

D. *Population* describes the number of different organisms living in the same area at the same time; *community* describes the area where these living things can be found.

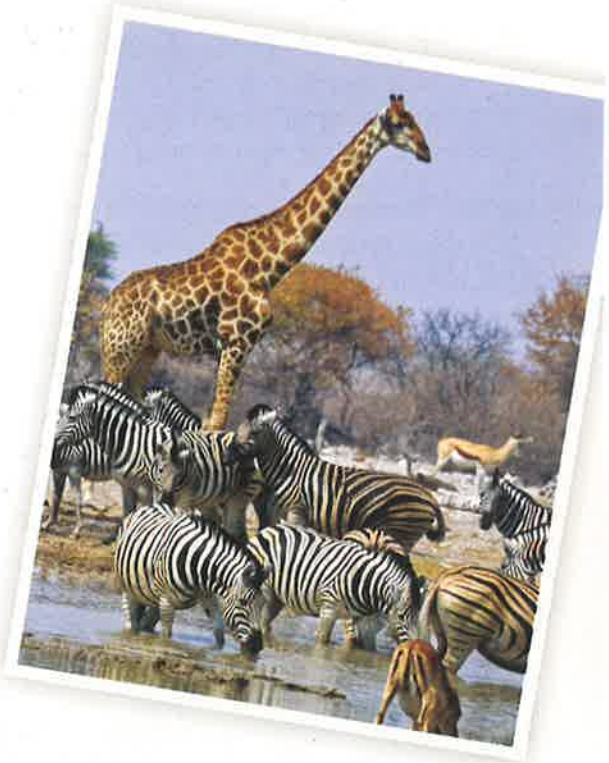
E. *Population* describes the changing types and numbers of organisms in an area; *community* describes the types and numbers of organisms in an area that do not change.

F. *Population* describes all the organisms of the same species living in the same area at the same time; *community* describes how different species get along and interact with one another.



Explain your thinking. How do you use the words *population* and *community*? You will revisit your response to the Science Probe at the end of the lesson.

ENCOUNTER
THE PHENOMENON



How does the availability of resources affect the animals living in Etosha National Park in Namibia?

GO ONLINE
Watch the video *Down at the Watering Hole* to see this phenomenon in action.

After watching the video, what did you notice? What are the relationships between the oryx, birds, springboks, and lions?

What resources do the animals in the video share? Record your thoughts in your Science Notebook.

EXPLAIN
THE PHENOMENON

You just observed many different animals surrounding a watering hole in Etosha National Park. Now make a claim about why these animals were gathered around the water. Use the outline below to guide your thinking.

Claim

The animals in the park were gathering near water because...

Evidence

A. What evidence have you discovered to explain how the animals of the park in Namibia are organized in their ecosystem?

B. What evidence have you discovered to explain how limiting factors, like water, affect the populations of animals living in the park?

Revise Claim

The animals in the park were gathering near water because...

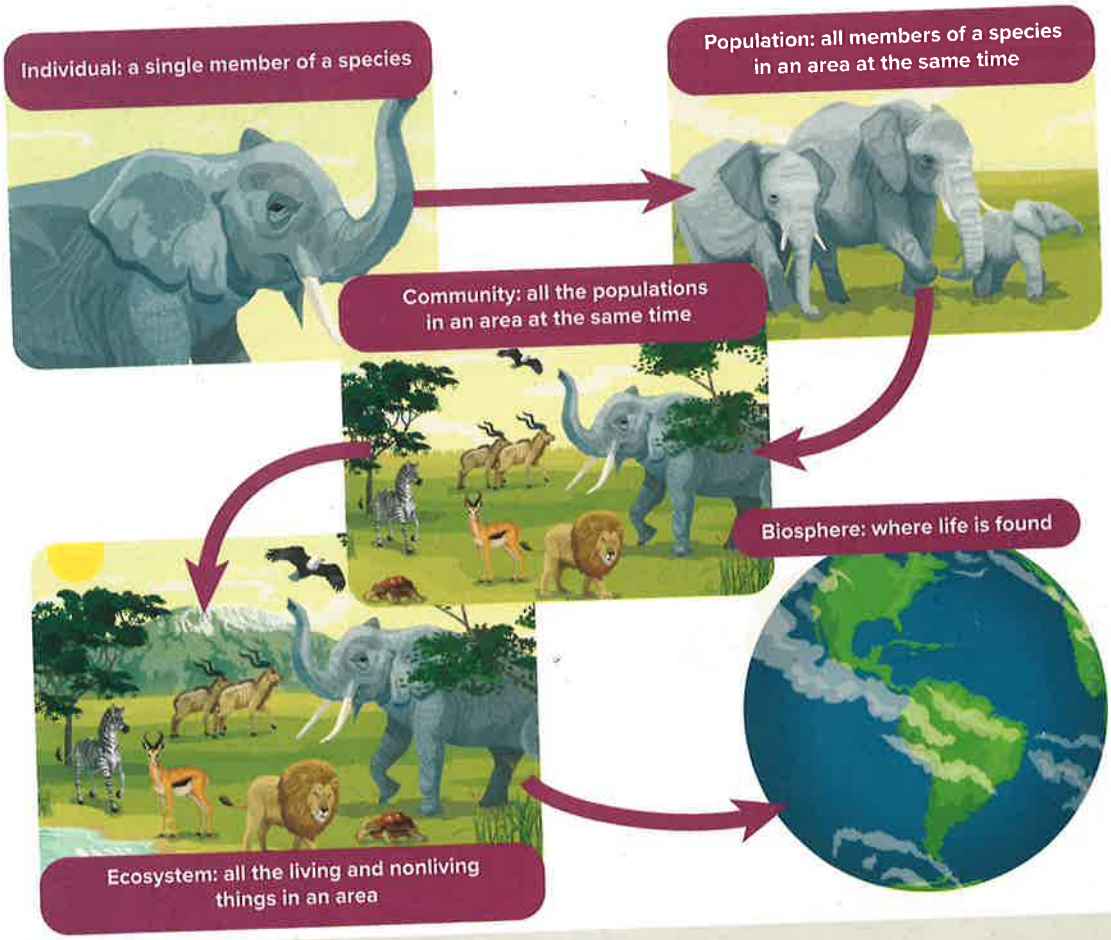
Reasoning

The evidence I collected supports my claim because...

What are the levels of organization in an environment?

When you observed the animals in the video, you may have noticed the environment around them. What were some of the living and nonliving things you noticed in the video?

In the video, while you noticed the antelope and the lions, you also may have seen grasses growing or birds flying by. The birds, mammals, and grasses are living things. The nonliving parts of the environment included the rocks and the water. Recall that all of the living and nonliving things in an area make up an ecosystem. All of the ecosystems on Earth make up the **biosphere**—the parts of Earth and the surrounding atmosphere where there is life. Examine the image below to see how an area, like the park seen in the video, is organized.



Want more information?
Go online to read more about resources in ecosystems.

FOLDABLES
Go to the Foldables® library to make a Foldable® that will help you take notes while reading this lesson.

Ecosystems As you can see, an individual elephant is part of an ecosystem. An elephant relies on interactions with other elephants to survive. They move in herds and keep each other safe. All of the elephants in the area make up a population. A **population** is all the organisms of the same species that live in the same area at the same time. A **species** is a group of organisms that have similar traits and are able to produce fertile offspring.

Many species besides elephants live in Etosha National Park. Zebras, tortoises, and lions all call the area their home. Plants that grow in the savanna include shrubs, grasses, and small trees. Together, all these plants, animals, and other organisms make up a community. A **community** is all the populations of different species that live together in the same area at the same time.

COLLECT EVIDENCE

How are the animals in Etosha National Park organized in their ecosystem? Record your evidence (A) in your Science Notebook.

Exploring the living and nonliving things that make up the Etosha National Park ecosystem may have made you think about your own ecosystem. What are the parts that make up the ecosystem where you live?

INVESTIGATION

There's No Place Like Home

Draw a chart like the one shown below in your Science Notebook to list the living and nonliving things in your local ecosystem.

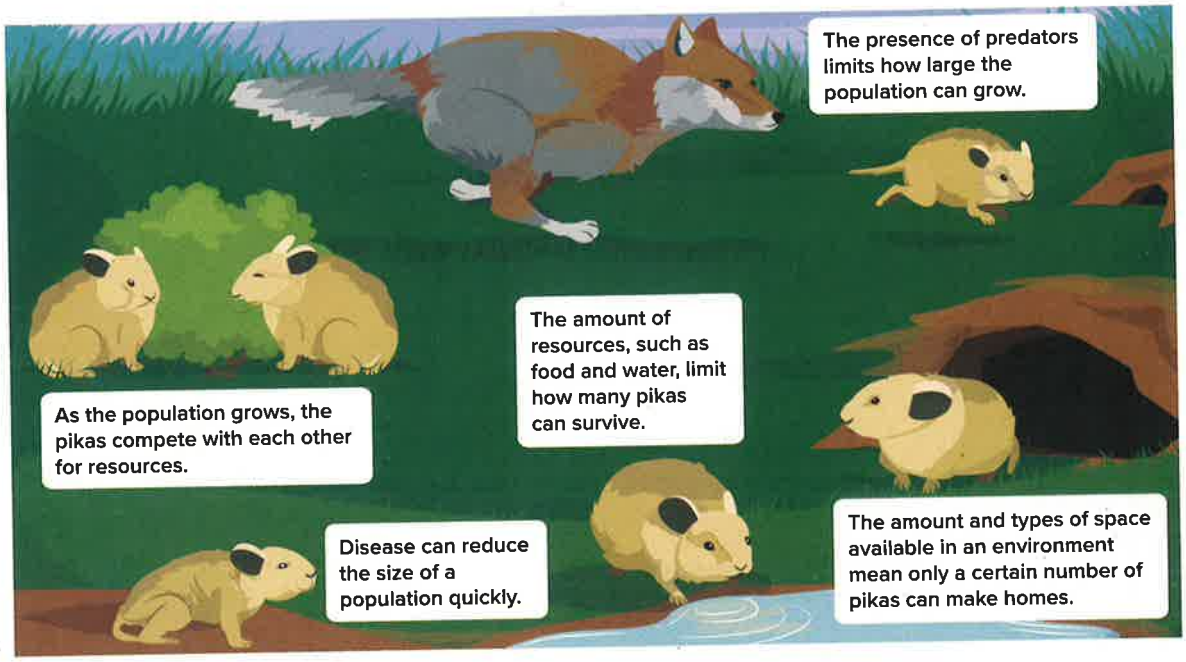
Living Things	Nonliving Things

How do you think the living and nonliving parts of your ecosystem interact?

INVESTIGATION

Pika Predicaments

Examine the figure of a population of pikas below. Read about how limiting factors affect their population.



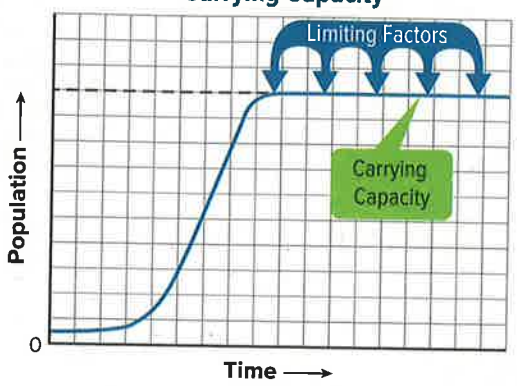
In the illustration of the pikas, you examined how limiting factors affected their survivability. Think about everything you need to survive. Choose one factor and construct an explanation in your Science Notebook about why it might be a limiting factor for the human population.

How big can populations get?

Without limiting factors, populations would keep growing until they reached their biotic potential. **Biotic potential** is the potential growth of a population if it could grow in perfect conditions with no limiting factors.

Almost no population reaches its biotic potential. Instead, it reaches its carrying capacity. **Carrying capacity** is the largest number of individuals of one species that an ecosystem can support over time. For example, in the *Fishy Population Changes* lab, the pond could only support 16 fish before it reached its carrying capacity. The limiting factors of an area determine the area's carrying capacity, as shown in the graph.

Population Growth and Carrying Capacity



THREE-DIMENSIONAL THINKING

Analyze and interpret the graph of Population Growth and Carrying Capacity above. How would the graph change if the population could reach its biotic potential? Explain your reasoning in your Science Notebook.

Overpopulation Sometimes a population becomes too large for its ecosystem to support. **Overpopulation** is when a population's size grows so large that it causes damage to the environment.

Overpopulation can cause problems for organisms. For example, a population of birds eats spiders. An overpopulation of birds causes the size of the spider population in that community to decrease. Populations of other animals that eat spiders also decrease when the number of spiders decreases.

Population Size Decrease Population size can increase, but it also can decrease. For example, a population of field mice might decrease in size in the winter because there is less food. Natural disasters such as floods, fires, or volcanic eruptions also affect population size. Sometimes, a population's size can decrease to such an extent that it may threaten the entire species. Examine the table to learn about what happens to species that see large decreases in population size.

Extinction If populations continue to decrease in numbers, they disappear. An extinct species is a species that has died out and no individuals are left. Extinctions can be caused by predation, natural disasters, or damage to the environment. For example, New Zealand was once home to a large, flightless bird called the giant moa. Humans first settled these islands about 700 years ago. They hunted the moa for food. As the size of the human population increased, the size of the moa population decreased. Within 200 years, all the giant moas had been killed and the species became extinct.	
	**Endangered Species** Mountain gorillas are an example of a species that is endangered. An endangered species is a species whose population is at risk of extinction. There are currently over 16,000 species that are categorized as endangered. Species that are considered critically endangered face an even higher risk of extinction.
Threatened Species California sea otters almost became extinct in the early 1900s due to overhunting. In 1977, California sea otters were classified as a threatened species—a species at risk, but not yet endangered. Laws were passed to protect the otters and by 2016 there were about 3,200 sea otters. Worldwide, approximately 7,000 species are classified as threatened.	

COLLECT EVIDENCE

How do limiting factors, like the water in the watering hole, affect populations of animals in the Etosha National Park? Record your evidence (B) in your Science Notebook.

A Closer Look: Water Crisis in California

Throughout its history, the state of California has endured many droughts. A drought is a period of below-average precipitation for a particular area. Droughts have been responsible for wildfires, famine, and habitat loss of aquatic species.

Between late 2011 and 2014, California experienced the driest period of its history since record-keeping began. As a major agricultural producer, California experiences negative economic impacts during dry periods. In 2016, for example, drought was responsible for the loss of 62 million trees.

Short term effects of drought include decreased quality and quantity of available water. Long term effects of drought include a permanent loss of groundwater storage. This may cause a loss in soil structure as well as sinking in areas where land is very heavy.

ENVIRONMENTAL Connection To mitigate the loss of water, in 2015, the governor instituted a 25 percent water restriction. This was meant to encourage Californians to use less water. Furthermore, implementing policies that combat climate change may reduce the likelihood of variable weather patterns which are known to cause droughts.

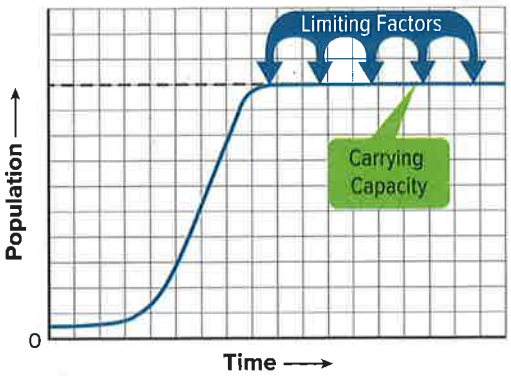
It's Your Turn

WRITING Connection With a partner, research the impact that a drought would have on your school. Write a report that includes who and what would be affected by a shortage of water.

Summarize It!

1. **Predict** A drought decreases the growth of prairie grass. How might this affect the deer population that eats the grass as its main food source? In your Science Notebook, write your response or illustrate your answer using a graphic organizer.

Population Growth and Carrying Capacity



REVISIT PAGE KEELEY SCIENCE PROBES

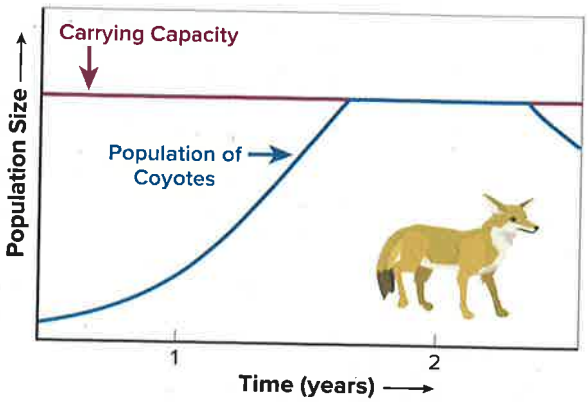
Do you still agree with the statement you chose at the beginning of the lesson? Return to the Science Probe at the beginning of the lesson. Explain why you agree or disagree with that statement now.

EXPLAIN THE PHENOMENON

Revisit your claim about the resources used by the animals in the Namibian park. Review the evidence you collected. Explain how your evidence supports your claim.

Three-Dimensional Thinking

Use the graph below to answer questions 2 and 3.



2. A population of coyotes lives in a habitat with plentiful food and no predators. Analyze the graph and interpret what is happening to their population size at the one year mark.

   A The population size is increasing.

   B The population size is decreasing.

   C The population size is remaining the same.

   D The population size cannot be inferred from the graph.

3. Which of the following explains what happened to the coyote population size when it reached its carrying capacity, and why?

   A The population size continued to increase because the ecosystem had not changed.

   B The population size stopped increasing because it had reached the largest number of coyotes that the ecosystem could support.

   C The population size became zero because the ecosystem could no longer support the coyote population.

   D The population size can no longer be inferred from the graph once carrying capacity is reached.

Real-World Connection

4. **Explain** Your fellow classmate thinks that populations can grow as large as they want to, with nothing to limit their growth. Explain why he or she is incorrect.

5. **Infer** A population of salamanders lives in a small lake community. Using what you have learned, infer what limiting factors may limit the growth of the salamander population.

LESSON

Interactions Within Ecosystems

PAGE KEELEY SCIENCE PROBES

What's the relationship?

Some organisms interact with other organisms over time and form relationships. Scientists describe these relationships as symbiotic. What do you think a symbiotic relationship is? In your Science Notebook, write down the letter of each of the examples that you think are symbiotic relationships.

A. Some microorganisms live inside a termite's digestive system and digest the wood that a termite eats.

B. A tick feeds on the blood of a dog.

C. A strangler fig vine grows around a tree and eventually kills the tree.

D. A cleaner shrimp feeds on the decaying food particles inside a fish's mouth.

E. Leafcutter ants provide a fungus with food (the leaves) and then eat the fungus.

F. A seed sticks to an animal's fur, but eventually falls off the animal.

G. A wasp lays its eggs inside a caterpillar. When the eggs hatch, the new wasps feed on the caterpillars.

Explain your thinking. Describe the rule or reasoning you used to decide if a relationship between two organisms is symbiotic. You will revisit your response to the Science Probe at the end of the lesson.

ENCOUNTER
THE PHENOMENON

What sort of relationship do the cleaner shrimp and the moray eel have?

Reflect on the video at the bottom of the page in your Science Notebook. What do you think these organisms were doing? What organisms in your environment have similar relationships?

EXPLAIN
THE PHENOMENON

You just observed the interaction between a cleaner shrimp and a moray eel. There are different types of interactions between organisms that occur across all ecosystems. Now make a claim about the type of relationship shared by the shrimp and eel. Use the outline below to guide your thinking.

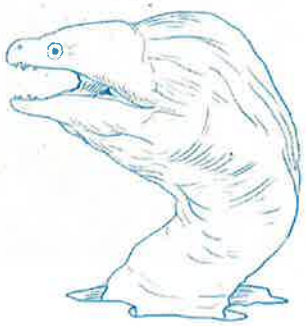
Claim

The relationship between the shrimp and the eel...

Evidence

A. What evidence have you discovered to explain why some organisms, such as the cleaner shrimp and the moray eel, have symbiotic relationships?

B. What evidence have you discovered to explain other types of relationships in ecosystems?



Revise Claim

The relationship between the shrimp and the eel...

Reasoning

The evidence I collected supports my claim because...

GO ONLINE
Watch the video *That's A-moray* to see this phenomenon in action.

How do living things interact in an ecosystem?

Recall that populations in the same area interact as a community. In addition to interacting with the nonliving things in their ecosystems, these populations interact with each other. Explore some relationships that organisms take part in below.

INVESTIGATION

Relationships in Communities

Examine each of the three relationships. Draw a table like the one shown below in your Science Notebook. In your table, write any observations you make about the characteristics of each relationship.

Cattle egrets live near cattle because the cattle kick up insects and worms while grazing. These are food sources for the bird.	Bees receive nectar they need to make honey by harvesting it from the beebalm flower. Traveling between plants, the bees bring pollen from one flower to another resulting in pollination.	Fleas and ticks are tiny animals that can live on cats and dogs. They feed off of the blood of the host they live on which can cause illness in the cat or dog.
		

Want more information?
Go online to read more about interactions within ecosystems.

FOLDABLES
Go to the Foldables® library to make a Foldable® that will help you take notes while reading this lesson.

How do some organisms benefit in relationships?

You may have determined that there are different kinds of relationships within communities. For example, bees and beebalm flowers both benefit from their relationship, while fleas are the only benefactor in their relationship with cats and dogs. Some relationships have different outcomes and benefits. Watch the video below to learn about the relationship between hippos and barbel fish!

INVESTIGATION

Mutually Bene-fish-al

GO ONLINE Watch the video *The Barbel Fish and Hippos.*

Watch the video again and take notes about the relationship between the barbel fish and the hippopotamuses in your Science Notebook. Once you are finished, answer the questions.

1. Who is benefiting in this relationship? Explain your answer.
2. Do you think all relationships in communities are like this? Explain.

Symbiosis Barbel fish and hippos have a unique relationship. The fish follow and groom the hippos to eat. The hippos have parasites removed and their mouths cleaned by the fish. Both rely on the interaction to stay healthy and survive. This relationship is a type of symbiosis. **Symbiosis** is a close, long-term relationship between two species that usually involves an exchange of food or energy.

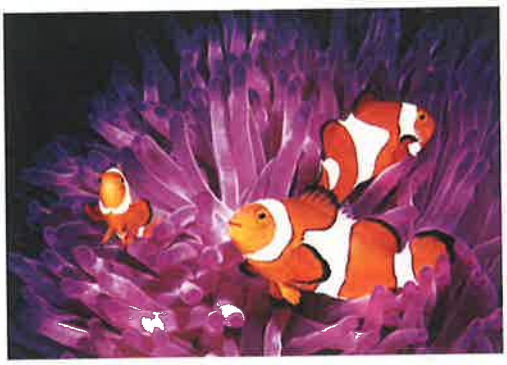
What are the different types of symbiotic relationships?

As you read earlier, organisms in communities can have many different types of relationships. Symbiotic relationships occur when two organisms live in direct contact and form a relationship. Some species have such close relationships that they are almost always found living together. Although communities around the world have symbiotic relationships, coral reef communities often include different types of symbiosis. Many of the organisms in these communities, such as clownfish, sea anemones, and even microscopic copepods, have some type of symbiotic relationship.

Commensalism A symbiotic relationship that benefits one species but does not harm or benefit the other is **commensalism.** Plants called epiphytes (EH puh fites) grow on the trunks of trees and other objects. The roots of an epiphyte anchor it to the object. The plant's nutrients are absorbed from the air. Epiphytes benefit from attaching to tree trunks by getting more living space and sunlight. The trees are neither helped nor harmed by the plants.

Parasitism A symbiotic relationship that benefits one species and harms the other is **parasitism.** The species that benefits is the parasite. The species that is harmed is the host. The larvae of the hunting wasp is a parasite. The female wasp, shown in the photo, stings a spider to paralyze it. Then she lays eggs in its body. When the eggs hatch into larve, they eat the paralyzed spider.

Mutualism A symbiotic relationship in which both partners benefit is called **mutualism.** Clownfish and sea anemones live in tropical coral reef communities. The clownfish receives protection from the anemone as the anemone will sting predators of the clownfish. The anemone in turn receives energy from the waste produced by the clownfish. The barbell fish and hippos you learned about earlier also share a mutualistic relationship.



THREE-DIMENSIONAL THINKING

With a partner, discuss the **patterns** that you notice in the relationships you have learned about. In your Science Notebook, **explain** how you can use this information to identify **cause and effect** relationships between organisms.

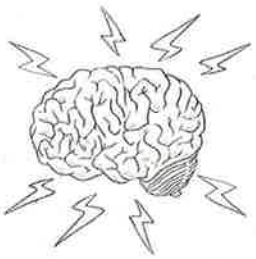
COLLECT EVIDENCE

Why do some organisms, such as the cleaner shrimp and the moray eel, have symbiotic relationships? Record your evidence (A) in your Science Notebook.

LAB Coral Colleagues

In this lab, you will research and model one type of symbiosis in a coral reef community. You will then present your model to the rest of your class.

Materials



symbiosis cards

Procedure

1. Read and complete a lab safety form.
2. Get a card from your teacher with the name of an organism that has a symbiotic relationship. Find your partner in the symbiotic relationship.
3. With your partner, brainstorm what the relationship between your organism and your partner's organism might look like. Record your ideas in your Science Notebook. Make a chart like the one below.
4. Using reference books or a computer, research the symbiotic relationship along with your partner. Add what you learn to the chart.

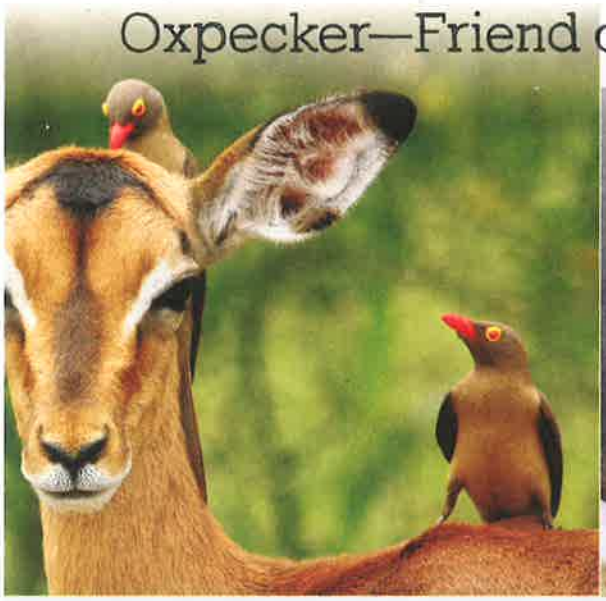
	Organism 1	Organism 2
Benefits to this organism		
Harm to this organism		
Other notes		

5. Develop a visual presentation, such as a skit, a slide show presentation, or a series of posters, with your partner showing how your symbiotic relationship works.
6. Show your presentation to the class.
7. Observe other students' presentations and take notes in your Science Notebook.

Analyze and Conclude

8. What was your organism's role in the relationship?
9. How would your organism interact in the community if its partner were not present?
10. What other organisms in the coral reef community have a similar type of relationship as your organism? If none, explain why.

A Closer Look: The African Oxpecker—Friend or Foe?



The oxpeckers are two species of bird found in the savanna of Sub-Saharan Africa. They acquired their name from their habit of perching on top of large African mammals, such as the water buffalo and impala above, as well as zebras, rhinos, and giraffes. The oxpecker feeds exclusively on the ticks and insects that live on these large animals.

The nature of the oxpecker's relationship with large mammals is the subject of ongoing research. Initially, this relationship was thought to be an example of mutualism, where the birds were thought to free the animal of parasites while gaining food in the process. However, oxpeckers have been known to drink the blood of their animal perches. They may even make wounds from ticks much worse by opening them up more. Because of this, elephants have been observed shaking the oxpeckers off after they land.

New evidence suggests that the oxpecker/mammal interaction is sometimes an example of a parasitic relationship. While the large mammals are cleared of parasites, they are sometimes harmed in the process.

It's Your Turn

Explain One of your classmates thinks that the oxpecker is a helpful organism, while another classmate believes that they are strictly a parasite. Which student do you agree with and why? With a partner, create a podcast to act out the debate.

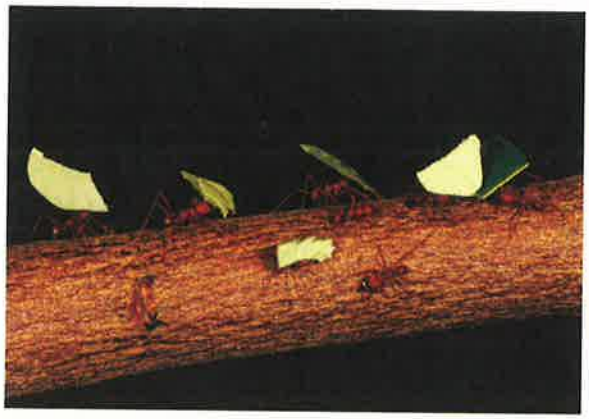
What other types of relationships exist in ecosystems?

You may have noticed that symbiotic relationships are found in a variety of ecosystems, from coral reefs to the deserts in Africa. Although the species involved in these symbiotic interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.

INVESTIGATION

Assorted Associations

Not all relationships in communities are considered symbiotic. Examine the figures below to learn more about other types of relationships and then answer the questions in your Science Notebook.



1. Describe what you think the ants are doing in the figure on the left.
2. How do you think the relationships between the ants differs from symbiosis?
3. In the figure on the right, explain which organism is benefitting and which is not. Explain why this is not a symbiotic relationship.

Cooperative Relationships The leaf-cutter ants in the *Assorted Associations* investigation work together in cooperative relationships for their survival. Together they carry leaves to their nest to be used to grow fungus for food and building. Cooperative relationships can be found in many different populations across the world. For example, elephants cooperate with each other to raise young and watch for predators. Squirrel monkeys benefit in a similar way by living in groups. They cooperate as they hunt for food and watch for danger.

Predator-Prey Relationships The osprey catching a fish in the *Assorted Associations* investigation is an example of a predator-prey relationship. A predator-prey relationship is one in which one organism, the predator, eats another, the prey. Predators help prevent prey populations from growing too large for the carrying capacity of the ecosystem. Predators often capture weak or injured individuals of a prey population. When the weak members of a population are removed, there are more resources available for the remaining members. This helps keep the prey population healthy.

Competitive Relationships Organisms that share the same habitat often compete for resources. This is known as a competitive relationship. Competition describes interactions between two or more organisms that need the same resource at the same time. For example, trees compete for sunlight, and the shade from tall trees can slow the growth of younger trees. Wolves compete with ravens for meat from the animals that wolves kill, as shown in the photo above.

THREE-DIMENSIONAL THINKING
Choose a predator from your local ecosystem. **Construct an explanation** about its relationship with a local prey species, including how the predator is benefiting. Record your ideas in your Science Notebook.

COLLECT EVIDENCE

How can you explain other types of relationships in ecosystems? Record your evidence (B) in your Science Notebook.

AMERICAN MUSEUM OF NATURAL HISTORY

CAREERS in SCIENCE

All for One, One for All

If you have ever watched ants move single file across a sidewalk, you might have wondered how they know which way to go. This is a question that Dr. Deborah M. Gordon, an ecologist at Stanford University, might ask. She studies the behavior of red harvester ants.

Gordon studies the organization of ant colonies. A colony has one or more reproductive queens and many sterile workers living together. At any given time, ants might be working together on a specific task such as building new tunnels, protecting the colony, or collecting food. However, no one ant in the colony directs the other ants. Gordon investigates how each ant within a colony takes on different tasks and how they work together as a group.

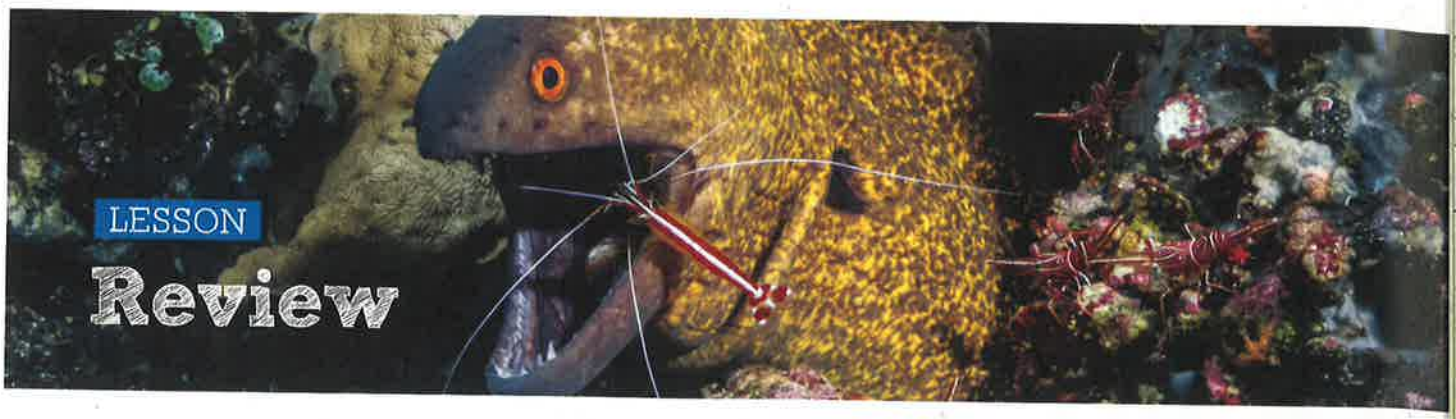
Ants communicate using chemicals. They release chemicals that other ants smell with their antennae. Each colony has its own unique odor, and only ants from that colony can recognize it. In addition, harvester ants have a chemical "vocabulary." They signal a specific task by communicating with a particular chemical.

To study ant communication, Gordon and her colleagues closely observe red harvester ants in their habitats and conduct experiments. Her team might isolate one of the communication chemicals and then place it in different locations or in the same location at different times of day. Gordon has learned that these ants can change tasks when they meet other ants. When one ant's antennae touch another ant, it can tell by the odor what task the other ant is doing. Gordon is studying how ants use encounters to interact with each other and their environments.

▲ The red harvester ant is one of only 50 ant species that have been well studied. Scientists have discovered more than 12,000 ant species in all.

It's Your Turn

Investigate Find two animals to observe in their natural habitats. Record your observations. How did they interact with the environment or with other animals? Share your results with your classmates.



LESSON

Review

Summarize It!

1. **Identify** how populations interact in a community. Copy the chart into your Science Notebook, and write descriptions.

Relationship	Description
Predator-prey	
Cooperative	
Competitive	
Symbiotic a. Mutualism b. Parasitism c. Commensalism	

REVISIT PAGE KEELEY SCIENCE PROBES

Do you still agree with the examples you chose at the beginning of the lesson? Return to the Science Probe at the beginning of the lesson. Explain why you agree or disagree with your responses now.

EXPLAIN THE PHENOMENON

Revisit your claim about the relationship shared between the cleaner shrimp and moray eel. Review the evidence you collected. Explain how your evidence supports your claim.

Three-Dimensional Thinking

The image on the right depicts *Rhizobium*, a type of bacteria, growing within plant root nodules.

2. Imagine that you are growing bean plants. You notice that every bean plant with *Rhizobium*, a type of nitrogen-fixing bacteria, is very healthy. You also notice that the plants without *Rhizobium* in their root nodules seem to be doing poorly. Through research, you learn that *Rhizobium* gains food from the plant. What can you infer about the relationship between the *Rhizobium* bacteria and the bean plants?

A *Rhizobium* and the bean plant are an example of commensalism.

B *Rhizobium* and the bean plant are an example of mutualism.

C *Rhizobium* and the bean plant are an example of a predator-prey interaction.

D *Rhizobium* and the bean plant are not part of a relationship.

3. A documentary on sharks shows a small remora fish attached to the shark. The remora fish eats any parasites on the shark and leftover food. Which explanation best fits this type of relationship?

A This relationship is parasitism because the fish are eating off the shark.

B This relationship is mutualism because the fish receive food and the sharks are cleared of dangerous parasites.

C This relationship is commensalism because only the fish is benefiting while the shark is neither helped nor harmed.

D This relationship is cooperative because both are working together to help the fish receive food.

Real-World Connection

4. **Infer** While fishing you see an organism on the gills of a fish that consumes the fish's blood. Infer the type of relationship the fish and the organism share and give your reasoning.

5. **Construct an Explanation** Bees and flowering plants share a mutualistic relationship. Bees receive the nectar they need to make honey, while the flower is pollinated by the bees. Can you apply this pattern to predict what might happen if all of the bees were to disappear?

LESSON

Changing Ecosystems

PAGE KEELEY SCIENCE PROBES

No More Plants

Imagine that all the plants in a particular area died. Which best predicts what would happen to the animals in that area? Choose the prediction that best matches your thinking.

A. The animals that eat plants would all die. The animals that eat only animals would live.

B. Some of the plant-eating animals would die. Others would live by switching to eat other animals.

C. All of the animals would eventually run out of food and die.

D. All of the animals would survive by eating other foods.

Explain your thinking. Describe the reasoning you used to make your prediction. You will revisit your response to the Science Probe at the end of the lesson.

ENCOUNTER
THE PHENOMENON

How are populations affected by changes to a forest ecosystem when it is destroyed by fire?

Examine the photo on this page. What do you think is happening to the ecosystem? Summarize your thoughts in your Science Notebook.

EXPLAIN
THE PHENOMENON

You just observed a forest after a fire had changed the ecosystem. Now make a claim about how physical changes to the ecosystem, like a forest fire, can affect other populations within the ecosystem. Use the outline below to guide your thinking.

Claim

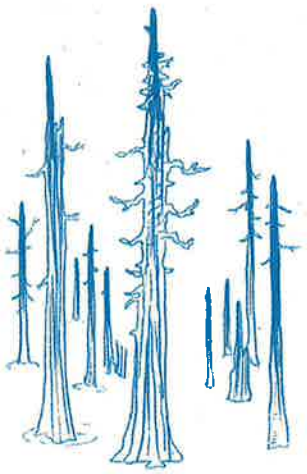
The fire has affected the ecosystem by...

Evidence

A. What evidence have you discovered to explain how physical changes such as a fire in a forest ecosystem occur?

B. What evidence have you discovered to explain how natural changes in ecosystems affect populations?

C. What evidence have you discovered to explain how human disruptions affect populations?



Revise Claim

The fire has affected the ecosystem by...

Reasoning

The evidence I collected supports my claim because...

GO ONLINE
Watch the video, *Mountain Ash*, to see this phenomenon in action.

How do land ecosystems change?

An ecosystem can change over time. Change usually happens so gradually that you might not notice the differences from day to day. Examine the pond community below to observe what changes occur.

INVESTIGATION

Change in Communities

Examine the two images below. One is labeled *A* and the other is labeled *B*. Imagine community *A* changes and becomes like community *B*. Answer the questions below in your Science Notebook.

1. How long do you think it would take community *A* to become like community *B*?
2. Summarize the changes you think would happen as the community changed from *A* to *B*.

Want more information?
Go online to read more about changing ecosystems.

FOLDABLES®
Go to the Foldables® library to make a Foldable® that will help you take notes while reading this lesson.

Ecological Succession The change in the pond you just observed is an example of ecological succession. **Ecological succession** is the process of one ecological community gradually changing into another. Ecological succession occurs in a series of steps. These steps can usually be predicted. For example, small plants usually grow first. Larger plants, such as trees, usually grow last. The final stage of ecological succession in a land ecosystem is a **climax community**—a stable community that no longer goes through major ecological changes.

Primary Succession Ecological succession in new areas of land with little or no soil or vegetation, such as on a lava flow, a sand dune, or exposed rock, is primary succession. Take a look at how an ecosystem changes after a volcanic eruption.

During a volcanic eruption, molten lava flows over the ground and into the water. After the eruption is over, the lava cools and hardens into bare rock.

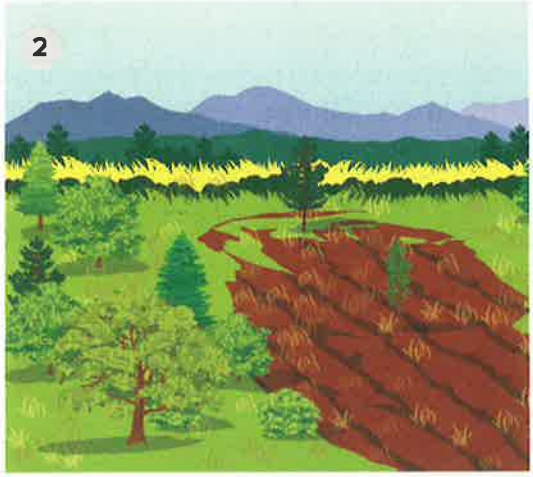
Lichen spores carried on the wind settle on the rock and create soil. Lichens add nutrients to the soil as they die and decay.

Airborne spores from mosses and ferns settle onto the thin soil and add to the soil when they die. The soil gradually becomes thick enough to hold water. Insects and other small organisms move into the area.

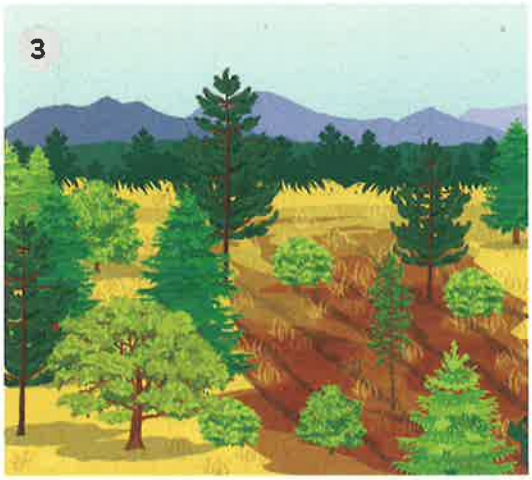
After many years the soil is deep and has enough nutrients for grasses, wildflowers, shrubs, and trees. The new ecosystem provides habitats for many animals. Eventually, a climax community develops.

Secondary Succession In areas where existing ecosystems have been disturbed or destroyed, secondary succession can occur. One example is forestland in New England that early colonists cleared hundreds of years ago. Some of the cleared land was not planted with crops. This land gradually grew back to a climax forest community of beech and maple trees.

Settlers in New England cleared many acres of forest to create cropland. In places where people stopped planting crops, the forest began to grow back.



Seeds of grasses, wildflowers, and other plants quickly began to sprout and grow. Young shrubs and trees also started growing. These plants provided habitats for insects and other small animals, such as mice.



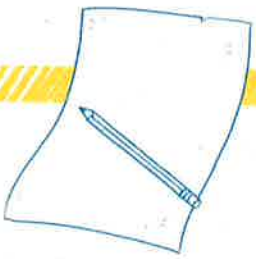
White pines and poplars were the first trees in the area to grow to their full height. They provided shade and protection to slower growing trees, such as beech and maple.

Eventually, a climax community of beech and maple trees developed. As older trees died, new beech and maple seedlings grew and replaced them.

Ecosystems and Time You just observed how ecosystems change over time because of primary and secondary succession. What might your local ecosystem look like after many years?

INVESTIGATION

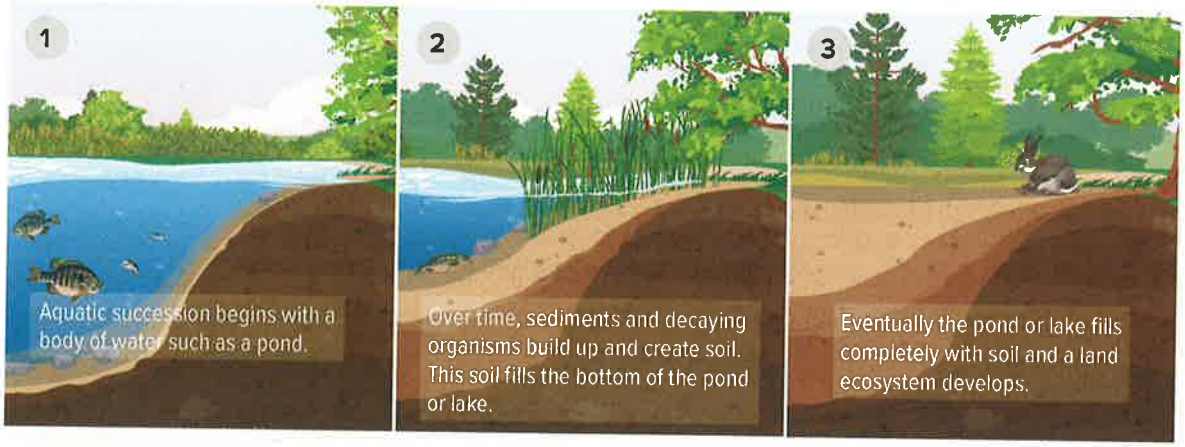
Class is Dismissed



1. In your Science Notebook, draw a picture of what your school might look like in 500 years if it were abandoned.
2. Describe changes that ecological succession would have on your school in the form of a narrative. Present a logical sequence with valid reasoning that supports your illustration. Share your illustration and story with the class.

How do aquatic ecosystems change?

Like land ecosystems, freshwater ecosystems change over time in a natural and predictable process. This process is called aquatic succession. Observe how freshwater ecosystems change over time.



GO ONLINE for an additional opportunity to explore!

Do you want to know more about how ecosystems can change over time? Investigate succession by watching the following animation.

Watch the animation *Aquatic Succession* to see a pond ecosystem transform.

THREE-DIMENSIONAL THINKING

In your Science Notebook, **construct an explanation** of how changes, such as the buildup of soil, could affect populations of organisms in a lake ecosystem.

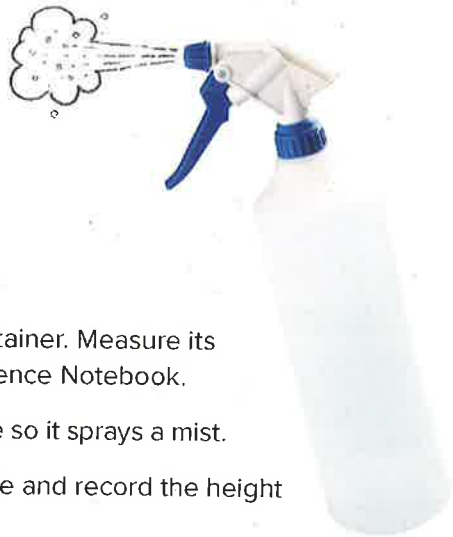
EARTH SCIENCE Connection As you just learned, sediments can build up at the bottom of bodies of water and become soil. Sediment is any material that is broken down by the process of weathering and then transported by wind, water, or gravity. Sediments are usually transported by water. Runoff can move sediment into streams and other water passages. How do you think this process affects populations of aquatic organisms?

LAB It's Sedimentary, My Dear Watson

Safety

Materials

foam cup	pencil	timer
sand	metric ruler	water
plastic container (2)	spray bottle	



Procedure

1. Read and complete a lab safety form.
2. Use a foam cup to build a sand castle in a plastic container. Measure its height with a metric ruler. Record the data in your Science Notebook.
3. Fill a spray bottle with water. Adjust the tip of the bottle so it sprays a mist.
4. Using a timer, spray your sand castle for 30 s. Measure and record the height of your sand castle in your Science Notebook.
5. Readjust the tip of the spray bottle so it sprays a stream of water. Then, rebuild your castle with fresh sand and repeat step 4.
6. Rebuild your sand castle with fresh sand. Poke three holes in the bottom of the foam cup with a pencil. Put your fingers over the holes and fill the cup with water. Repeat step 4, letting water run out of the holes onto your castle.

Analyze and Conclude

7. What natural events could each of your trials represent?
8. How might these natural events affect the quality of water resources?
9. How would water heavy with sediment affect the populations of organisms that use the water?

ENVIRONMENTAL Connection

Too much sediment can damage stream habitats, clog waterways, and cause flooding. Negative environmental impacts of sedimentation include habitat loss, change in available nutrients, and coastline alteration. Sediment that is suspended in water may reduce visibility and make it difficult for animals to find food. It may also prevent light from reaching plants that need sunlight for food. Sediment that has collected on the bottoms of rivers and streams may cover habitats of fish or other animals.

Read a Scientific Text

Eutrophication Like sediment, decaying organisms fall to the bottom of a pond, a lake, or a wetland, adding nutrients to the water. Runoff from fertilizers used in farming adds even more nutrients to water systems. **Eutrophication** is the process of a body of water becoming nutrient rich. Read about how nutrient pollution and eutrophication can affect an ecosystem.

CLOSE READING

Inspect

Read the passage *Too Much of a Good Thing: Human Activities Overload Ecosystems with Nitrogen.*

Find Evidence

Reread the passage. Identify words and phrases in which the author discusses nitrogen.

Make Connections

Collaborate With your partner, evaluate the claim that agricultural activities are responsible for eutrophication.

PRIMARY SOURCE

Too Much of a Good Thing: Human Activities Overload Ecosystems with Nitrogen

Humans are overloading ecosystems with nitrogen through the burning of fossil fuels and an increase in nitrogen-producing industrial and agricultural activities, according to a new study. While nitrogen is an element that is essential to life, it is an environmental scourge at high levels.

According to the study, excess nitrogen that is contributed by human activities pollutes fresh waters and coastal zones, and may contribute to climate change. Nevertheless, such ecological damage could be reduced by the adoption of time-honored sustainable practices.

[...]Much of nitrogen fertilizer that is used worldwide is applied inefficiently. As a result, about 60 percent of the nitrogen contained in applied fertilizer is never incorporated into plants and so is free to wash out of root zones, and then pollute rivers, lakes, aquifers and coastal areas through eutrophication.

"While the processes of eutrophication have been recognized for many years, only recently have scientists been able to begin placing the anthropogenic processes in the context of an understanding of the broader biogeochemical cycles of the planet," says Robert Burnap, an NSF program director. This is an important article because it concisely develops this understanding and also provides reasonable predictions regarding the economic and policy dimensions of the problem."

Source: National Science Foundation

Eutrophication is a natural part of aquatic succession. However, human activity also contributes to eutrophication. The fertilizers that farmers use on crops and the waste from farm animals can be very high in nutrients. High nutrient levels support large populations of algae and other microscopic organisms. These organisms use most of the dissolved oxygen in water and less oxygen is available for fish and other aquatic organisms.

COLLECT EVIDENCE

How do physical changes to ecosystems, like the forest fire in the beginning of the lesson, occur? Record your evidence (A) in your Science Notebook.

How do changing ecosystems affect populations?

Populations of organisms depend on resources in their ecosystems for food and shelter. The ecosystem operates under **dynamic equilibrium,** which describes the balance between different parts of the ecosystem. As you have learned, environments change, and the change can last for years. After such a change happens, the balance is lost and individual organisms of a species might not be able to find the resources they need to survive. These changes may disrupt all areas of the ecosystem. Discover how natural disruptions affect ecosystems in the following investigation.

Effects of Change Natural disruptions, such as forest fires, floods, volcanic eruptions, and disease, can cause massive amounts of damage to an ecosystem. These sudden changes may make it difficult for organisms to adapt. Some disruptions, like mountain formation, may not happen suddenly but over many years. In some cases, these changes have benefits. Sometimes disturbances control the size of populations or allow new growth of plant life.

COLLECT EVIDENCE

How do natural changes in ecosystems affect their populations, such as a population of trees in a forest? Record your evidence (B) in your Science Notebook.

INVESTIGATION

Natural Disruption

Look at the image and describe what is happening. Write your description in your Science Notebook. How might it affect the population of deer in the forest?

How does human activity cause disruptions in ecosystems?

Human activity can have a big impact on ecosystems. Even small changes may have big impacts that affect populations living in the ecosystem. Take a look at how humans create disruptions in an environment.

Resource Extraction Any activity that takes resources from nature is known as resource extraction. Resources such as water help people survive, while resources such as oil help the economy. However, in many instances the extraction of these materials causes problems. For example, habitat loss from deforestation can disrupt forest ecosystems. Drilling for oil can also have negative consequences, as oil spills can devastate aquatic environments.

Pollution When contaminants, also known as pollutants, are brought into an environment they cause negative change. Through human activity, contaminants are expelled into the environment. For example, water pollution occurs when drainage from houses and automobiles finds its way into natural water systems. Air pollution occurs when cars and factories give off harmful gases, such as carbon monoxide from burning fuel.

Nonnative Species When a species lives outside of its natural range, it is considered a nonnative species. Many times these species are introduced through human intervention. Competition and overcrowding can force species out of their natural habitats or cause them to die out. For example, brown tree snakes have become a nuisance on the island of Guam after being accidentally introduced. The snakes have caused populations of native forest vertebrates and birds to decline.

Human Impact As you observed, disruptions in the environment can happen from human activity as well as natural occurrences. Think about the ways these disruptions can impact your local ecosystem.

COLLECT EVIDENCE

How do human disruptions, such as the destruction of a forest, affect populations? Record your evidence (C) in your Science Notebook.

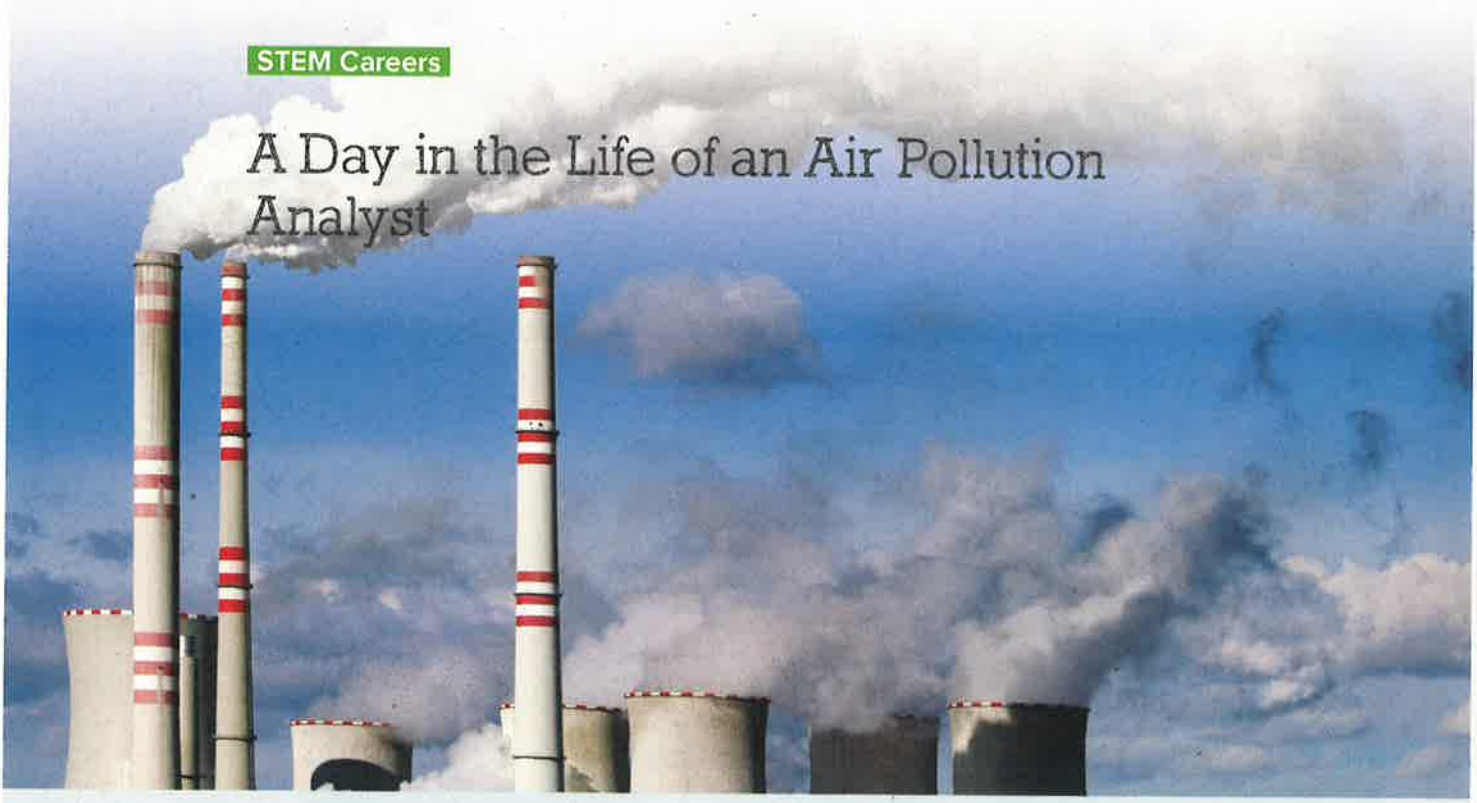
INVESTIGATION

Unnatural Disruptions

WRITING Connection Imagine that a local business is threatening to dispose of its waste in the local water supply to save money. In your Science Notebook, construct a written argument that you will present to your city council as to why the company's waste solution would negatively impact the local ecosystem. Be sure to include evidence that changes to one system may cause problems in others.

STEM Careers

A Day in the Life of an Air Pollution Analyst



ENVIRONMENTAL Connection Humans and animals alike require clean air to stay healthy. When harmful gases are released into the air, they can have negative health impacts. Air pollution analysts measure and analyze data from air that has been affected by pollutants.

Air pollution analysts collect samples from the field which may expose the analysts to hazardous weather conditions or toxic areas. They work with private companies and the government to assess the potential impact developments or activities may have on the environment. Analysts may also assess violations to environmental regulations and determine how to fix the problems the violations might cause.

Air pollution analysts spend a lot of time outdoors and in the laboratory, but they also may be employed to assess indoor environments to determine the quality of air in businesses and homes. This is important for the health of those who work in buildings where air quality is a concern.

It's Your Turn

Evaluate The text argues that indoor air quality is important for a person's health. Imagine that you are an air pollution analyst who is researching this claim. Using the scientific method, obtain and evaluate evidence to use in a blogpost which will detail your findings.

Summarize It!

1. **Write** a paragraph in your Science Notebook explaining the succession process that might occur in a small pond on a cow pasture. The pasture and pond are located on lush farmland with small hills. Explain how the placement of the pond near cattle and on farm land might affect local populations of fish, frogs, and aquatic insects in the pond. Include a main idea, supporting details, and a concluding sentence.

REVISIT PAGE KEELEY SCIENCE PROBES

Do you still agree with the prediction you chose at the beginning of the lesson? Return to the Science Probe at the beginning of the lesson. Explain why you agree or disagree with that prediction now.

EXPLAIN THE PHENOMENON

Revisit your claim about how changes in ecosystems affect populations. Review the evidence you collected. Explain how your evidence supports your claim.

Three-Dimensional Thinking

After a devastating forest fire, small green sprouts begin to appear on the forest floor.

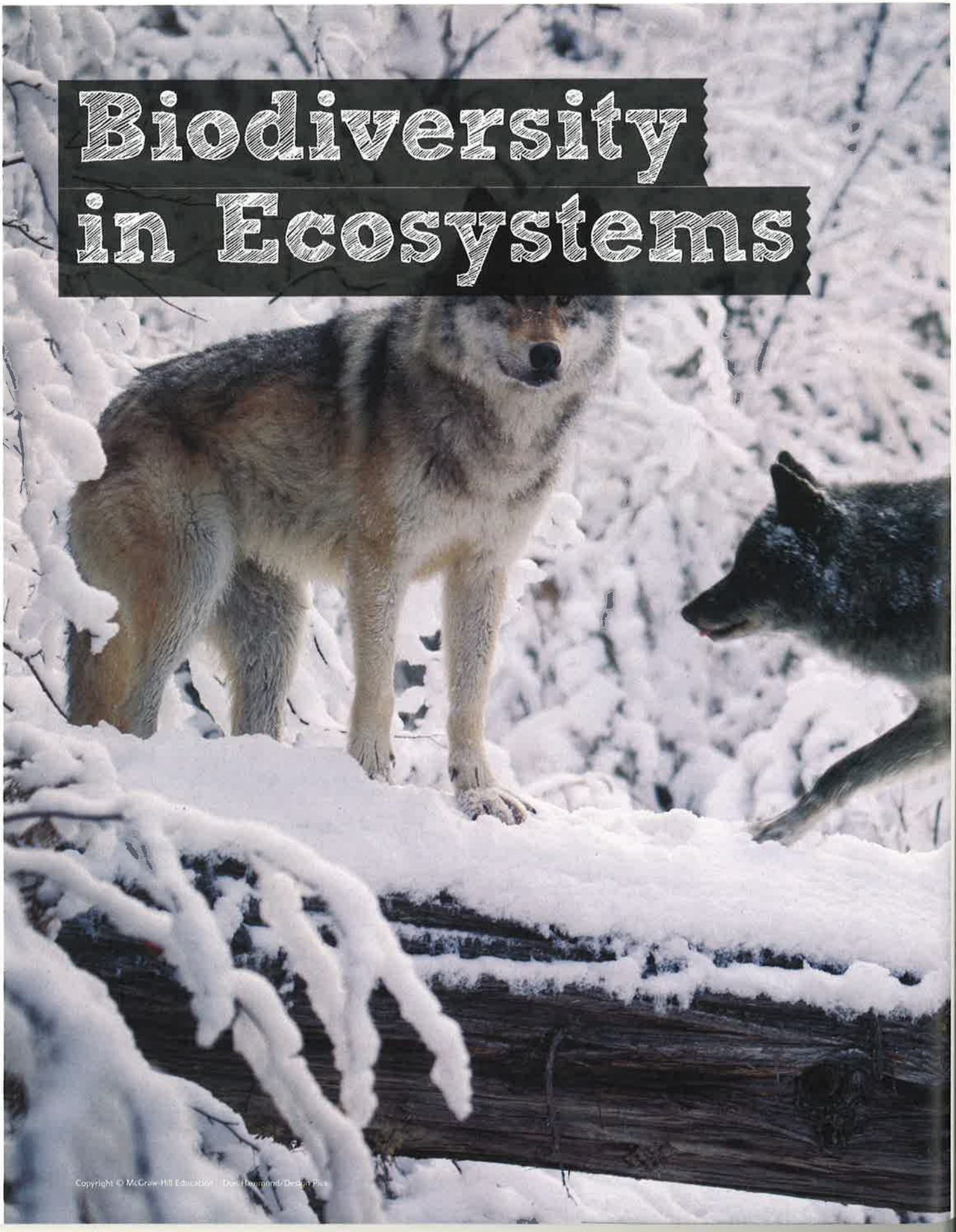
2. What is happening in the image?
   - **A** The forest is undergoing primary succession.
   - **B** The forest is undergoing secondary succession.
   - **C** The green sprouts will not grow into full plants and the forest will not recover.
   - **D** The forest is suffering from eutrophication.

3. How might a lake suffering from eutrophication affect a population of fish?
   - **A** The population will grow because of the extra nutrients.
   - **B** The population will suffer due to decreases in oxygen and habitat loss.
   - **C** The fish population will not be affected.
   - **D** The size of the population will waver.

Real-World Connection

4. **Argue** A city council member wants to implement a policy that will allow farmers to dump nitrogen-containing fertilizers in the local water systems. Construct an argument against this policy, focusing on the effect it would have on local aquatic species.

5. **Describe** Imagine a forest near you that has a high level of biological diversity. A flash flood has swept through the forest. Describe how such a disruption would change the populations within the forest.



Biodiversity in Ecosystems

ENCOUNTER
THE PHENOMENON

What can be done to protect the endangered gray wolf and its ecosystem in Yosemite National Park?

GO ONLINE
Check out *Return of the Wolves* to see this phenomenon in action.

Communicate Think about how the reemergence of the gray wolf impacts the ecosystem. Record your ideas for why you think this is important, and what can be done to protect the gray wolf in your Science Notebook. Discuss your ideas with three different partners. Revise or update your ideas, if necessary, after the discussions with your classmates.

STEM Project

The concepts you learn throughout this module will help you plan and complete the STEM Project. Go online to read more about the project and launch the science challenge!

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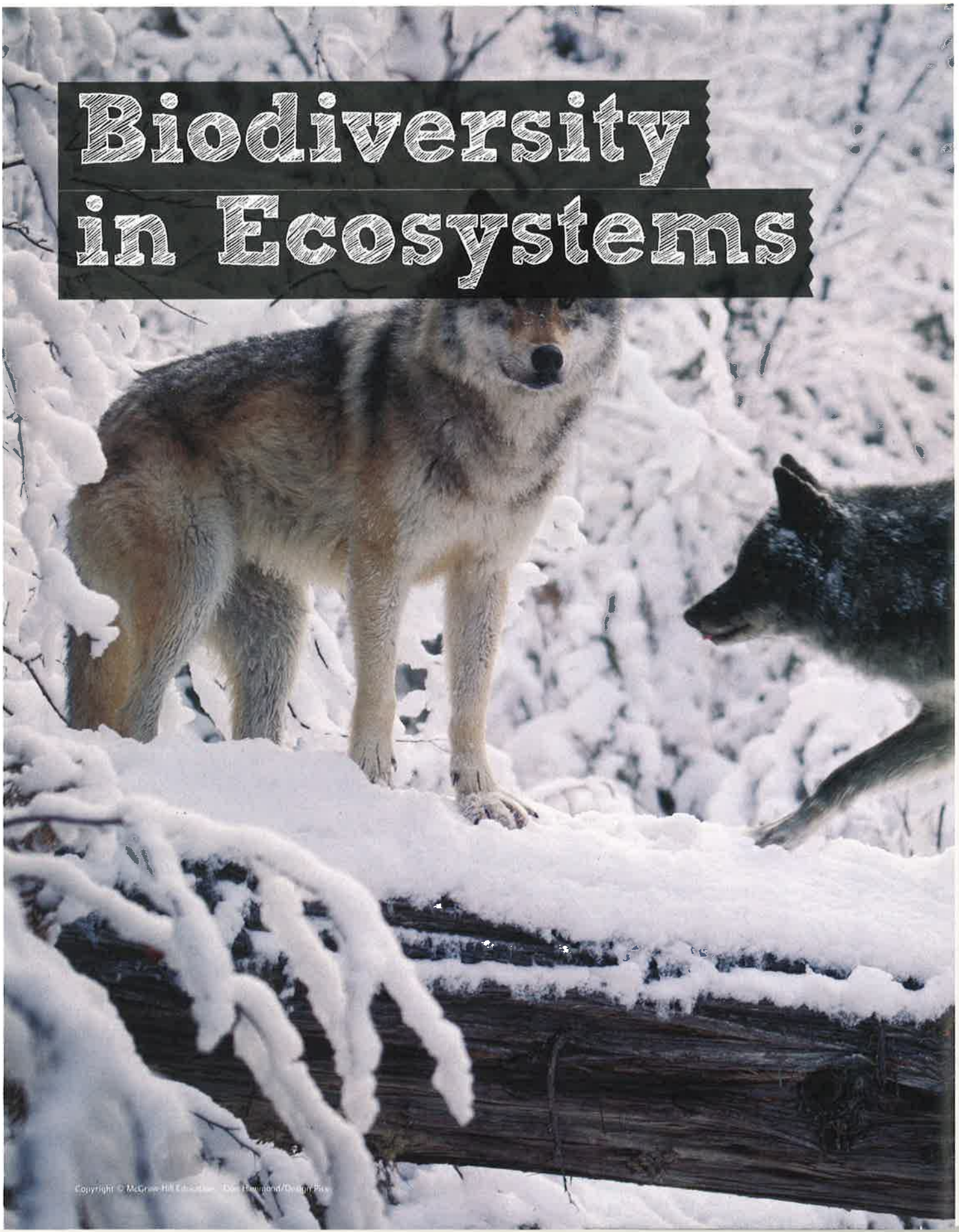
Biodiversity in Ecosystems



ENCOUNTER
THE PHENOMENON

What can be done to protect the endangered gray wolf and its ecosystem in Yosemite National Park?

GO ONLINE
Check out *Return of the Wolves* to see this phenomenon in action.

Communicate Think about how the reemergence of the gray wolf impacts the ecosystem. Record your ideas for why you think this is important, and what can be done to protect the gray wolf in your Science Notebook. Discuss your ideas with three different partners. Revise or update your ideas, if necessary, after the discussions with your classmates.

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STEM Project
Engineering Challenge

Good "greef"! The corals are dying!

Scientists are sometimes asked to use their knowledge to design a solution to a problem, such as protecting the endangered gray wolf in California. You are doing a summer internship in the Yucatan Peninsula in Mexico. You will study the Mesoamerican Reef, the second largest reef system in the world. Some of the coral reefs there, like others around the world, are dying for various reasons.

Your science professors have asked you to design an artificial reef to help maintain biodiversity and ecosystem services in the area. You will make a prototype of your design and evaluate other competing designs. As a final project, you will present your design to the science professors.

After You Read *Benefits of Biodiversity*

In your Science Notebook, define biodiversity and explain how this definition can be applied in your project planning.

Explain how coral reefs are important for biodiversity on Earth. This is information you could use to justify the cost of your artificial reef project.

How could an artificial reef design help to maintain biodiversity?

What other benefits, or ecosystem services, do humans receive from coral reefs? How will your artificial reef provide these ecosystem services?

After You Read *Maintaining Biodiversity*

Answer the following questions in your Science Notebook.

What are some factors that threaten the stability of biodiversity of coral reef ecosystems?

How do ecosystem services affect the stability of coral reef ecosystems?

How will your artificial reef design help maintain biodiversity and ecosystem services despite these threats?

STEM Project
Engineering Challenge

Design Your Solution

Answer the following questions in your Science Notebook as you begin to design an artificial reef.

What materials will you use to construct your artificial reef? Can you recycle any materials to build your reef? Remember, the structure must be able to remain underwater indefinitely and it should not release chemicals that could harm living organisms. Also, organisms will need to be able to attach themselves to the reef. How will the texture of your materials accommodate this behavior?

How will you anchor your reef to the bottom so that it does not move? Keep in mind that your reef will need to be able to withstand waves and storms, including hurricanes.

What needs will be met by your reef design?

Do you need to consider the culture of the people living near the location of your reef? Do they make their living by fishing on a coral reef? Do they rely on the fish and other organisms living on coral reefs for food? Are tourism and/or ecotourism important to the region?

What societal issues and environmental impacts do you feel are most important to consider when designing your solution?

Look back at the planning you did after each lesson and the answers to the questions. Use that information to fill in the first steps of the design process in your Science Notebook by copying the steps below and explaining them as they relate to your project.

Define the Problem (Be sure to include information about why biodiversity and ecosystem services are necessary to maintaining a healthy ecosystem.):

Brainstorm Possible Solutions:

Safety Considerations:

Agree Upon the Best Solution:

Identify Materials, Criteria, and Constraints (including time, materials, and costs):

Using the information you provided on this page and the previous page, construct your prototype.

STEM Project Engineering Challenge

Test

What kinds of tests will you perform to determine whether or not your design will be sturdy and able to withstand waves and storms? How will you collect data on these tests?

Conduct your tests. Record your data and observations in your Science Notebook.

Evaluate

In your Science Notebook, describe the competing design solutions for maintaining biodiversity and ecosystem services. Analyze the data you collected to evaluate the different design solutions.

Keeping in mind that one solution may not perform best across all tests, identify and describe the design that best met the criteria for success. Justify your selection.

Were there strengths of other designs that could be incorporated into the final solution to improve its performance? Were there weaknesses that should be avoided?

Keep in mind that a small change to one part of an ecosystem can cause a large change in another component of the ecosystem. With that in mind, assess possible side effects of the selected design solution on other aspects of the ecosystem. Describe one possible negative side effect.

Create Your Presentation

Prepare a presentation for your science professors. Be sure to include:

- background information on the importance of coral reefs to biodiversity and ecosystems services, and
- a description of your design solution and evidence about its performance.

What evidence of similarities and differences among the designs did you identify?

How did establishing criteria and constraints help you to better compare different design solutions?

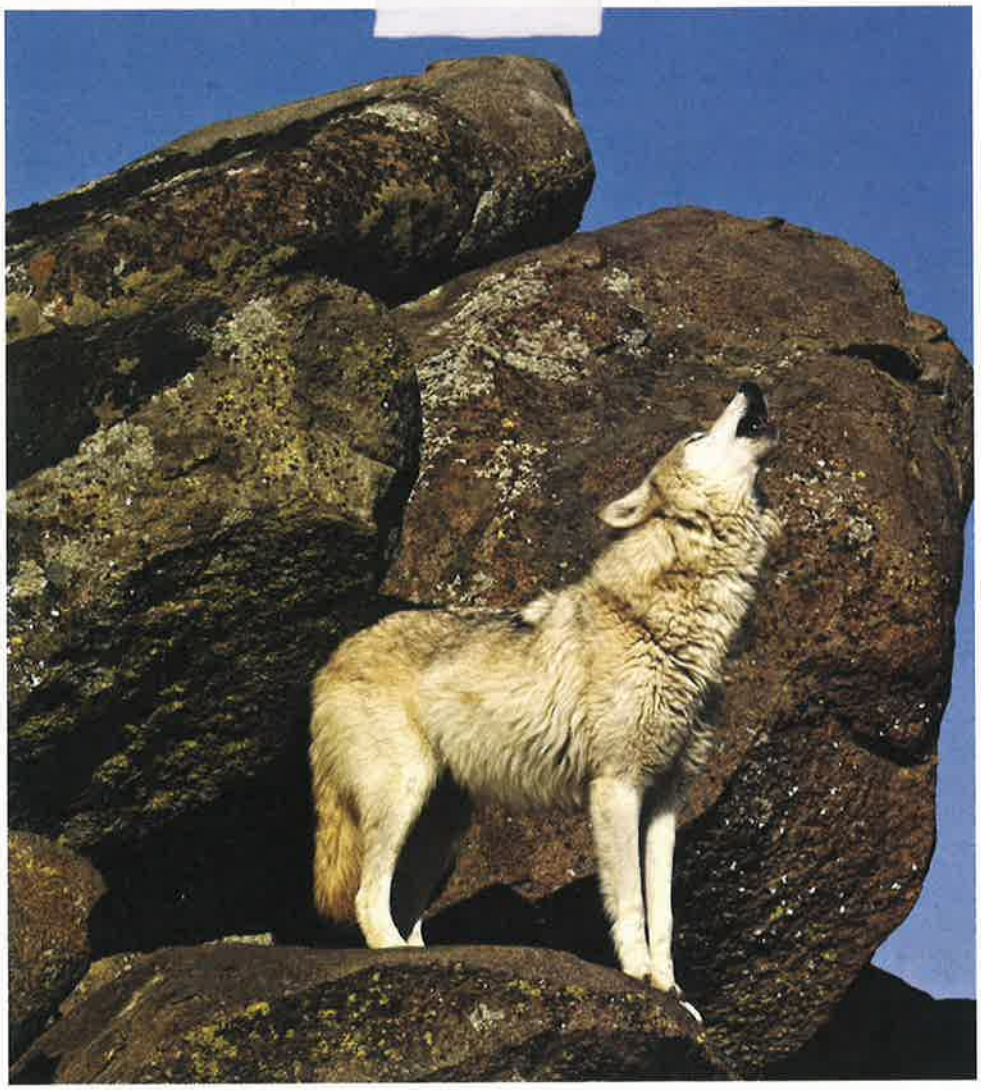
How does your research into biodiversity and ecosystem services provided by coral reef ecosystems help you understand the importance of wolves returning to California in 2011?

Share your presentation with the class.

Wrap-Up

REVISIT THE PHENOMENON

Using the concepts you have learned throughout this module, explain what can be done to protect ecosystems and the species living in them, such as the endangered gray wolf in California.



OPEN INQUIRY

If you had to ask one question about what you studied, what would it be?

Plan and conduct an investigation to answer this question.

LESSON

Benefits of Biodiversity

SCIENCE PROBES

So many beetles!

Three friends learned in their science class that there are more than 350,000 known types of beetles in the world. After class, they shared the different ideas that they had about this fact. Here is what they said:

Jenny: There are so many species of beetles that it doesn't matter if some of them go extinct.

Sweta: There are so many species of beetles that if one species goes extinct, another one can just take its place.

Jahrie: It is important that so many species of beetles exist because more species means healthier ecosystems, and each species has a certain role in the ecosystem.

Which friend do you agree with most? Explain why you agree with that friend. You will revisit your response to the Science Probe at the end of the lesson.

ENCOUNTER
THE PHENOMENON

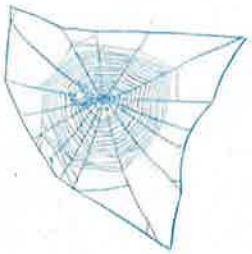
Why is it important that so many species exist in the rain forests of Madagascar?

There are millions of amazing animals that exist on our planet. Each type of animal is adapted to live in its unique environment. For example, the giraffe weevil shown here is a beetle native to Madagascar. It uses its long neck to build nests and to fight other giraffe weevils. Why is it important that so many animals exist, and why do scientists spend so much time trying to discover them? Brainstorm with a partner and summarize your ideas in your Science Notebook.

EXPLAIN
THE PHENOMENON

Did you see how each of the species in the video was unique to its environment, and how the scientists searched to find new species? Use your observations about the phenomenon to make a claim about why it is important that so many species exist in an ecosystem, such as the rain forests of Madagascar. Use the outline below to guide your thinking.

Claim



It is important that so many species exist in an ecosystem, such as the rain forests of Madagascar, because...

Evidence

A. What evidence have you discovered to explain how scientists measure biodiversity in an ecosystem, such as the rain forests of Madagascar?

B. What evidence have you discovered to explain why biodiversity is important in ecosystems, such as the rain forests of Madagascar?

C. What evidence have you discovered to explain how biodiversity differs in different ecosystems?

D. What evidence have you discovered to explain how humans benefit from biodiversity in ecosystems, such as the rain forests of Madagascar?

Revise Claim

It is important that so many species exist in an ecosystem, such as the rain forests of Madagascar, because...

Reasoning

The evidence I collected supports my claim because...

GO ONLINE
Watch the video *Animal Life in Madagascar* to see this phenomenon in action.

What is biodiversity?

You learned from watching the video that the rain forests of Madagascar are some of the most biodiverse places on Earth. They are home to thousands of species of plants and animals. What exactly is biodiversity?

INVESTIGATION

Discovering Biodiversity

Examine the photos below showing low biodiversity and high biodiversity. Then answer the questions that follow in your Science Notebook.

Low Biodiversity

High Biodiversity

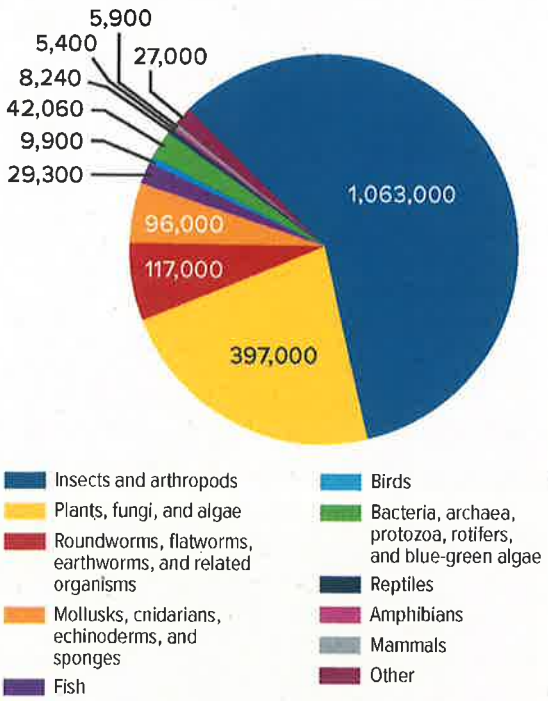
1. What do you notice about the organisms in each of the photos?
2. After examining the photos, what do you think biodiversity is?

Want more information?
Go online to read more about the benefits of biodiversity.

FOLDABLES
Go to the Foldables® library to make a Foldable® that will help you take notes while reading this lesson.

Biodiversity The number and variety of organisms found in a specific region, such as a small pond, a grassy field, a desert, or all of Earth is known as **biodiversity.** The coral reef in the photo on the previous page has high biodiversity because it has many organisms and many different types of organisms. What is the biodiversity of Earth? To date, scientists have identified about 2 million species. A **species** is a group of organisms that have similar traits and are able to produce fertile offspring. A recent estimate of the total number of species on Earth, both known and yet-to-be discovered, is approximately 9 million species. Observe how many of each type of known species exist in the graph to the right.

Number of Known Species by Taxonomic Group



Types of Biodiversity The variety of genes or inherited traits that are present in a population make up its **genetic diversity.** You can look at your friends and observe all of their different traits, such as eye color, hair texture, and height, to see the genetic variation that exists among humans. The difference in color and patterns on the snails to the right is another example of genetic diversity.

Look at the differences!

Diversity exists within species as well as within an ecological community as a whole. The number of different species and the quantity of each species in an ecological community is called **species diversity.**

Diversity also exists among ecosystems. The variety of ecosystems in the biosphere is called **ecosystem diversity.** Different ecosystems have different abiotic factors that support different types of life.

THREE-DIMENSIONAL THINKING

What type of biodiversity did you observe in the photo labeled *High Biodiversity* in the *Discovering Biodiversity* investigation on the previous page? **Construct an explanation** to support your answer and write it in your Science Notebook.

How do scientists measure biodiversity?

How do scientists determine the biodiversity in a given area? The first step is to collect data on the numbers and types of organisms that live there. The method and technology used depends on the types of organisms being counted and the habitat. For example, a scientist may not be able to use the same method or technology to collect data about insects in the rain forest as she would to collect data about the number of fish living around a coral reef.

Canopy Fogging Scientists use canopy fogging to collect data about the biodiversity of insects. It is often used in forests. A low dose of insecticide is sprayed up into the top of a tree or trees. The insecticide kills the insects, causing them to fall from the trees. When the insects fall, they are collected in a large screen, a large sheet, or several large funnels. To learn more about biodiversity, scientists study the insects, identify them, and count them.

INVESTIGATION

Collect That Data

Explore some of the different ways that people collect data on the biodiversity of an area.

GO ONLINE Watch the videos *Grey-Faced Sengi* and *Counting Species in California.*

Record your observations in your Science Notebook about the different ways people collect data on biodiversity. What different methods and technologies did they use?

Transect Sampling Scientists use a transect line to complete transect sampling. A transect line can be a rope, string, or measuring tape that is marked at set intervals, such as every meter or every 2 meters. The transect line is placed in or on the habitat surface and, at every interval, the number of species and individuals are recorded. Transect lines can be used in both terrestrial and aquatic habitats, such as the one in the photo to the right.

Mist Netting Fine mesh nets, called mist nets, are used to humanely capture animals in ecosystems. In terrestrial ecosystems, netting is often used to collect data on the biodiversity of bats and birds, as in the photo to the right. A large net is stretched across an area, and when a bat or bird flies into the net, it is removed and examined by scientists. In aquatic ecosystems, fish, shellfish, and other organisms may be captured. After organisms are captured, they are identified, counted, and often tagged and released.

Aerial Photos Photos of the ground taken from above, usually from an airplane, are called aerial photos. Aerial photos can be used to count and track species of whales and herds of migrating animals on land, such as moose and caribou. Aerial photos can also be used to assess the biodiversity of trees in temperate forests, but a limitation of the photos is that you can't see the forest floor. The photo to the right is an aerial photo showing walrus cows resting on sea ice.

Surveys An effective way for scientists to learn more about the biodiversity of certain groups of organisms, particularly birds, is by surveying. By analyzing data collected by expert bird watchers, field technicians, and scientists, a big picture of the biodiversity of bird species in an area can be seen. Surveys are usually conducted by people going through a habitat on foot or in a boat and, in the case of birds, using binoculars and a spotting scope to identify and count the number of birds in each species.

Quadrat Sampling A quadrat is a known square area that is marked using a pre-made square of plastic or stakes and string. Quadrats can range in size from 1 m^2 to 20 m^2 and can be used in both aquatic and terrestrial ecosystems. The size of the quadrat used depends on the type of habitat and organisms surveyed. Scientists set down the quadrat and count the number of species and the number of individuals of each species. This is repeated many times throughout the habitat so that the most accurate calculation of biodiversity can be made.

The Biodiversity Index After completing surveys, transect samples, or looking at aerial photos, how do scientists use the data they have collected to quantify the biodiversity of an area?

Interpreting a Biodiversity Index The biodiversity index ranges from 0 to 1. The closer to 0 the index is, the lower the biodiversity of an area. The closer to 1 the index is, the higher the biodiversity of an area.

The biodiversity index takes into account both the number of species and the total number of individuals. This is important because an area may have a large number of individuals, such as a cornfield (1,000 corn plants), but a low number of species (1). This would mean that the biodiversity index for this area would be very low (0.001). On the other hand, an area that has a greater number of species, say 5, but fewer individuals of each species, say 3 individuals of each species (15 total individuals), will have a higher biodiversity (0.3).

COLLECT EVIDENCE

How do people measure biodiversity in ecosystems, such as in the rain forests of Madagascar? Record your evidence (A) in your Science Notebook.

INVESTIGATION

Calculating Biodiversity

Scientists often use a simple formula called the biodiversity index to calculate the biodiversity of an area.

$$\text{Biodiversity Index} = \frac{\text{Number of species in an area}}{\text{Total number of individuals in the same area}}$$

Suppose scientists have the following data about a 20 m^2 area of a prairie that was surveyed using quadrats. Copy the table into your Science Notebook.

Number of Species	Number of Individuals of Each Species	Total Number of Individuals	Biodiversity Index
6	Species A = 4 Species B = 30 Species C = 1 Species D = 3 Species E = 1 Species F = 2		

1. **MATH Connection** To find the biodiversity index, first find the total number of individuals by adding up the number of individuals of each species.

   Total Number of Individuals = Species A + Species B + Species C + Species D + Species E + Species F

   Record your answer for the total number of individuals in your table.

2. Then calculate the biodiversity index by dividing the number of species by the total number of individuals.

   $$\text{Biodiversity Index} = \frac{\text{\# of species}}{\text{\# of individuals}}$$

LAB Bead Biodiversity

Safety

Materials

bottles filled with beads (1 per habitat type)

Procedure

1. Read and complete a lab safety form.
2. Your teacher will give your group a bottle full of beads that is labeled with a habitat name. The beads represent the animals that live in a 1 square meter area of that habitat. The different colors of beads represent different species of animals.
3. In your Science Notebook, create a table like the one below. Remove the beads from the bottle and record the data in the table.

Habitat Type	Number of Species	Number of Individuals of Each Species	Total Number of Individuals	Biodiversity Index
Tropical Rain Forest				
Coniferous Forest				
Deciduous Forest				
Desert				
Grassland				

4. **MATH Connection** Once all the beads are counted, calculate the biodiversity index for the habitat and record it in your table.
5. Rotate bottles with other groups and repeat steps 3 and 4 until your table is complete.
6. Follow your teacher's instructions for proper cleanup.

Analyze and Conclude

7. How could scientists use your data to make decisions?
8. Imagine that an area studied has 5 plants, but they are 5 different species. The biodiversity index would be 1. Does this area truly have such a high biodiversity index? Explain your reasoning.

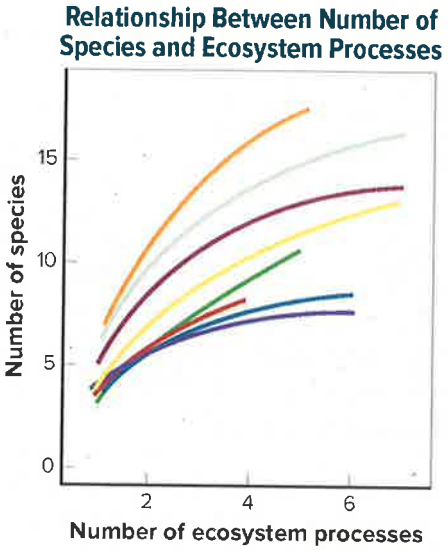
Why is biodiversity important?

You learned about the different ways that scientists collect data on biodiversity and how they calculate biodiversity. Why do they spend so much time and energy on this? Why is it important that so many species exist, and why is it important to monitor biodiversity? Explore below to find out.

INVESTIGATION

The More the Merrier

Study the graph which shows the relationship between the number of species and the number of processes carried out by eight ecosystems. Each color represents a different ecosystem. Examples of ecosystem processes include plant production, recycling nutrients, storing carbon, and water cycling. Use your analysis to answer the questions below in your Science Notebook.



1. What pattern do you observe between the number of ecosystem processes and the number of species in each ecosystem?
2. Why do you think having a higher number of species in an ecosystem would be beneficial to the organisms in the ecosystem?

Number of Species and Ecosystem Health The higher the biodiversity in an ecosystem, the healthier it is considered to be. Although there are several models that relate the impact that biodiversity has on the health of an ecosystem, scientists agree that decreasing biodiversity does lead to reduced ecosystem health and function. In order to determine a more exact relationship between biodiversity and ecosystem health, scientists carry out experiments. Examine the data from two experiments in the activity on the next page.

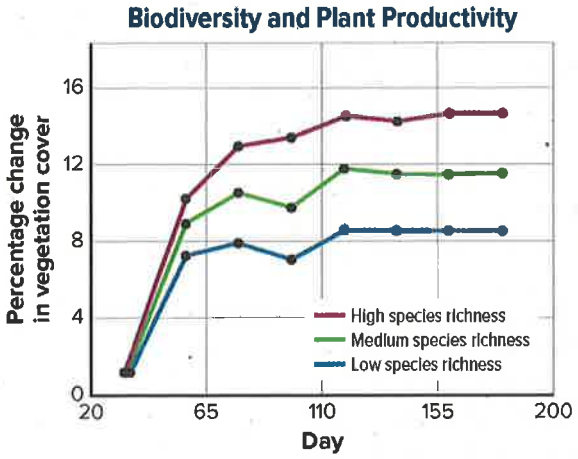
INVESTIGATION

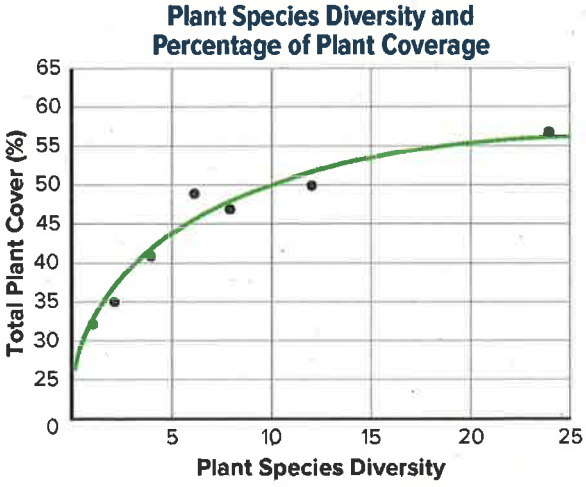
Plant Productivity

In one experiment, terrestrial ecosystems were modeled in separate chambers. All variables were held constant except for the amount of biodiversity in the chambers. Biodiversity was categorized as high, medium, or low. Plant productivity was measured by how much the plants grew and spread to cover the ground compared to the initial conditions. The data collected from the experiment are shown in the top graph.

In a similar experiment, researchers studied the impact of biodiversity on productivity in an ecosystem by growing plants on plots of land. Each plot had a specific number of native plant species, ranging from 1 to 24. Plant productivity was measured by the amount of ground covered by the plants. The results of the experiment are shown in the bottom graph.

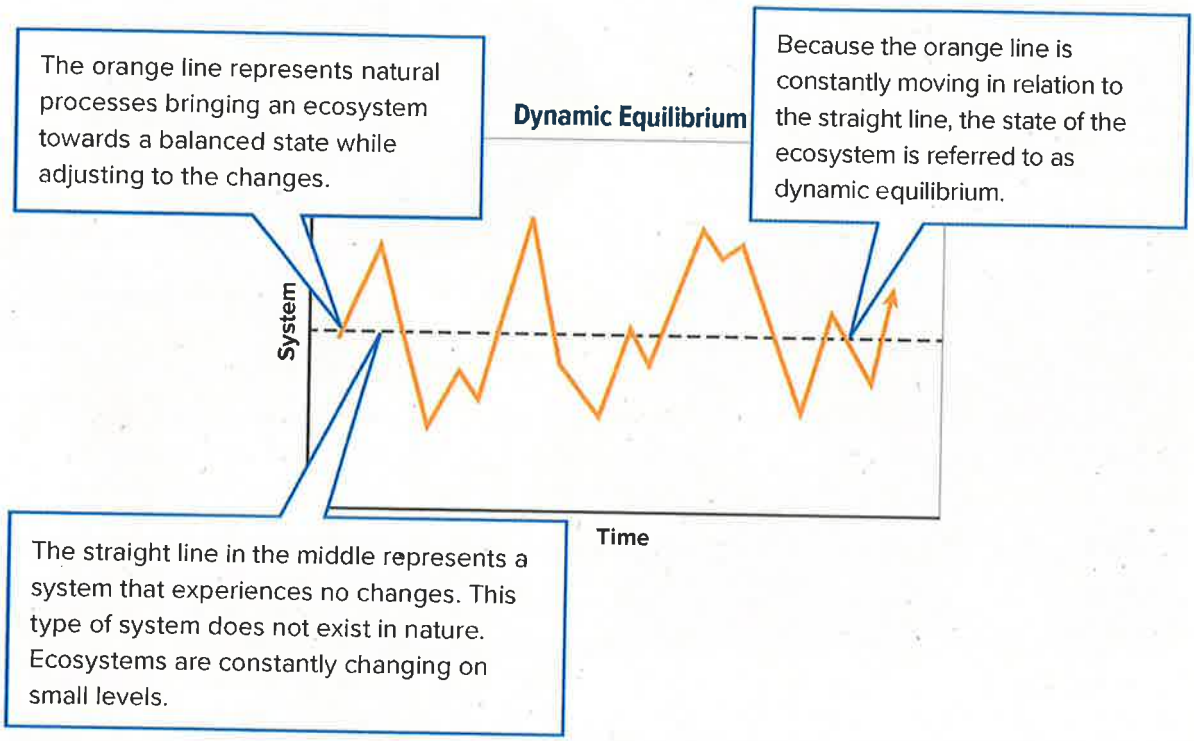
1. Analyze and interpret the data from both experiments shown in the graphs. What patterns do you notice? Write your answer in your Science Notebook.
2. How do these experiments compare to what you have read about biodiversity so far in this lesson? Write your answer in your Science Notebook.





Ecosystem Changes Even small changes in an ecosystem can lead to bigger changes in another part. When there are more species in an ecosystem, the ecosystem is better able to respond to changes or disruptions, such as an outbreak of disease. Abiotic and biotic factors both within and outside of an ecosystem are constantly changing. However, when an ecosystem is in a stable, or balanced, state, it can process these changes and remain stable.

A stable ecosystem is often described as being in a state of **dynamic equilibrium.** This means that, although the ecosystem may experience changes, or disturbances, natural processes will bring the ecosystem back into balance. Disturbances include storms, fire, floods, droughts, and human activities. Depending on the disturbance, there may be an increase or decrease in the amount of nutrients or food available, the amount of plant production, or the number of species. Dynamic equilibrium can be represented graphically.



Resilience is the ability of an ecosystem to maintain dynamic equilibrium even with significant outside disturbances. Sometimes even the most stable, resilient ecosystem cannot recover from a severe disturbance resulting in a change to the type of ecosystem. For example, in some parts of Africa, people have allowed their cattle and goats to overgraze on the savanna grasses. If all of the grasses are consumed and there are no grass roots to hold soil in place, the ecosystem will change from a savanna to a desert.

THREE-DIMENSIONAL THINKING

How does biodiversity relate to **stability and change** in an ecosystem? Summarize your ideas in your Science Notebook.

COLLECT EVIDENCE

Why is biodiversity important for ecosystems, such as the rain forests of Madagascar? Record your evidence (B) in your Science Notebook.

Temperate deciduous forests grow in temperate regions where winter and summer temperatures have more variation than those in temperate rain forests.

- These forests are the most common forest ecosystems in the United States.
- They contain mostly deciduous trees, which lose their leaves in the fall.

Taiga A **taiga** (TI guh) is a forest biome consisting mostly of cone-bearing evergreen trees.

- A taiga is also known as a boreal forest and exists only in the northern hemisphere.
- Due to colder temperatures fewer reptiles and amphibians can survive, and there are fewer species of mammals and birds.

Tundra A tundra biome is cold, dry, and treeless.

- Most tundra is just south of the North Pole.
- In the tundra, frozen ground makes it difficult for deep-rooted plants to grow.
- The tundra does feature a diverse range of mammalian life; however, reptiles and amphibians are rare.

Aquatic Ecosystems There are four major types of water, or aquatic, ecosystems on Earth: freshwater, wetlands, estuaries, and oceans. Freshwater ecosystems consist of streams, rivers, ponds, and lakes. **Wetlands** are aquatic ecosystems that have a thin layer of water covering soil that is wet most of the time. Wetlands contain freshwater, salt water, or both. **Estuaries,** such as the one in the photo to the right, are regions along coastlines where streams or rivers flow into a body of salt water. Most estuaries form along coastlines, where freshwater in rivers meets salt water in oceans.

An estuary has formed where the Klamath River meets the Pacific Ocean.

Important abiotic factors in aquatic ecosystems include temperature, sunlight, and dissolved oxygen gas. Aquatic species have adaptations that enable them to use the oxygen in water. For example, the gills of a fish separate oxygen from water and move it into the fish's bloodstream.

Each type of ecosystem contains a unique variety of organisms. Whales, dolphins, and corals live only in ocean ecosystems. Certain species of catfish and trout live only in freshwater ecosystems. Other organisms that do not live under water also depend on aquatic ecosystems for food and shelter.

This park is home to McWay Cove.

GO ONLINE for additional opportunities to explore!

Investigate aquatic ecosystems further by performing one of the following activities.

Model the flow of water into an estuary in the **Lab** *What happens when rivers and oceans mix?*

OR

Demonstrate differences in the response of three kinds of ocean ecosystems to surface wave action in the **Lab** *How do ocean ecosystems differ?*

Streams and Rivers Streams are usually narrow, shallow, and fast-flowing. Rivers are larger, deeper, and flow more slowly.

- Stream water is often clear. Soil that washes into a river from streams or nearby land can make river water muddy.
- Willows, cottonwoods, and other water-loving plants grow along streams and on riverbanks. Species adapted to fast-moving water include trout, salmon, crayfish, and many insects. Species adapted to slow-moving water include snails and catfish.

Ponds and Lakes Freshwater that is not flowing downhill makes up ponds and lakes.

- These bodies of water form in low areas on land.
- Ponds are shallow and smaller than lakes. Lakes are deeper and larger.
- Surface water in ponds and lakes contains plants, algae, and microscopic organisms that use sunlight for photosynthesis.
- Ponds and lakes offer habitats to a wide range of species including fish, reeds, and turtles.

Wetlands Some of Earth's most fertile ecosystems are wetlands. Freshwater wetlands form at the edges of lakes and ponds and in low areas on land, and saltwater wetlands form along ocean coasts.

- Nutrient levels and biodiversity are high.
- Water-tolerant plants, such as grasses and cattails, thrive in wetlands. Few trees live in saltwater wetlands. Trees in freshwater wetlands include cottonwoods, willows, and swamp oaks.
- Insects are abundant and include flies, mosquitoes, dragonflies, and butterflies.

Estuaries Nutrient levels and biodiversity are high in estuaries.

- Plants that grow in estuaries include mangroves, pickleweeds, and seagrasses.
- Animals include worms, snails, and many species that people use for food, including oysters, shrimp, crabs, and clams.
- Many species of birds depend on estuaries for breeding, nesting, and feeding.

Open Oceans The open ocean extends from the steep edges of continental shelves to the deepest parts of the ocean.

- Microscopic algae and other producers form the base of most ocean food chains. Other species include jellyfish, tuna, mackerel, dolphins, sea cucumbers, and brittle stars.

Intertidal Zones The intertidal zone is the ocean shore between the lowest low tide and the highest high tide.

- As the tide rises each day, the rocks and beach are covered by water. When the tide falls, the rocks and beach are left uncovered and exposed to the air.
- Intertidal zones provide habitat for many organisms and nursery areas for many fish and crustacean species.

Coral Reefs A **coral reef** is an ocean ecosystem that consists of an underwater structure made from outside skeletons of tiny, soft-bodied animals called coral.

- Most coral reefs form in shallow tropical oceans.
- Parrotfish, groupers, angelfish, eels, shrimp, crabs, scallops, clams, fireworms, snails, grasses, and algae are some of the many organisms that live in coral reef ecosystems.

COLLECT EVIDENCE

How does biodiversity in tropical rain forest ecosystems, such as those in the rain forests of Madagascar, differ from biodiversity in other ecosystems? Record your evidence (C) in your Science Notebook.

How do humans benefit from biodiversity?

The benefits that humans receive from biodiversity and healthy ecosystems are extremely valuable. Changes to biodiversity can influence the benefits we receive from an ecosystem. Some studies have helped show the importance of these benefits by translating them into dollar values, which total thousands of trillions of dollars. What kinds of benefits do we receive from ecosystems that are healthy due to biodiversity?

INVESTIGATION

Benefits of Healthy Ecosystems

ENVIRONMENTAL Connection Observe the ecosystem in the image to the right. With a partner, brainstorm the benefits that humans receive from that ecosystem in your Science Notebook.

Ecosystem Services The benefits experienced by organisms, including humans, which are provided by healthy ecosystems are called **ecosystem services.** There are four main types of ecosystem services—supporting services, provisioning services, regulating services, and cultural services. Learn about each type of ecosystem service by completing the activity on the next page.

Types of Ecosystem Services As you have discovered, biodiversity leads to healthy ecosystems, which provide humans with a variety of different benefits. **Supporting services** are ecosystem services that allow for the existence of all other ecosystem services. These include primary production, water cycling, and nutrient cycling.

Ecosystem services that provide products from an ecosystem are called **provisioning services.** Provisioning services provide us with food, medicine, natural resources, including those used to produce energy, and water.

The benefits that are received through the regulation of ecosystem processes are defined as **regulating services.** These include pollination, water purification, protection from natural disasters, erosion control, and climate regulation.

Cultural services are the benefits that people obtain through their experiences with the ecosystem. They differ from other ecosystem services in that the benefits are nonmaterial, offering value that stems from recreational activities and the artistic appearance of the environment.

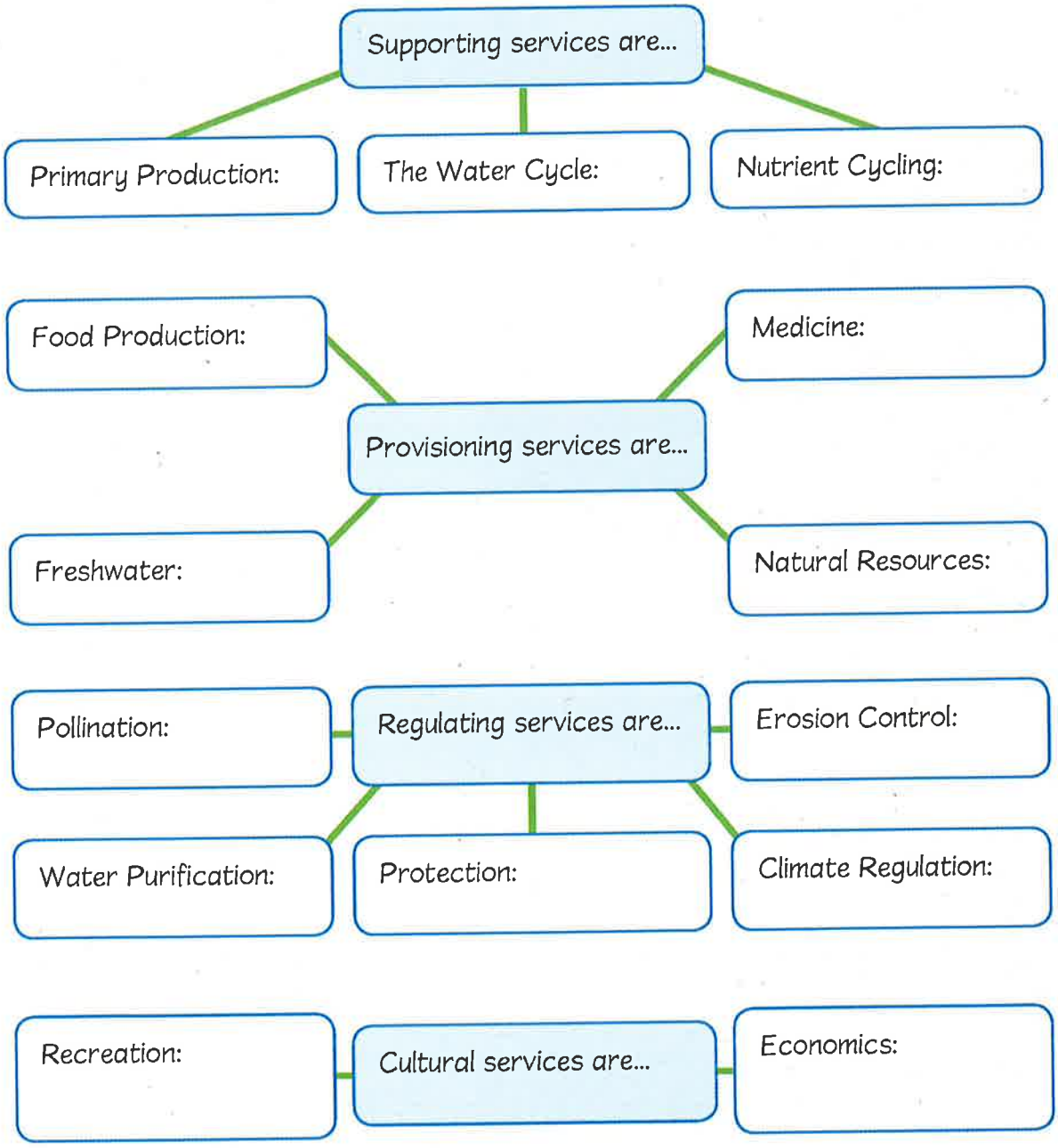
COLLECT EVIDENCE

How do humans benefit from biodiversity in ecosystems, such as the rain forests of Madagascar? Record your evidence (D) in your Science Notebook.

INVESTIGATION

Ecosystem Services

What is each type of ecosystem service, and what are some examples of each? With your group, research the type of ecosystem service assigned by your teacher, and create a graphic organizer for your assigned ecosystem in your Science Notebook. When you are finished, you will present your findings to the class. Be prepared to answer questions from your classmates. Create other graphic organizers as the other groups present their findings.



STEM Careers

A Day in the Life of a Wetland Conservationist

Wetland conservationists work to protect various wetland ecosystems, such as swamps, bogs, and marshes. Wetlands are important ecosystems because they provide valuable ecosystem services that are unique to wetlands.

On a typical day, a wetland conservationist could be working on a number of duties, such as taking samples of soil, tracking birds and aquatic wildlife, surveying, monitoring chemical composition of water, and writing reports. They try to determine the health of wetlands by looking at plant life, animal life, and water levels to monitor any changes.

Wetland conservationists spend much of their time outdoors, but also spend time writing papers and doing work on policy legislation. Wetland conservationists use technologies such as geographic monitoring systems and computer modeling programs in their work.

It's Your Turn

Research a wetland near where you live. What types of organisms live there? Using information from multiple sources, create a slide show presentation on your findings. Record any other questions that you have as you conduct your research.

LESSON
Review

Summarize It!

1. **Create** a flyer that will be used to educate people in your community about biodiversity and its importance. Use text and illustrations to convey your message. Use creativity to make sure your flyer catches and holds people's attention.

Biodiversity is Important

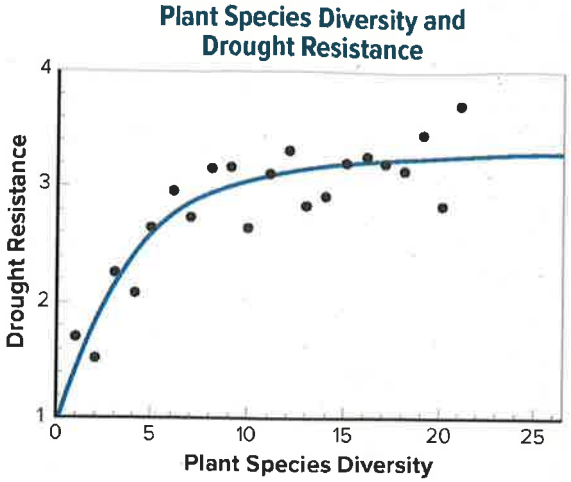
REVISIT SCIENCE PROBES Do you still agree with the friend you chose at the beginning of the lesson? Return to the Science Probe at the beginning of the lesson. Explain why you agree or disagree with that person now.

EXPLAIN THE PHENOMENON

Revisit your claim about why it is important that so many species exist in an ecosystem. Review the evidence you collected. Explain how your evidence supports your claim.

Three-Dimensional Thinking

The graph shows more data from the second experiment described in the Investigation *Plant Productivity.* During the course of the experiment, the region experienced an extended drought. The researchers tracked the relationship between plant species diversity and the ecosystem's resilience to the drought. Values closer to zero on the vertical axis imply less resilience to the drought.



2. What conclusion can be made by analyzing the data from the graph?

A As plant biodiversity increases, resistance to drought decreases.

B As plant biodiversity increases, resistance to drought increases.

C Ecosystems with lower biodiversity are better able to respond to changes.

D Ecosystems with higher biodiversity are less able to respond to changes.

3. What would happen to the biodiversity index of an ecosystem if a change in the ecosystem caused the number of species to stay the same and the total number of individuals to increase?

A The biodiversity index would increase.

B The biodiversity index would decrease.

C The biodiversity index would stay the same.

D The biodiversity index would increase, and then decrease.

Real-World Connection

4. **Argue** Imagine that you are attending a meeting regarding the funding of programs dedicated to protecting the biodiversity of organisms in your area. A group of policy makers wants to cut funding for these programs. Construct an argument supported by evidence for why funding for these programs should not be cut.

5. **Describe** ways that you and others could help collect data on the biodiversity of organisms in the area in which you live.

LESSON

Maintaining Biodiversity

SCIENCE PROBES

Chopping Trees

Three students were discussing a forest near their community that was being cut down so the wood could be sold. They had different ideas about the topic. Here is what they said:

Vicki: Cutting down the forest won't threaten biodiversity in the area because eventually the trees will grow back.

Dariana: Cutting down the forest destroys the habitat for many different organisms and threatens biodiversity.

Wei: Cutting down the forest won't threaten biodiversity in the area because the organisms that live there will just find another place to live.

Name the student you most agree with. Explain why you agree with that student. You will revisit your response to the Science Probe at the end of the lesson.

ENCOUNTER
THE PHENOMENON

What can be done to protect the biodiversity of this lake from invasive zebra mussels?

Brainstorm ways that the ecosystems can be protected from the threat of invasive species, such as the zebra mussels in the photo and the cane toads in the video. Record your ideas in your Science Notebook.

EXPLAIN
THE PHENOMENON

Did you see how the zebra mussels and cane toads were taking over their entire ecosystems? Use your observations about the phenomenon to make a claim about ways that biodiversity can be protected. Use the outline below to guide your thinking.

Claim

Biodiversity can be protected by...

Evidence

A. What evidence have you discovered to explain how biodiversity can be threatened, for example by invasive species, such as zebra mussels and cane toads?

B. What evidence have you discovered to explain solutions to maintaining and protecting biodiversity against threats, such as the invasive zebra mussel and cane toad?

Revise Claim

Biodiversity can be protected by...

Reasoning

The evidence I collected supports my claim because...

GO ONLINE
Watch the video *Too Many Toads* to see this phenomenon in action.

In what ways is biodiversity threatened?

There are five major threats to biodiversity: habitat destruction, invasive species, pollution, overexploitation, and climate change. Explore one of these threats in the lab below.

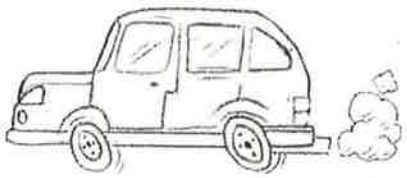
LAB Air Pollution

Small particles of harmful substances, or pollutants, can be transported by air movement. Once a pollutant is in the air, how far can it travel?

Safety

Materials

measuring tape stopwatch lab candle



Procedure

1. Read and complete a lab safety form.
2. Use a tape measure to determine the distance from your desk to the lab candle. Record your measurement in your Science Notebook.
3. As soon as your teacher blows out the candle, start a timer. Stop the timer when you smell the blown-out candle. Record the time.
4. Follow your teacher's instructions for proper cleanup.

Analyze and Conclude

5. To find the rate at which the smoke traveled, divide your distance from the lab candle by the time it took you to smell the blown-out candle. How fast did the smell move?
6. Compare your results with students in different parts of the room. Why do you think the speeds varied?
7. How do you think the movement of the smell from the blown-out candle is similar to the movement of a pollutant in the air?

Want more information?
Go online to read more about maintaining biodiversity.

FOLDABLES
Go to the Foldables® library to make a Foldable® that will help you take notes while reading this lesson.

Threats to Biodiversity You just explored how one type of pollution—air pollution—moves through an environment. **Pollution** is the contamination of the environment with substances that are harmful to life. You observed another threat to biodiversity at the beginning of this lesson—an invasive species. An **invasive species** is an organism that is introduced into an ecosystem, either by accident or on purpose, that spreads on its own and outcompetes native species for resources, such as space, food, light, and nutrients. Read about other threats to biodiversity in the table below.

Threat to Biodiversity	Description	Example
Habitat Destruction	**Habitat destruction** involves cutting down forests, draining wetlands, or generally changing a habitat so much that it is no longer usable by the organisms that live there. The photo to the right shows a wetland being drained.	
Overexploitation	**Overexploitation** is the overuse of animal and plant species by humans for purposes including food, medicine, or clothing.	
Climate Change	**Climate change** refers to changes in climate patterns over time. Recently there has been an increase in Earth's average surface temperature both on land and in oceans, referred to as global warming.	

COLLECT EVIDENCE

Zebra mussels and cane toads are invasive species. What are some other threats to biodiversity? Record your evidence (A) in your Science Notebook.

Read a Scientific Text

HISTORY Connection Kudzu—a vine—is an invasive species from Japan that was introduced to the U.S. in 1876. When it was first introduced to the United States, it was marketed as an ornamental vine, food for livestock, and used as a way to control erosion. Growing at a rate of 150,000 acres per year, the vine quickly became a menace. Kudzu blocks light and space that other plants and organisms need, killing trees and causing millions of dollars of damage each year.

CLOSE READING

Inspect

Read the passage *Kudzu Greatest Forage Crop, Declares Local Authority* from a 1918 newspaper article.

Find Evidence

Reread the passage. Create a two-column chart in your Science Notebook. List phrases that are facts in one column and words or phrases that are opinions, or speculation, in the other.

Make Connections

Communicate In your Science Notebook, summarize the author's argument. Is there evidence to support his claim? Explain why or why not.

PRIMARY SOURCE

Kudzu Greatest Forage Crop, Declares Local Authority

Sometime ago I wrote an article on the greatest forage crop in the world—the kudzu. I have had several inquiries from farmers about the kudzu and if you will kindly publish a few facts it will give the readers of your valuable paper information that cannot be had in any other way.

The first year after this the kudzu cowpea or velvet bean, and is also a perennial. It is planted from the roots as it neither blooms or seeds in field culture. It never needs replanting, it is a self-fertilizer, and a soil builder. At the first planting, it requires a good soil but after this it requires no fertilizer or cultivation from the planting of the first year.

It is possible from one acre to plant out five acres the second and third year, it grows on the ground like the strawberry vine, and taken root at every joint. [...]

The kudzu is a legume like the will cover the entire ground and eradicate all obnoxious grasses, such as nut grass or Johnson grass. [...] Being a perennial it comes up of itself, and will grow on any land that is too poor, or rocky to yield other profitable crops.

[...]

The writer has no axe to grind. I don't own any kudzu. I have none for sale but I will be glad to give information to anyone how to get the plant and also I will see that you get them with full instructions how to plant. The only object I have is to see that every farmer or stock raiser in my beloved state and especially in Escambia county, will raise and cultivate the greatest forage in the world [...] You need never be afraid that the kudzu will ever be a disappointment, because when you wish to get rid of it all you have to do is to cut the crown with a disc plow and it is dead.

Source: J.C. Petterson, *The Pensacola Journal*, January 25, 1918

GREEN SCIENCE

Purple Loosestrife:

An Invasive Plant Species

Stamping Out the Purple Plague

AMERICAN MUSEUM OF NATURAL HISTORY

Wetlands, such as swamps and marshes, are important ecosystems. These soggy areas control flooding, affect the flow of rivers, and filter pollution from water. They also are home to a diversity of wildlife, such as birds, fishes, mammals, and plants. Most of them are native species, but some have been introduced more recently, often by human activity. When new species dramatically outcompete native species, they are considered invasive. In North America, one invasive species in particular has caused trouble for many wetland ecosystems.

In the early 1800s, European ships brought a hardy plant to America's shores—purple loosestrife. Settlers used it as a medicinal herb to treat digestive problems, such as diarrhea and ulcers. Before long, the tall plant with reddish-purple flowers was growing in wetlands across the United States.

The fast-growing plant is devastating for wetlands. Its thick roots crowd out native plants that provide food, shelter, and nesting sites for many animal species. Loosestrife also can disrupt the flow of water to rivers and canals and clog irrigation systems. The effect of loosestrife on biodiversity and local communities is so harmful that the plants have become known as the purple plague.

Scientists have tried many ways of controlling purple loosestrife, including plant-eating animals, bacteria, and herbicides. Cutting down the plants doesn't work because new plants sprout from even tiny pieces of root left in the soil. The best solution to date has been the introduction of organisms that eat purple loosestrife. Scientists have identified five species of beetles that eat purple loosestrife in its native range in Europe. These beetles do not harm other North American plants, so they have been released into the wetlands. Since 1996, the insects have successfully controlled the spread of purple loosestrife in many regions.

▲ A sea of purple loosestrife overruns a wetland. It spreads quickly because one plant can produce up to three million seeds a year. The hardy seeds are scattered long distances by wind, water, animals, and even people.

It's Your Turn

Research Choose another invasive species. Describe how it was introduced into an ecosystem, its impact on the environment, and the steps taken to control it. Present your findings to the class.

How can we protect biodiversity and ecosystem services?

You've learned about the different types of threats to biodiversity. What can we do to protect biodiversity?

LAB Turning Trash into Treasure

Safety

Materials

trash collection

craft materials

Procedure

1. Read and complete a lab safety form.
2. Carefully consider the materials in the trash collection.
3. **ART Connection** Using craft materials, create a piece of art out of the trash. Try to convey a message with your art. For example, your message might be "Protect Earth."
4. Display your artwork to the class.
5. Follow your teacher's instructions for proper cleanup.

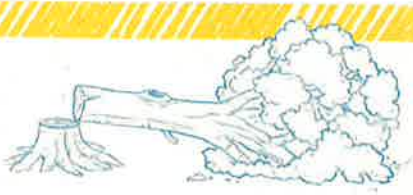
Analyze and Conclude

6. Describe your artwork. What kind of trash did you use? What kind of art did you create? What message did you try to convey?
7. How do you think reusing materials helps protect biodiversity and ecosystem services?

ENVIRONMENTAL Connection All human activities use natural resources, and have short and long-term consequences. Reusing materials helps reduce the natural resources needed to make something new. It also reduces the amount of discarded trash. What else can be done to combat threats to biodiversity and keep ecosystems healthy? Complete the activity below to learn more about solutions for maintaining and protecting biodiversity.

INVESTIGATION

Save the Earth



Your teacher will give each group a different card with a scenario of an ecosystem experiencing a threat to its biodiversity. Your job is to research and evaluate possible solutions for your scenario.

1. With your group, define the problem and brainstorm different solutions to your assigned scenario in your Science Notebook. After you have some ideas written down, research solutions to your scenario using print and digital sources. Write down what you learn from your research. Try to come up with as many solutions as possible.
2. What are some different considerations to keep in mind when evaluating these solutions. Record your ideas in your Science Notebook.
3. Decide on your top four best solutions. In your Science Notebook, create a table like the one below to evaluate them.

Solution	Benefits	Constraints	Ranking and Reasoning (lowest number = most important/do first)

Solutions for Protecting Biodiversity There are many solutions to maintaining and protecting biodiversity. Which solution or combination of solutions is used depends on which ecosystem is affected, how the ecosystem has been affected, and which species may need the most help.

Habitat Restoration and Conservation Two processes seek to restore land that was damaged by human intervention. **Reforestation** involves planting trees to replace trees that have been cut or burned down. **Reclamation** refers to the process of restoring land disturbed by mining.

Controlling Invasive Species Three main methods, or technologies, are used to control invasive species:

- mechanical controls—the use of physical means, such as fences, barriers, weeding, and trapping;
- chemical controls—the use of chemicals, such as herbicides and pesticides; and
- biological controls—the use of other species to combat an invasive species.

These people are working towards reforestation by planting ponderosa pine seedlings.

Which method (or methods) is used depends on the life history of the species, such as how it reproduces and spreads, the number of organisms in a defined area, and financial cost.

After a cargo ship runs into the San Francisco-Oakland Bay Bridge, an oil spill crew cleans up the pollution.

Cleaning Up and Reducing Pollution One action that has reduced water pollution is the United States Clean Water Act, which regulates sources of water pollution. People can help reduce pollution by reducing the use of harmful chemicals and properly disposing of wastes. Sometimes living organisms, such as bacteria and plants, are used to remove chemicals from soil.

Sustaining Populations There are many regulations in place to help keep populations of organisms at sustainable levels. In the United States, hunting and fishing regulations are in place for sports people.

Reducing Impacts of Climate Change

Scientists have concluded that the main cause of current climate change on Earth is an increase in the concentration of greenhouse gases in the atmosphere. The increase is the result of burning fossil fuels (coal, petroleum, and natural gas) for electricity and heat in homes, businesses, and industries, as well as to run motor vehicles.

One way to reduce the impacts of climate change is to make changes that lessen the amount of greenhouse gases being released into the atmosphere. Switching from fossil fuels as sources of energy to renewable energy sources such as solar power, wind power, and geothermal power can help, as none of these energy sources release greenhouse gases.

As an individual, you can reduce your use of energy by walking or riding your bike rather than riding in a vehicle. Using public transportation is also more efficient than riding in a car with only one other person. Recycling metal, paper, plastic, and glass reduces the amount of fuel required to manufacture these materials.

These solar panels and wind turbines create power without using fossil fuels.

THREE-DIMENSIONAL THINKING

ENVIRONMENTAL Connection Read the following scenario and think of several different possible solutions for the threat to biodiversity and ecosystem services being described. Evaluate the solutions and **construct an argument** in your Science Notebook for which solution should be used.

The cutting of forests in the Pacific Northwest resulted in such a severe decrease in the population of northern spotted owls that they are now an endangered species.

COLLECT EVIDENCE

What are solutions to maintain and protect biodiversity from threats, such as zebra mussels and cane toads? Record your evidence (B) in your Science Notebook.

SCIENCE & SOCIETY

Saving an Underwater Wilderness

How do scientists help protect coral reefs?

Pollution and human activities, such as mining and tourism, have damaged many ecosystems, including coral reefs. Scientists and conservation groups are working together to help protect coral reefs and areas that surround them. One way is to create marine reserves where no fishing or collection of organisms is allowed.

A team of scientists, including marine ecologists Dr. Dan Brumbaugh and Kate Holmes from the American Museum of Natural History, are investigating how well reserves are working. These scientists compare how many fish of one species live both inside and outside reserves. Their results indicate that more species of fishes and greater numbers of each species live inside reserves than outside—one sign that reefs in the area are improving.

Reef ecosystems do not have to be part of a reserve in order to improve, however. Scientists can work with local governments to find ways to limit damage to reef ecosystems. One way is to prevent overfishing by limiting the number of fishes caught. Other ways include eliminating the use of destructive fishing practices that can harm reefs and reducing runoff from farms and factories.

By creating marine reserves, regulating fishing practices, and reducing runoff, humans can help reefs that were once in danger become healthy again.

It's Your Turn

Write a paragraph about the methods scientists use to count marine organisms and why this work is important.

American Museum of Natural History

LESSON
Review

Summarize It!

1. **Design** a pamphlet to distribute to people in your community detailing threats to biodiversity in the area in which you live, why people should be concerned about these threats, and what they can do to help. Include text and images to convey your message.

habitat destruction

climate change

overexploitation

REVISIT SCIENCE PROBES Do you still agree with the student you chose at the beginning of the lesson? Return to the Science Probe at the beginning of the lesson. Explain why you agree or disagree with that person now.

EXPLAIN THE PHENOMENON

Revisit your claim about ways that biodiversity can be maintained and protected. Review the evidence you collected. Explain how your evidence supports your claim.

Three-Dimensional Thinking

The orange-spotted filefish, a fish that lives on coral reefs, is highly sensitive to changes in water temperature. After an extended period of warm water temperatures in 1988, the fish disappeared from the coral reefs off the coasts of Japan.

2. Which threat to biodiversity caused the change in the population of orange spotted filefish?

A invasive species

B overexploitation

C habitat destruction

D climate change

3. Evaluate the following possible solutions to combat the threats to biodiversity shown in the image above. Which of the following would be the least effective solution?

A regulating fishing

B bioremediation

C proper disposal of wastes

D reducing the use of harmful chemicals

Real-World Connection

4. **Explain** You see a group of younger students throwing trash into a stream in a local park. Explain to them in terms that they would understand how the consequences of their actions could affect biodiversity and ecosystem services.

5. **Write a plan** for how you can reduce the impact of climate change.

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