To the Student

In today's world, knowing science is important for thinking critically, solving problems, and making decisions. But understanding science sometimes can be a challenge.

*Reading Essentials* takes the stress out of reading, learning, and understanding science. This book covers important concepts in science, offers ideas for how to learn the information, and helps you review what you have learned.

In each chapter:

- **Before You Read** sparks your interest in what you’ll learn and relates it to your world.
- **Read to Learn** describes important science concepts with words and graphics. Next to the text you can find a variety of study tips and ideas for organizing and learning information:
  - The **Study Coach** offers tips for getting the main ideas out of the text.
  - **Foldables™ Study Organizers** help you divide the information into smaller, easier-to-remember concepts.
  - **Reading Checks** ask questions about key concepts. The questions are placed so you know whether you understand the material.
  - **Think It Over** elements help you consider the material in-depth, giving you an opportunity to use your critical-thinking skills.
  - **Picture This** questions specifically relate to the art and graphics used with the text. You’ll find questions to get you actively involved in illustrating the concepts you read about.
  - **Applying Math** reinforces the connection between math and science.
- **Use After You Read** to review key terms and answer questions about what you have learned. The **Mini Glossary** can assist you with science vocabulary. Review questions focus on the key concepts to help you evaluate your learning.

See for yourself. *Reading Essentials* makes science easy to understand and enjoyable.
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Exploring and Classifying Life

section 1 What is science?

Before You Read

Look at the title of Section 1. On the lines below, write what you think science is.

What You’ll Learn

- how to apply scientific methods to problem solving
- how to measure using scientific units

Read to Learn

The Work of Science

One way scientists find out about the world is by asking questions. Science is an organized way of studying things and finding answers to questions.

There are many types of science. The names of the sciences describe what is being studied. For example, a life scientist might study the millions of different animals, plants, and other living things on Earth. Life scientists who study plants are botanists. Those who study animals are zoologists.

Critical Thinking

You solve problems every day. To figure things out, you have to think about them. You have to think about what will work and what will not. Suppose your portable CD player stops working. To figure out the problem, you have to think about it. You know that the CD player runs on batteries, so your first thought would be to replace the batteries. If replacing the batteries does not work, you have to think of other possible solutions. Thinking this way is called critical thinking. It is the way you use skills to solve problems. Separating important information from information that is not important is a skill. Identifying the problem is another skill you may have.
### Solving Problems

Scientists use critical-thinking skills to try to solve problems and answer questions. Solving problems requires organization. In science, this organization often takes the form of a series of procedures called **scientific methods**. The procedures shown in the figure below are one way that scientific methods might be used to solve a problem.

#### How are scientific problems stated?

The first step in solving a problem scientifically is to state the problem. For example, four cats were being boarded at a veterinarian’s office. The veterinary technician noticed that two of the cats were scratching and had patches of skin with red sores. They had both been fine when they first arrived. The technician identified this as a problem. Now she must decide how to gather information about the problem.

#### How is scientific information gathered?

Scientists collect information through laboratory observations and experiments. Sometimes information is collected from fieldwork done outside the laboratory. For example, scientists might find out how a bird builds a nest by going outside and watching it.
Observation  The technician gathers information about the problem with the cats by watching them closely. She watches to see if the behavior of the cats with the sores is different than the behavior of the other two cats. She observes that other than the scratching, the behavior of the four cats is the same. The technician finds out that the brand of cat food used at the clinic is the same as the one the cats get at home. She decides that the two cats are reacting to something in their environment. She notices that they seem to scratch most after using their litter boxes.

How do scientists form a hypothesis?  
After scientists collect the information, they form a hypothesis. A hypothesis is a prediction that can be tested. After collecting the information, the technician hypothesizes that something in the cat litter is irritating the cats’ skin.

How do scientists test a hypothesis?  
Scientists test a hypothesis by performing an experiment. In an experiment, the hypothesis is tested using controlled conditions.

The technician gets permission from the owner to test her hypothesis by running an experiment. The technician reads the label on two brands of cat litter. She finds that the ingredients of each brand are the same except that one has a deodorant. The cat litter used in the clinic has a deodorant. The technician finds out that the litter the cats have at home does not have a deodorant.

How do scientists use controls in an experiment?  
The technician separates the cats with sores from the other two cats. She puts each of the cats with sores in a cage by itself. One cat is called the experimental cat. This cat gets a litter box with litter that does not have deodorant. The other cat gets a litter box that has cat litter with deodorant. The cat with deodorant cat litter is the control.

A control is the standard to which the outcome of a test is compared. The control cat will be compared with the experimental cat at the end of the experiment. Whether or not the cat litter has deodorant is the variable. A variable is something in an experiment that can change. An experiment should have only one variable. Other than the difference in the cat litter, the technician treats the cats the same.
How do scientists analyze data?

During the week, the technician observes both cats. She collects data on how often and when the cats scratch or chew. She records the data in a journal. The data show that the control cat scratches more often than the experimental one does. The sores on the experimental cat begin to heal. The sores on the control cat do not.

How do scientists draw conclusions?

The technician draws the conclusion that the deodorant in the cat litter probably irritated the skin of the two cats. To draw a conclusion is to get a logical answer to a question based on data and observation. The next step is to accept or reject the hypothesis. In this case, the technician accepts the hypothesis. If she had rejected it, then she would need to conduct new experiments.

The technician realizes that even though she accepted the hypothesis, she should continue her experiment to be surer of her results. She should switch the cats to see if she gets the same results again. However, if she did this, the healed cat might get new sores. She makes an ethical decision and does not continue the experiment. Ethical decisions are important in deciding what experiments should be done.

What do scientists do with results of experiments?

It is important to share the information when using scientific methods. The veterinary technician shares her results with the cats’ owner. She tells him she has stopped using the cat litter with the deodorant.

Developing Theories

After a scientist reports the results of an experiment that supports the hypothesis, many scientists repeat the experiment. If the results always support the hypothesis, the hypothesis can be called a theory. A scientific theory is an explanation of things or events based on scientific knowledge that is the result of many observations and experiments. It is not a guess. A theory usually explains many hypotheses. For example, scientists made observations of cells and experimented for more than 100 years before enough information was collected to propose a theory. A theory raises many new questions. Data or information from new experiments might change conclusions and theories can change.
What is scientific law?

A scientific law is a statement about how things work in nature that seems to be true all the time. Although laws can be modified as more information becomes known, they are less likely to change than theories.

Laws tell you what will happen under certain conditions but do not necessarily explain why it happened. For example, in life science you might learn about laws of heredity. These laws explain how genes are inherited, but do not explain how genes work. There is a great variety of living things, but few laws to explain them. A law that describes how all cells work may never be developed.

How do scientific methods help answer questions?

You can use scientific methods to answer all kinds of questions. Using these methods does not guarantee that you will get an answer. Often they lead to more questions and more experiments. Science is about looking for the best answers to your questions.

Measuring with Scientific Units

An important part of scientific investigations is making accurate measurements. Many things you use every day are measured. In your science classes, you will use the same standard system of measurement that scientists use in their work. This system is called the International System of Units, or SI. For example, you may need to calculate the distance a bird flies in kilometers. Perhaps you will be asked to measure the amount of air your lungs can hold in liters. Some of the SI measurements are shown in this table.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Unit</th>
<th>Symbol</th>
<th>Equal to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>1 millimeter</td>
<td>mm</td>
<td>0.001 (1/1,000) m</td>
</tr>
<tr>
<td></td>
<td>1 centimeter</td>
<td>cm</td>
<td>0.01 (1/100) m</td>
</tr>
<tr>
<td></td>
<td>1 meter</td>
<td>m</td>
<td>100 cm</td>
</tr>
<tr>
<td></td>
<td>1 kilometer</td>
<td>km</td>
<td>1,000 m</td>
</tr>
<tr>
<td>Volume</td>
<td>1 milliliter</td>
<td>mL</td>
<td>0.001 (1/1,000) L</td>
</tr>
<tr>
<td></td>
<td>1 liter</td>
<td>L</td>
<td>1,000 mL</td>
</tr>
<tr>
<td>Mass</td>
<td>1 gram</td>
<td>g</td>
<td>1,000 mg</td>
</tr>
<tr>
<td></td>
<td>1 kilogram</td>
<td>kg</td>
<td>1,000 g</td>
</tr>
<tr>
<td></td>
<td>1 tonne</td>
<td>t</td>
<td>1,000 kg = 1 metric ton</td>
</tr>
</tbody>
</table>

7. Explain what scientific laws can tell you about nature.

8. Calculate How many centimeters are there in 2.5 meters? (Show your work.)
Safety First

Some of the scientific equipment that you use in the classroom or laboratory is the same as the equipment scientists use. Laboratory safety is important. It is important to wear proper eye protection. Make sure you wash your hands after handling materials. Following safety rules, as shown in the figure, will protect you and others from injury.

Symbols are often used in texts and laboratories to alert you to situations that require special attention. Some of these symbols are shown below.

Picture This

9. Apply What part of your body will be protected by wearing safety goggles?

10. Identify Several symbols indicate safety equipment that you might wear when working in the lab. Circle two of the symbols.
After You Read

Mini Glossary

control: the standard to which the outcome of a test is compared

hypothesis: a prediction that can be tested

law: a statement about how things work in nature

scientific methods: an organized series of procedures used to solve a problem

theory: an explanation of things or events based on scientific knowledge that is the result of many observations and experiments

variable: something in an experiment that can change

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the difference between a control and a variable.

2. Decide on a problem you would like to solve. Use the steps in the scientific method to explain how you would solve the problem.

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End of Section
What You’ll Learn

- the difference between living and nonliving things
- what living things need to survive

Before You Read

List three living things in your environment. What do these things need to live?

Read to Learn

What are living things like?

Any living thing is called an organism. Organisms vary in size from microscopic bacteria to giant trees. They are found just about everywhere. They have different behaviors and food needs. However, all organisms have similar traits. These traits determine what it means to be alive.

How are living things organized?

Living things are made up of small units called cells. A cell is the smallest unit of an organism that carries on the functions of life. Some organisms are made up of just one cell. Others are made up of many cells. Cells take in materials from their surroundings. They use the materials in complex ways. Each cell has an orderly structure and has hereditary material. The hereditary material has instructions for cell organization and function. All the things organisms can do are possible because of what their cells can do.

How do living things respond?

Living things interact with their surroundings. Anything that causes some change in an organism is a stimulus (plural, stimuli). The reaction to a stimulus is a response. Often that response results in movement.
Response to Stimuli To carry on its daily activity and to survive, an organism must respond to stimuli. Organisms respond to external stimuli such as movement and light.

Living things also respond to stimuli that occur inside them. For example, water or food levels in organisms’ cells can increase or decrease. The organisms then make internal changes to keep the right amounts of water and food in their cells. An organism’s ability to keep the proper conditions inside no matter what is going on outside the organism is called homeostasis.

How do living things get energy?

The energy that most organisms use to perform life activities comes from the Sun. Plants and some other organisms get energy directly from the Sun. They do this by combining sunlight with carbon dioxide and water to make food. People and most other organisms cannot use the energy of sunlight directly. Instead, they take in and use food as a source of energy. People get food by eating plants or other organisms that eat plants. Most organisms, including plants, must take in oxygen in order to release the energy found in their food.

Some organisms, such as bacteria that live at the bottom of the oceans where sunlight cannot reach, cannot use the Sun’s energy to make food. These organisms use chemical compounds and carbon dioxide to make food. They do not need oxygen to release the energy found in their food.

How do living things grow and develop?

Organisms grow by taking in raw materials. One-celled organisms grow by increasing in size. Most growth in many-celled organisms is due to an increase in the number of cells.

Organisms change as they grow. All of the changes that take place during an organism’s life are called development. Complete development can take a few days for the butterfly shown below, or several years for a dog. The length of time an organism is expected to live is its life span. Some organisms have a short life span. Some have long life spans.

Picture This

1. Circle the animal that completes its development cycle in a few days.
Why do living things reproduce?

Organisms eventually reproduce. They make more of their own kind. Some bacteria reproduce every 20 minutes. A pine tree might take two years to produce seeds. Without reproduction, living things would not exist to replace those individuals that die.

What do living things need?

To survive, all living things need a place to live and raw materials. The places where they live and the raw materials they use can vary.

In what places do organisms live?

The environment limits where organisms can live. Not many organisms can live in extremely hot or extremely cold environments. Most cannot live at the bottom of the ocean or on the tops of mountains. All organisms need living space in their environment. For example, thousands of penguins build their nests on an island. The island becomes too crowded for all the penguins. They fight for space and some may not find space to build nests. An organism’s surroundings must provide for all its needs.

What raw materials do organisms need?

Water is important for all living things. Most organisms are made of more than 50 percent water. Humans are made of 60 to 70 percent water. Plants and animals take in and give off large amounts of water each day. Organisms use homeostasis to balance the amount of water taken in and lost.

Organisms use water for many things. Blood is about 90 percent water. Blood transports food and wastes in animals. Plants use water to transport materials between roots and leaves.

Living things are made up of substances such as sugars, proteins, and fats. Animals get these substances from the food they eat. Plants and some bacteria make the substances using raw materials from their surroundings. These important substances are used over and over again. When organisms die, substances from their bodies are broken down and released into the soil or air. The substances can then be used again by other organisms.
After You Read

Mini Glossary

cell: the smallest unit of an organism that carries on the functions of life

homeostasis: an organism’s ability to regulate internal, life-maintaining conditions

organism: any living thing

1. Review the terms and their definitions in the Mini Glossary. Write a sentence explaining how homeostasis works in humans.

2. Complete the web diagram below by describing traits that tell what living things are like.
Define Words  Read all the headings for this section and circle any word you cannot define. At the end of each section, review the circled words and underline the part of the text that helps you define the words.

What You’ll Learn
■ about spontaneous generation experiments
■ how scientific methods led to the idea of biogenesis

Before You Read
On the lines below, describe what you think the universe was like before Earth and the solar system developed.

Life Comes from Life
Before the seventeenth century, many people thought that insects and fish came from mud. They believed that earthworms fell from the sky when it rained. For that time, these were logical conclusions based on repeated personal experiences.

What is spontaneous generation?
The idea that living things come from nonliving things is known as spontaneous generation. This idea became a theory that was accepted for several hundred years. When scientists began to use controlled experiments to test this theory, the theory changed.

Experiments were done to test the theory of spontaneous generation. In 1668 Francesco Redi put decaying meat in some jars. He covered half of the jars. Fly maggots appeared on the meat in the uncovered jars, but not on the meat in the covered jars. Redi concluded that the maggots came from hatched fly eggs, not from the meat. In the 1700s, John Needham and Lazzaro Spallanzani conducted more experiments to test the theory of spontaneous generation. These early experiments did not disprove the theory entirely.
What is biogenesis?

In the mid-1800s, the work of Louis Pasteur, a French chemist, provided enough evidence to disprove the theory of spontaneous generation. The theory was replaced with biogenesis (bi oh JE nuh suhs). **Biogenesis** is the theory that living things come only from other living things.

Life’s Origins

If living things come only from other living things, then how did life on Earth begin? Some scientists hypothesize that about 5 billion years ago, Earth’s solar system was a whirling mass of gas and dust. They hypothesize that the Sun and planets formed from this mass.

It is estimated that Earth is about 4.6 billions years old. Fossils of once-living organisms more than 3.5 billion years old have been found. Where did these living organisms come from?

What is Oparin’s hypothesis?

In 1924, Alexander I. Oparin, a Russian scientist, suggested that Earth’s early atmosphere had no oxygen. He said that it was made up of the gases ammonia, hydrogen, methane, and water vapor. Oparin hypothesized that these gases could have combined to form the more complex compounds found in living things.

American scientists Stanley L. Miller and Harold Urey set up an experiment to test Oparin’s hypothesis in 1953. They used the gases and conditions that Oparin described. The experiment sent electricity through a mixture of Earth’s earliest gases. When the gases cooled, they condensed to form an oceanlike liquid. The liquid contained materials such as amino acids that are found in present-day cells. Their experiment is summarized below. However, it did not prove that life began in this way. Today, some scientists continue to investigate ideas about life’s origins. ☑

---

Gases of Earth’s early atmosphere

- Electric current
  - Oceanlike mixture forms
  - Cools
  - Materials in present-day cells
After You Read

Mini Glossary

biogenesis (bi oh JE nuh sus) the theory that living things come only from other living things

spontaneous generation: the idea that living things come from nonliving things

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the difference between biogenesis and spontaneous generation.

2. Choose one of the question headings in the Read to Learn section. Write the question in the space below. Then write your answer to that question on the lines that follow.

Write your question here.

3. How did circling and underlining words and definitions help you understand where life comes from?

End of Section

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about where life comes from.
Exploring and Classifying Life

section 4 How are living things classified?

Before You Read

On the lines below, list the different ways you could classify the place where you live (examples: city, suburb, state).

Read to Learn

Classification

When similar items are placed together, they are being classified. Organisms also are classified into groups. Early classifications of organisms included grouping plants that were used in medicines. Animals were often classified by human traits. For example, lions were classified as courageous animals and owls were classified as wise.

More than two thousand years ago, Aristotle, a Greek, decided that any organism could be classified as either a plant or an animal. Then he broke these two groups into smaller groups. For example, his groups included animals that had hair and animals that did not have hair, and animals with and without blood.

Who was Carolus Linnaeus?

In the late 1700s, Carolus Linnaeus, a Swedish naturalist, developed a new system of grouping organisms. His system was based on organisms with similar structures. For example, plants that had a similar flower structure were grouped together. His system was accepted and used by most other scientists.
What classification do modern scientists use?

Modern scientists also use similarities in structure to classify organisms. They also use similarities in both external and internal features. For example, scientists use the number of chromosomes in cells to understand which organisms may be genetically related to each other.

In addition, scientists study fossils, hereditary information, and early stages of development. Scientists use the information to determine an organism’s phylogeny. **Phylogeny** (fi LAH juh nee) is the organism’s evolutionary history. This tells how the organism has changed over time. It is the basis for the classification of many organisms.

### How are organisms grouped?

A classification system commonly used today groups organisms into six kingdoms. A **kingdom** is the first and largest category. Kingdoms are divided into smaller groups. The smallest classification is a species. Organisms in the same species can mate and produce fertile offspring. The figure below shows how a bottle-nosed dolphin can be classified.

**Scientific Names**

If scientists used only common names of organisms, it would be confusing. For example, a jellyfish is neither a fish nor jelly. A sea lion is more closely related to a seal than a lion. To avoid confusion, scientists use a naming system developed by Linnaeus when referring to a particular species. Each species has a unique, two-word scientific name.
What is binomial nomenclature?
The two-word naming system used to name organisms is called **binomial nomenclature** (bi NOH mee ul · NOH mun klay chur). The first word of the two-word name identifies the genus of the organism. A **genus** is a group of similar species. The second word of the name might tell you something about the organism. It might tell what it looks like or where it is found.

Why are scientific names used?
Two-word scientific names are used for four reasons.

- They help avoid mistakes.
- Animals with similar evolutionary history are classified together.
- Scientific names give descriptive information about the species.
- Scientific names allow information about organisms to be organized easily and efficiently.

Tools for Identifying Organisms

Tools used to identify organisms include field guides and dichotomous (di KAH tuh mus) keys. Field guides include descriptions and pictures of organisms. They give information about where each organism lives. You can use a field guide to identify species from around the world.

What are dichotomous keys?
A dichotomous key is a detailed list of identifying characteristics that includes scientific names. The keys are set up in steps. Each step has two descriptive statements, such as hair or no hair. You can use a dichotomous key, such as the one below, to identify and name a species.

<table>
<thead>
<tr>
<th>Key to Some Mice of North America</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Tail hair</td>
</tr>
<tr>
<td>a. no hair on tail; scales show plainly; house mouse, <em>Mus musculus</em></td>
</tr>
<tr>
<td>b. hair on tail, go to 2</td>
</tr>
<tr>
<td>2. Ear size</td>
</tr>
<tr>
<td>a. ears small and nearly hidden in fur, go to 3</td>
</tr>
<tr>
<td>b. ears large and not hidden in fur, go to 4</td>
</tr>
<tr>
<td>3. Tail length</td>
</tr>
<tr>
<td>a. less than 25 mm; woodland vole, <em>Microtus pinetorum</em></td>
</tr>
<tr>
<td>b. more than 25 mm; prairie vole, <em>Microtus ochrogaster</em></td>
</tr>
<tr>
<td>4. Tail coloration</td>
</tr>
<tr>
<td>a. sharply bicolor, white beneath and dark above; deer mouse, <em>Peromyscus maniculatus</em></td>
</tr>
<tr>
<td>b. darker above than below but not sharply bicolor; white-footed mouse, <em>Peromyscus leucopus</em></td>
</tr>
</tbody>
</table>

Reading Check

4. Explain What does the first word in an organism’s binomial nomenclature indicate?

5. List two tools that can be used to identify organisms.

6. Identify the mouse that has a mostly dark, hairy tail and large ears.
After You Read

Mini Glossary

binomial nomenclature (bi NOH mee ul · NOH mun klay chur): the two-word naming system used to name organisms

kingdom: the first and largest category of organisms

phylogeny (fi LAH juh nee): the evolutionary history of an organism

genus: a group of similar species

1. Review the terms and their definitions in the Mini Glossary. Choose one of the terms and explain its role in classifying organisms.

2. Complete the diagram below by explaining what binomial nomenclature is and the reasons for using it.

Binomial Nomenclature

What is it?

Reasons for Using

Visit life.mssscience.com to access your textbook, interactive games, and projects to help you learn more about how living things are classified.
Before You Read

Think about the different jobs people have in a restaurant. List three of those jobs on the lines below. Then explain how these people work together to provide food to customers.

What You’ll Learn

- the names and functions of cell parts
- the importance of a nucleus in a cell
- about tissues, organs, and organ systems

Read to Learn

Common Cell Traits

Living cells have many things in common. A cell is the smallest unit that can perform life functions. All cells have an outer covering called a cell membrane. Inside every cell is a gelatinlike material called cytoplasm (SI tuh pla zum). Cytoplasm contains hereditary material that controls the life of the cell.

How do cells differ?

Cells come in different sizes and shapes. A cell’s shape might tell you something about its function. A nerve cell has many branches that send and receive messages to and from other cells. A nerve cell in your leg could be a meter long. A human egg cell is no bigger than the dot on this i. A human blood cell is much smaller than the egg cell. A bacterium is even smaller—8,000 of the smallest bacteria can fit inside one red blood cell.

A nerve cell cannot change its shape. Muscle cells and some blood cells can change shape. Some cells in plant stems are long and hollow and have openings at their ends. These cells carry food and water throughout the plant.

Identify Important Words As you read the section, circle all the words you do not understand. Highlight the part of the text that helps you define those words.

1. Infer Why are cells in plant stems hollow with openings at both ends?
**Picture This**

2. **Identify** Circle the features that are the same in both types of cells.

---

**What types of cells are there?**

Scientists separate cells into two groups, as shown in the figure below. A prokaryotic (proh KAYR ee yah tihk) cell does not have membrane-bound structures inside the cell. A cell with membrane-bound structures inside the cell is called a eukaryotic (yew KAYR ee yah tihk) cell.

---

**Cell Organization**

Just as restaurant workers have specific jobs, each cell in your body has a certain job to do. Cells take in nutrients, release and store chemicals, and break down substances 24 hours a day.

**What protects a cell and gives it shape?**

A **cell wall** is a tough, rigid outer covering that protects the cell and gives it shape. The cells of plants, algae, fungi, and most bacteria are enclosed in a cell wall.

A plant cell wall is mostly made up of a carbohydrate called cellulose. The long, threadlike fibers of cellulose form a thick mesh. The mesh allows water and dissolved materials to pass through the cell wall.

Cell walls may contain pectin, which is used to thicken jams and jellies. Cell walls also contain lignin. Lignin is a compound that makes cell walls rigid. Plant cells responsible for support have large amounts of lignin in their walls.

---

**Reading Check**

3. **List** three things found in the cell wall of a plant.
What is the function of the cell membrane?
The protective layer around all cells is the cell membrane. If a cell has a cell wall, the cell membrane is inside the cell wall. The cell membrane controls what happens between a cell and its environment. Water and some food particles move freely into and out of a cell through the cell membrane. Waste products leave through the cell membrane.

What is cytoplasm?
Cytoplasm is a gelatinlike material in the cell. Many important chemical reactions occur within the cytoplasm. Cytoplasm has a framework called the cytoskeleton, which helps the cell keep or change its shape. The cytoskeleton helps some cells to move. The cytoskeleton is made up of thin, hollow tubes of protein and thin, solid protein fibers.

What are the functions of organelles?
Most of a cell's life processes happen in the cytoplasm. Within the cytoplasm of eukaryotic cells are structures called organelles. Some organelles process energy. Others make materials needed by the cell or other cells. Some organelles move materials. Others store materials. Most organelles are surrounded by membranes.

Why is the nucleus important?
The nucleus (NEW klee us) directs all cell activities. The nucleus usually is the largest organelle in a cell. It is separated from the cytoplasm by a membrane. Materials enter and leave the nucleus through openings in the membrane. The nucleus contains DNA. DNA is the chemical that contains the code for the cell's structure and activities.

Which organelles process energy?
Cells need energy to do their work. In plant cells, food is made in green organelles called chloroplasts (KLOR uh plasts). Chloroplasts contain chlorophyll (KLOR uh fihl), which captures light energy that is used to make a sugar called glucose. Animal cells and some other cells do not have chloroplasts. Animals must get food from their environment.

The energy in food is stored until it is released by organelles called mitochondria (mi tuh KAHN dree uh). Mitochondria release energy by breaking down food into carbon dioxide and water. Some types of cells, such as muscle cells, are more active than other types of cells. These cells have large numbers of mitochondria.
What organelle makes proteins?
Protein takes part in almost every cell activity. Cells make their own proteins on structures called ribosomes, which are shown below. Ribosomes are considered organelles, even though they are not membrane bound. Hereditary material in the nucleus tells ribosomes how, when, and in what order to make proteins. Ribosomes are made in the nucleolus (new klee OHL us) and move out into the cytoplasm. Some ribosomes are free-floating in the cytoplasm and some attach to the endoplasmic reticulum.

![Diagram of ribosomes and other cell structures]
What is the endoplasmic reticulum?
The endoplasmic reticulum (en duh PLAZ mihk • rih TIHK yuh lum), or ER, is a series of folded membranes in which materials can be processed and moved around inside the cell. Smooth ER processes materials such as lipids that store energy. Rough ER has ribosomes that make proteins. The proteins are used within the cell or moved out of the cell.

What types of organelles transport or store materials?
The Golgi (GAWL jee) bodies sort proteins and other cellular materials and put them into structures called vesicles. Vesicles deliver the cellular materials to areas inside the cell and to the cell membrane where they are released. Cells have membrane-bound spaces called vacuoles. Vacuoles store cellular materials, such as water, wastes, and food.

How does a cell recycle its materials?
Active cells break down and recycle materials. An organelle called a lysosome (LI suh sohm) contains digestive chemicals that help break down materials in the cell. The lysosome’s membrane stops the digestive chemicals from leaking into the cytoplasm and destroying the cell. When a cell dies, a lysosome’s membrane breaks down. The released digestive chemicals destroy the cell’s contents.

From Cell to Organism
The figure below shows how a many-celled organism is organized. A cell in a many-celled organism performs its own work and depends on other cells in the organism. Similar cells grouped together to do one job form a tissue. Each cell works to keep the tissue alive. Tissues are organized into organs. An organ is made up of two or more different types of tissue that work together. For example, your heart is an organ that is made up of cardiac tissue, nerve tissue, and blood tissues. An organ system is a group of organs that work together to perform a function. Your cardiovascular system is made up of your heart, arteries, veins, and capillaries. Organ systems work together to keep an organism alive.

---

**Picture This**
8. **Sequence** Write a number from 1 to 5 beside each label on the diagram. A 1 is the simplest level of organization and a 5 is the most complex level of organization.
After You Read

Mini Glossary

cell membrane: the protective layer around a cell, which controls what happens between a cell and its environment
cell wall: a tough, rigid outer covering that protects the cell and gives it shape
chloroplast (KLOR uh plast): a green organelle that makes food in plant cells
cytoplasm (SI tuh pla zum): gelatinlike material inside every cell where hereditary material is contained
endoplasmic reticulum: a series of folded membranes in which materials can be processed and moved around inside the cell
Golgi (GAWL jee) bodies: organelles that sort proteins and other cellular materials and put them into structures called vesicles
mitochondria: organelles that release energy by breaking down food into carbon dioxide and water
nucleus (NEW klee us): directs all cell activities
organ: a structure made up of two or more different types of tissues that work together
organelle: a structure within a eukaryotic cell; some process energy and others make substances needed by the cell or other cells
ribosome: a small structure where a cell makes its own protein
tissue: a group of similar cells that work together to do one job

1. Review the terms and their definitions in the Mini Glossary. Choose one term that describes a cell structure and write a sentence to explain its function.

2. Complete the diagram below to show the organization of many-celled organism.

3. Beside each organelle listed below, write Plant, Animal, or Both to show where the organelle is found.
   a. Nucleus _________________
   b. Chloroplast _______________
   c. Golgi bodies _______________
   d. Ribosome _________________
   e. Lysosome _________________
   f. Mitochondrion ______________

End of Section

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about cell structure.
Before You Read

Have you ever looked at anything using a magnifying lens or a microscope? On the lines below, describe what you saw.

What You’ll Learn

- the differences among microscopes
- the discoveries that led to the cell theory

Read to Learn

Magnifying Cells

The number of living things in your environment that you can’t see is greater than the number you can see. Many of the things you can’t see are only one cell in size. Most cells are so small that you need a microscope to see them. A microscope has one or more lenses that directs light toward your eye and enlarges the appearance of the cell so you can see its parts.

What were early microscopes like?

In the mid-1600s, Antonie van Leeuwenhoek made a simple microscope with a tiny glass bead for a lens. It could magnify images of things up to 270 times their normal size. The microscope’s lens had a power of 270×. Early microscopes made an image larger, but that image was not always sharp or clear.

What are modern microscopes like?

Today there are simple and compound microscopes. A simple microscope has just one lens. It is like a magnifying lens. The compound light microscope has two sets of lenses—eyepiece lenses and objective lenses. The eyepiece lenses are placed in one or two tubelike structures. Compound light microscopes have two to four movable objective lenses.

Foldables

- B Compare Make a three-tab Foldable, as shown below. Compare compound light microscopes and electron microscopes.

K-W-L Fold a sheet of paper into three columns. In the first column, write what you know about microscopes. In the second column, write what you want to know about microscopes. Fill in the third column with facts you learned about microscopes after you have read this section.

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Before You Read

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Magnification  The larger image produced by a microscope is called magnification. The powers of the eyepiece and objective lenses determine the total magnification of a compound microscope. For example, if the eyepiece lens has a power of $10\times$ and the objective lens has a power of $43\times$, then the total magnification is $430\times (10\times \text{times } 43\times)$. A $430\times$ microscope can make an image of an object 430 times larger than its actual size.

How does an electron microscope magnify objects?

Things that are too small to be seen with compound light microscopes can be viewed with an electron microscope. An electron microscope uses a magnetic field in a vacuum to direct beams of electrons. Some electron microscopes can magnify up to one million times. Electron microscope images must be photographed or electronically produced.

Cell Theory

In 1665, Robert Hooke looked at a thin slice of cork under a microscope. He thought the cork looked like it was made up of empty little boxes, which he named cells.

What discoveries led to the cell theory?

In the 1830s, Matthias Schleiden used a microscope to study plants. He concluded that all plants are made of cells. Theodor Schwann observed different animal cells. He concluded that all animals are made of cells. These two scientists put their ideas together and concluded that all living things are made of cells.

Several years later, Rudolf Virchow hypothesized that cells divide to form new cells. He suggested that every cell came from a cell that already existed. Virchow’s ideas about cells and those of other scientists are called the cell theory, as described in the table below.

<table>
<thead>
<tr>
<th>The Cell Theory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. All organisms are made up of one or more cells.</td>
</tr>
<tr>
<td>2. The cell is the basic unit of organization in organisms.</td>
</tr>
<tr>
<td>3. All cells come from cells.</td>
</tr>
</tbody>
</table>

Picture This

1. Identify  Highlight Rudolf Virchow’s contribution to cell theory.
After You Read

Mini Glossary

**cell theory**: states that all organisms are made up of one or more cells; the cell is the basic unit of organization in organisms; and all cells come from other cells

1. Review the term and its definition in the Mini Glossary. Write a sentence describing one part of the cell theory. Include the name of the scientist connected to that part of the cell theory.

________________________________________________________________________

________________________________________________________________________

2. Complete the table below to list the discovery made by each scientist that led to the cell theory.

<table>
<thead>
<tr>
<th>Matthias Schleiden</th>
<th>Theodor Schwann</th>
<th>Rudolf Virchow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. How did the K-W-L chart help you organize the information about microscopes?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
What You’ll Learn

- how a virus copies itself
- how vaccines help people
- some uses of viruses

Before You Read

Think about the vaccinations you have had when at the doctor’s office or at a health clinic. On the lines below, list the kinds of diseases these shots will help prevent.

Read to Learn

What are viruses?

Cold sores, measles, chicken pox, colds, the flu, and AIDS are some diseases caused by nonliving particles called viruses. A **virus** is a strand of hereditary material surrounded by a protein coating.

What are characteristics of viruses?

Viruses don’t have a nucleus or other organelles. They also lack a cell membrane. Viruses have a variety of shapes. A virus is so small it can be seen only by an electron microscope. Before the electron microscope was invented, scientists only hypothesized about viruses.

How do viruses multiply?

The only way a virus can reproduce is by making copies of itself. A virus, however, must have the help of a living cell called a **host cell**. Crystalized forms of some viruses can be stored for years. Then, if they enter an organism, they can multiply quickly.

Once a virus enters a host cell, the virus can act in two ways. It can be either active or latent, which is an inactive stage.
What happens when a virus is active?

When a virus enters a cell and is active, it causes the host cell to make new viruses. This process destroys the host cell. Follow the steps in the figure below to see one way that an active virus works inside a cell.

What happens when a virus is latent?

When a latent, or inactive, virus enters a host cell, its hereditary material can become part of the cell’s hereditary material. It does not immediately make new viruses or destroy the cell. As the host cell reproduces, the virus’s DNA is copied. A virus can be inactive for many years. Then, at any time, something inside or outside the body can make the virus active.

If you have a cold sore on your lip, a latent virus in your body has become active. The cold sore is a sign that the virus is active and destroying cells in your lip. When the cold sore goes away, the virus has become latent again. The virus is still in your body’s cells, but it is hiding and doing no harm.
4. Define the term **vaccine**.

**How do viruses affect organisms?**

Viruses attack animals, plants, fungi, protists, and all prokaryotes. Some viruses can infect only certain kinds of cells. For example, the potato leafroll virus infects only potato crops. A few viruses can infect many kinds of cells. The rabies virus can infect humans and many other animal hosts.

**How does a virus reach a host cell?**

A virus cannot move by itself. There are several ways it can reach a cell host. For example, a virus can be carried to a host cell by the wind or by being inhaled. When a virus infects an organism, the virus first attaches to the surface of the host cell. The virus and the place where it attaches on the host cell must fit together exactly, as shown below. This is why most viruses attack only one kind of host cell.

**What are bacteriophages?**

Viruses that infect bacteria are called bacteriophages (bak TIHR ee uh fay jihz). They differ from other kinds of viruses in the way that they enter bacteria. Bacteriophages attach to a bacterium and inject their hereditary material. The entire cycle takes about 20 minutes. Each virus-infected cell releases an average of 100 viruses.

**Fighting Viruses**

A vaccine is a kind of medicine used to prevent a disease. It is made from weakened virus materials that cannot cause disease anymore. Vaccines have been made to prevent many diseases, including chicken pox, measles, and mumps.
How was the first vaccine developed?
Edward Jenner developed the first vaccine in 1796. The vaccine was for smallpox. Jenner noticed that people who got cowpox did not get smallpox. He made a vaccine from the sores of people who had cowpox. He injected the cowpox vaccine into healthy people. The cowpox vaccine protected them from smallpox.

How are viral diseases treated?
One way your body can fight viral infections is by making interferons. Interferons are proteins that are made quickly by virus-infected cells and move to noninfected cells in the host. Interferons cause the noninfected cells to make protective materials.

Antiviral drugs can be given to an infected patient to help fight a virus. A few drugs are helpful against viruses. Some of these drugs are not used widely because they have harmful side effects.

How can viral diseases be prevented?
There are many ways to prevent viral diseases. People can get vaccinated against diseases. Sanitary conditions can be improved. People who have viral diseases can be kept away from healthy people. Animals, such as mosquitoes, that spread disease can be kept under control.

Research with Viruses
Scientists are discovering helpful uses for some viruses. One use, called gene therapy, substitutes normal hereditary material for a cell’s flawed hereditary material. Normal hereditary material is placed into viruses. These altered viruses then are used to infect those cells that contain flawed hereditary material. The normal hereditary material in the altered viruses enters the cells and replaces the flawed hereditary material. Using gene therapy, scientists hope to help people with genetic disorders and find a cure for cancer.
After You Read

Mini Glossary

host cell: a living cell that a virus enters

virus: a strand of hereditary material surrounded by a protein coating that can infect and multiply in a host cell

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that describes the relationship between a virus and a host cell.

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

2. Choose one of the question headings in the Read to Learn section. Write the question in the space below. Then write your answer to that question on the lines that follow.

Write your question here.

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

3. Complete the diagram below to identify two ways viruses can act inside host cells.

Viruses enter host cells and become

[ ]

or

[ ]
Cell Processes

section ● Chemistry of Life

Before You Read

On the lines below, list five things that are in the room around you. Then write something that these items have in common.

What You’ll Learn

- the differences among atoms, molecules, and compounds
- how chemistry and life science are related
- the differences between organic compounds and inorganic compounds

Read to Learn

The Nature of Matter

Look at the things around you. What are they made of? Each item looks different, but all of them are made of matter. Matter is anything that has mass and takes up space. You are made of matter. The chair you sit in is made of matter. The book you read is made of matter.

Energy holds matter together and breaks matter apart. Energy is anything that brings about change. The food you eat is matter. It is held together by chemical energy. When you cook food, energy in the form of heat breaks some of the bonds that hold the matter in food together.

What makes up matter?

Matter exists in three forms—solids, liquids, and gases. All forms of matter are made up of atoms. The oxygen atom shown on the next page will help you understand the parts of the atom. The nucleus is the center of the atom. The nucleus holds the protons and neutrons. Notice that the protons and neutrons are about the same size. They also have about the same masses. Protons have a positive charge, while neutrons have no charge.
Where are electrons found?
Electrons are outside the atom’s nucleus. They have a negative charge. It takes about 1,837 electrons to equal the mass of one proton. Electrons are the part of the atom that is involved in chemical reactions.

Look at the figure of the oxygen atom again. It shows that most of the atom is empty space. Energy holds the parts of an atom together.

What are elements?
When something is made up of only one kind of atom, it is called an element. An element can’t be broken down into a simpler form by chemical reactions. The element oxygen is made up of only oxygen atoms. Hydrogen is made up of only hydrogen atoms. Scientists give each element its own one- or two-letter symbol.

All matter is made up of elements. Most things, including all living things, are made up of a combination of elements.

Six elements make up 99 percent of living matter—oxygen (O), carbon (C), hydrogen (H), nitrogen (N), phosphorus (P), and sulfur (S).

What are compounds?
Water is a compound made up of two elements—oxygen and hydrogen. Compounds are made up of two or more elements in set ratios. For example, the ratio of hydrogen and oxygen in water is always two hydrogen atoms to one oxygen atom. Compounds have properties different from the elements they are made of. There are two types of compounds—molecular compounds and ionic compounds.
What is a molecule?
The smallest part of a molecular compound is a molecule. A molecule is a group of atoms held together by the energy of chemical bonds. When chemical reactions occur, chemical bonds break and the atoms move around to form new bonds. The molecules formed after the reaction are different from those that began the reaction.

How do molecular compounds form?
Molecular compounds form when different atoms share their electrons that are farthest from the nucleus. Water is a molecular compound that has two hydrogen atoms and one oxygen atom. The two hydrogen atoms each share one electron on one oxygen atom. This molecular compound is shown in the figure at the right.

Water does not have the same properties as oxygen and hydrogen. Oxygen and hydrogen are gases. Yet, water can be a liquid, a solid, or a gas. When hydrogen and oxygen combine, a change occurs and a new substance forms.

What are ions?
Atoms also combine when they become negatively or positively charged. Most atoms have no electric charge. They are neutral. When an atom loses an electron, it has more protons than electrons. Protons have a positive charge so the atom becomes positively charged. When an atom gains an electron, it has more electrons than protons. This creates a negatively charged atom. These electrically charged atoms—positive or negative—are called ions.

How do ionic compounds form?
Ions of opposite charges attract each other to form neutral compounds, or compounds with the same number of protons and electrons. These neutral compounds are called ionic compounds.

Table salt is an ionic compound made up of sodium (Na) and chlorine (Cl) ions. When sodium and chlorine atoms combine, the chlorine atom gains an electron from the sodium atom. The chlorine atom becomes a negatively charged ion. The sodium atom becomes a positively charged ion. These opposite charges attract each other. The neutral ionic compound sodium chloride (NaCl) is formed.

Applying Math
3. Use Numbers Write a simple addition problem that shows how the compound water is formed.

4. Explain What are ionic compounds?
Why are ions important?

Ions are important to many life processes that take place in your body and in other organisms. For example, when you touch something hot, a message is sent from your hand to your brain to tell you to move your hand. This message travels along your nerve cells as potassium and sodium ions move in and out of the nerve cells. Ions also help move oxygen throughout your body. Some substances could not move into and out of a cell without ions.

Mixtures

Not all substances form compounds when combined together. Some substances do not change each other or combine chemically when they are put together. A mixture is a combination of substances in which individual substances keep their own properties. For example, if you combine sugar and salt, you create a mixture. No chemical reaction occurs. You simply have sugar and salt mixed together. Mixtures can be solids, liquids, gases, or any combination of them.

Most chemical reactions in living organisms take place in mixtures called solutions. A solution is a mixture in which substances are mixed evenly. Sweat is a solution of salt and water.

Living things also contain mixtures called suspensions. A suspension forms when a liquid or a gas has another substance evenly spread throughout it. Unlike solutions, the substances in a suspension eventually sink to the bottom. For example, if a blood sample is left standing, the red blood cells and white blood cells will sink to the bottom of the test tube. In your body, your heart keeps your blood moving, and the red and white blood cells stay suspended.

Organic Compounds

All compounds are classified as organic or inorganic. Rocks and other nonliving things are made up of inorganic compounds. Living things such as humans and plants are made up of organic compounds. Organic compounds always have carbon and hydrogen atoms. Some nonliving things also include organic compounds. Coal, for example, is a nonliving thing that was formed from dead and decaying plants. It contains organic compounds because the plants were once living things.
How are organic compounds organized?

Organic molecules contain many atoms that can be arranged in many different ways. Organic compounds are organized into four groups—carbohydrates, lipids, proteins, and nucleic acids. The table below describes these groups of organic compounds.

<table>
<thead>
<tr>
<th>Organic Compounds Found in Living Things</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrates</td>
</tr>
<tr>
<td><strong>Elements</strong></td>
</tr>
<tr>
<td><strong>Examples</strong></td>
</tr>
<tr>
<td><strong>Function</strong></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

What are carbohydrates?

Carbohydrates supply energy for cell processes. Cells use carbohydrates for energy. Sugars and starches are carbohydrates. Some carbohydrates also are important parts of cell structures. For example, cellulose is a carbohydrate that is an important part of plant cells.

What are lipids?

Lipids are organic compounds that do not mix with water. Fats and oils are lipids that store energy. These lipids release more energy than carbohydrates. One type of lipid, the phospholipid, is a major part of cell membranes.

Why are proteins important?

Proteins have many important jobs in living organisms. They are made up of smaller molecules called amino acids. Proteins are the building blocks of many structures in living organisms. Certain proteins called enzymes control most chemical reactions in cells.
What are nucleic acids?

Nucleic acids are large molecules that store important coded information in cells. One nucleic acid is deoxyribonucleic acid, or DNA—genetic material. DNA is found in all cells at some point in their life. It carries the information that tells the cell what to do. Ribonucleic acid, or RNA, is another nucleic acid. It makes enzymes and other proteins.

Inorganic Compounds

Most inorganic compounds are made from elements other than carbon. They usually have fewer atoms than organic molecules. Many foods you eat contain inorganic compounds. Your body needs the elements found in inorganic compounds. Water is an inorganic compound that is important to all living things.

Why is water important?

Living things are made up of more than 50 percent water and depend on water to survive. You can live for weeks without food but only a few days without water.

Some seeds and spores can exist without water. But they, like all organic compounds, need water to grow and reproduce. All chemical reactions in living things happen in water solutions. Most organisms use water to move materials throughout their bodies. For example, plants use water to move minerals and sugars between the roots and leaves. Water also helps cells keep their temperature constant.

About two-thirds of your body’s water is located in your body’s cells, as the circle graph shows. Water helps the cells keep their shapes and sizes. About one-third of your body’s water is outside the cells.
After You Read

Mini Glossary

**enzymes:** proteins that control most chemical reactions in cells

**inorganic compound:** compound that is made from elements other than carbon; compounds that make up most nonliving things

**mixture:** a combination of substances in which individual substances keep their own properties

**organic compound:** compounds that have carbon and hydrogen atoms; compounds that make up all living things

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the difference between inorganic and organic compounds.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

2. Choose one of the question headings in the Read to Learn section. Write the question in the space below. Then, write your answer to that question on the lines that follow.

Write your question here.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

3. How did underlining the main ideas help you understand what you read in this section?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Visit [life.msscience.com](http://life.msscience.com) to access your textbook, interactive games, and projects to help you learn more about the chemistry of life.
Cell Processes

section 2 Moving Cellular Materials

What You’ll Learn
- how selectively permeable membranes work
- about diffusion and osmosis
- the differences between passive transport and active transport

Before You Read

On the lines below, describe the purpose of window screens. Think of what they keep out and what they allow to pass through.

---

Read to Learn

Passive Transport

Window screens keep unwanted things, such as bugs, leaves, and birds, outside. But screens do let some things, such as air and smoke, pass through.

Cells get food, oxygen, and other substances from their environments. They release waste materials into their environments. The membrane around the cell works like a window screen works for a room. A window screen is selectively permeable (PUR mee uh bul). It lets things like air come into the room and keeps some things like bugs out of the room. A cell’s membrane also is selectively permeable. It lets some things come into or leave the cell. It also keeps other things from entering or leaving the cell.

Things move through a cell membrane in several ways. The movement depends on the size of the molecules, the path the molecules take, and whether energy is needed. When substances move through the cell membrane without using energy, this movement is known as passive transport. Three types of passive transport are diffusion, osmosis, and facilitated diffusion. The type of transport depends on what is moving through the cell membrane.
How does diffusion create equilibrium?

Molecules move constantly and randomly. You might smell perfume when you walk past someone who is wearing it. The perfume molecules move freely throughout the air. This random movement of molecules from an area where there are more of them into an area where there are fewer of them is called **diffusion**. Diffusion is a type of passive transport. Molecules will keep moving from one area to another until the number of these molecules is equal in the two areas. When this occurs, **equilibrium** is reached and diffusion stops.

All cells in your body use oxygen. Oxygen moves through your body in the red blood cells. When your heart pumps blood to your lungs, your red blood cells contain few oxygen molecules. Your lungs have many oxygen molecules. Oxygen molecules move, or diffuse, from your lungs into your red blood cells. The blood continues its journey through your body. When the blood reaches your big toe, there are more oxygen molecules in your red blood cells than in the cells of your big toe. The oxygen diffuses from your red blood cells to your big toe’s cells. The process is shown in the figure below.

**Reading Check**

1. **Determine** How does diffusion create equilibrium?

2. **Explain** Use the figure to explain to a partner how diffusion works.
3. Describe What do transport proteins do?

Some substances pass easily through the cell membrane by diffusion. Larger substances may need help passing through the cell membrane. Transport proteins in the cell membrane help these substances enter the cell. This process is called facilitated diffusion. Transport proteins are similar to the gates at a stadium. Gates are used to move people into and out of the stadium. Similarly, transport proteins are used to move substances into and out of a cell.

What is facilitated diffusion?

Some substances pass easily through the cell membrane by diffusion. Larger substances may need help passing through the cell membrane. Transport proteins in the cell membrane help these substances enter the cell. This process is called facilitated diffusion. Transport proteins are similar to the gates at a stadium. Gates are used to move people into and out of the stadium. Similarly, transport proteins are used to move substances into and out of a cell.

What is osmosis?

Remember that water makes up a large part of living matter. Water molecules move by diffusion in and out of cells. The diffusion of water through the cell membrane is called osmosis.

What happens when you do not water plants? As a plant cell loses water, its cell membrane pulls away from the cell wall. This reduces pressure against the cell wall, and the plant cell becomes limp, as shown on the left in the figure below. The plant wilts because more water leaves the plant’s cells than enters them.

When you water the plant, the water moves through the cell membranes and fills the cells with water. The plant’s cell membranes push against their cell walls, and the cells become firm, as shown on the right in the figure below.

![Diagram of osmosis](image)

The carrot stick becomes limp when more water leaves each of its cells than enters them.

Equilibrium occurs when water leaves and enters the cells at the same rate.
Osmosis in Animal Cells

Osmosis also takes place in animal cells. If animal cells were placed in pure water, they too would swell up. However, animal cells are different from plant cells. Just like an overfilled balloon, animal cells will burst if too much water enters the cell.

Active Transport

Suppose you have just left a theater at the end of a movie when you remember that you left your jacket inside. You have to move against the crowd to enter the theater and get your jacket. Which takes more energy—leaving the theater with the crowd or moving against the crowd to get back into the theater? Something similar to this happens in cells.

Active transport takes place when energy is needed to move substances through a cell membrane. For example, root cells require minerals from the soil. The root cells already have more molecules of the minerals than the surrounding soil. Normally, the mineral molecules would move out of the root into the soil until equilibrium is reached. But the root cells need to take in the minerals from the soil.

Like facilitated diffusion, active transport uses transport proteins. In active transport, transport proteins bind with the needed substance and cellular energy is used to move it through the cell membrane.

Endocytosis and Exocytosis

Some molecules are too large to move through the cell membrane by diffusion or by using transport proteins. Large protein molecules, for example, can enter a cell when they are surrounded by the cell membrane. The cell membrane folds around the molecule, completely surrounding it. The sphere created is called a vesicle. The sphere pinches off and moves the molecule into the cell. The process of taking substances into a cell by surrounding it with the cell membrane is known as endocytosis (en duh si TOH sus).

Some one-celled organisms take in food this way.

Exocytosis (ek soh si TOH sus) is the process in which the contents of a vesicle are moved outside a cell. A vesicle’s membrane joins with a cell’s membrane, and the vesicle’s contents are released. Exocytosis occurs in the opposite way that endocytosis does. Cells in your stomach use exocytosis to release chemicals that help digest food.
**After You Read**

**Mini Glossary**

**active transport:** takes place when energy is needed to move substances through a cell membrane; uses transport proteins

**diffusion:** random movement of molecules from an area where there are more of them into an area where there are fewer of them

**endocytosis (en duh si TOH sus):** process of taking substances into a cell by surrounding them with the cell's membrane

**equilibrium:** the number of molecules in two areas are the same

**exocytosis (ek soh si TOH sus):** process in which the contents of a vesicle are moved outside a cell

**osmosis:** the diffusion of water through the cell membrane

**passive transport:** movement of substances through the cell membrane without using energy

1. Review the terms and their definitions in the Mini Glossary. Choose one term that explains how substances move into and out of cells and write a sentence explaining how the process works.

2. Complete the Venn diagram below to help you compare active and passive transport.

---

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about the movement of cellular materials.
Before You Read

Describe on the lines below why you think your body needs food.

What You’ll Learn

- the differences between producers and consumers
- that photosynthesis and respiration store and release energy
- how cells get energy

Read to Learn

Trapping and Using Energy

Chemical energy is stored in food molecules. This chemical energy is changed inside cells into other forms of energy needed for life. In every cell, these changes involve chemical reactions. In fact, all of an organism’s activities involve chemical reactions. All the chemical reactions in an organism make up metabolism.

The chemical reactions of metabolism need enzymes. Enzymes cause changes, but the enzymes are not changed during the reaction and can be used again. In the figure below, an enzyme attaches to a large molecule and helps it to change. At the end of the chemical reaction, the molecule has changed into two smaller molecules, but the enzyme has not changed.

Picture This

1. Explain What happens to the enzyme during the chemical reaction?
What happens during photosynthesis?
Living things are divided into two groups—producers and consumers—based on how they obtain their food. Organisms that make their own food, such as plants, are producers. Organisms that cannot make their own food are consumers.

Plants and many other producers can convert light energy into chemical energy. Producers use a process called **photosynthesis** to change light energy from the Sun into sugars, which can be used for food. Plants and other producers that use photosynthesis are usually green because they contain a green pigment called chlorophyll (KLOOR uh fihl).

In plant cells, these pigments are found in chloroplasts. Chlorophyll is used in photosynthesis to capture light energy. Plants use chlorophyll to make sugar and oxygen (O₂) from the raw materials carbon dioxide (CO₂), water (H₂O), and light energy. Plants get their raw materials from the air, soil, and Sun. Some of the light energy is stored in the chemical bonds that hold the sugar molecules together. Enzymes also are needed for the reactions to occur. The process of photosynthesis is shown in the figure below. Review the chemical equation for photosynthesis to identify the raw materials and the results of the chemical process.
How do plants store and use carbohydrates?

Plants make more sugar during photosynthesis than they need for survival. The extra sugar is changed and then stored as starches and other carbohydrates. Plants, such as apple trees, use these carbohydrates for growth, for keeping up cells, and for reproduction.

Why is photosynthesis important to consumers?

Consumers get energy by eating producers and other consumers. No matter what food you eat, photosynthesis was involved directly or indirectly in its production. For example, an apple tree uses photosynthesis to make apples. When you eat an apple, the stored sugars help feed your body. Some cheese comes from milk, which is produced by cows that eat plants. The plants the cows eat are producers. The cows and humans are consumers.

How do you use energy?

Imagine that you get up late for school. You dress quickly and run three blocks to school. When you get to school, you feel hot and are breathing fast. Why? Your muscle cells use a lot of energy when you run. To get this energy, muscle cells break down food. Some of the energy in the food is used when you run and some of it becomes thermal energy, which is why you feel warm or hot. Most cells need oxygen to break down food. You are breathing fast because your body was working to get oxygen to your muscles.

What is respiration?

When you ran, your muscle cells were using the oxygen for the process of respiration. During respiration, chemical reactions break down food molecules into simpler substances and release stored energy. Just as in photosynthesis, enzymes are needed for the chemical reactions of respiration.

Respiration occurs in the cells of all living things. As you are reading this page, millions of cells in your body are breaking down food molecules and releasing energy. Two waste products, carbon dioxide and water, are produced during respiration. Your body gets rid of the carbon dioxide and some of the water when you breathe out, or exhale.
What is fermentation?

Even though you breathe harder when you run, your muscle cells might not receive enough oxygen for respiration. When this happens, a process in the muscle cells known as fermentation releases some of the energy stored in glucose (sugar) molecules.

Fermentation also releases energy and produces wastes. The type of wastes produced depends on the type of cell. They may be lactic acid, alcohol, and carbon dioxide. Fermentation in your muscle cells changes simple molecules into lactic acid while releasing energy, as shown in the figure below. The presence of lactic acid is why your muscles might feel stiff or sore after you have run to school.

What products come from fermentation?

Some organisms, such as bacteria, carry out fermentation and make lactic acid. Some of these organisms are used to make yogurt and some cheeses. These organisms break down a sugar in milk to release energy. The lactic acid produced causes the milk to become more solid. Some of the flavor in yogurt and cheese comes from this process.

Have you ever used yeast to make bread? Yeasts are one-celled living organisms. Fermentation in yeast cells breaks down the sugar in bread dough. The cells produce alcohol and carbon dioxide as wastes. The carbon dioxide waste is a gas that makes the bread dough rise. The alcohol is lost as the bread bakes.

---

**Picture This**

5. **Identify** What are three waste products created during fermentation?

- Lactic acid
- Carbon dioxide
- Alcohol

---

**Reading Check**

6. **Identify** What waste products come from the fermentation of yeast cells?

- Carbon dioxide
- Alcohol
How do photosynthesis and respiration work together?

Some producers make food through photosynthesis. All living things release energy stored in food through respiration or fermentation. If you think carefully about photosynthesis and respiration, you will note that what is produced by one process is used by the other process.

Photosynthesis and respiration are almost the opposite of each other. Photosynthesis produces sugars and oxygen, and respiration uses these products. The carbon dioxide and water produced during respiration are used during photosynthesis.

As you fill in the products in the figure below, review how the products of one process are the wastes of the other process. Photosynthesis and respiration cannot take place without each other. And most life would not be possible without these important chemical reactions.

Picture This

7. Illustrate In the figure below, fill in the products released by photosynthesis and respiration.
After You Read

Mini Glossary

**fermentation**: chemical reaction that releases energy stored in glucose (sugar) molecules and produces carbon dioxide, lactic acid, and alcohol as wastes

**metabolism**: all chemical reactions that take place in an organism

**photosynthesis**: process that uses light energy, carbon dioxide, and water to produce the sugars and oxygen needed by all living things

**respiration**: chemical reaction that uses oxygen and breaks down food molecules into simpler substances to release their stored energy

1. Review the terms and their definitions in the Mini Glossary. Write a short paragraph that describes how photosynthesis and respiration are related.

2. Fill in the table below to identify what is needed by each chemical reaction and what is produced by each chemical reaction.

<table>
<thead>
<tr>
<th></th>
<th>Photosynthesis</th>
<th>Respiration</th>
<th>Fermentation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What is needed?</strong></td>
<td>1.</td>
<td>1.</td>
<td>1. glucose molecules</td>
</tr>
<tr>
<td></td>
<td>2.</td>
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<tr>
<td></td>
<td>3.</td>
<td>3.</td>
<td></td>
</tr>
<tr>
<td><strong>What is produced?</strong></td>
<td>1.</td>
<td>1.</td>
<td>1.</td>
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<td>2.</td>
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<td>3.</td>
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</tr>
</tbody>
</table>

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Before You Read

List five living things on the lines below. Then write one thing that these items have in common with each other and with you.

---

What You’ll Learn

- why mitosis is important
- the steps of mitosis
- the similarities and differences between mitosis in plant and animal cells
- examples of asexual reproduction

---

Read to Learn

Why is cell division important?

All living things are made up of cells. Many organisms start as one cell. The cell divides and becomes two cells, two cells become four, four become eight, and so on. Through the process of cell division, the organism grows.

Cell division is still important after an organism stops growing. For example, every day billions of your red blood cells wear out and are replaced through cell division. During the time it takes you to read this sentence, your bone marrow produced about six million red blood cells.

Cell division is the way a one-celled organism makes another organism of its kind. When a one-celled organism reaches a certain size, it reproduces by dividing into two cells.

The Cell Cycle

Every living organism has a life cycle. A life cycle has three parts. First, the organism forms. Next, it grows and develops. Finally, the life cycle ends when the organism dies. Right now, you are in a part of your life cycle called adolescence (a doh LEH sence), which is a time of active growth and development.
How long is the life cycle of a cell?
Every cell has a life cycle. A cell's life cycle is called a cell cycle, as shown in the figure below. A cell cycle is not completed in the same amount of time in all cells. For example, the cell cycle of some human cells takes about 16 hours. The cell cycle of some plant cells takes about 19 hours. A cell cycle has three parts—interphase, mitosis, and cytoplasm division.

What is the longest part of the cell cycle?
For cells that have a nucleus, the longest part of the cell cycle is a period of growth and development called **interphase**. Cells in your body that no longer divide, such as nerve and muscle cells, are always in interphase.

During interphase, an actively dividing cell, such as a skin cell, copies its DNA and prepares for cell division. DNA is the chemical code that controls an organism's growth and operation. A copy of a cell's DNA must be made before dividing so that each of the two new cells will get a complete copy. Each cell needs a complete set of hereditary material to carry out life functions.

Mitosis

After interphase, cell division begins. Mitosis is the first step in cell division. **Mitosis** (mi TOH sus) is the process in which the cell's nucleus divides to form two nuclei. Each new nucleus is identical to the original nucleus. The steps of mitosis are called prophase, metaphase, anaphase, and telophase.
What happens to chromosomes during cell division?

A chromosome (KROH muh sohm) is a structure in the nucleus that contains DNA. During interphase, each chromosome is copied. When the nucleus is ready to divide, the two copies of each chromosome coil tightly into two thickened, identical DNA strands called chromatids (KROH muh tidz). In the figure to the right, the chromatids are held together at a place called the centromere.

**Prophase** During prophase, the chromatid pairs can be seen. The nuclear membrane breaks apart. Two small structures called centrioles (SEN tree olz) move to opposite ends of the cell. Between the centrioles, threadlike spindle fibers stretch across the cell. Animal cells have centrioles, but plant cells do not.

**Metaphase** In metaphase, the chromatid pairs line up across the center of the cell. The centromere of each pair usually becomes attached to two spindle fibers—one from each side of the cell.

**Anaphase** In anaphase, each centromere divides. The spindle fibers become shorter, and each chromatid separates from its partner. The separated chromatids begin to move to opposite ends of the cell. They are now called chromosomes.

**Telophase** The final step of mitosis is telophase. During telophase, the spindle fibers start to disappear. The chromosomes start to uncoil, and a new nucleus forms.

**How does the cytoplasm divide?**

For most cells, after the nucleus divides, the cytoplasm separates and two new cells are formed. Each new cell contains one of the new nuclei. In animal cells, the cell membrane pinches in the middle, like a balloon with a string tightened around it. The cell divides at the pinched area to form two new cells. Each new cell contains half the cytoplasm from the old cell.

After the division of the cytoplasm, most new cells begin interphase again. Use the figure on the next page to review the cell division of an animal cell.

---

Visual References:

**Picture This**

2. **Identify** Circle the place where the chromatids are held together.

3. **Explain** what happens to the centrioles during prophase.

---

**Reading Check**
5. Explain In plant cells, what divides the cytoplasm into two parts?

How do plant cells divide after mitosis?

In plant cells, a cell plate forms in the middle of the cell. The cell plate divides the cytoplasm into two parts. New cell walls form along the cell plate, and new cell membranes develop inside the cell walls.
What are the results of mitosis?

You should remember two important things about mitosis. First, mitosis is the division of a cell’s nucleus. Second, it produces two new nuclei that are identical to each other and to the original nucleus. Every cell in your body, except sex cells, has a nucleus with 46 chromosomes—23 pairs. This is because you began as one cell with 46 chromosomes in its nucleus. Skin cells, produced to replace or repair your skin, have the same 46 chromosomes as the original single cell you developed from.

The 46 chromosomes of a human cell are shown below. Notice that the last pair is labeled XY. This is the chromosome pair that determines sex. The XY label indicates a male. Females have XX chromosome pairs.

Chromosomes of a human cell

<table>
<thead>
<tr>
<th>1</th>
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<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>19</td>
<td>20</td>
<td>21</td>
<td>22 (XY)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

___ (No. of chromosome pairs) × 2 = ___ (No. of chromosomes)

Each of the trillions of cells in your body, except sex cells, has a copy of the same DNA. All of your cells, however, use different parts of the DNA to become different types of cells. Skin cells and blood cells contain a copy of the same DNA. They use different parts of the DNA to perform their different functions.

Cell division allows growth and replaces worn out or damaged cells. You are much larger than you were when you were a baby. This is possible because of cell division. If you cut yourself, the wound heals because cell division replaces damaged cells.

7. **Explain** What is the purpose of cell division?

___

___

_✅_ Reading Check
Asexual Reproduction

The way an organism produces others of its kind is called reproduction. Among living organisms, there are two types of reproduction—sexual and asexual. Sexual reproduction usually involves two parent organisms. In asexual reproduction, a new organism (sometimes more than one) is produced from only one parent organism. The new organism has the same DNA as the parent. New strawberry plants can be reproduced asexually from horizontal stems called runners. The figure below shows the asexual reproduction of a strawberry plant.

How do cells divide using fission?

Remember, mitosis involves the division of a nucleus. Bacteria do not have a nucleus, so they can not use mitosis. Instead, bacteria reproduce asexually by a process called fission. During fission, a bacteria cell’s DNA is copied. The cell then divides into two identical organisms. Each new organism has a complete copy of the parent organism’s DNA.

How do organisms reproduce using budding?

Budding is a type of asexual reproduction in which a new organism grows from the body of the parent. When the bud on the adult becomes large enough, it breaks away to live on its own.

How do some organisms regrow body parts?

Some organisms, such as sponges and sea stars, can regrow damaged or lost body parts. The process that uses cell division to regrow body parts is called regeneration. If a sea star breaks into pieces, a whole new organism can grow from each piece.
After You Read

**Mini Glossary**

- **asexual reproduction**: the way a new organism is produced from one organism
- **chromosome (KROH muh sohm)**: a structure in the nucleus that contains hereditary material
- **mitosis (mi TOH sus)**: the process in which the nucleus divides to form two identical nuclei; the four steps include prophase, metaphase, anaphase, telophase

1. Review the terms and their definitions in the Mini Glossary. Write a sentence to explain mitosis using a skin cell as an example.

2. Complete the Venn diagram below to help you compare mitosis in plant and animal cells. Write one similarity at each phase in the overlapping area.

![Venn diagram](image)

ScienceOnline Visit [life.msscience.com](http://life.msscience.com) to access your textbook, interactive games, and projects to help you learn more about cell division and mitosis.
Cell Reproduction

section 2 Sexual Reproduction and Meiosis

What You’ll Learn
- the stages of meiosis
- how sex cells are produced
- why meiosis is needed for sexual reproduction
- the names of the cells involved in fertilization
- how fertilization occurs in sexual reproduction

Before You Read
On the lines below, explain what makes you different from anyone else in your class.

Read to Learn

Sexual Reproduction

A new organism can be produced through sexual reproduction. During sexual reproduction, two sex cells, sometimes called a sperm and an egg, come together. Usually the sperm and the egg come from two different organisms of the same species.

Sex cells are formed in reproductive organs. The male reproductive organ forms sperm. The female reproductive organ forms eggs. The joining of a sperm and an egg is called fertilization. The cell that forms from fertilization is called a zygote (ZI goht).

What two types of cells does your body make?

Your body makes body cells and sex cells. Body cells form your brain, skin, bones, and other tissues and organs. A human body cell usually has 46 chromosomes. Each chromosome has a mate that is similar in size and shape and has similar DNA, or hereditary information. This means that a body cell has 23 pairs of similar chromosomes. Cells that have pairs of similar chromosomes are called diploid (DIH ployd) cells.
What are haploid cells?
A sex cell has half the number of chromosomes found in a body cell, or 23 chromosomes. A sex cell has only one chromosome from each pair. A cell that does not have pairs of chromosomes is called a **haploid** (HA ployd) cell.

**Meiosis and Sex Cells**
A process called **meiosis** (mi OH sus) produces haploid sex cells. During meiosis, two divisions of the nucleus occur. These divisions are called meiosis I and meiosis II. The steps of each division of meiosis are named like the steps in mitosis—prophase, metaphase, anaphase, and telophase. The figure below shows what happens during meiosis I.

**What happens to a cell during meiosis I?**
Before meiosis begins, each chromosome is copied. When the cell is ready for meiosis, the two copies of each chromosome can be seen under a microscope as two chromatids. Follow the steps in meiosis I in the figure above. Notice that in prophase I, each pair of duplicated chromosomes comes together.

In metaphase I, the pairs of duplicated chromosomes line up in the center of the cell. As you can see, the centromere of each chromatid pair attaches to one spindle fiber.

In anaphase I, the two copies of the same chromosome, the chromatids, move away from each other to opposite ends of the cell. Notice that each duplicated chromosome still has two chromatids.

In telophase I, the cytoplasm divides and two new cells form. Each new cell has one duplicated chromosome from each similar pair.

**Picture This**
1. Identify How many cells form in meiosis I?

**Reading Check**
2. Explain What happens in a cell before meiosis I begins?
4. Explain What is the usual result of too many or too few chromosomes?

3. Explain how metaphase I and metaphase II differ.

What happens in meiosis II?

The two cells that formed in meiosis I now begin meiosis II. Follow the steps in meiosis II in the figure below. As you can see in prophase II, the duplicated chromosomes and spindle fibers reappear in each new cell.

In metaphase II, the duplicated chromosomes move to the center of each cell. The centromere of each chromatid pair attaches to two spindle fibers.

In anaphase II, the centromere in each cell divides. Then the chromatids separate and move to opposite ends of each cell. Each chromatid becomes an individual chromosome.

In telophase II, the spindle fibers disappear, and a nuclear membrane forms around the chromosomes at each end of the cell. When meiosis II is finished, the cytoplasm of each cell divides.

What is the final result of meiosis?

During meiosis I, one cell divides into two cells. During meiosis II, those two cells divide. When meiosis II ends, there are four sex cells. Each sex cell has 23 unpaired chromosomes. This is one-half the number of chromosomes that were in the original nucleus—46 chromosomes.

What can go wrong in meiosis?

Mistakes sometimes occur during meiosis. These mistakes can produce sex cells with too many or too few chromosomes. Zygotes, cells that form from fertilized eggs, produced from these sex cells sometimes die. If the zygote lives, every cell that grows from the zygote will have the wrong number of chromosomes. Organisms with the wrong number of chromosomes usually do not grow normally.
**After You Read**

**Mini Glossary**

- **diploid (DIH ployd):** cells that have pairs of similar chromosomes
- **egg:** sex cell formed in the female reproductive organs
- **fertilization:** the joining of a sperm and an egg
- **haploid (HA ployd):** cells that do not have pairs of chromosomes, such as sex cells
- **meiosis (mi OH sis):** a process that produces haploid sex cells
- **sexual reproduction:** two sex cells come together to produce a new organism
- **sperm:** sex cell formed in the male reproductive organs
- **zygote (ZI goht):** the cell that forms from fertilization

1. Review the terms and their definitions in the Mini Glossary. Choose the terms that explain the process of sexual reproduction and write one or two sentences explaining how the process works.

2. Complete the graphic organizer below to label the steps that occur during meiosis I and meiosis II.

   - **Meiosis I**
     - [Diagram]
     - [Diagram]
     - [Diagram]
     - [Diagram]

   - **Meiosis II**
     - [Diagram]
     - [Diagram]
     - [Diagram]
     - [Diagram]

3. How do your journal entries help you understand sexual reproduction and meiosis?

   - [Response]

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about sexual reproduction and meiosis.
What You’ll Learn

- the parts of a DNA molecule and its structure
- how DNA copies itself
- the structure and role of each kind of RNA

Before You Read

Write on the lines below how police departments use DNA to solve crimes.

Read to Learn

What is DNA?

Before you could learn to read, you learned the alphabet. The letters of the alphabet are a code you needed to know before you could read. A cell also uses a code. That code contains information for an organism’s growth and function. It is stored in a cell’s hereditary material. The code is a chemical called deoxyribonucleic (dee AHK sih ri boh noo klay ihk) acid, or DNA. The figure to the right shows the spiral-shaped structure of DNA.

When a cell divides, the DNA code is copied and passed to the new cells. New cells get the same DNA code that was in the original cell. Every cell that has ever been formed in your body or in any organism has DNA.

Picture This

1. Infer

Examine the DNA strand in the figure. What do the letters “P” and “S” represent?
What does DNA look like?
In 1952, scientist Rosalind Franklin discovered that DNA is two chains of molecules. As you can see in the figure on the previous page, DNA looks like a twisted ladder. Each side of the ladder is made up of sugar-phosphate molecules. The sugar in each molecule is called deoxyribose (dee AHK sih ri bohs). In 1953, scientists James Watson and Francis Crick made a model of a DNA molecule.

What are the four nitrogen molecules that make up DNA?
The rungs, or steps, of the DNA ladder are made up of molecules called nitrogen bases. The four kinds of nitrogen bases found in DNA are adenine (A duh neen), guanine (GWAH neen), cytosine (SI tuh seen), and thymine (THI meen). In the DNA model on the previous page, the first letters of the name of each base, A, G, C, and T, are used to stand for the bases. Also notice that adenine (A) always pairs with thymine (T), and guanine (G) always pairs with cytosine (C).

How is DNA copied?
When chromosomes are copied before mitosis or meiosis, the amount of DNA in the nucleus is doubled. The figure below shows how the DNA copies itself. The two sides of DNA unwind and separate. Each side then becomes a pattern on which a new side can form. The new DNA pattern is exactly the same as the original DNA pattern.

Picture This
3. Determine Write one quiz question in the space below based on one of the steps in this figure.

2. Identify What did Rosalind Franklin discover?

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Genes

What color are your eyes? How tall are you? The answers to questions like these depend on the kinds of proteins your cells make. Proteins build cells and tissues or work as enzymes. The instructions for making certain proteins are found in genes. A gene is a section of DNA on a chromosome. Each chromosome has hundreds of genes.

What are proteins?

Proteins build cells and tissues. Proteins are made of chains of many amino acids. The gene decides the order of amino acids in a protein. Changing the order of the amino acids makes a different protein. Genes are found in the nucleus, but proteins are made on ribosomes in cytoplasm.

What is RNA?

The codes for making proteins are carried from the nucleus to the ribosomes by ribonucleic acid, or RNA. RNA is made in the nucleus on a DNA pattern, but it is different from DNA. Look at the model of an RNA molecule below. Notice that RNA is like a ladder with its rungs sawed in half. Like DNA, RNA has the bases A, G, and C. But it has the base uracil (U) instead of thymine (T). The sugar-phosphate molecules in RNA contain the sugar ribose.
What does RNA do?

There are three main kinds of RNA made from DNA in a cell’s nucleus. They are messenger RNA (mRNA), ribosomal RNA (rRNA), and transfer RNA (tRNA). Protein is made when mRNA moves into the cytoplasm. In the cytoplasm, ribosomes, which are made of rRNA, attach to the mRNA. The ribosomes get amino acids from tRNA molecules that are already in the cytoplasm. Inside the ribosomes, three nitrogen bases on the mRNA temporarily match with three nitrogen bases on the tRNA. The same thing happens for the mRNA and another tRNA molecule. The amino acids that are attached to the two tRNA molecules connect. This is the beginning of a protein.

How do cells control genes?

Even though most cells in an organism have exactly the same genes, they do not make the same proteins. Each cell uses only the genes that make the proteins that it needs. For example, muscle proteins are made in muscle cells but not in nerve cells.

Cells control genes by turning some genes off and turning other genes on. Sometimes the DNA is twisted so tightly that no RNA can be made. Other times, chemicals attach to DNA so that it cannot be used.

Mutations

If DNA is not copied exactly, proteins may not be made correctly. These mistakes, called mutations, are permanent changes in the DNA sequence of a gene or chromosome.

What are the results of a mutation?

An organism with a mutation may not be able to grow, repair, or maintain itself. A mutation in a body cell may or may not cause problems for the organism. A mutation in a sex cell, however, makes changes to the species when the organism reproduces. Many mutations are harmful to organisms, often causing their death. Some mutations have no effect on an organism. Other mutations can be helpful to an organism.
**After You Read**

**Mini Glossary**

- **DNA:** a chemical in a cell that contains information for an organism’s growth and function
- **Gene:** a section of DNA on a chromosome that contains the instructions for making a specific protein
- **Mutations:** any permanent change in the DNA sequence of a gene or chromosome of a cell
- **RNA:** a nucleic acid that carries the codes for making proteins from the nucleus to the ribosomes

1. Review the terms and their definitions in the Mini Glossary. Write a short paragraph that contrasts DNA and RNA.

2. Moving from left to right, write the letters (A, T, C, or G) in the empty circles of the bases that will pair with the bases on the top strand to this DNA molecule. The first three pairs have been created for you.

---

**ScienceOnline** Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about DNA.
Heredity

section Genetics

Before You Read
Think of a parent and a child that you know. On the lines below, list four ways the child looks like the parent.

What You’ll Learn
- how traits are inherited
- Mendel’s role in the history of genetics
- how to use a Punnett square
- the difference between genotype and phenotype

Read to Learn

Inheriting Traits
Do you look more like one parent or grandparent? Do you have your father’s eyes? Eye color, nose shape, and many other physical features are traits. Traits also include things that cannot be seen, such as your blood type. An organism is a collection of traits, all inherited from its parents.

Heredity (huh REH duh tee) is the passing of traits from parent to offspring, or children.

What is genetics?
Usually, genes on chromosomes control an organism’s shape and function. The different forms of a trait that a gene may have are called alleles (uh LEELZ). When a pair of chromosomes separates during meiosis (mi OH sus), alleles for each trait also separate into different sex cells. As a result, every sex cell has one allele for each trait, as shown in the figure on the next page. The allele in one sex cell may control one form of the trait, such as dimples. The allele in another sex cell may control a different form of the trait, such as no dimples. The study of how traits are inherited through the interactions of alleles is called genetics (juh NE ihks).

Create a Vocabulary Quiz
Write a question about each vocabulary word or term in the section. Exchange quizzes with another student. Together discuss the answers to the quizzes.

1. Define the word genetics.

Reading Check
Mendel—the Father of Genetics

Did you know that an experiment with pea plants helped scientists understand why your eyes are the color they are? Gregor Mendel was an Austrian monk who studied mathematics and science. His job at the monastery where he lived was gardening. His interest in plants began as a boy in his father’s orchards. He learned to predict the possible types of flowers and fruits that would result from crossbreeding plants.

In 1856, Mendel began experimenting with garden peas. He wanted to know the connection between the color of a pea flower and the type of seed the plant produced. Before Mendel, scientists relied on observation and description. They often studied many traits at one time. This made it hard to develop good hypotheses about how traits are inherited. Mendel used scientific methods in his study. Mendel was the first person to trace one trait through many generations. He was the first person to record the study of how traits pass from one generation to another. He was also the first person to use the mathematics of probability to explain heredity.

In 1900, three plant scientists repeated Mendel’s experiments and reached the same conclusions as Mendel. For this reason, Mendel is known as the father of genetics.
Genetics in a Garden

When Mendel studied a trait, he crossed two plants with different forms of the trait. He found that the new plants all looked like one of the two parents. Mendel called each new plant a hybrid (HI brud) because it received different genetic information, or different alleles, for a trait from each parent.

What is a purebred?

Garden peas are easy to breed for pure traits. An organism that always produces the same traits, generation after generation, is called a purebred. For example, plants can be purebred for the trait of tall height. The table below shows the pea plant traits that Mendel studied.

What are dominant and recessive factors?

In nature, insects carry pollen as they move from plant to plant. The pollination by insects is random. In his experiments, Mendel pollinated the plants by hand to control the results. He used pollen from the flowers of purebred tall plants to pollinate the flowers of purebred short plants. This process is called cross-pollination. He found that tall plants crossed with short plants produced seeds that produced all tall plants. Mendel called the tall form the dominant (DAH muh nunt) factor because it dominated, or covered up, the short form. He called the short form the recessive (rih SE sihv) factor because this form seemed to disappear. Today, these factors are called dominant alleles and recessive alleles.
What is probability?
A branch of mathematics that helps you predict the chance that something will happen is called probability. For example, there are two sides to a coin. If you toss the coin in the air, the probability that one side of the coin will land facing up is one out of two, or 50 percent. Mendel used probabilities in his study of genetics. His predictions were very accurate because he studied large numbers of plants over a long period of time. He studied almost 30,000 pea plants over a period of eight years. This increased Mendel's chances of seeing a repeatable pattern. Valid scientific conclusions need to be based on results that can be repeated.

What is a Punnett square?
Scientists use a tool called a Punnett (PUH nut) square to predict results in genetics. A Punnett square is used to predict the number of times certain traits will occur. In a Punnett square, letters stand for dominant and recessive alleles. An uppercase letter stands for a dominant allele, and a lowercase letter stands for a recessive allele. The letters are a form of code. They show the genotype (JEE nuh tipe), or genetic makeup, of an organism. The way an organism looks and behaves as a result of its genotype is its phenotype (FEE nuh tipe). If you have brown hair, the phenotype for your hair color is brown.

How do alleles determine traits?
Most cells in your body have two alleles for every trait. An organism with two alleles that are the same is called homozygous (hoh muh ZI gus). In his experiments, Mendel would have written TT (homozygous for the tall-dominant trait) or tt (homozygous for the short-recessive trait). An organism that has two different alleles for a trait is called heterozygous (he tuh roh ZI gus). Mendel would have written Tt for plant hybrids that were heterozygous for height.

How do you make a Punnett square?
The letters representing the two alleles from one parent are written in the top row of the Punnett square. The letters representing the two alleles from the other parent are written down the left column. Each square in the grid is then filled in with one allele from each parent. The combinations of letters in the completed Punnett square are the genotypes of the possible offspring those parents could produce.
How do you use a Punnett square?

You want to know the possible offspring of two dogs. One dog carries heterozygous black-fur traits (Bb). The other dog carries homogeneous blond-fur traits (bb). How do you complete the Punnett square to find the results? Follow the steps in the figure above.

1. Write the letters representing the alleles from the black dog (Bb) in the top row. Write the letters from the blond dog (bb) in the left column.
2. Write the letter in each column (B or b) in the two squares for that column.
3. Add the letter for each row (b or b) to the squares. You then have two letters in each square.
4. The squares show the possible genotypes of the offspring.

An offspring with a Bb genotype will have black fur, and an offspring with a bb genotype will have blond fur. In this case, there is one chance in two, or a 50 percent chance, that the offspring will have black fur.

What are the main principles of heredity?

Mendel spent many years repeating his experiments and observing the results. He analyzed the results and reached several conclusions. Mendel’s principles of heredity are summarized in the table below.

<table>
<thead>
<tr>
<th>Mendel’s Principles of Heredity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traits are controlled by alleles on chromosomes.</td>
</tr>
<tr>
<td>An allele’s effect is dominant or recessive.</td>
</tr>
<tr>
<td>When a pair of chromosomes separates during meiosis, the different alleles for a trait move into separate sex cells.</td>
</tr>
</tbody>
</table>
After You Read

Mini Glossary

alleles (uh LEELZ): the different forms of a trait that a gene may have

dominant (DAH muh nunt): factor that dominates, or covers up, another factor

genetics (juh NE tihks): the study of how traits are inherited through the interactions of alleles

genotype (JEE nuh tipe): genetic makeup of an organism

heredity (huh REH duh tee): passing of traits from parent to offspring

heterozygous (he tuh roh ZI gus): an organism that has two different alleles for a trait

homozygous (hoh muh ZI gus): an organism with two alleles that are the same for a trait

hybrid (HI brud): a plant that receives different genetic information for a trait from each parent

phenotype (FEE nuh tipe): the way an organism looks and behaves as a result of its genotype

Punnett (PUH nut) square: a tool used to predict the number of times certain traits will occur

recessive (rih SE sihv): factor that disappears if a dominant trait is present

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the difference between a dominant allele and a recessive allele.

2. Complete the Punnett square below to show the probability of an offspring having the \(DD, Dd,\) and the \(dd\) genotypes.

\[
\begin{array}{c|c}
\text{D} & \text{d} \\
\hline
\text{D} & \text{Dd} \text{ or } \text{Dd} \\
\text{d} & \text{dd} \text{ or } \text{dd}
\end{array}
\]

3. How can taking a quiz that another student wrote help you prepare for a test?
Before You Read

At dog and cat shows, an animal’s owner may be asked to show its pedigree. What do you think a pedigree shows?

What You’ll Learn

■ how traits are inherited by incomplete dominance
■ the difference between multiple alleles and polygenic inheritance
■ how sex-linked traits are passed to offspring

Read to Learn

Incomplete Dominance

A scientist crossed purebred red four-o’clock plants with purebred white four-o’clock plants. He thought the new plants would have all red flowers, but they were pink. Neither allele for flower color was dominant. Next, he crossed the pink-flowered plants with each other. The new plants had red, white, and pink flowers.

He discovered that when the allele for red flowers and the allele for white flowers combined, the result included red flowers, white flowers, and an intermediate, or in-between, phenotype—pink flowers. When the offspring of two homozygous parents show an intermediate phenotype, this inheritance is called incomplete dominance.

What are multiple alleles?

A trait that is controlled by more than two alleles is said to be controlled by multiple alleles. A trait controlled by multiple alleles will produce more than three phenotypes of that trait.
What traits are controlled by multiple alleles?

Blood type in humans is an example of a trait controlled by multiple alleles. The alleles for blood type produce six genotypes but only four phenotypes. The alleles for blood type are called A, B, and O. The O allele is recessive to both the A and B alleles. When a person inherits one A allele and one B allele, his or her phenotype is AB. A person with phenotype A blood has the genotype AA or AO. Someone with the phenotype B blood has the genotype BB or BO. A person with phenotype O blood has the genotype OO.

Polygenic Inheritance

Eye color is an example of a trait that is produced by a combination of many genes, or polygenic (pah lih JEH nihk) inheritance. Polygenic inheritance occurs when a group of gene pairs acts together to produce a trait. Polygenic inheritance results in a wide variety of phenotypes. Examine the eye colors of your classmates. You will likely notice many different shades. For example, you may notice several shades of brown, several shades of green, and so on.

How does the environment affect your genes?

Your environment plays a role in how some of your genes are expressed. Genes can be influenced by an organism’s internal or external environment. For example, most male birds are more brightly colored than females. Chemicals in their bodies determine whether or not the gene for brightly colored feathers is expressed.

Your environment plays a role in whether your genes are expressed at all. For example, some people have genes that make them at risk for developing skin cancer. Whether or not they get cancer might depend on external environmental factors. If people who are at risk for skin cancer limit their time in the sun and take care of their skin, they may never develop skin cancer.

Human Genes and Mutations

Sometimes genes change. Also, sometimes errors occur in the DNA when it is being copied during cell division. These changes and errors are called mutations. Many mutations are harmful. Some mutations are helpful or have no effect on an organism. Certain chemicals, X rays, and radioactive materials can cause mutations.
What are chromosome disorders?

Problems can happen if the incorrect number of chromosomes is inherited. Mistakes in the process of meiosis can result in an organism with more or fewer chromosomes than normal. Down’s syndrome is a disorder in which the person has one more chromosome than normal.

Recessive Genetic Disorders

Many human genetic disorders are caused by recessive genes. Such genetic disorders occur when both parents have a recessive allele responsible for the disorder. Because the parents are heterozygous, they do not show any symptoms of the disorder. However, if each parent passes a recessive allele to the child, the child inherits two recessive alleles and will have the disorder. Cystic fibrosis is a homozygous recessive disorder. It is the most common genetic disorder that can lead to death among Caucasian Americans. People with cystic fibrosis produce thicker mucus than normal. The thick mucus builds up in the lungs and makes it hard to breathe.

Sex Determination

Each egg produced by a female normally contains one X chromosome. Males produce sperm that normally have either one X or one Y chromosome. When a sperm with an X chromosome fertilizes an egg, the offspring is a female, XX. When a sperm with a Y chromosome fertilizes an egg, the offspring is a male, XY. Sometimes chromosomes do not separate during meiosis. When this happens, a person can inherit an unusual number of sex chromosomes.

Sex-Linked Disorders

Some inherited conditions are linked with the X and Y chromosomes. An allele inherited on a sex chromosome is called a sex-linked gene. Color blindness is a sex-linked disorder in which people cannot tell the difference between certain colors. The color-blind trait is a recessive allele on the X chromosome. Because males have only one X chromosome, a male with this recessive allele on his X chromosome is color-blind. However, a color-blind female occurs only when both of her X chromosomes have the allele for this trait.

Reading Check

3. Explain How is cystic fibrosis inherited?

4. Identify What is one sex-linked disorder?
Pedigrees Trace Traits

You can trace a trait through a family using a pedigree like the one shown below. Males are represented by squares. Females are represented by circles. A completely filled square or circle shows that the person has the trait. A half-colored square or circle shows that the person carries an allele for the trait, but does not have the trait. The pedigree in the figure below shows how the trait for color blindness is carried through a family. In this pedigree, the grandfather was color blind. He married a woman who did not carry the color-blind allele.

Picture This

5. Infer In the pedigree, why are there no color-blind women in this family?

Think it Over

6. Draw Conclusions

Why do you think pedigrees are important for animals bred for show, such as dogs?

How can pedigrees be helpful?

A pedigree can be used by a geneticist to trace a trait in members of a family over several generations. The pedigree allows the geneticist to determine the trait’s pattern of inheritance. The geneticist can identify if the trait is recessive, dominant, sex-linked, or follows some other pattern. Geneticists use this information to predict the probability that a baby will be born with a specific trait.

Pedigrees also are used to breed animals and plants for desirable traits. Livestock and plant crops are food sources for humans. Using pedigrees, these organisms can be bred to increase their yield and nutritional content.
After You Read

Mini Glossary

incomplete dominance: the offspring of two homozygous parents show an intermediate phenotype

polygenic (pah lih JEH nihk) inheritance: a group of gene pairs act together to produce a trait

sex-linked gene: an allele inherited on a sex chromosome

1. Review the terms and their definitions in the Mini Glossary. Choose one term and use it to explain one way that traits can be inherited.

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

2. Choose one of the question headings in the Read to Learn section. Write the question in the space below. Then write your answer to that question on the lines that follow.

Write your question here.

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

3. List the words that you circled in the Read to Learn section. Select one of those words and write its definition below.

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about genetics since Mendel.
What You’ll Learn

- the importance of advances in genetics
- the steps in making genetically engineered organisms

Before You Read

Describe on the lines below what you have heard or read about recent advances in medical research.

Read to Learn

Why is genetics important?

New developments in genetic research are happening all the time. The principles of heredity are being used to change the world.

Genetic Engineering

Genetic engineering is the use of biological and chemical methods to change the arrangement of DNA that makes up a gene. One use for genetic engineering is to produce large amounts of different medicines. Genes also can be inserted into cells to change how those cells perform their normal functions. Genetic engineering researchers are also looking for new ways to improve crop production and quality.

How is recombinant DNA made?

Making recombinant DNA is one method of genetic engineering. Recombinant DNA is made by inserting a useful section of DNA from one organism into a bacterium. This process is used to make large amounts of insulin, which is used to treat diabetes. Other uses include the production of a growth hormone to treat dwarfism and chemicals used to treat cancer.
How does gene therapy work?

Gene therapy is another kind of genetic engineering. It is used to replace abnormal alleles. In gene therapy, a normal allele is placed in a virus, as shown in the figure below. The virus then delivers the normal allele when it infects the target cell. The normal allele replaces the abnormal one. Scientists are conducting experiments that use gene therapy to test ways of controlling cystic fibrosis and some kinds of cancer. With continued research, gene therapy may be used to cure genetic disorders in the future.

How are plants genetically engineered?

Before people knew about genotypes, they selected plants with the most desired traits to breed for the next generation. This process is called selective breeding. Today people also use genetic engineering to improve crop plants. One method is to find the genes that produce desired traits in one plant and then insert those genes into a different plant. Scientists recently made genetically engineered tomatoes with a gene that allows them to be picked green. As these tomatoes are being sent to stores, they continue to ripen. You can then buy ripe, firm tomatoes in the store. The long-term effects of eating genetically engineered plants are not known.
After You Read

Mini Glossary

**genetic engineering**: biological and chemical methods to change the arrangement of DNA that makes up a gene

1. Review the term and its definition in the Mini Glossary. Write a sentence that explains how genetic engineering can improve crop plants.

2. Complete the concept web below to show three kinds of genetic engineering and the methods used to carry them out.

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Visit [life.msscience.com](http://life.msscience.com) to access your textbook, interactive games, and projects to help you learn more about advances in genetics.

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Adaptations over Time

section 6 Ideas About Evolution

Before You Read
In what ways are you like your parents or other relatives?

Read to Learn

Early Models of Evolution
There are millions of species of plants, animals, and other organisms living on Earth today. A species is a group of organisms that share similar characteristics and can reproduce among themselves to produce fertile offspring. The characteristics of a species that are passed from parent to offspring are called inherited characteristics. Change in these inherited characteristics over time is evolution.

What was Lamarck’s hypothesis?
In 1809, Jean Baptiste de Lamarck proposed a hypothesis to explain how species change over time. He said that characteristics, or traits, that a parent organism develops during its lifetime are inherited by its offspring. Lamarck’s hypothesis is called the inheritance of acquired characteristics. According to Lamarck’s hypothesis, if a parent develops large muscles through exercise or hard work, the trait of large muscles would be passed on to the offspring. Scientists tested Lamarck’s hypothesis by collecting data on traits that are passed from parent to offspring. The data did not support Lamarck’s hypothesis.
Darwin’s Model of Evolution

In 1831, Charles Darwin set out on a journey from England that took him to the Galápagos Islands. The Galápagos Islands, shown on the map below, are off the coast of Ecuador. Darwin was amazed by the variety of life he saw on these islands. He hypothesized that plants and animals living on the Galápagos Islands originally came from Central and South America. He noted that the species on the islands were similar in many ways to the species he had seen on the mainland. However, Darwin observed different traits in many species on the islands as well. Darwin studied several species and developed hypotheses to explain the differences in traits he observed.

What did Darwin observe?

Darwin observed 13 species of finches on the Galápagos Islands. He noticed that all 13 species were similar except for three characteristics—body size, beak shape, and eating habits. Darwin concluded that the different species of finches must have had to compete with each other for food. Finches that had beak shapes that allowed them to eat available food survived longer and had more offspring than finches without those kinds of beak shapes. After many generations, these groups of finches became separate species.

Darwin observed that the beak shape of each species of Galápagos finch is related to its eating habits. Darwin observed finches that ate nuts and seeds. Their beaks were short and strong for breaking hard shells. He observed finches that fed on insects. They had long, narrow beaks for finding the insects beneath tree bark.
Natural Selection

In the mid-1800s, Darwin developed a theory of evolution that is accepted by most scientists today. He described his ideas in a book called *On the Origin of Species.*

What was Darwin’s theory?

Darwin’s theory became known as the theory of evolution by natural selection. **Natural selection** means that organisms with traits best suited to their environment are more likely to survive and reproduce. Their traits are passed to more offspring. The principles of natural selection are shown in the table below.

<table>
<thead>
<tr>
<th>The Principles of Natural Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Organisms produce more offspring than can survive.</td>
</tr>
<tr>
<td>2. Differences, or variations, occur among individuals of a species.</td>
</tr>
<tr>
<td>3. Some variations are passed to offspring.</td>
</tr>
<tr>
<td>4. Some variations are helpful. Individuals with helpful variations are better able to survive and reproduce.</td>
</tr>
<tr>
<td>5. Over time, the offspring of individuals with helpful variations increase and become a larger percentage of the population. Eventually, they may become a separate species.</td>
</tr>
</tbody>
</table>

Variation and Adaptation

Darwin’s theory of evolution by natural selection focuses on the variations of species’ members. A **variation** is an inherited trait that makes an individual organism different from other members of its species. Variations happen when there are permanent changes, or mutations, in an organism’s genes. Some mutations produce small variations, such as differences in the shape of human hairlines. Other mutations produce large variations, such as fruit without seeds. Over time, more and more members of a species might inherit these variations. If individuals with these variations continue to survive and reproduce over time, a new species can evolve.

Some variations are more helpful than others. An **adaptation** is any variation that makes an organism better suited to its environment. Adaptations can include an organism’s color, shape, behavior, or chemical makeup. Camouflage (KA muh flahj) is an adaptation. An organism that is camouflaged can blend into its environment. Camouflage makes it easier for the organism to hide, increasing the chances that it will survive and reproduce.
How do changes in genes affect species?

Over time, changes in the genes of a species might change the appearance of the species. As the inherited traits of a species of seed-eating Galápagos finch changed, so did the size and shape of its beak. Environmental conditions can help bring about these changes. When individuals of the same species move into an area, they bring genes and variations. When they move out of an area, they remove their genes and variations. Suppose a family from a different country moves to your neighborhood. They might bring different foods, customs, and ways of speaking. In a similar way, when new individuals enter an existing population, they can bring different genes and variations.

Does geographic isolation affect evolution?

Sometimes geologic features such as mountains or lakes can separate a group of individuals from all the other members of the population. Over time, variations that are not found in the larger population might become common in the smaller, separate population. Also, gene mutations could add variations to the smaller population. After many generations, the two populations can become so different that they can no longer breed with each other. They become two different species. For example, Portuguese sailors brought European rabbits to the Canary Islands. European rabbits feed during the day and grow fairly large. In order to survive the warm temperatures of the Canary Islands, the European rabbits, over many generations, developed large eyes and fed at night. The Canary Island rabbits eventually became a separate species.

The Speed of Evolution

Scientists do not agree on how quickly evolution happens. Some hypothesize that it happens slowly, over hundreds of millions of years. Others hypothesize that it can happen quickly. Most scientists agree that there is evidence to support both hypotheses.

What is gradualism?

Darwin hypothesized that evolution happens slowly. His hypothesis is called gradualism. **Gradualism** is a hypothesis that describes evolution as a slow, continuing process in which one species changes to a new species over millions or hundreds of millions of years.
What is punctuated equilibrium?

Gradualism does not explain the evolution of all species. For some species, fossil records show that one species suddenly changes into another. **Punctuated equilibrium** is a hypothesis that describes evolution as a rapid process in which one species changes suddenly to a new species. Rapid evolution happens when the mutation of a few genes results in a new species over a fairly short period of time. The figure below shows how punctuated equilibrium describes the evolution of the brown bear.

![Hypothesized Evolution of the Brown Bear](image_url)

**Is punctuated equilibrium happening today?**

Evolution by punctuated equilibrium can happen over a few thousand or hundreds of thousands of years. Sometimes, evolution can happen even faster than that. For example, many species of bacteria have changed into new species in only a few decades. Many disease-causing bacteria species were once easily killed by the antibiotic penicillin. Some of these species are no longer harmed by penicillin. These bacteria have become resistant to penicillin.

These penicillin-resistant bacteria evolved quickly. The bacteria changed because some individuals had variations that allowed them to survive even when exposed to penicillin. Other individuals could not survive. The bacteria that had the penicillin-resistant variation survived to reproduce and pass this trait to their offspring. Over a period of time, all of the bacteria in the population had the variation for penicillin resistance.

**Picture This**

7. **Identify** Circle the name of the common ancestor of the giant panda and the brown bear.

8. **Analyze** What allowed some bacteria to survive while other bacteria were killed by penicillin?
After You Read

Mini Glossary

adaptation: any variation that makes an organism better suited to its environment

evolution: change in inherited characteristics over time

gradualism: hypothesis that describes evolution as a slow, ongoing process by which one species changes to a new species

natural selection: theory that states that organisms with traits best suited to their environment are more likely to survive and reproduce

punctuated equilibrium: hypothesis that says rapid evolution comes about when the mutation of a few genes results in the appearance of a new species over a relatively short period of time

species: group of organisms that share similar characteristics and can reproduce among themselves to produce fertile offspring

variation: inherited trait that makes an individual different from other members of its species

---

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that describes a variation that helps an organism survive.

---

2. Complete the chart below to explain the models of evolution listed in the chart.

<table>
<thead>
<tr>
<th>Theory or Model</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothesis of acquired characteristics</td>
<td></td>
</tr>
<tr>
<td>Theory of evolution by natural selection</td>
<td></td>
</tr>
<tr>
<td>Gradualism</td>
<td></td>
</tr>
<tr>
<td>Punctuated equilibrium</td>
<td></td>
</tr>
</tbody>
</table>

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Adaptations over Time

section 2 Clues About Evolution

Before You Read
Have you ever seen a fossil? On the lines below, tell what kind of fossil it was and where you saw it.

What You’ll Learn
- why fossils provide evidence of evolution
- how relative and radiometric dating are used to estimate the age of fossils
- five types of evidence for evolution

Read to Learn

Clues from Fossils
Paleontologists are scientists who study the past by collecting and examining fossils. A fossil is the remains of an ancient organism or an imprint left behind by the organism.

The Green River Formation is one of the richest fossil deposits in the world. It covers parts of Wyoming, Utah, and Colorado. About 50 million years ago, during the Eocene Epoch, this area was covered by lakes. By studying fossils from the Green River Formation, paleontologists have learned that fish, crocodiles, and lizards lived in the lakes. After the animals died, they were covered with silt and mud. Over millions of years, they became fossils.

Types of Fossils
Most of the evidence for evolution comes from fossils. Most fossils are found in sedimentary rock. Sedimentary rock is formed when layers of sand, silt, clay, or mud are pressed and cemented together or when minerals are deposited from a solution. Fossils are most often found in a sedimentary rock called limestone.

1. Explain What is the main source of evidence for evolution?
Determining a Fossil’s Age

Paleontologists study the rock layers that fossils are found in. The rocks provide clues about the age of the fossils. Some of these clues include information about the geologic time period in which it was formed. Information may include weather, geology, and other organisms that were alive. Paleontologists have two ways of estimating the age of rocks and fossils—relative dating and radiometric dating.

What is relative dating?

Relative dating is based on the fact that younger rock layers usually lie on top of older rock layers. Relative dating gives only an estimate of a fossil’s age. Scientists compare the ages of rock layers found above and below the fossil layer. For example, if a 50-million-year-old rock layer lies below a fossil and a 35-million-year-old rock layer is above the fossil, then the fossil is probably between 35 million and 50 million years old.

What is radiometric dating?

Radiometric dating gives an estimate of the age of a rock layer that is more exact. This method of dating fossils uses radioactive elements. A radioactive element gives off a steady amount of radiation as it slowly changes to a nonradioactive element. Each radioactive element gives off radiation at a different rate. Scientists estimate the age of the rock by comparing the amount of radioactive element with the amount of nonradioactive element in the rock.

Fossils and Evolution

Fossils provide a record of organisms that lived in the past. However, the fossil record has gaps, much like missing pages in a book. The gaps exist because most organisms do not become fossils. Even though there are gaps, scientists have still been able to draw conclusions from the fossil records. For instance, they have learned that simple organisms were the first forms of life to appear on Earth. More complex forms of life appeared later.

Fossil discoveries are made all over the world. When scientists find fossils, they make models that show what the organisms might have looked like when they were alive. Scientists can use fossils to find out whether organisms lived in family groups or alone, what they ate, and what kind of environment they lived in. Most fossils are from extinct organisms.
More Clues About Evolution

Besides fossils, there are other clues about evolution. Some kinds of evolution can be observed today. The development of penicillin-resistant bacteria is a direct observation of evolution. Another direct observation of evolution is the development of insect species that are resistant to pesticides.

What is embryology?

The study of embryos and their development is called embryology (em bree AH luh jee). An embryo is the earliest growth stage of an organism. The embryos of many different species are similar. The embryos of fish, birds, reptiles, and mammals have tails. As the organisms grow, the fish, birds, and reptiles keep their tails, but many mammals do not. Because the embryos of vertebrates are similar, scientists hypothesize that vertebrates come from a common ancestor.

What are homologous structures?

Body parts that are similar in origin and structure are called homologous (hoh MAH luh gus). Some homologous structures have the same function, but others do not. If two or more species have homologous structures, they probably have common ancestors. The figure below shows several homologous structures.
What are vestigial structures?

The bodies of some organisms have structures known as vestigial (veh STIH jee ul) structures. Vestigial structures do not seem to have any use, or function. Vestigial structures provide evidence for evolution. Scientists hypothesize that vestigial structures are body parts that were useful in an ancestor. Humans have three small muscles around each ear that are vestigial. The figure below shows the location of these muscles. In some mammals, such as horses, these muscles are large. They allow a horse to turn its ears toward the source of a sound.

How does DNA provide clues about evolution?

If you enjoy science fiction, you probably have read books or seen movies in which scientists recreate dinosaurs from DNA taken from fossils. DNA is the molecule that controls heredity. It directs the development of every organism. DNA is found in the genes of all organisms. Scientists can compare the DNA of living organisms to find similarities among species. Scientists also can study the DNA of extinct species. They can learn how some species evolved from their extinct ancestors.

Studying DNA helps scientists see how closely related the organisms are. For example, DNA studies show that dogs are the closest relatives of bears.

If organisms from two species have DNA that is similar, the two species may share one or more common ancestors. For example, DNA evidence suggests that all primates have a common ancestor. Primates include chimpanzees, gorillas, orangutans, and humans.
After You Read

Mini Glossary

embryology (em bree AH luh jee): the study of embryos and their development

homologous (hoh MAH luh gus): body parts that are similar in origin and structure

radioactive element: an element that gives off a steady amount of radiation as it slowly changes to a nonradioactive element

sedimentary rock: rock in which most fossils are found, formed when layers of sand, silt, clay, or mud are pressed and cemented together, or when minerals are deposited from a solution

vestigial (veh STIH jee ul) structures: structures that do not seem to have a function

1. Review the terms and their definitions in the Mini Glossary. Choose one of the terms and write a sentence that explains how it provides a clue to evolution.

2. In the web diagram below, list the clues that scientists have as evidence of evolution.

ScienceOnline Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about the clues of evolution.
Adaptations over Time

section 6 The Evolution of Primates

What You’ll Learn

■ the differences among living primates
■ the adaptations of primates
■ the evolutionary history of modern primates

Before You Read

Describe the appearance and behavior of a primate such as monkeys and gorillas.

Read to Learn

Primates

Humans, monkeys, and apes belong to a group of mammals known as primates. Primates have several characteristics that show they have evolved from a common ancestor. These characteristics include opposable thumbs, binocular vision, and flexible shoulders.

An opposable thumb can cross over the palm and touch the fingers. You have an opposable thumb that lets you grasp and hold things with your hand. Binocular vision means that you have two eyes that look in the same direction. Binocular vision lets you judge distance with your eyes. It allows primates that live in trees to judge distances as they move between branches. Flexible shoulders allow primates to use their arms to swing from branch to branch. Flexible shoulders allow humans to do such moves as the backstroke in swimming.

What are some characteristics of hominids?

Hominids are humanlike primates that are the ancestors of modern humans. Hominids are different from all the other primates. They first appeared on Earth about 4 million to 6 million years ago. They ate both meat and plants and they walked upright on two legs.
Where have fossils of hominids been found?

In the 1920s, scientists discovered a fossil skull in South Africa. The skull had a small space for the brain, but it had a humanlike jaw and teeth. The fossil was named *Australopithecus*. It was one of the oldest hominids that had ever been discovered. In 1974, scientists found an almost-complete skeleton of *Australopithecus* in northern Africa. It had a small brain and may have walked upright. This fossil shows that modern hominids might have evolved from a common ancestor.

Who were the ancestors of early humans?

In the 1960s, scientists discovered a hominid fossil named *Homo habilis* that was estimated to be 1.5 million to 2 million years old. Scientists hypothesize that *Homo habilis* changed into another species, called *Homo erectus*, about 1.6 million years ago. These two hominids are thought to be ancestors of humans because they had larger brains and more humanlike features than *Australopithecus*.

Humans

Fossil records show that *Homo sapiens* evolved about 400,000 years ago. By 125,000 years ago, two early human groups probably lived in parts of Africa and Europe. These two groups were the Neanderthals (nee AN dur tawlz) and Cro-Magnon humans.

Who were the Neanderthals?

Neanderthals had short, heavy bodies with thick bones, small chins, and heavy browridges. They lived in caves in family groups. They used stone tools to hunt large animals. Neanderthals are probably not direct ancestors of modern humans.

Who were the Cro-Magnon humans?

The fossils of Cro-Magnon humans have been found in Europe, Asia, and Australia. They are between 10,000 and about 40,000 years old. Cro-Magnon humans looked very much like modern humans. They lived in caves, made stone carvings, and buried their dead. Cro-Magnon humans are thought to be direct ancestors of early humans. Early humans are called *Homo sapiens*. Modern humans are called *Homo sapiens sapiens*. Fossil evidence shows that modern humans evolved from *Homo sapiens*.
After You Read

Mini Glossary

hominids: humanlike primates that lived about 4 million to 6 million years ago and were different from the other primates

Homo sapiens: direct ancestors of humans

primate: group of mammals to which humans, monkeys, and apes belong

1. Review the terms and their definitions in the Mini Glossary. Choose one term and write a sentence that describes how it is related to modern humans.

2. In the boxes below, show the sequence of the evolution of the ancestors of modern humans. Write down how long ago scientists believe each of the following human ancestors first appeared: hominids, *Homo habilis*, *Homo erectus*, *Homo sapiens*, Neanderthals and Cro-Magnon humans. The first box has been completed for you.

![Sequence of human evolution boxes]

3. How did you benefit from underlining main ideas in paragraphs?

End of Section

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about the evolution of primates.
Before You Read
What do you think an antibacterial soap does? Why do people use antibacterial products? Write your answer below.

What You’ll Learn
- the characteristics of bacterial cells
- the difference between aerobic and anaerobic organisms

Read to Learn

Characteristics of Bacteria
In the 1600s, Antonie van Leeuwenhoek, a Dutch merchant, observed scrapings from his teeth under his microscope. He did not know it, but the organisms he was observing were bacteria. A hundred years later, bacteria were proven to be living cells.

Where do bacteria live?
Bacteria (singular, bacterium) live in the air, in foods, and on the surfaces of things you touch. They are found underground and deep underwater. Bacteria live on your skin and in your body. Some kinds of bacteria live in extremely hot and extremely cold environments. Very few other organisms can survive these conditions.

What are the shapes of bacterial cells?
Bacteria are found in three different shapes—spheres, rods, and spirals. Bacteria that are shaped like a sphere are called cocci (KAHK si) (singular, coccus). Rod-shaped bacteria are called bacilli (buh SIH li) (singular, bacillus). Spiral-shaped bacteria are called spirilla (spi RIH luh) (singular, spirillum). Bacteria are one-celled organisms that live alone or in chains or groups.
What do bacterial cells look like?
The figure below shows you what a bacterial cell looks like. A bacterial cell contains cytoplasm surrounded by a cell membrane and a cell wall. A bacterial cell is classified as prokaryotic (pro KAYR ee yah thik) because its nucleus is not surrounded by a cell membrane. A bacterial cell’s genetic material is in its one chromosome, found in the cytoplasm. A bacterial cell’s cytoplasm also contains ribosomes. Ribosomes make proteins that every cell needs to survive.

What special features do bacteria have?
Some bacteria, such as the one in the figure above, have a thick, gelatinlike capsule around the cell wall. The capsule protects the bacterium from other cells that might destroy it. The capsule and the hairlike structures found on many bacteria help them stick to surfaces. Some bacteria also have an outer coating called a slime layer. The slime layer helps a bacterium stick to a surface and reduces water loss. Many bacteria that live in moist places have tails called flagella (singular, flagellum) that help them move.

What is fission?
Bacteria usually reproduce by fission. Fission produces two new cells that have genetic material identical to each other and to that of the original cell. Fission is the simplest form of asexual reproduction.

Reading Check
What results from fission in bacteria?

Picture This
1. Identify Underline the names of the parts of the cell that are inside the cell’s membrane.

2. Explain What special features do bacteria have?
Do bacteria reproduce sexually?

Some bacteria reproduce through a process similar to sexual reproduction. In this process, two bacteria line up beside each other and exchange DNA through a thin tube. The cells then have different combinations of genetic material than they had before the exchange. The new combinations may improve the bacteria’s chances for survival.

How do producers and consumers differ?

Some bacteria make their own food. These bacteria are called producers. Bacteria that contain chlorophyll make their food using energy from the Sun. Other bacteria use energy from chemical reactions to make food.

Most bacteria do not make their own food. They get their food from the environment. These bacteria are called consumers. Some consumers break down dead organisms to get energy. Others live as parasites of living organisms and get food from their hosts.

What are aerobes and anaerobes?

Most organisms need oxygen to break down food. They obtain energy through a process called respiration. An organism that uses oxygen for respiration is called an aerobe (AY rohb). Humans and most bacteria are aerobic organisms. An organism that lives without oxygen is called an anaerobe (AN uh rohb). Several kinds of anaerobic bacteria live in human intestines. Some bacteria cannot survive in places with oxygen.

Eubacteria

Bacteria are classified into two kingdoms—eubacteria (yew bak TIHR ee uh) and archaebacteria (ar kee bak TIHR ee uh). Most eubacteria are grouped by the following characteristics.

• The shape and structure of the cell
• How they get food
• The kind of food they consume
• The wastes they produce
• How they move
• Whether they are aerobic or anaerobic

3. Identify What is the difference between producer bacteria and consumer bacteria?

4. Determine Into what two kingdoms are bacteria classified?
**What bacteria live in intestines of humans?**

Many different kinds of bacteria can live in the intestines of humans and other animals. The figure below identifies bacteria based on the foods they use and the wastes they produce.

**Think it Over**

6. **Explain** Why are cyanobacteria important?

**What are cyanobacteria?**

An important group of producer eubacteria is the cyanobacteria (si an oh bak TIHR ee uh). Cyanobacteria live in water and use carbon dioxide, water, and energy from sunlight to make their own food. They produce oxygen as waste. Cyanobacteria have chlorophyll and a blue pigment, or coloring.

**Why are cyanobacteria important?**

Some cyanobacteria live together in long chains. They are covered with a gelatinlike substance that helps them live in groups called colonies. Cyanobacteria are food for some organisms that live in ponds, lakes, and oceans. Other water organisms use the oxygen that cyanobacteria produce.

However, cyanobacteria can harm water organisms. When a pond has large amounts of nutrients, the number of cyanobacteria increases. When the cyanobacteria population gets large enough, a mat of bubbly green slime appears on the surface of the water. This slime is called a bloom. The cyanobacteria use up the nutrients in the water and they die. Then other bacteria that are aerobic consumers feed on the dead cyanobacteria and use up the oxygen in the water. Because there is less oxygen in the water, fish and other organisms die.
How are consumer eubacteria categorized?

There are two categories of consumer eubacteria. The categories are based on the result of the Gram's stain. Gram-positive cells stain purple because they have thicker cell walls. Gram-negative cells stain pink because their cell walls are thinner.

Doctors and veterinarians use antibiotics (anti bi AH tiks) to treat infections caused by bacteria. Some gram-positive bacteria are harder to treat with antibiotics than gram-negative bacteria.

One group of eubacteria does not have cell walls. Because they don't have cell walls, their shapes change. They can't be described as coccus, bacillus, or spirillum. The bacteria that cause pneumonia in humans do not have cell walls.

Archaebacteria

Kingdom Archaebacteria contains certain kinds of bacteria that live in extreme conditions, such as hot springs. The conditions in which some archaebacteria live today are similar to conditions found during Earth's early history. Archaebacteria is grouped according to where the bacteria live or how they get energy.

Where do archaebacteria live?

One group lives in salty environments, such as the Great Salt Lake in Utah. Other groups live in environments that are acidic or hot, such as in hot springs. The temperature of the water in hot springs is more than 100°C.

How do archaebacteria get energy?

Some archaebacteria use carbon dioxide for energy and give off methane gas as waste. Methane producers are anaerobic. They live in swamps, in the intestines of cattle, and in humans. These archaebacteria are used in sewage treatment. The bacteria break down the waste material that has been filtered from sewage water.
After You Read

Mini Glossary

aerobe (AY rohb): an organism that uses oxygen for respiration

anaerobe (AN uh rohb): an organism that is adapted to live without oxygen

fission: a reproductive process that produces two new cells with genetic material identical to each other and that of the original cell

flagella: whiplike tails that help bacteria move

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the difference between aerobes and anaerobes.

2. Select one of the question headings and write it below. Then write an answer to the question on the lines that follow.

Write your question here.

3. You made an outline as you read this section. How did it help you understand bacteria?

Science online Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about what bacteria are.
Bacteria

section 7 Bacteria in Your Life

Before You Read
Doctors sometimes prescribe antibiotics for their patients. What is the purpose of the antibiotics? Write your answer on the lines below.

What You’ll Learn
- how some bacteria are helpful
- why nitrogen-fixing bacteria are important
- how some bacteria cause human disease

Read to Learn

Beneficial Bacteria
Only a few bacteria cause diseases. Most bacteria are more important because of the benefits they provide.

What kinds of bacteria help you?
Bacteria are important for keeping you healthy. Large numbers of bacteria are found in the large intestine of your digestive system. They are generally harmless and help you stay healthy. For example, some bacteria in your intestine produce vitamin K, which you need for blood clotting.

Some bacteria produce antibiotics. Antibiotics are chemicals that slow or stop the growth of other bacteria. Many bacterial diseases in humans and animals can be treated with antibiotics.

How do bacteria help the environment?
Consumer bacteria help keep balance in nature. Without bacteria, there would be layers of dead material all over Earth. A saprophyte (SAP ruh fite) is any organism that uses dead organisms for food and energy. Saprophytes help recycle nutrients that other organisms can use. Most sewage-treatment plants use saprophytes. They break down wastes into carbon dioxide and water.

Identify Key Words
As you read this section, circle the ways bacteria are helpful. Underline the ways bacteria are harmful.

Mark the Text

Foldables

Describe Make a two-tab book, as shown below. Describe helpful and harmful bacteria.

Helpful bacteria
Harmful bacteria
How do plants and animals obtain nitrogen?

Plants and animals must use nitrogen to make proteins and nucleic acids. Animals can eat plants or other animals that contain nitrogen. Plants have to take in nitrogen from the soil or air. Although the air is about 78 percent nitrogen, plants and animals cannot use it directly. Nitrogen-fixing bacteria change the nitrogen from the air into forms that plants and animals can use. The roots of some plants such as peanuts and peas develop structures that contain nitrogen-fixing bacteria.

What is bioremediation?

Bioremediation uses organisms to clean up or remove pollutants from the environment. One kind of bioremediation uses bacteria to break down wastes into harmless compounds. Other bacteria use pollutants as food. Bioremediation has been used to clean up oil spills.

How is bacteria used to make food?

Bacteria have been used to make foods for a long time. One of the first uses of bacteria was to make yogurt. Bacteria break down substances in milk to make dairy products such as cheeses and buttermilk. Foods such as sauerkraut, pickles, and soy sauce also are made with the help of bacteria.

How do industries use bacteria?

Industries use bacteria to make products, such as medicines, cleansers, and adhesives. Methane gas that is released as waste by certain bacteria can be used as fuel. In landfills, methane-producing bacteria break down plant and animal material. The amount of methane gas released is so large that some cities collect and burn it.

Harmful Bacteria

Some bacteria, known as pathogens, are harmful. A pathogen is any organism that causes disease. One bacterial pathogen, for example, causes strep throat.

How do pathogens make you sick?

Bacterial pathogens cause illness and disease in several ways. They can enter your body when you breathe. They also can enter through a cut in the skin. Once these pathogens are inside the body, they can multiply, damage cells, and cause illness and disease.
What are toxins?

Toxins are poisonous substances produced by some pathogens. Botulism is a type of food poisoning caused by a toxin-producing bacteria. Botulism is able to grow and produce toxins inside sealed cans of food.

Some bacteria, like the one that causes botulism, can survive unfavorable conditions by making thick-walled structures called endospores. Endospores can exist for hundreds of years before they start growing again. If botulism endospores are in canned food, they can develop into regular bacterial cells and make toxins again. Canned foods that you buy in the store go through a process that uses steam under high pressure, which kills bacteria and most endospores.

What is pasteurization?

All food contains bacteria. You can kill the bacteria by sterilizing it with heat. Heating food to high temperatures can change the taste of the food. Pasteurization is a way of heating food to a temperature that kills most harmful bacteria but causes little change in the food’s taste. The photo below shows some of the foods that are pasteurized.

How are bacterial diseases treated?

Antibiotics are used to treat many bacterial diseases. Penicillin is an antibiotic that works by preventing bacteria from making cell walls. Some kinds of bacteria cannot survive without cell walls.

Vaccines are produced to treat many bacterial diseases. A vaccine can be made from damaged particles taken from bacterial cell walls or from killed bacteria. When the body is injected with a vaccine, white blood cells in the blood recognize that kind of bacteria. If the same kind of bacteria enters the body at a later time, the white blood cells attack them.
After You Read

Mini Glossary

- **antibiotics**: chemicals, produced by bacteria, that limit the growth of other bacteria
- **endospores**: thick-walled structures produced by a pathogen when conditions are not favorable for survival
- **nitrogen-fixing bacteria**: bacteria that change nitrogen from the air into forms that plants and animals can use
- **pathogen**: any organism that causes disease
- **saprophyte**: any organism that uses dead organisms for food and energy
- **toxins**: poisonous substances produced by some pathogens
- **vaccine**: a treatment for some kinds of bacterial diseases, made from damaged particles taken from bacterial cell walls or from killed bacteria

1. Review the terms and their definitions in the Mini Glossary. Choose one term that refers to helpful bacteria and write a sentence describing how it is helpful.

2. In the chart below, list the ways bacteria are helpful to humans and the environment.

---

**Helpful Roles of Bacteria**

<table>
<thead>
<tr>
<th>To humans</th>
<th>To the environment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about bacteria in your life.
Before You Read
Describe what you come to mind when you hear the words *slime*, *mold*, and *mildew*. Where are these organisms usually found?

What You’ll Learn
- the characteristics of protists
- the three groups of protists
- why protists are hard to classify

Read to Learn
What is a protist?
A protist is a one-celled or many-celled organism that lives in moist or wet places. Look at the organisms below. They have one thing in common—they belong to the protist kingdom. All protists have eukaryotic cells. Eukaryotic cells have a nucleus and other internal structures that are surrounded by membranes.

Study Coach
Make Flash Cards Write a quiz question on one side of a flash card. Write the answer on the other side. Use the flash cards to quiz yourself until you know the answers.

Picture This
1. Compare and Contrast Name two things these cells have in common.
**What are characteristics of protists?**

Some protists have plantlike features. They contain chlorophyll and make their own food. Other protists have animal-like features. They do not have chlorophyll and they can move. Some protists have a hard shell-like covering on the outside of their bodies.

**How do protists reproduce?**

Protists usually reproduce asexually by cell division. The hereditary material in the nucleus is duplicated and the nucleus divides. Two genetically identical copies of the cell result. Asexual reproduction of many-celled protists occurs by regeneration. Parts of the protist break off and grow into new protists that are genetically identical.

Most protists also can reproduce sexually. A process called meiosis produces sex cells. Two sex cells, one from each of two different protists, join to form a new protist. The new protist is genetically different from the two protists that provided the sex cells. How and when sexual reproduction in protists happens depends on the specific type of protist.

**What are the three groups of protists?**

Protists are usually divided into three groups—plantlike, animal-like, and funguslike. The table below shows characteristics that help scientists classify protists.

<table>
<thead>
<tr>
<th>Characteristics of Protist Groups</th>
<th>Food Source</th>
<th>Cell Structure</th>
<th>Movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plantlike</td>
<td>Have chlorophyll and make their own food using photosynthesis</td>
<td>Have cell walls</td>
<td>No specialized way to move from place to place</td>
</tr>
<tr>
<td>Animal-like</td>
<td>Capture other organisms for food</td>
<td>Do not have cell walls</td>
<td>Have specialized ways to move from place to place</td>
</tr>
<tr>
<td>Funguslike</td>
<td>Absorb food from their surroundings</td>
<td>May or may not have cell walls</td>
<td>Have specialized ways to move from place to place</td>
</tr>
</tbody>
</table>

**How did protists evolve?**

Protists with hard outer coverings have left many fossils. Scientists also study genetic material and features of modern protists to understand how they relate to each other and to other organisms. Scientists hypothesize that the common ancestor of most protists was a one-celled organism with a nucleus and other cellular structures. However, modern protists may have more than one ancestor.
Plantlike Protists

Like plants, protists in this group have chlorophyll in chloroplasts. Chlorophyll is a green pigment, or coloring, that traps light energy. Plantlike protists use the light energy to make their own food. These protists do not have roots, but some have structures that hold them in place. Some have cell walls like plants.

Plantlike protists are known as algae (AL jee) (singular, alga). Some algae have one cell; others have many cells. All algae have chlorophyll, but not all of them look green. Many have other pigments that cover up the chlorophyll.

What are diatoms?

Diatoms live in both freshwater and salt water. Their golden-brown pigment covers up the green chlorophyll. Diatoms form glasslike boxes around themselves. The boxes sink when the protists die. Over thousands of years, these boxes collect and form deep layers.

What are dinoflagellates?

Dinoflagellates are algae. They move using two long, thin, whiplike structures, called a flagellum (plural, flagella). One flagellum circles the cell like a belt. The other flagella is attached to one end of the organism like a tail. As the two flagella move, they cause the organism to spin. Their name means “spinning flagellates.” Most dinoflagellates live in salt water, and most have chlorophyll. Dinoflagellates without chlorophyll feed on other organisms.

What are euglenoids?

Euglenoids (yoo GLEE noydz) are plantlike protists that also have characteristics of animals. Many of these one-celled algae have chloroplasts and use chlorophyll to produce their own food. Euglenoids that do not have chlorophyll feed on bacteria and other protists. Although euglenoids have no cell wall, they do have a strong flexible layer inside the cell membrane that helps it move and change shape. Many euglenoids have flagella that help them move.

How are red, green, and brown algae alike?

Most of the many-celled red, green, and brown algae are called seaweeds. These algae usually live in water. Green algae are the most plantlike. In fact, some scientists propose that plants evolved from green algae.
Brown Algae  Brown algae vary greatly in size. One brown algae, called kelp, is an important food source for many fish and invertebrates. Giant kelp is the largest protist and can grow to be 100 m long. The chart below compares algae.

<table>
<thead>
<tr>
<th>Common Names</th>
<th>Number of Cells</th>
<th>Contain Chlorophyll</th>
<th>Main Pigment</th>
<th>Places Found</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red seaweed</td>
<td>many</td>
<td>yes</td>
<td>red</td>
<td>salt water, up to 200 m deep</td>
</tr>
<tr>
<td>Green algae; seaweed</td>
<td>one or many</td>
<td>large amounts</td>
<td>green</td>
<td>in water, damp tree trunks, wet sidewalks</td>
</tr>
<tr>
<td>Brown seaweed; kelp</td>
<td>many</td>
<td>yes</td>
<td>brown</td>
<td>cool, saltwater environments</td>
</tr>
</tbody>
</table>

**Importance of Algae**

Many animals that live on land, such as cattle and deer, depend on grasses for food. Algae are sometimes called the grasses of the ocean. Most animals that live in the oceans eat algae or eat other animals that eat algae. One-celled diatoms and dinoflagellates are an important food source for many organisms that live in oceans. Euglenoids are an important food source for freshwater organisms.

**How do algae affect the environment?**

Algae produce oxygen as a result of photosynthesis. The oxygen produced by green algae is important for most organisms on Earth, including you. Under certain conditions, algae can reproduce rapidly and form an algal bloom. The color of the water where the algal bloom forms appears to change. The color change occurs because of the large number of organisms. Dinoflagellates form blooms along the east and Gulf coasts of the United States. They produce toxins that can cause other organisms to die and can cause health problems in humans.

**How do humans use algae?**

Many people around the world eat some species of red and brown algae. A substance in the cell walls of red algae is used to make cosmetics and food products. The substance also gives toothpaste, puddings, and salad dressings their smooth, creamy texture. A substance in the cell walls of brown algae helps thicken some foods and is used in making rubber tires and hand lotion.
**Uses of Diatoms** The glasslike remains of ancient diatoms are mined and used in insulation, filters, and road paints. The cell walls of diatoms produce the sparkle that makes some road lines visible at night and the crunch you might feel in toothpaste.

**Animal-like Protists**

Animal-like protists that have one cell are known as protozoans. Protozoans usually are classified by how they move. They live in or on other living or dead organisms. Many protozoans have specialized vacuoles for digesting food and getting rid of excess water.

**What are ciliates?**

Some protists have short, threadlike structures called cilia (SIH lee uh) that stick out of the cell membrane. Ciliates have cilia that move back and forth similar to rowboat oars. The cilia help ciliates move quickly in any direction.

The *Paramecium* shown in the figure below is a common ciliate. *Paramecium* has two nuclei—a large nucleus, the macronucleus, and a small nucleus, the micronucleus. The micronucleus is involved in reproduction. The macronucleus controls feeding, the exchange of oxygen and carbon dioxide, the amount of water and salts entering and leaving *Paramecium*, and other functions of the organism.

**What do ciliates eat?**

Ciliates usually feed on bacteria that are swept into the oral groove by cilia. A vacuole forms around the bacteria and the food is digested. Wastes are removed from the ciliate through the anal pore.

**Picture This**

8. **Identify** Circle the name of the structure involved in reproduction.
What are flagellates?

Protozoans called flagellates move through the water by whipping their long flagella. Many flagellates live in freshwater. Some are parasites that harm their hosts. Some flagellates may live in colonies. The colonies consist of many cells that are similar in structure to cells found in animals called sponges. The cells perform different functions.

What are pseudopods?

Some protozoans use temporary extensions of their cytoplasm called pseudopods (SEW duh pahdz) to move through their environment and to get food. The word pseudopod means “false foot.” These organisms seem to flow along as they extend their pseudopods. They are found in freshwater and saltwater environments. Certain types are parasites in animals. The amoeba is a member of this group.

How do pseudopods work?

To get food, an amoeba extends the cytoplasm of a pseudopod on either side of the food, such as a bacterium. Then the two parts of the pseudopod flow together, trapping the food in the organism. A vacuole forms around the trapped food, and digestion takes place inside the vacuole. A food vacuole is shown in the amoeba below.

Some members of this group, such as the amoeba, have no outer covering. Others secrete hard shells around themselves. The white cliffs of Dover, England are composed mostly of the remains of some of these shelled protozoans. Some shelled protozoans extend pseudopods through holes in their shells.
What other protozoans exist?

One group of protozoans has no way of moving on their own. All of the organisms in this group are parasites of humans and other animals. These protozoans have complex life cycles. The life cycle involves both sexual and asexual reproduction. They often live part of their lives in one animal and part of their lives in another animal. The parasite that causes malaria belongs to this group of protozoans. Asexual reproduction of the malaria parasite takes place inside a human host. Sexual reproduction takes place in the intestine of a mosquito.

Importance of Protozoans

Some protozoans are an important source of food for larger organisms. Other protozoans are indicator species for petroleum reserves. When these shelled protozoans die, their shells sink to the bottom of the water and build up over many years. Large buildups of protozoan shells mean that petroleum reserves might be found in the area.

One type of flagellated protozoan lives in the digestive tract of termites. Termites feed on wood. The protozoans make enzymes that help the termites break down the wood. Termites would not be able to use chemical energy from the wood as well if the protozoans did not live in their digestive tracts.

What diseases do protozoans cause?

In tropical environments, parasitic flagellates enter humans when humans are bitten by mosquitoes or other insects. Other parasitic flagellates live in water that is contaminated with wastes from humans or animals. If humans drink this water, they might get a diarrhea-causing parasite.

Some amoebas also are parasites that cause disease. One parasitic amoeba, found in ponds and streams, can cause a brain infection that kills the host.

Funguslike Protists

Funguslike protists include several small groups of organisms such as slime molds, water molds, and downy mildews. All funguslike protists produce spores like fungi. Most have pseudopods, like the amoeba, to move from place to place. Funguslike protists cannot make their own food. They must take in food from outside sources.
What are slime molds?
Slime molds have some protozoan features. During part of their life cycle, slime molds move using pseudopods and behave like amoebas.
Most slime molds live on rotting logs or dead leaves in moist, cool, shady environments. Slime molds form weblike structures on the surface of their food supply. These structures often are brightly colored.

What are water molds and downy mildews?
Most members of this group of funguslike protists live in water or moist places. They grow as a mass of threads over a plant or animal. They absorb nutrients from the organism they live on. The spores of a water mold or downy mildew have flagella. The spore’s cell walls are more like the cell walls of plants than those of fungi.
Some water molds are parasites of plants, and others feed on dead organisms. Most water molds look like fuzzy, white growths on rotting matter.
Downy mildews form when days are warm and nights are cool and moist. Downy mildews weaken plants and even can kill them.

Importance of Funguslike Protists
Some funguslike protists are helpful because they help break down dead organisms. Most funguslike protists are harmful and cause diseases in plants and animals. Water molds cause disease in some organisms that live in water.

Do funguslike protists affect the economy?
Downy mildews have caused widespread damage several times throughout history. In the 1840s, downy mildews were responsible for the Irish potato famine. Potatoes were Ireland’s main crop and the main source of food. Potatoes infected with downy mildew rotted in the fields, leaving people with no food. A similar problem occurred in the 1870s in France. The mildew affected grapes and nearly destroyed the French wine industry. Downy mildews continue to infect crops, such as lettuce, corn, cabbage, avocados, and pineapples.

Reading Check
13. Identify In what environment are most slime molds found?

14. Explain How did the downy mildew affect the Irish potato crop?
After You Read

Mini Glossary

algae: many-celled, plantlike protists that have chlorophyll and produce their own food; can be different colors

cilia (SIH lee uh): short, threadlike structures that stick out from the cell membrane and help the organism move quickly in any direction

flagellum: long, thin, whiplike structure of some protists that helps them move from place to place

protist: a one-celled or many-celled eukaryotic organism that lives in moist or wet places

protozoans: one-celled, animal-like protists that live in water or soil, or on living and dead organisms

pseudopods (SEW duh pahdz): temporary extensions of cytoplasm in some protists that help them move through their environment and get food

1. Review the terms and their definitions in the Mini Glossary. List the three terms that describe structures or ways that a protist moves.

2. Place each of the items in the following list in the correct category of the table.

<table>
<thead>
<tr>
<th>amoebas</th>
<th>downy mildews</th>
<th>protozoans</th>
</tr>
</thead>
<tbody>
<tr>
<td>brown algae</td>
<td>euglenoids</td>
<td>red algae</td>
</tr>
<tr>
<td>ciliates</td>
<td>flagellates</td>
<td>slime molds</td>
</tr>
<tr>
<td>diatoms</td>
<td>green algae</td>
<td>water molds</td>
</tr>
<tr>
<td>dinoflagellates</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paramecium</td>
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<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plantlike Protists</th>
<th>Animal-like Protists</th>
<th>Funguslike Protists</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about protists.
Before You Read

Think about the places that you have seen mushrooms growing. What do those places have in common?

Read to Learn

What are fungi?

Mushrooms are common fungi. The yeasts used to make some breads and cheeses are a type of fungus. Fungus may grow on a loaf of bread or on your shower curtain.

How did fungi evolve?

Some fossils of fungi have been found, but they do not help scientists determine how fungi are related to other organisms. Some scientists hypothesize that fungi share an ancestor with ancient, flagellated protists and slime molds. Other scientists hypothesize that their ancestor was a green or red alga.

What are hyphae?

Most species of fungi are many-celled. The body of a fungus usually is made up of many-celled threadlike tubes called hyphae (HIF ee). The figure below shows the inside structure of hyphae.
How do most fungi get food?

Hyphae produce enzymes that help break down food that the fungus absorbs from another organism. Most fungi are saprophytes (SAP ruh fites), meaning they get food by absorbing dead or decaying tissues of other organisms.

What characteristics do fungi share?

Some fungi grow anchored in soil and have a cell wall around each cell. Fungi do not have specialized tissues and organs such as leaves and roots. Fungi do not have chlorophyll and do not make their own food. Fungi grow best in warm, damp areas, such as tropical forests or between toes.

How do fungi reproduce?

Fungi reproduce both asexually and sexually. For both types of reproduction, fungi produce spores. A spore is a waterproof reproductive cell that can grow into a new organism. In asexual reproduction, the cells divide to produce spores. These spores grow into new fungi that are genetically identical to the fungus from which the spores came.

Fungi are not identified as either male or female. For sexual reproduction to take place, the hyphae of two genetically different fungi of the same species grow close together. If the hyphae join, a reproductive structure, such as the one in the figure below, forms. Meiosis, or cell division that produces sex cells, results in spores that will grow into new fungi. These fungi are genetically different from either of the two fungi whose hyphae joined together.

Reading Check

2. Identify What is a saprophyte?

3. Identify Circle the reproductive structure formed when two genetically different fungi reproduce.
How are fungi classified?

Fungi are classified into three main groups. The groups are identified by the type of structure formed when the hyphae join together.

Club Fungi

Mushrooms, such as those shown above, are examples of club fungi. The mushroom is the reproductive structure of the fungus. Most of the fungus grows as hyphae in the soil or on the surface of its food source. The spores of club fungi are produced in a club-shaped structure called a **basidium** (buh SIH dee uhm) (plural, **basidia**).

Sac Fungi

This varied group of fungi includes yeasts, molds, and truffles. There are more than 30,000 different species of sac fungi. The spores of sac fungi are produced in a little, saclike structure called an **ascus** (AS kus), as shown in the figure below.

![ 질문 4. Identify Highlight the ascus in the figure. ]

Although most fungi are many-celled, yeasts are one-celled organisms. Yeasts reproduce sexually by forming spores like other fungi. Yeasts reproduce asexually by **budding**, in which a new organism forms on the side of the parent organism. The two organisms are genetically identical.
Zygote Fungi and Other Fungi

Black molds that you might see growing on old bread or old fruit are a type of zygospore fungus. Zygospore fungi produce spores in a round spore case called a **sporangium** (spuh RAN jee uhm) (plural, **sporangia**). Sporangia form on the tips of some hyphae. When a sporangium splits open, hundreds of spores are released into the air, as shown in the figure below. Each spore that lands on a warm, moist surface will grow and reproduce if it has a food source.

What are imperfect fungi?

Some fungi either never reproduce sexually or never have been seen reproducing sexually. They usually are called imperfect fungi because there is no evidence that their life cycle has a sexual reproduction stage. ✓

Some scientists classify *Penicillium* as an imperfect fungi. Other scientists classify it as a sac fungi because of the type of spores it produces during asexual reproduction.

Lichens

A **lichen** (LI kun) is an organism made up of a fungus and either a green alga or a cyanobacterium. These two organisms have a relationship that benefits both of them. The alga or cyanobacterium lives among the threadlike strands of the fungus. The fungus gets food made by the green algae or cyanobacterium. The green alga or cyanobacterium gets a moist, protected place to live.
Why are lichens important?

Lichens are an important food source for many animals, including caribou and musk oxen. Lichens also are important because they help produce soil. Lichens grow on bare rock and produce acids as part of their metabolism. The acids help break down the rock. This process is known as weathering. Soil forms from the bits of rock and lichens that have died.

Many species of lichens are sensitive to pollution. When these organisms decline in their health or die quickly, scientists look for possible problems for larger organisms.

Fungi and Plants

Some fungi and plants form a network of hyphae and roots known as mycorrhizae (mi kuh RI zee). About 80 percent of plants develop mycorrhizae. The fungus helps the plants absorb more of certain nutrients from the soil. The plant supplies food and other nutrients to the fungus. Both the plants and the fungi benefit. Some plants cannot grow without mycorrhizae.

How did fungi help plants evolve?

Scientists have known that the first plants could not have survived moving from water to land alone. Early plants did not have specialized roots to absorb nutrients. Also, tubelike cells used to transport water and nutrients to leaves were too simple to survive on land.

In 1999, scientists discovered a fossilized fungus in a 460 million-year-old rock. The fossil was a type of fungus that forms relationships with plant roots. Scientists have hypothesized that fungi attached themselves to the roots of early plants, passing along nutrients taken from the soil to the plant. Scientists suggest that this relationship began about 500 million years ago.

Importance of Fungi

Mushrooms, one type of fungi, are an important food crop. However, some wild mushrooms are poisonous and should never be eaten.

Fungi are used to make some cheeses and breads. Yeasts use sugar for energy and produce alcohol and carbon dioxide as waste products. The carbon dioxide causes bread dough to rise.
What problems do fungi cause in plants and animals?

Many fungi cause disease in plants and animals. Many sac fungi damage or destroy plant crops. Diseases caused by sac fungi include Dutch elm disease and apple scab. Smuts and rust are club fungi. They damage billions of dollars worth of food crops each year.

Ringworm and athlete’s foot are skin infections caused by species of imperfect fungi. Some respiratory infections are caused by inhaling fungi or their spores.

How are fungi helpful to animals and humans?

Some fungi naturally produce antibiotics (anti bi AH tihks) to help keep bacteria from growing near them. The antibiotic penicillin is produced by the imperfect fungi *Penicillium*. *Penicillium* is grown commercially, and the antibiotic is sold to help humans and other animals fight infections caused by bacteria. The drug cyclosporine comes from a fungus. Cyclosporine helps fight the body’s rejection of transplanted organs.

There are many more examples of breakthroughs in medicine as a result of studying fungi. Scientists worldwide continue to study fungi to find more useful drugs.

Why are fungi called nature’s recyclers?

Fungi’s most important role is as decomposers. Fungi break down, or decompose, organic material such as food scraps and dead plants and animals. As these materials decompose, they release chemicals into the soil, where plants can reuse them. Fungi, along with bacteria, are nature’s recyclers. They keep Earth from becoming buried under mountains of organic wastes.

9. List one problem that fungi cause and one benefit that they provide.

______________

______________

______________
After You Read

Mini Glossary

ascus (AS kus): little saclike reproductive structures in which sac fungi produce spores
basidium (buh SIH dee uhm): club-shaped reproductive structures in which club fungi produce spores
budding: form of asexual reproduction in which a new, genetically identical organism forms on the side of the parent organism
hyphae (HI fee): many-celled, threadlike tubes that form the body of a fungus
lichen (LI kun): an organism made up of a fungus and either a green alga or a cyanobacterium
mycorrhizae (mi kuh RI zee): a network of hyphae and roots that helps plants absorb more of certain nutrients from the soil
saprophyte (SAP ruh fite): organism that gets food by absorbing dead and rotting tissues of other organisms
sporangium (spuh RAN jee uhm): round spore case of a zygospore fungus
spore: a waterproof reproductive cell of a fungus that can grow into a new organism

1. Review the terms and their definitions above. Fill in the table below with the term from the Mini Glossary that describes the reproductive structure of each type of fungus.

<table>
<thead>
<tr>
<th>Club Fungi</th>
<th>Sac Fungi</th>
<th>Zygote Fungi</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Select one of the question headings from this section and write it below. Then write an answer to the question on the lines that follow.

Write your question here.

3. How did underlining the answers to the question heads help you learn about fungi?

Scienceonline Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about fungi.
Before You Read

What are your favorite plants? Why are they your favorites?

Read to Learn

What is a plant?

Plants include trees, flowers, vegetables, and fruits. More than 260,000 plant species have been identified. Scientists expect more species will be found, mostly in tropical rain forests. Plants are important sources of food for humans. Most life on Earth would not be possible without plants.

All plants are made of cells and need water to live. Many have roots that hold them in the ground or onto an object such as a rock. Plants come in many sizes and live in almost every environment on Earth. Some grow in cold, icy regions. Others grow in hot, dry deserts.

What are the parts of a plant cell?

Every plant cell has a cell wall, a cell membrane, a nucleus, and other cell structures. A cell wall surrounds every plant cell. The cell wall gives the plant structure and provides protection. Animal cells do not have cell walls.

Many plant cells have the green pigment, or coloring, called chlorophyll (KLOR uh fihl). Most green plants use chlorophyll to make food through a process called photosynthesis. Chlorophyll is found in cell structures called chloroplasts. The green parts of a plant usually have cells that contain many chloroplasts.
Central Vacuole  Most of the space inside a plant cell is taken up by a large structure called the central vacuole. The central vacuole controls the water content of the cell. Many other substances also are stored in the central vacuole, including the pigments that make some flowers red, blue, or purple.

Origin and Evolution of Plants

The first land plants probably could survive only in damp areas. Their ancestors may have been green algae that lived in the sea. Green algae are one-celled or many-celled organisms that use photosynthesis to make food. Because plants and green algae have the same type of chlorophyll, they may have come from the same ancestor.

Plants do not have bones or other hard parts that can become fossils. Plants usually decay instead. But there is some fossil evidence of plants. The oldest fossil plants are about 420 million years old. Scientists hypothesize that some of these early plants evolved into the plants that live today.

Plants that have cones, such as pine trees, probably evolved from plants that lived about 350 million years ago. Plants that have flowers most likely did not exist until about 120 million years ago. Scientists do not know the exact beginning of flowering plants.

Life on Land

Life on land has some advantages for plants. One advantage is that more sunlight and carbon dioxide are available on land than in water. Plants need sunlight and carbon dioxide for photosynthesis. During photosynthesis, plants give off oxygen. Over millions of years, as more plants grew on land, more oxygen was added to Earth’s atmosphere. Because of this increase in oxygen, Earth’s atmosphere became an environment in which land animals could live.

Adaptations to Land

Algae live in water or in very moist environments. Like green plants, algae make their own food through photosynthesis. To stay alive, algae need nutrients that are dissolved in the water that surrounds them. The water and dissolved nutrients enter and leave through the algae’s cell membranes and cell walls. If the water dries up, the algae will die. Land plants have adaptations that allow them to conserve water.
How are land plants supported and protected?

Plants cannot live without water. Plants that live on land have adaptations that help them conserve water. The stems, leaves, and flowers of many land plants are covered with a cuticle (KYEW tih kul). The cuticle is a waxy, protective layer that slows the loss of water. The cuticle is a structure that helps plants survive on land.

Land plants also have to be able to support themselves. The cell walls that surround all plant cells contain cellulose (SEL yuh lohs). Cellulose is a chemical compound that plants can make out of sugar. Long chains of cellulose molecules form fibers in plant cell walls. These fibers give the plant structure and support.

The cell walls of some plants contain other substances besides cellulose. These substances help make the plant even stronger. Trees, such as oaks and pines, could not grow without very strong cell walls. Wood from trees can be used for building because of strong cell walls.

Life on land means that each plant cell is not surrounded by water. Land plants have tubelike structures that deliver water, nutrients, and food to all plant cells. These structures also help provide support for the plant.

How do plants reproduce on land?

Land plants reproduce by forming spores or seeds. These structures can survive dryness, cold, and other harsh conditions. They grow into new plants when the environmental conditions are right.

Classification of Plants

Plants can be classified into two major groups, vascular (VAS kyuh lur) and nonvascular plants. Vascular plants have tubelike structures that carry water, nutrients, and other substances to all the cells of the plant. Nonvascular plants do not have these tubelike structures.

Scientists give each plant species its own two-word name. For example, the scientific name for a pecan tree is Carya illinoiensis and the name for a white oak is Quercus alba. In the eighteenth century a Swedish scientist, Carolus Linnaeus, created this system for naming plants.
After You Read

Mini Glossary

- **cellulose**: a chemical compound that forms the walls of plants; plants make it out of sugar
- **cuticle**: a waxy, protective layer on the surface of the plant
- **nonvascular plants**: plants without tubelike structures; move water and other substances through the plant in other ways
- **vascular plants**: plants that have tubelike structures to carry water, nutrients, and other substances to the cells of the plant

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the difference between vascular and nonvascular plants.

2. In the boxes below, describe four adaptations in plants that allow them to live on land. One adaptation is supplied for you.

---

End of Section

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about plants.
Plants

section 3 Seedless Plants

Before You Read

Ferns are a type of seedless plant that people grow as house plants. What do you think you would need to do to keep a fern alive indoors?

What You’ll Learn

■ the differences between seedless nonvascular plants and seedless vascular plants
■ the importance of some nonvascular and vascular plants

Read to Learn

Seedless Nonvascular Plants

Nonvascular plants are small and not always easy to notice. They include mosses, which you may have seen as green clumps on moist rocks or stream banks. Some other nonvascular plants are called hornworts and liverworts.

What are characteristics of seedless nonvascular plants?

Nonvascular plants do not grow from seeds. Instead, they reproduce by forming spores. They also do not have all of the parts that plants that grow from seed have. Nonvascular plants are usually only a few cells thick. They are not very tall, usually about 2 cm to 5 cm high. Nonvascular plants have structures that look like stems and leaves. Nonvascular plants do not have roots. Instead, they have rhizoids (RI zoydz). Rhizoids are threadlike structures that help to anchor the plants where they grow. Most nonvascular plants grow in damp places. They absorb water through their cell membranes and cell walls.

Study Coach

Summarize As you read, make an outline to summarize the information in the section. Use the main headings in the section as the main headings in the outline. Complete the outline with the information under each heading in the section.

Reading Check

1. Identify How do rhizoids help a plant?
**Mosses** Most nonvascular plants are mosses. Mosses have green, leaflike growths arranged around a stalk. They also have rhizoids that anchor them to the ground. Moss rhizoids are made up of many cells. Mosses often grow on tree trunks, rocks, or the ground. Although most mosses live in damp places, some can live in deserts. Like all nonvascular plants, mosses reproduce by forming spores. In many moss species, a stalk grows up from the plant when it is ready to reproduce. Spores form in a cap at the top of the stalk.

**Liverworts** Liverworts got their name because people who lived during the ninth century used them to treat diseases of the liver. Liverworts have flattened, leaflike bodies. They usually have one-celled rhizoids.

**Hornworts** Hornworts have flattened, leaflike bodies like liverworts. Hornworts are usually less than 2.5 cm in diameter. Hornworts have one chloroplast in each of their cells. They get their name from the structures that produce spores, which look like tiny cattle horns.

**How are nonvascular plants important?**

Nonvascular plants need damp conditions to grow and reproduce. However, many species can withstand long, dry periods. Nonvascular plants can grow in thin soil and in soils where other plants cannot grow.

The spores of mosses, liverworts, and hornworts are carried by the wind. When a spore lands on the ground, it will grow into a new plant only if there is enough water and if other growing conditions are right.

Mosses, such as those pictured below, often are the first plants to grow in a new or disturbed environment, such as after a forest fire. Organisms that are the first to grow in new or disturbed areas are called **pioneer species**. As pioneer plant species die, they decay. As more and more plants grow and die, the decayed matter builds up. The decaying material and slow breakdown of rocks build soil. After enough soil is made, other organisms can move into the area.
Seedless Vascular Plants

Both ferns and mosses reproduce by spores instead of seeds. But ferns are different from mosses because ferns have vascular tissues. Their long, tubelike cells carry water, minerals, and food to cells throughout the plant. Vascular plants can grow larger and thicker than nonvascular plants because the vascular tissue carries water and nutrients to all plant cells.

What are the types of seedless vascular plants?

Seedless vascular plants include ferns, ground pines, spike mosses, and horsetails. Many species of seedless vascular plants are known only from fossils because they are now extinct. These plants covered much of Earth 360 million to 286 million years ago.

What are ferns?

Ferns are the largest group of seedless vascular plants. Ferns have stems, leaves, and roots. Fern leaves are called fronds as shown in the figure to the right. Spores form in structures found on the underside of the fronds. Although thousands of species of ferns are found on Earth today, many more species existed long ago. Scientists have used clues from rock layers to learn that 360 million years ago much of Earth was covered with steamy swamps. The tallest plants were species of ferns that grew as tall as 25 m. The tallest ferns today are 3 m to 5 m tall and grow in tropical areas.

What are club mosses?

Ground pines and spike mosses are groups of plants that often are called club mosses. Club mosses are more closely related to ferns than to mosses. Club mosses have needle-like leaves. Their spores form at the end of the stems in structures that look like tiny pinecones. Ground pines grow in cold and hot areas. Ground pines are endangered in some places. They have been over-collected to make decorations such as wreaths.
Spike mosses look a lot like ground pines. One species of spike moss, the resurrection plant, lives in desert areas. When there is not enough water, the plant curls up and looks dead. When water becomes available, the resurrection plant unfolds its green leaves and begins making food again. The plant can curl up again whenever conditions make it necessary.

**How are horsetails different from other vascular plants?**

Horsetails have a stem structure that is different from other vascular plants. The stem has a hollow center surrounded by a ring of vascular tissue. The stem also has joints. Leaves grow out around the stem at each joint. Horsetail spores form in conelike structures at the tips of some stems. The stems of horsetails contain silica, a gritty substance found in sand. In the past, horsetails were used for polishing objects and scouring cooking utensils.

**Importance of Seedless Plants**

Long ago, when ancient seedless plants died, they sank into water and mud before they decayed. Over time, many layers of this plant material built up. Top layers became heavy and pressed down on the layers below. Over millions of years, this material turned into coal.

Today, the same process is happening in bogs. A bog is a watery area of land that contains decaying plants. Most plants that live in bogs are seedless plants like mosses and ferns.

When bog plants die, the watery soil slows the decaying process. Over time, the decaying plants are pressed into a substance called peat. Peat is mined from bogs to use as a low-cost fuel in places such as Ireland and Russia. Scientists hypothesize that over time, if the peat remains in the bog, it will become coal.

**How are seedless vascular plants used?**

Peat is used to enrich garden soil. Many people keep ferns as houseplants. Ferns also are sold as landscape plants for shady outdoor areas. Ferns sometimes are woven into baskets.

The rhizomes and fronds of some ferns can be eaten. The dried stems of one kind of horsetail can be ground into flour. Some seedless plants have been used as medicines for hundreds of years. For example, ferns have been used to treat bee stings, burns, and fevers.
1. Review the terms and their definitions in the Mini Glossary. Write a sentence to explain the importance of pioneer species to the environment.

2. Complete the Venn diagram below to help you compare nonvascular and vascular seedless plants. Include phrases that describe how the plant cells get nutrients and how the plants reproduce.

3. How did summarizing the information in this section help you learn about nonvascular and vascular seedless plants?
Before You Read

What are your favorite fruits? Where do these fruits come from?

Read to Learn

Characteristics of Seed Plants

Seed plants reproduce by forming seeds. A seed contains a plant embryo and stored food. The stored food provides energy for the embryo so that it can grow into a plant. Scientists classify seed plants into two groups: gymnosperms (JIHM nuh spurmz) and angiosperms (AN jee uh spurmz). Most seed plants have four main parts: roots, stems, leaves, and vascular tissue.

Why are leaves important?

The leaves of seed plants are the organs where food is made. The food-making process is called photosynthesis. Leaves come in many shapes, sizes, and colors.

What are the cell layers of a leaf?

A leaf has several layers of cells. A thin layer of cells called the epidermis covers and protects the top and bottom of the leaf. The epidermis of some leaves is covered with a waxy cuticle. Most leaves have small openings in the epidermis called stomata (STOH muh tuh) (singular, stoma). The stomata allow carbon dioxide, water, and oxygen to enter and exit the leaf. Guard cells located around each stoma open and close the stoma.
The palisade layer of a leaf is located just below the upper epidermis. This layer has long, narrow cells that contain chloroplasts. Plants make most of their food in the palisade cells.

The spongy layer is found between the palisade layer and the lower epidermis. The spongy layer is made of loosely arranged cells separated by air spaces. The veins of a leaf are made of vascular tissue and are located in the spongy layer. All the parts of the leaf can be seen in the figure below.

What is the purpose of a plant’s stem?

Plant stems are usually found above the ground. They support the branches, leaves, and reproductive structures of the plant. Materials move between the leaves and roots through vascular tissues in the stem. The stems of some plants also store food and water.

Plant stems can be woody or herbaceous (hur BAY shus). Herbaceous stems are soft and green, like those of a tulip. Woody stems are hard and rigid, like those of trees and shrubs. The trunk of a tree is a stem.

What do plant roots do?

The root system of most plants is the largest part of the plant. Roots contain vascular tissue. Water and dissolved substances move from the soil into the roots, and on up through the stems to the leaves. Roots also anchor plants and prevent them from being blown or washed away. Roots support the parts of the plant that are above ground—the stem, branches, and leaves.
Roots can store food and water. They can take in oxygen that the plant needs for the process of respiration. For plants that grow in water, part or all of a plant’s roots may grow above ground. Water does not have as much oxygen as air. The roots take in more oxygen from the air.

**What are vascular tissues made of?**

The vascular system in a seed plant contains three kinds of tissue—xylem, phloem, and cambium. **Xylem** (ZI lum) tissue is made of hollow, tubelike cells that are stacked one on top of the other to form a structure called a vessel. Vessels move water and dissolved substances from the roots to the rest of the plant. Xylem’s thick cell walls also help support the plant.

**Phloem** (FLOH em) tissue is made of tubelike cells that are stacked to form structures called tubes. Phloem tubes move food from where it is made to other parts of the plant where the food is used or stored. ✓

Some plants have a layer of cambium tissue between xylem and phloem. **Cambium** (KAM bee um) tissue produces most of the new xylem and phloem cells.

**Gymnosperms**

**Gymnosperms** are vascular plants that produce seeds that are not protected by a fruit. Gymnosperms do not have flowers. The leaves of gymnosperms are usually shaped like needles or scales. Many gymnosperms are called evergreens because some green leaves always stay on their branches.

The gymnosperms are divided into four divisions. These four divisions are conifers, cycads, ginkgoes, and gnetophytes (NE tuh fites). The conifers are the most familiar gymnosperm division. Pines, firs, spruces, redwoods, and junipers are conifers. Conifers produce two types of cones—male and female. Seeds develop only on the female cone.

**Angiosperms**

An **angiosperm** is a vascular plant that forms flowers and produces one or more seeds that are protected inside a fruit. Peaches, apples, and tulips are examples of angiosperms. Angiosperms are common in all parts of the world. More than half of all known plant species are angiosperms.
What are the flowers of angiosperms like?
The flowers of angiosperms come in different shapes, sizes, and colors. Some parts of a flower grow into a fruit. Most fruits have seeds inside, like an apple. Some fruits have seeds on the surface, like a strawberry. Angiosperms are divided into two groups—monocots and dicots.

How do monocots and dicots differ?
A cotyledon (kah tul EE dun) is the part of a seed that stores food for the new plant. **Monocots** are angiosperms that have one cotyledon inside their seeds. **Dicots** are angiosperms that have two cotyledons inside their seeds.

Many foods come from monocots, including corn, rice, and wheat. Bananas and pineapples also are monocots. Familiar foods such as peanuts, peas, and oranges come from dicots. Most shade trees, such as oaks and maples, are dicots.

What is the life cycle of an angiosperm?
All organisms have life cycles—a beginning and an end. The angiosperm’s life cycle begins with the seed and ends when the mature plant flowers and/or produces seed. Some angiosperms grow from seeds to maturity in less than a month. Some plants take as long as 100 years to grow from seed to maturity. Plants that complete their life cycles in one year are called annuals. Annuals must be grown from new seeds each year.

Plants that complete their life cycles in two years are called biennials (bi EH nee ulz). Biennials produce flowers and seeds only during the second year of growth. Angiosperms with life cycles that take longer than two years are called perennials. Most trees and shrubs are perennials.

Importance of Seed Plants
Gymnosperms are used for many purposes. Conifers are the most commonly used gymnosperm. Most of the wood used in building comes from conifers. Resin used to make chemicals found in soap, paint, and varnish also comes from conifers.

Angiosperms are widely used by humans. Many of the foods you eat come from seed plants. Angiosperms are the source of many of the fibers used in making clothes. Paper is made from wood pulp that comes from trees. Desks and chairs are made from wood.
1. Review the terms and their definitions in the Mini Glossary. Write two sentences that explain what xylem and phloem do.

2. Complete the chart below to list the four main parts of seed plants and describe what they do.

<table>
<thead>
<tr>
<th>Parts of Seed Plants</th>
<th>What They Do</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about seed plants.
Plant Reproduction
section ● Introduction to Plant Reproduction

Before You Read
List four things you need to survive. Then circle the items on your list that you think plants also need to survive.

What You’ll Learn
- the differences between the two types of plant reproduction
- the two stages in a plant’s life cycle

Read to Learn

Types of Reproduction
What do humans and plants have in common? Both need water, oxygen, energy, and food to grow. Like humans, plants reproduce and make similar copies of themselves. Most plants can reproduce in two different ways—by sexual reproduction and by asexual reproduction.

What happens in asexual plant reproduction?
Asexual reproduction does not require the production of sex cells. Instead, one organism produces a new organism that is genetically identical to it. Under the right conditions, an entire plant can grow from one leaf or part of a stem or root. When growers use these methods to start new plants, they must make sure that the plant part has plenty of water and anything else it needs to survive. The stems of lawn grasses grow underground and produce new grass plants asexually along the length of the stem.

What is sexual plant reproduction?
Sexual reproduction in plants requires the production of sex cells—usually called sperm and eggs—in reproductive organs. The organism produced by sexual reproduction is genetically different from either parent organism.

Identify Main Ideas
Underline the important ideas in this section. Review these ideas as you study the section.

Think it Over
1. Analyze A cutting from a plant can be placed in water and roots grow. Is this an example of asexual or sexual reproduction? Explain your answer.
**Fertilization** An important part of sexual reproduction is fertilization. Fertilization happens when a sperm and egg combine to produce the first cell of the new organism, the zygote. In plants, water, wind, or animals help bring the sperm and the egg together.

**What reproductive organs do plants have?**

A plant’s female reproductive organs produce eggs. The male reproductive organs produce sperm. Some plants have both reproductive organs. A plant with both reproductive organs can usually reproduce by itself. Other plants have either female or male reproductive organs. For fertilization to happen, the male and female plants must be near each other.

**Plant Life Cycles**

A plant has a life cycle with two stages—the gametophyte (guh MEE tuh fite) stage and the sporophyte (SPOHR uh fite) stage. The figure below shows the two stages.

**Gametophyte Stage** When reproductive cells undergo meiosis and produce haploid cells called spores, the gametophyte stage begins. Spores divide by cell division to form plant structures or an entire new plant. The cells in these structures or plants are haploid and have half a set of chromosomes. Some of these cells undergo cell division and form sex cells.

**Sporophyte Stage** Fertilization—the joining of haploid sex cells—begins the sporophyte stage. Cells formed in this stage are diploid and have the full number of chromosomes. Meiosis in some of these cells forms spores, and the cycle repeats.
After You Read

Mini Glossary

**gametophyte (guh MEE tuh fite) stage:** the stage in plant reproduction when reproductive cells undergo meiosis

**spores:** haploid cells produced in the gametophyte stage

**sporophyte (SPOHR uh fite) stage:** the stage in plant reproduction when fertilization begins

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the difference between the gametophyte stage and the sporophyte stage.

2. Choose one of the question headings in the Read to Learn section. Write the question in the space below. Then write your answer to that question on the lines that follow.

   **Write your question here.**

3. Fill in the table below with either “yes” or “no” to compare asexual and sexual reproduction in plants.

<table>
<thead>
<tr>
<th></th>
<th>Asexual Reproduction</th>
<th>Sexual Reproduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Requires production of sex cells?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Produces organism that is genetically identical to parent?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. Requires fertilization?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about the basics of plant reproduction.
Before You Read

Describe what happens when you suddenly open a bag of candy or a bag of chips.

Read to Learn

The Importance of Spores

If you want to grow ferns and moss plants, you can’t go to a garden store and buy a package of seeds. Ferns and moss plants don’t produce seeds. They reproduce by forming spores. The sporophyte stage of these plants produces haploid spores in structures called spore cases.

If you break open a bag of candy, the candy may spill out. In the same way when a spore case breaks open, the spores spill out and are spread by wind or water. The spores can grow into plants that will produce sex cells. Seedless plants include all nonvascular plants and some vascular plants.

Nonvascular Seedless Plants

A nonvascular plant does not have structures that transport water and materials throughout the plant. Instead, water and materials move from cell to cell. Mosses, liverworts, and hornworts are all nonvascular plants. They cover the ground or grow on fallen logs in damp, shaded forests.

The sporophyte stage of most nonvascular plants is very small. Moss plants have a life cycle typical of how sexual reproduction occurs in this plant group.
How do nonvascular plants reproduce sexually?

A moss is a green, low-growing plant when in the gametophyte stage. When brownish stalks grow up from the tip of the plant, moss is in the sporophyte stage. The sporophyte stage does not carry on photosynthesis. It depends on the gametophyte for nutrients and water. On the tip of the stalk is a tiny spore case where millions of spores have been produced. Under the right environmental conditions, the spore case opens and the spores are released.

New moss gametophytes can grow from each spore and the cycle repeats. This process is shown in the figure below.

How do nonvascular plants reproduce asexually?

If a piece of moss gametophyte plant breaks off, it can grow into a new plant. Liverworts can form small balls of cells on the surface of the gametophyte plant. These can be carried away by water and grow into new gametophyte plants.
2. Identify Highlight the name of the structure that contains the male and female reproductive structures.

Vascular Seedless Plants

Vascular plants have tubelike cells that transport water and materials throughout the plant. Most vascular seedless plants are ferns. Horsetails and club mosses are other vascular seedless plants. Unlike nonvascular plants, the gametophyte of a vascular seedless plant is the part that is small.

How do ferns reproduce sexually?

A fern leaf is called a frond and grows from an underground stem called a rhizome. Roots grow from the rhizome. Roots anchor the plant and absorb water and nutrients.

Fern sporophytes make their own food by photosynthesis. Fern spores are produced in a spore case called a sorus (plural, sori). Sori are dark colored bumps on the underside of a frond. A spore that falls on the ground can grow into a small, green, heart-shaped gametophyte plant called a prothallus (proh THA lus). It contains chlorophyll and can make its own food. The life cycle of a fern is shown below.

How do ferns reproduce asexually?

Fern rhizomes grow and form branches in asexual reproduction. New fronds and roots develop from each branch. The new rhizome branch can be separated from the main plant. It can grow on its own and form more fern plants.

Picture This

2. Identify Highlight the name of the structure that contains the male and female reproductive structures.
1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the relationship between a frond and a sorus.

2. Complete the flow chart below to show the life cycle of a moss.

A. The diploid zygote begins the sporophyte stage and develops into the stalk and spore case.

B. 

C. 

D. 

3. How does discussing what you have read help you remember the important ideas?

Visit life.mssciences.com to access your textbook, interactive games, and projects to help you learn more about seedless reproduction in plants.
Define Terms

Before You Read

On the lines below, write the names of three fruits or vegetables. Next to each name, describe its seed.

---

1. Identify one way a pollen grain reaches the female part of the plant.

What You’ll Learn

- the life cycles of most gymnosperms and angiosperms
- the structure and function of the flower
- the ways seeds are scattered

Read to Learn

The Importance of Pollen and Seeds

All plants described so far have been seedless plants. However, the fruits and vegetables that you eat come from seed plants. Oak, maple, and other shade trees also are produced by seed plants. All flowers are produced by seed plants. In fact, most plants on Earth are seed plants. Reproduction that involves pollen and seeds helps explain why seed plants are so successful.

What is pollen?

In seed plants, some spores develop into small structures called pollen grains. A pollen grain has a waterproof covering and contains gametophyte parts that can produce sperm. The waterproof covering of a pollen grain can be used to identify the plant that the pollen grain came from.

The sperm of seed plants are carried as part of the pollen grain by gravity, wind, water, or animals. The transfer of pollen grains to the female part of the plant is called pollination.

After the pollen grain reaches the female part of the plant, a pollen tube is produced. The sperm moves through the pollen tube, then fertilization can happen.
What are the three main parts of a seed?

After fertilization, the female part can develop into a seed. As shown in the figure below, a seed has three main parts, an embryo, stored food, and a protective seed coat. The embryo will grow to become the plant’s stem, leaves, and roots. The stored food gives the embryo energy when it begins to grow into a plant. Because a seed contains an embryo and stored food, a new plant develops faster from a seed than from a spore.

Gymnosperms and Angiosperms Gymnosperms (JIHM nuh spurmz) and angiosperms are the two groups of seed plants. In gymnosperms, seeds usually develop in cones. In angiosperms, seeds develop in flowers and fruit.

Gymnosperm Reproduction

Cones are the reproductive structures of gymnosperms. Gymnosperm plants include pines, firs, cedars, cycads, and ginkgoes. Each kind of gymnosperm has a different cone.

A pine tree is a gymnosperm. The way pines produce seeds is typical of most gymnosperms. The pine is a sporophyte plant that produces both male cones and female cones. Male and female gametophyte structures are produced in the cones, but they are very small. A mature female cone is made up of woody scales on a short stem. At the base of each scale are two ovules. The egg is produced in the ovule. Pollen grains are produced in the smaller male cones. In the spring, clouds of pollen are released from the male cones.

How are gymnosperm seeds produced?

Pollen is carried from the male cones to the female cones by the wind. The pollen must land between the scales of a female cone to be useful. There it can be trapped in the sticky fluid given off by the ovule. If the pollen grain and the female cone are the same species, fertilization can take place. It can take from two to three years for the seed to develop.
Angiosperm Reproduction

Most seed plants are angiosperms. All angiosperms have flowers, which are the reproductive organs. Flowers have gametophyte structures that produce sperm or eggs for sexual reproduction.

Most flowers have four main parts—petals, sepals, stamen, and pistil, as shown in the figure below. The petals usually are the most colorful parts of the flower. Sepals often are small, green, leaflike parts. In some flowers, the sepals are as colorful and as large as the petals.

Inside the flower are the reproductive organs of the plant. The stamen is the male reproductive organ of the plant. The stamen has a thin stalk called a filament. On the end of the filament is an anther. Pollen grains form inside the anther. Sperm develop in each pollen grain.

The pistil is the female reproductive organ. It consists of a stigma, a long stalklike style, and an ovary. Pollen grains land on the stigma and move down the style to the ovary. The ovary is the swollen base of the pistil where the ovules are found. Eggs are produced in the ovules. Not all flowers have both male and female reproductive parts.

How is pollen spread?

Insects and other animals eat the flower, its nectar, or pollen. As insects and other animals move about the flower, they get pollen on their body parts. These animals spread the flower’s pollen to other plants they visit. Some flowers depend on the wind, rain, or gravity to spread their pollen. Following pollination and fertilization, the ovules of flowers can develop into seeds.
How do angiosperm seeds develop?

A flower is pollinated when pollen grains land on a pistil. A pollen tube grows from the pollen grain. The pollen tube enters the ovary and reaches an ovule. The sperm then travels down the pollen tube and fertilizes the egg in the ovule. A zygote forms and grows into a plant embryo.

Parts of the ovule develop into the stored food and the seed coat that surround the embryo, and a seed is formed. The seeds of some plants, like beans and peanuts, store food in structures called cotyledons. The seeds of other plants, like corn and wheat, store food in a tissue called endosperm.

Seed Dispersal

Some plant seeds are spread by gravity. They fall off the parent plant. Other seeds have attached structures, like wings or sails, which help the wind carry them.

Some seeds are eaten by animals and spread after the seeds are digested. Other seeds are stored or buried by animals. Raindrops can knock seeds out of dry fruit. Some fruits and seeds float on flowing water or ocean currents.

What is germination?

A series of events that results in the growth of a plant from a seed is called germination. Seeds will not germinate until the environmental conditions are right. Conditions that affect germination include temperature, light, water, and oxygen. Germination begins when seed tissues absorb water. This causes the seed to get larger and the seed coat to break open.

As you can see in the figure below, a root eventually grows from the seed. Then a stem and leaves grow. Once the plant grows above the soil, photosynthesis begins. Photosynthesis provides food as the plant continues to grow.
1. Review the terms and their definitions in the Mini Glossary. Write a sentence that describes either the male or the female reproductive organs of a flower.

germination: a series of events that result in the growth of a plant from a seed

ovary: the swollen base of the pistil where ovules are found

ovule: the place where eggs are produced

pistil: the female reproductive organ in the flower of an angiosperm

pollen grain: a small structure in seed plants that has a waterproof covering and that contains gametophyte parts that can produce sperm

pollination: the transfer of pollen grains to the female part of the plant

stamen: the male reproductive organ in the flower of an angiosperm

2. Complete the concept web below to identify the ways seeds are spread.

Ways Seeds Are Spread

a. gravity

b.

c.

d.

End of Section

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Plant Processes

section • Photosynthesis and Respiration

Before You Read
Name the parts of a plant that you have seen recently. For one of the parts, describe its function.

What You’ll Learn
■ how plants take in and give off gases
■ the differences and similarities between photosynthesis and respiration
■ why photosynthesis and respiration are important

Read to Learn

Taking in Raw Materials
Plants make their own food using the raw materials water, carbon dioxide, and inorganic chemicals in the soil. Plants also produce wastes.

Which plant structures move water into the plant?
The figure below shows the plant structures that take in raw materials. Most of the water used by plants is taken in through the roots and moves through the plant to where it is used.

Summarize Main Ideas
Read the section. Recall and write down the main ideas. Go back and check the main ideas to make sure they are accurate. Then use your notes to summarize the main ideas of this section.

Picture This
1. Identify Circle the raw materials that a plant takes in.
What is the function of a leaf?
Gas is exchanged in the leaves. Most of the water taken in by the roots of a plant exits the plant through its leaves. Carbon dioxide, oxygen, and water vapor enter and exit the plant through openings in the leaves.

What is the structure of a leaf?
A leaf is made up of many different layers. The outer layer of the leaf is called the epidermis. The epidermis is nearly transparent and allows sunlight, which is used to make food, to reach the cells inside the leaf.

The epidermis has many small openings called stomata (stoh MAH tuh) (singular, stoma). Raw materials such as carbon dioxide, water vapor, and waste gases enter and exit the leaf through the stomata. Many plants have stomata on their stems. Guard cells surround each stoma to control how much water enters and exits the plant. Stomata close when a plant is losing too much water.

As you can see in the figure below, the inside of a leaf is made up of a spongy layer and a palisade layer. Carbon dioxide and water vapor fill the spaces of the spongy layer. Most of the plant’s food is made in the palisade layer.

Why are chloroplasts important?
Some cells of a leaf contain small green structures called chloroplasts. Chloroplasts are green because they contain a green pigment, or coloring, called chlorophyll (KLOR uh fihl). Chlorophyll is important to plants because the light energy that it absorbs is used to make food. This food-making process, photosynthesis (foh toh SIHN thuh suhs), happens in the chloroplasts. ✓
The Food-Making Process

Photosynthesis is the process during which a plant’s chlorophyll traps light energy and sugars are produced. In plants, photosynthesis occurs only in cells with chloroplasts. For example, photosynthesis occurs only in a carrot plant’s green leaves. The carrot’s root cells do not have chlorophyll, so they cannot perform photosynthesis. But excess sugar produced in the leaves is stored in the root. The familiar orange carrot you eat is the root of the carrot plant. When you eat a carrot, you benefit from the energy stored as sugar in the plant’s root.

Plants need light, carbon dioxide, and water for photosynthesis. The chemical equation for photosynthesis is shown below.

\[
\text{chlorophyll} \quad \text{6CO}_2 + 6\text{H}_2\text{O} + \text{light energy} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2
\]

What are light-dependent reactions?

Chemical reactions that occur during photosynthesis that need light are called the light-dependent reactions. During light-dependent reactions, chlorophyll and other pigments trap light energy that will be stored in sugar molecules. Light energy causes water molecules, which were taken up by the roots, to split into oxygen and hydrogen. The oxygen exits the plant through the stomata. This is the oxygen that you breathe. The hydrogen produced when water is split is used in light-independent reactions.

What are light-independent reactions?

Chemical reactions that occur during photosynthesis that do not need light are called light-independent reactions. The light energy trapped during the light-dependent reactions is used to combine carbon dioxide and hydrogen to make sugars, such as glucose. The chemical bonds that hold glucose and other sugars together are stored energy.

What happens to the oxygen and glucose that are made during photosynthesis?

Most of the oxygen produced during photosynthesis is a waste product and is released through the stomata. Glucose is the main form of food for plant cells. A plant usually produces more glucose than it can use. The extra glucose is stored in plants as other sugars and starches. When you eat carrots or potatoes, you are eating the stored product of photosynthesis.

4. List two other foods that are stored products of photosynthesis.
How does a plant use glucose?
Glucose also is the basis of a plant’s structure. Plants grow larger by taking in carbon dioxide gas and changing it to glucose. Cellulose, an important part of plant cell walls, is made from glucose. Leaves, stems, and roots are made of cellulose and other materials produced using glucose.

Why is photosynthesis important?
Photosynthesis produces food. Photosynthesis uses carbon dioxide and releases oxygen. This removes carbon dioxide from the atmosphere and adds oxygen to it. Most organisms need oxygen to live. About 90 percent of the oxygen in the atmosphere today is a result of photosynthesis.

The Breakdown of Food
Respiration is a series of chemical reactions that breaks down food molecules and releases energy. Respiration that uses oxygen to break down food chemically is called aerobic respiration. The overall chemical equation for aerobic respiration is shown below.

\[
\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{energy}
\]

Where does aerobic respiration occur?
Before aerobic respiration begins, glucose molecules in the cytoplasm are broken down into two smaller molecules. These molecules enter a mitochondrion, where aerobic respiration takes place. Oxygen is used to break down the molecules into water and carbon dioxide and to release energy. The figure below shows aerobic respiration in a plant cell.
Why is respiration important?

Food contains energy. But it is not in a form that can be used by cells. Respiration changes food energy into a form that cells can use. This energy drives the life processes of almost all organisms on Earth.

Plants use energy produced by respiration to transport sugars, to open and close stomata, and to produce chlorophyll. When seeds sprout, they use energy from the respiration of stored food in the seed. The figure below shows some uses of energy in plants.

The waste product carbon dioxide also is important. Aerobic respiration returns carbon dioxide to the atmosphere, where plants and some other organisms use it for photosynthesis.

Comparison of Photosynthesis and Respiration

Aerobic respiration is almost the reverse of photosynthesis. Photosynthesis combines carbon dioxide and water by using light energy. The end products are glucose (food) and oxygen. Aerobic respiration combines oxygen and food to release the energy in the chemical bonds of the food. The end products of aerobic respiration are energy, carbon dioxide, and water. Look at the table below to compare the differences between photosynthesis and aerobic respiration.

<table>
<thead>
<tr>
<th>Comparing Photosynthesis and Aerobic Respiration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy</strong></td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>stored</td>
</tr>
<tr>
<td><strong>Raw materials</strong></td>
</tr>
<tr>
<td><strong>End products</strong></td>
</tr>
<tr>
<td><strong>Where</strong></td>
</tr>
</tbody>
</table>

Picture This

7. **List** two uses of energy produced by respiration in plants.

8. **Compare and Contrast** Highlight water and carbon dioxide for each process in one color and glucose and oxygen in another color.
After You Read

Mini Glossary

chlorophyll (KLOR uh fihl): a green pigment found in chloroplasts
photosynthesis (foh toh SIHN thuh suhs): the process during which a plant’s chlorophyll traps light energy and sugars are produced
respiration: a series of chemical reactions that breaks down food molecules and releases energy
stomata (stoh MAH tah): small openings in the leaf epidermis, which act as doorways for raw materials to enter and exit the leaf

1. Review the terms and their definitions in the Mini Glossary. Write one or two sentences that explain the difference between photosynthesis and respiration.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

2. Choose one of the question headings in the Read to Learn section. Write the question in the space below. Then write your answer to that question on the lines that follow.

Write your question here.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

3. How did your notes help you summarize what you read in this section?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about photosynthesis and respiration.
Before You Read

Have you ever been suddenly surprised? On the lines below, describe what surprised you and how your body responded to the surprise.

What You’ll Learn

- the relationship between a stimulus and a tropism in plants
- about long-day and short-day plants
- how plant hormones and responses are related

Read to Learn

What are plant responses?

A stimulus is anything in the environment that causes a response in an organism. A stimulus may come from outside (external) or inside (internal) the organism. An outside stimulus could be something that startles or surprises you. An inside stimulus is usually a chemical produced by the organism. Many of these chemicals are hormones. Hormones are substances made in one part of an organism for use somewhere else in the organism. The response to the stimulus often involves movement toward or away from the stimulus. All living organisms, including plants, respond to stimuli.

Tropisms

Some plant responses to external stimuli are called tropisms (TROH pih zumz). A tropism can be seen as movement caused by a change in growth. It can be positive or negative. A positive tropism would be growth toward a stimulus. A negative tropism would be growth away from a stimulus. You may have seen plants responding to touch, light, and gravity. Plants also can respond to electricity, temperature, and darkness.
Touch If a pea plant touches a solid object, it responds by growing faster on one side of its stem than on the other side. As a result, the stem bends and twists around any object it touches.

Light When a plant responds to light, the cells on the side of the plant opposite the light get longer than the cells facing the light. Because of this, the plant bends toward the light. The leaves turn and can absorb more light. This positive response to light is called positive phototropism.

Gravity Plants respond to gravity. The downward growth of plant roots is a positive response to gravity. A stem growing upward is a negative response to gravity.

Plant Hormones

Plants have hormones that control the changes in growth that result from tropisms and affect other plant growth. These hormones include ethylene, auxin, gibberellin, cytokinin, and abscisic acid.

How does ethylene affect plants?

Many plants produce the hormone ethylene (EH thuh leen) gas and release it into the air around them. This hormone helps fruits ripen. Ethylene also causes a layer of cells to form between a leaf and the stem. The cell layer causes the leaf to fall from the stem.

What is auxin?

The plant hormone auxin (AWK sun) causes a positive response to light in stems and leaves. The figure below shows the effect of auxin.

When light shines on a plant from one side, the auxin moves to the shaded side of the stem where it causes a change in growth. Auxin causes plants to grow toward light.
How do gibberellins and cytokinins affect plant growth?

Two other groups of plant hormones also affect a plant’s growth. Gibberellins (jih buh REH lunz) can be mixed with water and sprayed on plants and seeds to stimulate plant stems to grow and seeds to germinate. Cytokinins (si tuh KI nunz) promote growth by causing faster cell division. Cytokinins can keep stored vegetables fresh longer.

How does abscisic acid affect plant growth?

Abscisic (ab SIH zihk) acid is a plant hormone that keeps seeds from sprouting and buds from developing during the winter. This hormone also causes stomata to close in response to water loss on hot summer days. ☑

Photoperiods

A plant’s response to the number of hours of daylight and darkness it receives daily is called photoperiodism (foh toh PIHR ee uh dih zum). Because Earth is tilted about 23.5° from a line perpendicular to its orbit, the hours of daylight and darkness change with the seasons. These changes in the length of daylight and darkness affect plant growth.

How does darkness affect flowers?

Many plants must have a certain length of darkness to flower. Plants that need less than 10 h to 12 h of darkness to flower are called long-day plants. These plants include spinach, lettuce, and beets. Plants that need 12 or more hours of darkness to flower are called short-day plants. These plants include poinsettias, strawberries, and ragweed. If a short-day plant receives less darkness than it needs to flower, it will produce larger leaves instead of flowers.

What are day-neutral plants?

Plants that do not need a set amount of darkness to flower are called day-neutral plants. They can flower within a range of hours of darkness. These plants include dandelions and roses. Knowing the photoperiods of plants helps farmers and gardeners know which plants will grow best in the area where they live.
1. Review the terms and their definitions in the Mini Glossary. Write one or two sentences to explain the differences among the long-day, short-day, and day-neutral plants.

- **long-day plant**: a plant that needs less than 10 h to 12 h of darkness to flower
- **short-day plant**: a plant that needs 12 h or more of darkness to flower
- **day-neutral plant**: a plant that does not have a specific photoperiod to flower
- **auxin**: a plant hormone that causes plant stems and leaves to exhibit positive response to light
- **photoperiodism**: a plant's response to the number of hours of daylight and darkness it receives daily
- **tropism**: a response of a plant to an external stimulus

2. Complete the cause-and-effect chart below to show how plant hormones affect plant growth.

<table>
<thead>
<tr>
<th>Cause</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethylene</td>
<td></td>
</tr>
<tr>
<td>Auxin</td>
<td></td>
</tr>
<tr>
<td>Gibberellin</td>
<td></td>
</tr>
<tr>
<td>Cytokinin</td>
<td></td>
</tr>
</tbody>
</table>

Visit [life.msscience.com](http://life.msscience.com) to access your textbook, interactive games, and projects to help you learn more about plant responses.
Introduction to Animals

section Is it an animal?

Before You Read
List five different animals on the lines below. Read over your list. Name two things all the animals have in common.

What You’ll Learn
- what most animals have in common
- how animals get what they need
- the difference between invertebrates and vertebrates

Read to Learn
Animal Characteristics
There are many different kinds of animals but all animals share certain characteristics. Animals can be identified by the following characteristics.

1. Animals are made of many cells.
2. Animal cells have a nucleus and other parts inside the cells called organelles. The nucleus directs all cell activities.
3. Animals get their food from other living things in their environment. Some animals eat plants. Some animals eat other animals. Some animals eat both plants and animals.
4. All animals digest their food. During digestion, the carbohydrates, proteins, and fats in the food are broken into small particles that can move into the animal’s cells. Once inside the cell, some of the particles give the cell energy.
5. Many animals move from place to place. Animals move to escape from their enemies. Animals move to find food, mates, and shelter. Some animals move slowly or not at all. These animals have ways, called adaptations, to survive while living in one place.
6. All animals can reproduce sexually. Some animals also can reproduce asexually.

Think it Over
1. Explain one way that an animal differs from a plant.

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How Animals Meet Their Needs

Animals adapt, or change, over time. Adaptations are passed down from generation to generation. Adaptations help animals survive in a changing environment. An adaptation might be a body structure, a process, or a behavior.

How do adaptations help animals get energy?

Food is a basic need. Without food, living things die. Animals have adaptations that allow them to find, eat, and digest different foods.

**Herbivores** Animals that eat only plants are called herbivores. Deer, some fish, and many insects are herbivores. Plants do not give animals as much energy as other kinds of foods. To get the energy they need, herbivores usually eat more food than other animals do.

**Carnivores** Animals that eat other animals are called carnivores. Most carnivores, like lions and red-tailed hawks, catch and kill other animals for food. Some carnivores eat only the remains of other animals. These carnivores are called scavengers. A buzzard is a scavenger that can be seen eating animals that may have been hit by cars.

The meat from animals supplies more energy than plants supply. For this reason, carnivores do not need to eat as much or as often as herbivores do.

**Omnivores** Animals that eat both plants and animals are called omnivores. Bears, raccoons, robins, and humans are examples of omnivores.

Millipedes and many beetles eat tiny bits of decaying matter called detritus (dih TRI tus). These animals are called detritivores (dih TRI tih vorz).

---

**Picture This**

2. List one more example of an omnivore.
What physical adaptations help animals survive?

Animals that capture and eat other animals are called predators. Some animals have physical features that help them avoid predators. A turtle has a hard shell that protects it. A porcupine has sharp quills that keep it safe from predators.

**Size** Many animals avoid danger because of their size. Large animals are usually safer than small animals. Moose and bison are large animals. Because they are so large, most predators will not attack them.

**Mimicry** Some animals avoid predators because they act or look like other animals. The scarlet king snake looks like the coral snake. The coral snake is poisonous and will kill predators that attack it. The scarlet king snake is not poisonous. Because the two snakes look alike, predators usually leave both kinds of snakes alone. The scarlet king snake is adapted to help it survive. This type of adaptation is called mimicry (MIHM ih kree).

**Camouflage** Some animals hide from predators by blending in with their environment. For example, a trout has a speckled back. From above, its back looks like the gravel bottom of the stream it lives in. Some animals can change their coloring to match their surroundings. A lizard can have light green skin while resting on a light green leaf. The same lizard can have dark brown skin when resting on a dark brown tree. Any marking or coloring that helps an animal hide from other animals is called camouflage.

What physical adaptations do predators have?

Camouflage is an adaptation that helps some predators sneak up on their prey. A tiger has stripes that help it hide in tall grasses. A killer whale is black on top and white underneath. From above, the black looks like the dark ocean. From underneath, the white looks like the light of the sky above. The killer whale’s coloring helps it hunt its prey.

How do behavioral adaptations help animals survive?

Many animals have behaviors that help them avoid predators or catch their prey. Some animals use chemicals produced by their bodies. A skunk sprays a bad-smelling liquid at predators. An octopus squirts ink when it is in danger. The ink darkens the water and confuses predators, giving the octopus time to escape.
Run from Predators  Some animals run away from predators. The Thomson’s gazelle can run faster than a lion and usually escapes.

Live in Groups  Some animals live in groups. This is a behavior used by both predators and prey. Herring swim in groups called schools. Predators do not attack the school because the group appears to be one large fish.

Some predators also travel in groups. Wolves live and travel in groups called packs. A pack of wolves works together to hunt, exhaust, and kill prey. The pack hunts larger prey than one wolf could capture on its own.

Animal Classification  Scientists have identified and named more than 1.8 million species of animals. Scientists estimate that there are millions more animals to be identified and named. To help organize so many animals, scientists have ways to sort, name, and group them.

How do scientists classify animals?  Scientists classify animals into two main groups, vertebrates and invertebrates. A vertebrate is an animal with a backbone. Fish, frogs, snakes, birds, and humans are vertebrates. An invertebrate is an animal without a backbone. Sponges, jellyfish, worms, insects, and clams are all invertebrates. The figure below shows how animals are classified and lists several classes of invertebrates.
Invertebrates  About 97 percent of all animal species are invertebrates. Many invertebrates have outer coverings to protect them. Some invertebrates have shells. Some have skeletons on the outsides of their bodies. Others have spiny outer coverings.

What does a backbone do?
A backbone is a stack of structures called vertebrae. The backbone supports the animal. It also protects and covers the spinal cord. The spinal cord contains nerves that carry messages from the brain to other parts of the body. It also carries messages back to the brain.

How is symmetry used to classify animals?
Animals are first classified as invertebrates or vertebrates. Next, animals are grouped by symmetry (SIH muh tree). Symmetry is how the body parts of an animal are arranged. Some animals have no definite shape. An animal with no definite shape is called asymmetrical. Most sponges are asymmetrical.

Radial symmetry is the arrangement of body parts around a center point, like spokes on a bicycle wheel. Jellyfish, anemones, and sea urchins have radial symmetry.

Most animals have bilateral symmetry. An animal with bilateral symmetry has a body that can be divided into right and left halves. Each half is nearly a mirror image of the other. Crayfish, humans, butterflies, and birds have bilateral symmetry. The figure below shows the types of symmetry.
After You Read

**Mini Glossary**

- **bilateral symmetry:** arrangement of body parts divided into right and left halves; each half is nearly a mirror image of the other
- **carnivore:** an animal that eats only animals
- **herbivore:** an animal that eats only plants
- **invertebrate:** an animal without a backbone
- **omnivore:** an animal that eats both plants and animals
- **radial symmetry:** arrangement of body parts around a center point
- **vertebrate:** an animal with a backbone

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that compares two of the terms.

   

2. Fill in the tables below with appropriate animal examples to review physical and behavioral adaptations in animals.

<table>
<thead>
<tr>
<th>Physical Adaptations</th>
<th>Behavioral Adaptations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptation</td>
<td>Animal</td>
</tr>
<tr>
<td>size</td>
<td></td>
</tr>
<tr>
<td>mimicry</td>
<td></td>
</tr>
<tr>
<td>camouflage</td>
<td></td>
</tr>
</tbody>
</table>

3. How did reviewing the main ideas after you have read the section help you remember the important ideas about animals?

   

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Visit [life.msscience.com](http://life.msscience.com) to access your textbook, interactive games, and projects to help you learn more about animal characteristics.
Before You Read

The artificial sponge you use for dishwashing is similar to a dried natural sponge. On the lines below, describe how a sponge looks and feels.

Read to Learn

Sponges

Sponges are invertebrates that live in water. They play many roles. Worms, shrimp, snails, and sea stars live on, in, and under sponges. Sponges are an important source of food for some snails, sea stars, and fish. Some sponges contain organisms that provide oxygen to the sponge and remove its wastes.

For many years, humans have dried sponges and used them for bathing and cleaning. Today, most sponges you see are artificial. Scientists are finding new uses for natural sponges. Chemicals found in sponges may be used to make drugs that help fight diseases.

When did sponges first appear on Earth?

Fossil records show that sponges appeared on Earth about 600 million years ago. Because sponges have little in common with other animals, many scientists have concluded that sponges developed separately from all other animals. Today's sponges are similar to sponges that lived 600 million years ago.

Create a Chart

Make a two-column chart. Label the left column Sponges and the right column Cnidarians. As you read about each, list the facts you learn in the correct column.

What You’ll Learn

- the characteristics of sponges and cnidarians
- how sponges and cnidarians get food and oxygen
- why living coral reefs are important

1. Identify two uses for natural sponges.
Characteristics of Sponges

There are more than 5,000 species of sponges. Most live in salt water near coastlines. Others live deep in the ocean. A few species are found in freshwater.

Sponges are different shapes, sizes, and colors. Saltwater sponges are bright red, orange, yellow, or blue. Freshwater sponges are usually a dull brown or green. Some sponges have radial symmetry, but most are asymmetrical. Sponges can be smaller than a marble or larger than a compact car.

Adult sponges are sessile (SE sile). A sessile organism remains attached to one place during its lifetime. Sponges often live in groups called colonies.

Because sponges do not move around, early scientists classified sponges as plants. Later scientists found that sponges could not make their own food. Because animals cannot make their own food, scientists reclassified sponges as animals.

How is a sponge’s body organized?

The figure below shows the body of a sponge. Sponges have a simple body structure. They do not have tissues, organs, or organ systems. A sponge’s body is a hollow tube. It is closed at the bottom and open at the top. A sponge has many tiny openings in its body called pores. Water moves through the pores.

Many sponge bodies have sharp, pointed structures called spicules (SPIH kyewliz). You can see these sharp structures in the figure above. Some sponges have skeletons made of a fiber-like material called spongín. Spicules and spongín provide support for a sponge and protect it from predators.
How do sponges get food and oxygen?
Sponges pull water into their bodies through their pores. The water contains tiny food particles. Cells filter out bits of food from the water. Oxygen also is removed from the water. The filtered water carries away wastes through the opening in the top of the sponge.

How do sponges reproduce?
Sponges can reproduce sexually as shown in the figure below. Most sponges are hermaphrodites (hur MA fruhr dites). A hermaphrodite is an animal that produces both sperm and eggs in the same body.

Sponges release sperm into the water. The sperm float until they are drawn into another sponge. A sperm fertilizes an egg. From this, a larva develops inside the sponge. A larva looks different from an adult sponge. A sponge larva has short, threadlike structures, called cilia, that allow it to swim. The larva swims from the sponge, and eventually settles on a surface. It will slowly grow into an adult.

Sponges also can reproduce asexually. A bud forms on a parent sponge, then drops off and grows on its own. Sponges also can grow by regeneration from small pieces of a sponge. In regeneration, an organism grows new body parts to replace lost or damaged ones. Sponge growers cut sponges into small pieces, then throw the pieces into the ocean to regenerate.
Cnidarians

Cnidarians (ni DAR ee uhnz) are another group of invertebrates that live in water. Cnidarians include corals, jellyfish, sea anemones, hydras, and the Portuguese man-of-war.

Where are cnidarians found?
Most cnidarians live in salt water, although many types of hydras live in freshwater. Sea anemones and jellyfish live as single organisms. Hydras and corals often live in colonies.

What body forms do cnidarians have?
Cnidarians have two different body forms—medusa and polyp. The medusa (mih DEW suh) form is shaped like a bell or an umbrella. It is free-swimming and floats along on the ocean currents. A jellyfish spends most of its life as a medusa.

The polyp (PAH lup) form is shaped like a vase and usually is sessile. Sea anemones, corals, and hydras live most of their lives as polyps.

How is the cnidarian body organized?
Cnidarians have radial symmetry. A cnidarian has two layers of cells that form tissues and a digestive area. In this two-cell-layer body plan, all of the cnidarian’s cells are close to the water. In the cells, oxygen from the water is exchanged for carbon dioxide and other cell wastes.

A cnidarian has a system of nerve cells called a nerve net. The nerve net carries messages to all parts of the body. This makes cnidarians capable of simple movements. They can somersault away in response to danger.

Most cnidarians have tentacles (TEN tih kulz) around their mouths. Tentacles are armlike structures used for getting food.

How do cnidarians get food?
A cnidarian has one body opening, a mouth, through which food enters and undigested food is removed. Cnidarians are predators. They have stinging cells on their tentacles. A stinging cell has a capsule with a threadlike structure with toxins that helps the cnidarian capture food.

When prey lightly touch or swim near the stinging cells, the thread goes into the prey, and the toxin stuns it. The tentacles then move the prey into the cnidarian’s mouth.

Some fish live among the tentacles of large sea anemones. The fish are not harmed by the sea anemone’s sting because they are protected by a special covering.
How do cnidarians reproduce?
Cnidarians reproduce sexually and asexually. Polyp forms reproduce asexually by producing buds that fall off the cnidarian and develop into new polyps.

Polyp forms also reproduce sexually. Eggs are produced and released into the water. Sperm are released into the water and fertilize the eggs, which develop into new polyps.

Medusa (plural, medusae) forms have two stages of reproduction—a sexual stage and an asexual stage. The stages are shown in the figure below. During the sexual stage, free-swimming medusae produce eggs or sperm. The eggs and sperm are released into the water. The sperm from one medusa fertilize the eggs from another medusa. The fertilized eggs grow into larvae.

The larvae grow into polyps. During the asexual stage, the polyp forms buds that become tiny medusae. The medusae buds off the polyp, and the cycle continues.

Picture This
6. Identify Circle the two body forms of the cnidarian.
**Origin of Cnidarians**

Scientists hypothesize that cnidarians have been on Earth for more than 600 million years. The medusa body was probably the first form. Polyps may have formed from medusae larvae that became permanently attached to a surface. Most of the cnidian fossils are corals.

**Corals**

Corals live in colonies called coral reefs. Coral polyps form hard, protective shells or skeletons. A reef forms as each new generation of coral polyps builds on top of existing coral skeletons. It takes millions of years for large reefs to form.

**Why are corals important?**

Coral reefs are important in the ecology of tropical waters. The diversity of life in coral reefs is similar to that in tropical rain forests. Some of the most beautiful and interesting animals in the world live in the formations of coral reefs.

- Coral reefs protect beaches and shorelines from rough seas. When coral reefs are destroyed, large amounts of shoreline can be washed away.
- Corals, like sponges, produce chemicals that protect them from disease. Medical researchers are learning that some of these chemicals might fight cancer in humans. Some coral is even used to replace missing sections of bone in humans.
After You Read

Mini Glossary

hermaphrodite (hur MA fruh dite): an animal that produces both sperm and eggs in the same body
medusa (mih DEW suh): a free-floating bell-shaped cnidarian body form
polyp (PAH lup): a sessile vase-shaped cnidarian body form

sessile (SE sile): staying attached to one place for most of an animal’s life
stinging cells: cells with coiled threads that help cnidarians get food
tentacle (TEN tih kul): armlike structure used for obtaining food

1. Review the terms and their definitions in the Mini Glossary. Use a term related to reproduction in sponges and cnidarians in a sentence.

2. Use the Venn diagram below to compare and contrast the body forms and structures of sponges and cnidarians.

[Diagram of Venn diagram with Sponges and Cnidarians as categories and Both Sponges and Cnidarians as the intersection]

ScienceOnline Visit life.mssscience.com to access your textbook, interactive games, and projects to help you learn more about sponges and cnidarians.

End of Section
Introduction to Animals

section 3 Flatworms and Roundworms

What You’ll Learn

■ about flatworms and roundworms
■ how free-living and parasitic organisms are different
■ the diseases caused by flatworms and roundworms

Before You Read

List four things you know about worms on the lines below.


Read to Learn

What is a worm?

Worms are invertebrates with soft bodies and bilateral symmetry. Their soft bodies have three layers of tissues, as shown in the figure below. A tissue is a group of cells that work together. The tissue layers are organized into organs and organ systems.

Flatworms

Flatworms have flat bodies. Planarians, flukes, and tapeworms are all flatworms. Most flatworms are parasites. A parasite depends on another organism, called a host, for food and a place to live.

Some flatworms are free-living organisms. Free-living organisms do not depend on another organism for food or a place to live.
What is a planarian?

A planarian is a free-living flatworm. Most planarians live under rocks, on plant materials, or in freshwater. Planarians range in size from 3 mm to 30 cm. They have triangle-shaped heads with two eyespots, as shown in the figure below.

How does a planarian eat?

A planarian has one opening—a mouth. The opening is on the underside of the body. A planarian feeds on small organisms and the dead bodies of larger organisms. A muscular tube called the pharynx connects the mouth to the digestive tract. The digestive tract breaks down food into nutrients for the worm.

How does a planarian move?

A planarian’s body is covered with cilia, which are fine, hairlike structures. As the cilia move, the worm slides along a slimy mucous track. The mucus is secreted from the underside of the planarian.

How does a planarian reproduce?

Planarians reproduce asexually and sexually. Planarians reproduce asexually by dividing in two. They also can regenerate, like sponges. If a planarian is cut in two, each piece will grow into a new worm.

Planarians reproduce sexually by producing eggs and sperm. Most planarians are hermaphrodites. They exchange sperm with each other and then lay fertilized eggs that hatch in a few weeks.

What are flukes?

Flukes are parasitic flatworms that feed on the blood, cells, and other fluids of their hosts. A fluke’s life cycle requires more than one host.

**Picture This**

2. Trace the shape of the head with a colored marker or pen. What shape does it form?
3. Explain how tapeworms reproduce.

Most flukes reproduce sexually. The male worm deposits sperm in the female worm. The female lays fertilized eggs inside the host. The eggs leave the host in its waste products. Fertilized eggs that end up in water usually infect snails. The eggs grow into young worms. The young worms leave the snail and enter the body of a new host through the skin.

The most common disease caused by blood flukes is schistosomiasis (shis tuh soh MI uh sus). Many people die from diseases caused by blood flukes. Other types of flukes can infect the eyes, lungs, liver, and other organs of their host.

What are tapeworms?

Tapeworms are another type of parasitic flatworm. An adult tapeworm uses hooks and suckers to attach itself to the intestine of its host. Dogs, cats, other animals, and humans are the hosts for tapeworms. A tapeworm absorbs food that is being digested by the host from the host’s intestine.

How does a tapeworm reproduce?

The figure below shows the reproductive cycle of a tapeworm. A tapeworm’s body segments have both male and female reproductive organs. Sperm in a segment often fertilizes the eggs in the same segment. When a mature segment at the end of the worm is full of fertilized eggs, the segment breaks away. This segment passes out of the host’s body with the host’s other wastes. If another host eats a fertilized egg, the egg hatches and grows into an immature tapeworm called a bladder worm.
Origin of Flatworms

Scientists do not know when flatworms first appeared on Earth. Evidence does suggest that flatworms are the first animal group to have bilateral symmetry with nerves and senses around the head area. Flatworms also are probably the first animals to have a third tissue layer that develops into organs and organ systems. Some scientists hypothesize that flatworms and cnidarians may have had a common ancestor.

Roundworms

Roundworms also are called nematodes. More roundworms live on Earth than any other type of many-celled organism. More than half a million species of roundworm are found in soil, in animals, in plants, in freshwater, and in salt water. Some are parasitic, but most are free-living. Most nematode species have male and female worms and reproduce sexually.

A roundworm is long and thin like a piece of thread. Its body tapers like a carrot tip on both ends. The roundworm’s body is a tube with another tube inside. Fluid separates the two tubes. Roundworms have two body openings, a mouth and an anus. An **anus** is an opening at the end of the digestive tract through which wastes leave the body.

What is the origin of roundworms?

Roundworms first appeared on Earth about 550 million years ago. They were the first animals to have a digestive system with a mouth and an anus. They may be closely related to arthropods.

Why are roundworms important?

Roundworms can cause diseases in humans and animals. Some roundworms cause damage to plants, fabrics, crops, and food.

Not all roundworms are a problem for humans. Some roundworm species feed on fleas, ticks, ants, beetles, and other insects that cause damage to crops and humans. Researchers are studying roundworms that kill deer ticks that cause Lyme disease.

Roundworms are important to the health of soil. They break down organic material and put nutrients in the soil. They also help in cycling elements such as nitrogen.
After You Read

Mini Glossary

**anus:** an opening at the end of the digestive tract through which waste leaves the body

**free-living organism:** an organism that does not depend on another organism for food or a place to live

1. Review the terms and their definitions in the Mini Glossary. Write a sentence using one of the terms.

2. Fill in facts for each row to describe flatworms and roundworms.

<table>
<thead>
<tr>
<th></th>
<th>Flatworms</th>
<th>Roundworms</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of body openings</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Type of symmetry</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Food sources</strong></td>
<td>Parasites:</td>
<td>Free-living:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Reproduction</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Visit [life.msscience.com](http://life.msscience.com) to access your textbook, interactive games, and projects to help you learn more about flatworms and roundworms.
Build Vocabulary
Read all the headings for this section and circle any word you cannot define. At the end of the section, review the circled words and underline the part of the text that helps you define them.

Before You Read
Look at the picture on this page. Have you ever seen this kind of animal? If so, where?

Read to Learn

Characteristics of Mollusks
Mollusks (MAH lusks) are soft-bodied invertebrates. They have bilateral symmetry and usually one or two shells. The organs are in a fluid-filled cavity. Most mollusks live in water, but some live on land. Snails, clams, and squid are mollusks.

What do the bodies of mollusks look like?
Mollusks have a thin layer of tissue called a mantle. As you can see in the figure below, the mantle covers the body organs. It secretes the shell or protects the body if the mollusk doesn’t have a shell. Between the soft body and the mantle is a space called the mantle cavity. It contains gills—the organs in which carbon dioxide from the mollusk is exchanged for oxygen in the water.

What You’ll Learn
■ the characteristics of mollusks
■ about gastropods, bivalves, and cephalopods
■ why mollusks are important

Mark the Text
Build Vocabulary Read all the headings for this section and circle any word you cannot define. At the end of the section, review the circled words and underline the part of the text that helps you define them.

Picture This
1. Highlight the part of the mollusk that covers the body organs.
2. Explain What type of circulatory system do most mollusks have?

What is an open circulatory system?
The circulatory system of most mollusks is an open system. In an open circulatory system, the heart moves blood out into the open spaces around the body organs. The blood completely surrounds and nourishes the body organs.

What other features do mollusks have?
Most mollusks have a head with a mouth and some sensory organs. Some mollusks, such as squid, have tentacles. The muscular foot located on the underside of a mollusk is used for movement.

Classification of Mollusks
Mollusks are classified according to whether or not they have a shell. Mollusks with a shell are then classified by the kind of shell and kind of foot that they have. Gastropods, bivalves, and cephalopods are the three most common groups of mollusks.

What are gastropods?
Gastropods make up the largest group of mollusks. The group includes snails, conchs, and garden slugs. All gastropods, except slugs, have a single shell. Many have a pair of tentacles with eyes at the tips.

Gastropods use a radula (RA juh luh), which is a tonguelike organ with rows of teeth, to get food. The radula works like a file to scrape and tear food materials. That’s why snails are helpful in an aquarium. They use their radula to scrape the algae off the walls of the tank.

Slugs and many snails can live on land. The muscular foot helps them move. Glands in the foot secrete a layer of mucus on which they slide. Slugs do not have shells. They are protected by a layer of mucus instead, so they must live in moist places. Slugs and land snails damage plants when they eat leaves and stems.

What are bivalves?
Bivalves are mollusks that have a hinged, two-part shell joined by strong muscles. Clams, oysters, and scallops are bivalves. They pull their shells closed by contracting the muscles near the hinge. They relax these muscles to open the shell. Bivalves are well adapted to living in water.
What are cephalopods?
Cephalopods (SE fuh luh pawdz) are the most specialized and complex mollusks. Squid and octopuses belong to this group. A cephalopod has a large, well-developed head. Its foot is divided into many tentacles with strong suction cups or hooks for capturing prey. Cephalopods are predators. They feed on fish, worms, and other mollusks.

Squid and octopuses have a well-developed nervous system and large eyes. Unlike other mollusks, cephalopods have a closed circulatory system. In a closed circulatory system, blood containing food and oxygen moves through the body in a series of closed vessels, just as blood moves through blood vessels in a human body.

How do cephalopods propel themselves?
All cephalopods live in oceans and are adapted for swimming. They have a water-filled cavity between an outer muscular covering and the internal organs. When the cephalopod tightens its muscular covering, water is forced out through an opening near the head. The jet of water propels, or moves, the cephalopod backwards, and it moves away quickly. The figure below compares a squid’s movement to releasing air from a balloon.

A squid can propel itself at speeds of more than 6 m/s. However, it can only maintain this speed for a few seconds. Octopuses also can swim by jet propulsion. However, they usually use their tentacles to move slowly over the ocean floor.

Picture This
4. Explain Use the figure to explain to a partner how a squid moves.
5. Identify two uses of mollusks.

When did mollusks first appear on Earth?

Some species of mollusks have changed little from their ancestors. Mollusk fossils date back more than 500 million years. Many species of mollusks became extinct about 66 million years ago. Today’s mollusks are descendants of ancient mollusks.

Value of Mollusks

Mollusks have many uses. They are food for fish, birds, and humans. Many people make their living raising or collecting mollusks to sell for food. Other invertebrates, such as hermit crabs, use empty mollusk shells as their homes. Mollusk shells are used for jewelry and decoration. Several species of mollusks make pearls, but most pearls come from pearl oysters.

Mollusk shells provide information about the conditions in an ecosystem. Scientists use the shells to find the source and distribution of water pollutants. The internal shell of a cuttlefish is called the cuttlebone. Cuttlebones are used to provide calcium to caged birds. Squid and octopuses are able to learn new tasks, so scientists are studying their nervous systems to understand how learning takes place and how memory works.

What problems do mollusks cause?

Although they are helpful in many ways, mollusks can cause problems for humans. Land slugs and snails damage plants. Some species of snails are hosts of parasites that infect humans.

Shipworms, a bivalve, cause millions of dollars in damage each year by making holes in the underwater wood of docks and boats. Clams, oysters, and other mollusks are filter feeders. Because of this, bacteria, viruses, and toxic protists from the water can become trapped in these animals as they feed. When humans eat infected mollusks, they can become sick or die.
1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the difference between a closed circulatory system and an open circulatory system.

2. Complete the chart below by listing the characteristics of the three main groups of mollusks.

<table>
<thead>
<tr>
<th>Type of Mollusk</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gastropods</td>
<td></td>
</tr>
<tr>
<td>Bivalves</td>
<td></td>
</tr>
<tr>
<td>Cephalopods</td>
<td></td>
</tr>
</tbody>
</table>

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about mollusks.
Mollusks, Worms, Arthropods, Echinoderms

section 2 Segmented Worms

What You’ll Learn

- the characteristics of segmented worms
- the structures of an earthworm
- why segmented worms are important

Before You Read

Where can you find worms in your community?

Read to Learn

Segmented Worm Characteristics

The worms that you see crawling on sidewalks after it rains are called annelids (A nuh ludz). They have tube-shaped bodies that are divided into many segments. On the outside of each segment are bristlelike structures called setae (SEE tee). Segmented worms use these structures to hold on to the soil and to move.

Segmented worms have bilateral symmetry and a body cavity that holds the organs. They also have two body openings—a mouth and an anus. Annelids are found in freshwater, salt water, and moist soil.

Earthworm Body Systems

Earthworms are the most well-known annelids. They have a front end, a back end, and more than 100 body segments. Except for the first and last segments, each body segment has four pairs of setae. Earthworms move by using their setae and two sets of muscles in the body wall. When an earthworm contracts one set of muscles, some of the segments bunch up and the setae stick out. This holds the worm to the soil. When the earthworm contracts the other set of muscles, the setae are pulled in and the worm moves forward.
How do digestion and excretion happen in earthworms?

The figure below shows the parts of an earthworm. As the earthworm burrows through the soil, it takes soil into its mouth. It gets energy from the leaves and other organic matter found in the soil.

The soil that the worm takes in moves to the crop, which is a sac used for storage. Behind the crop is a muscular structure called the gizzard, which grinds the soil and the bits of organic matter. The ground material passes to the intestine. There the organic matter is broken down and nutrients are absorbed by the blood. Wastes leave the body through the anus. The wastes pile up at the openings to their burrows. The piles are called castings. Castings help fertilize the soil.

What kind of circulatory system do earthworms have?

Earthworms have a closed circulatory system. There are two blood vessels located along the top of the body and one along the bottom. They meet in the front end of the earthworm, where they connect to heartlike structures called aortic arches. These structures pump blood through the body. Smaller vessels go into each body segment.

Earthworms have no lungs or gills. They exchange oxygen and carbon dioxide through their skin. The skin is covered with a thin film of watery mucus. If the mucus layer is removed, the earthworm could suffocate.
How do earthworms respond and reproduce?

Earthworms have a small brain located in the front segment. Each segment has nerves that join to form a nerve cord that connects to the brain. Earthworms respond to light, temperature, and moisture.

Earthworms are hermaphrodites (hur MA fruh dites). That means they produce eggs and sperm in the same body. A worm cannot fertilize its own eggs. It needs to receive sperm from another earthworm in order to reproduce.

Marine Worms

There are more than 8,000 species of marine worms, or polychaetes (PAH lee keets). This is more than any other kind of annelid. Marine worms float, burrow, build structures, or walk along the ocean floor. Some polychaetes produce their own light.

Marine worms have segments with bundles of setae. Some marine worms live attached to one place all their lives. These worms have specialized tentacles that are used for exchanging oxygen and carbon dioxide and gathering food. Some marine worms build tubes around their bodies to hide in when something startles them.

Leeches

Leeches are segmented worms. However, their bodies are not as round or as long as those of earthworms. They also do not have setae. They feed on the blood of other animals. A sucker on each end of a leech’s body is used to attach itself to an animal. Leeches produce an anesthetic (an us THE tihk) that numbs the wound so the animal won’t feel the bite. After it attaches itself, the leech cuts into the animal and sucks out blood. They also can survive by eating aquatic insects and other organisms.

Leeches and Medicine

Sometimes leeches are used after surgery to keep blood flowing to the surgical site. As the leeches feed on the blood, chemicals in their saliva prevent the blood from clotting. Other chemicals dilate the blood vessels, improving blood flow and helping the wound heal more quickly. Scientists are studying ways to use the chemicals that leeches produce to treat people with heart disease and arthritis.
Value of Segmented Worms

Different kinds of segmented worms are helpful to other animals in a variety of ways. Earthworms help aerate, or add air, to soil by burrowing through it. By grinding and partially digesting soil and plant material, earthworms speed up the return of nitrogen to the soil for plants to use.

Scientists are developing drugs based on the chemicals in the leeches’ saliva. They hope the drugs will prevent blood clots. Marine worms are food for many fish, invertebrates, and mammals.

Origin of Segmented Worms

Some scientists hypothesize that segmented worms evolved in the sea. The fossil record for segmented worms is limited because of their soft bodies. The tubes of marine worms are the most common fossils of the segmented worms. Some of these fossils date back about 620 million years.

There are similarities between mollusks and segmented worms. Scientists use these similarities to suggest that mollusks and segmented worms could have a common ancestor. These groups were the first animals to have a body cavity with space for body organs. Mollusks and segmented worms have a one-way digestive system with a separate mouth and anus. Their larvae, shown in the figure below, are similar. This provides the best evidence that they have a common ancestor.

5. Describe how earthworms help aerate the soil.

6. Identify Look at the figure. What do the similarities between the two larvae suggest?
### After You Read

**Mini Glossary**

- **crop**: storage sac to which ingested soil moves
- **gizzard**: muscular structure behind the crop, which grinds the ingested soil and organic matter
- **setae (SEE tee)**: bristlelike structures on the outside of each body segment of earthworms and marine worms; used to hold on to the soil and to move

1. Review the terms and their definitions in the Mini Glossary. Choose one of the terms and write a sentence explaining its role in the earthworm’s body.

   

   

   

2. Complete the web diagram below by describing the importance of segmented worms to people and other organisms.

   ![Web Diagram](image)

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Visit [life.mssscience.com](http://life.mssscience.com) to access your textbook, interactive games, and projects to help you learn more about segmented worms.
Mollusks, Worms, Arthropods, Echinoderms

section 3 Arthropods

Before You Read

On the lines below, write the name of an insect and describe it.

Read to Learn

Characteristics of Arthropods

There are more than a million different species of arthropods (AR thruh pahdz). They are the largest group of animals. The jointed appendages of arthropods include legs, antennae, claws, and pincers. The appendages are adapted for moving around, capturing prey, feeding, mating, and sensing the environment.

Arthropods have bilateral symmetry. They have segmented bodies, an exoskeleton, a body cavity, a digestive system with two openings, and a nervous system. Most arthropods have separate sexes and reproduce sexually.

Arthropods are adapted to live in almost every environment. They vary in size from microscopic dust mites to the large Japanese spider crab that can have a leg span of more than 3 m.

How are the bodies of arthropods divided?

Arthropods have segments like those of segmented worms. The segments of some arthropods are fused together to form body regions, such as those of insects and spiders.
What is the purpose of exoskeletons?

All arthropods have a hard, outer covering called an **exoskeleton**. It covers, supports, and protects the internal body. It also provides places for muscles to attach. In many land-dwelling arthropods, such as insects, the exoskeleton has a waxy layer to prevent water loss.

An exoskeleton does not grow as the animal grows. From time to time, the exoskeleton is shed and replaced by a new one in a process called **molting**. While they are molting, the arthropod’s exoskeleton is soft and offers little protection from predators. Before the new exoskeleton hardens, the animal swallows air or water to increase its size. This way the new exoskeleton allows room for growth.

Insects

There are more species of insects than all other animal groups put together. Insects have three body regions—a head, a thorax, and an abdomen.

What does an insect’s head look like?

An insect’s head has a pair of antennae, eyes, and a mouth. Insects use the antennae for touch and smell. The eyes are simple or compound. Simple eyes can recognize light and dark. Compound eyes have many lenses and can detect colors and movement. The kind of mouthpart an insect has depends on what it eats.

What body parts are attached to the thorax?

The thorax has three pairs of legs and one or two pairs of wings. Some insects do not have wings. Other insects have wings only for part of their lives. Insects are the only invertebrate animals that can fly. Flying helps insects to find mates, food, and places to live. It also helps them escape from their predators.

What is the purpose of an insect’s abdomen?

An insect’s reproductive structures are found in the abdomen. Females lay thousands of eggs. But only a small number of the eggs develop into adults. Insects have an open circulatory system. It carries digested food to cells and removes wastes. However, insect blood does not carry oxygen. Instead, insects have openings called **spiracles** (SPIHR ih kulz) on the abdomen and thorax. Air enters and waste gases leave the insect’s body through these openings.
How do insects grow?

The body forms of many insects change as they grow. This series of changes is called **metamorphosis** (me tuh MOR fuh sihs). Insects such as grasshoppers and crickets go through incomplete metamorphosis. The first figure below shows the stages of incomplete metamorphosis. They are egg, nymph, and adult. In incomplete metamorphosis, nymphs are smaller versions of their parents. The nymph form molts several times before becoming an adult.

Many insects, such as butterflies, beetles, ants, and bees, go through complete metamorphosis. The second figure shows the stages of complete metamorphosis. They are egg, larva, pupa, and adult. Caterpillar is the common name for the larva of a moth or butterfly. Other insect larvae are called grubs, maggots, or mealworms. Only larval forms molt.

How do insects get food?

Insects feed on plants, the blood of animals, flower nectar, decaying materials, wood, and clothes. Insects have varied mouthparts, depending on what they feed upon. Grasshoppers and ants have large mandibles (MAN duh bulz) for chewing plants. Butterflies and honeybees have siphons for drinking nectar in flowers. Praying mantises eat other animals. Some moth larvae eat wool clothing. Mosquitos, fleas, and lice drink the blood and body fluids of other animals. The mouthparts of grasshoppers, butterflies, and mosquitoes are shown at the top of the next page.
5. Identify  Match the following foods with the insect that feeds on them: blood, nectar, plants. Write your choices on the lines below the names of the insects.

6. List the two body regions of arachnids.

What makes insects successful?

Insects are extremely successful. This is because they have a tough exoskeleton, they can fly, they have rapid reproductive cycles, and they are small.

Most insects have short life spans. So genetic traits can change more quickly in insects than in organisms that take longer to reproduce. Insects are small, which means that they can live in a variety of places. They can also avoid their enemies. Because insects are so specialized in what they eat, they do not compete with one another for food.

Insects’ protective coloring, or camouflage, helps them blend in with their surroundings. Some moths resting on trees look like part of the bark. Some caterpillars look like twigs. When a leaf butterfly folds its wings, it looks like a dead leaf.

Arachnids

Spiders, scorpions, mites, and ticks are examples of arachnids (uh RAK nudz). They have two body regions—a head-chest region that is called the cephalothorax (se fuh luh THOR aks) and an abdomen. Arachnids have four pairs of legs but no antennae. Some arachnids kill prey with venom, or poison, glands. Some use stingers or fangs to kill prey. Other arachnids are parasites.
What are scorpions like?
A scorpion has a sharp, venom-filled stinger at the end of its abdomen. The venom from the stinger paralyzes the prey. Scorpions have a pair of appendages, called pincers, with which they catch their prey. A scorpion sting can be fatal to humans.

What are spiders like?
Spiders cannot chew their food. Instead they release enzymes, or chemicals, into their prey that help digest it. The spider then sucks the liquid into its mouth.
Oxygen and carbon dioxide are exchanged in a spider’s book lungs, shown in the figure below. Air circulates between the moist folds of the book lungs bringing oxygen to the blood. Openings on the abdomen allow the gases to move into and out of the lungs.

What are mites and ticks like?
Most mites are so small that they look like tiny specks to the human eye. Most mites are animal or plant parasites. All ticks are animal parasites. They attach to the skin of their hosts and take blood from their hosts through specialized mouthparts. Ticks often carry bacteria and viruses that cause disease in humans and other animals. Lyme disease and Rocky Mountain spotted fever are carried by ticks.
**Centipedes and Millipedes**

Centipedes and millipedes are two groups of arthropods that have long bodies with many segments and many legs. They have antennae and simple eyes. They live in damp places, such as in woodpiles and in basements. Centipedes and millipedes reproduce sexually. They lay eggs in nests and stay with them until they hatch. Centipedes have one pair of legs per segment.

Centipedes are predators—they capture and eat their prey, which includes snails, slugs, and worms. They have claws that they use to inject venom into their prey. Their pinches are painful to humans, but are not fatal.

Millipedes have two pairs of legs per segment. They feed on plants and decaying material. They are often found under damp plant material.

**Crustaceans**

Crustaceans include crabs, shrimp, pill bugs, and water fleas. They have one or two pairs of antennae and mandibles used to crush food. Most crustaceans live in water, but some, like pill bugs, live in moist environments on land. You can find pill bugs in gardens and near house foundations. They are harmless to people.

Crustaceans have five pairs of legs. The first pair catches and holds food. The other four pairs are walking legs. They also have five pairs of appendages, called swimmerets, on the abdomen. They help crustaceans move and are used in reproduction. The swimmerets also force water over the gills where the oxygen and carbon dioxide are exchanged. If a crustacean loses an appendage, it will grow back.

**Value of Arthropods**

Arthropods play several roles in the environment. They are food for many animals, including humans. Many humans eat shrimp, crab, crayfish, and lobster. In Africa and Asia, many people eat insect larvae and insects such as grasshoppers, termites, and ants. These insects are excellent sources of protein.

Agriculture would not be possible without bees and other insects that pollinate crops. Bees make honey, and silkworms make silk. Many insects and spiders are predators of harmful species, such as stableflies. Some arthropods provide useful chemicals. Bee venom is used to treat rheumatoid arthritis.
What problems do arthropods cause?

Some arthropods are not useful to people. Almost every crop has some insect pest that feeds on it. Many arthropods—mosquitoes, tsetse flies, fleas, and ticks—carry diseases that harm humans and other animals. Other arthropods, such as carpenter ants, moths, and termites, destroy food, clothing, and property. However, insects are important to ecosystems. Removing all insects from an ecosystem would cause more harm than good.

How are insects controlled?

Insecticides are used to control problem insects. But many insecticides also kill helpful insects. In addition, many poisonous substances that kill insects stay in the environment. They can build up in the bodies of animals that eat them. As other animals eat the contaminated animals, the insecticides find their way into human food. The toxins can harm people.

Different types of bacteria, fungi, and viruses are being used to control some insect pests. In some cases, natural predators of insect pests have been successful in controlling them. Other ways of controlling insect pests include using chemicals that interfere with the reproduction or behavior of insect pests.

What is the origin of arthropods?

Because of their hard body parts, arthropod fossils are among the oldest and best-preserved fossils of many-celled animals. One of the most recognized types of fossils is an arthropod—the trilobite. The figure below shows one of the more than 15,000 species of trilobites that have been classified. Some arthropod fossils are more than 500 million years old. Scientists hypothesize that arthropods came from an ancestor of segmented worms. This is because both earthworms and leeches have individual body segments. Over time, groups of body segments fused and became adapted for locomotion, feeding, and sensing the environment. The hard exoskeleton and walking legs allowed arthropods to be among the first successful land animals.
After You Read

Mini Glossary

appendages: in arthropods, includes legs, antennae, claws, and pincers
exoskeleton: hard, outer covering
metamorphosis (me tuh MOR fuh sihs): a series of changes in body form
molt: process in which exoskeleton is shed and replaced by a new one
spiracle (SPIHR ih kul): opening on the abdomen and thorax of an arthropod through which air enters and waste gases leave the insect’s body

1. Review the terms and their definitions in the Mini Glossary. Choose one of the terms above and write a sentence that explains the role of the term in an arthropod’s body.

2. Complete the web diagram to identify five types of arthropods discussed in this section.

3. How did the outline help you organize what you learned about arthropods?

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about arthropods.
Identify the Main Point

Read each subhead. Then work with a partner to write questions about the information found under each subhead. Take turns asking and answering the questions. Use the questions as a study guide about echinoderms.

What You’ll Learn
- the characteristics of echinoderms
- how sea stars obtain and digest food
- why echinoderms are important

Before You Read

If you were walking on a beach by an ocean, what animals would you expect to see? After you read this section, see if any of the animals you named are echinoderms.

Read to Learn

Echinoderm Characteristics

Echinoderms (ih KI nuh durmz) are found in oceans. They have a hard endoskeleton covered by a thin, bumpy, or spiny skin. Because they have radial symmetry, they can sense things in their environment from all directions.

All echinoderms have a mouth, stomach, and intestines, as shown in the figure below. They feed on plants and animals. Echinoderms have no head or brain. They do have a nerve ring that surrounds the mouth. They also have cells that respond to light and touch.

![Echinoderm Diagram](image)

Picture This

1. **Identify** Shade the mouth and intestines of the sea star.
What is the water-vascular system?

Echinoderms have a water-vascular system, which is a network of water-filled canals with thousands of tube feet connected to it. The water-vascular system allows echinoderms to move, exchange carbon dioxide and oxygen, capture food, and release wastes.

Tube feet are hollow, thin-walled tubes that end in suction cups. As the pressure in the tube feet changes, the animal is able to move along by pushing out and pulling in its tube feet.

Types of Echinoderms

There are about 6,000 species of echinoderms living today. More than one third are sea stars. Other groups of echinoderms include brittle stars, sea urchins, sand dollars, and sea cucumbers.

What do sea stars look like?

Sea stars have at least five arms arranged around a central point. The arms have thousands of tube feet. Sea stars use the tube feet to open the shells of their prey. When the shell opens a little, the sea star pushes its stomach through its mouth and into its prey. The sea star’s stomach surrounds the soft body of the prey and gives off enzymes that help digest it. When the meal is over, the sea star pulls its stomach back into its own body.

Sea stars reproduce sexually. Females release eggs and males release sperm into the water. Females can produce millions of eggs in one season.

Sea stars can grow new body parts through regeneration. If a sea star loses an arm, a new one will grow. If enough of the center disk is left attached to a severed arm, a whole new sea star can grow from the piece of arm.

What do brittle stars look like?

Brittle stars have fragile, branched arms that break off easily. This adaptation helps brittle stars survive attacks by predators. While a predator is eating the broken arm, the brittle star escapes. The broken part grows back, or regenerates quickly.

Brittle stars live under rocks on the ocean floor. They use their flexible arms for movement instead of their tube feet. They use the tube feet to move food particles into their mouth.
What do sea urchins and sand dollars look like?

Another group of echinoderms includes sea urchins, sea biscuits, and sand dollars. They are disk-shaped animals covered with spines. They do not have arms, but sand dollars have a five-pointed pattern on their surface.

Sand dollars have stiff, hairlike spines and sea urchins have long, pointed spines that protect them from predators. Some sea urchins have sacs near the end of the spines that hold toxic fluid that is injected into predators. The spines also help the animals move and burrow. Sea urchins have five toothlike structures around their mouth.

What do sea cucumbers look like?

Sea cucumbers are soft-bodied echinoderms with a leathery covering. They have tentacles around their mouth and rows of tube feet on their upper and lower surfaces. When sea cucumbers are threatened, they force out their internal organs. These organs grow back in a few weeks. Some sea cucumbers feed on dead and decaying matter called detritus (de TRI tus) found on the ocean floor.

Value of Echinoderms

Echinoderms are important to ocean environments because they feed on dead organisms and help recycle materials. Sea urchin eggs and sea cucumbers are used for food in some places. Many echinoderms are used in research and some might be possible sources of medicines. Sea stars are predators that control the populations of other animals. However, because sea stars eat oysters and clams, they also destroy millions of dollars’ worth of mollusks each year.

What is the origin of echinoderms?

A good fossil record of echinoderms exists. Echinoderms date back more than 400 million years. The earliest echinoderms might have had bilateral symmetry as adults and may have been attached to the ocean floor by stalks. Many larval forms of modern echinoderms have bilateral symmetry.

Scientists hypothesize that echinoderms more closely resemble animals with backbones than any other group of invertebrates. This is because echinoderms have complex body systems and an embryo that develops the same way that embryos of animals with backbones develop.
1. Review the terms and their definitions in the Mini Glossary. Write a sentence explaining how echinoderms use the water-vascular system.

2. Choose one of the question headings in the Read to Learn section. Write the question in the space below. Then write your answer to that question on the lines that follow.

Write your question here.

3. Complete the diagram below by identifying five types of echinoderms.

Types of Echinoderms

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Fish, Amphibians, and Reptiles

section ● Chordates and Vertebrates

Before You Read
Describe what happens to your body temperature when you go outside on a cold day or on a hot day.

What You’ll Learn
■ the characteristics of chordates
■ the characteristics of vertebrates
■ the difference between ectotherms and endotherms

Read to Learn

Chordate Characteristics
Many types of animals are classified as chordates. A chordate (KOR dayt) is an animal that has four characteristics present at some stage of its development—a notochord, postanal tail, nerve cord, and pharyngeal pouches. These are shown in the figure below.

Postanal tail

Pharyngeal pouches

Notochord

Nerve cord

Write a Summary of the section using all the vocabulary words. Be sure your summary includes the main idea from the section.

Study Coach

Picture This
1. Identify Select one of the four characteristics of chordates identified in the figure. skim the section to find the function of this feature. Write the function on the line below the label.
What is a notochord?
The notochord is located inside the chordate and supports the animal and extends along the upper part of the animal's body. The notochord is flexible but firm. Some chordates, such as fish, amphibians, reptiles, birds, and mammals develop backbones that partly or completely replace the notochord. These animals are called vertebrates. Some animals, such as the sea squirt, keep the notochord into adulthood.

What is the postanal tail?
The notochord extends into the postanal tail. The postanal tail is a muscular structure at the end of the developing chordate.

Why is the nerve cord important?
The nerve cord is a tubelike structure along the length of the developing chordate's body. As most chordates develop, the front end of the nerve cord enlarges to form the brain and the rest becomes the spinal cord. The brain and the spinal cord become the central nervous system.

Where are the pharyngeal pouches?
The pharyngeal pouches are found between the mouth and the digestive tube. They are pairs of openings to the outside of a developing chordate. Ancient chordates used them for filter feeding. Some chordates today, such as lancelets, still use pharyngeal pouches for filtering food. In humans, pharyngeal pouches are present only as the embryo develops. One pair of these pouches becomes the tubes that go from the ears to the throat.

Vertebrate Characteristics
Vertebrates have the same characteristics of chordates plus some other characteristics. Endoskeletons, cartilage, and vertebrae are characteristics that set vertebrates apart from other chordates.

What is the structure of vertebrates?
All vertebrates have an internal framework called an endoskeleton. It is made up of bone and/or flexible tissue called cartilage. In humans, the endoskeleton is made of all the bones in the body. There also is some cartilage in your endoskeleton. This gives shape to your ears and the tip of your nose. The endoskeleton provides a place for muscle attachment and supports and protects the body's organs.
What is the backbone?

Part of the endoskeleton is the flexible column called the backbone. It is a stack of *vertebrae* alternating with cartilage. The backbone surrounds and protects the spinal nerve cord. Vertebrates also have a head with a skull that encloses and protects the brain. Most of a vertebrate’s internal organs are in the central part of the body. A vertebrate has skin covering its body. Sometimes hair, feathers, scales, or horns grow from the skin.

What are the main vertebrate groups?

The table below shows the seven main groups of vertebrates found on Earth today. Vertebrates are either ectotherms or endotherms.

<table>
<thead>
<tr>
<th>Group</th>
<th>Estimated Number of Species</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jawless fish</td>
<td>60</td>
<td>lamprey, hagfish</td>
</tr>
<tr>
<td>Jawed cartilaginous fish</td>
<td>500 to 900</td>
<td>shark, ray, skate</td>
</tr>
<tr>
<td>Bony fish</td>
<td>20,000</td>
<td>salmon, bass, guppy, sea horse, lungfish</td>
</tr>
<tr>
<td>Amphibians</td>
<td>4,000</td>
<td>frog, toad, salamander</td>
</tr>
<tr>
<td>Reptiles</td>
<td>7,970</td>
<td>turtle, lizard, snake, crocodile, alligator</td>
</tr>
<tr>
<td>Birds</td>
<td>8,700</td>
<td>stork, eagle, sparrow, turkey, duck, ostrich</td>
</tr>
<tr>
<td>Mammals</td>
<td>4,600</td>
<td>human, whale, bat, mouse, lion, cow, otter</td>
</tr>
</tbody>
</table>

An ectotherm is a cold-blooded animal. An *ectotherm* has an internal body temperature that changes with the temperature of its surroundings. Fish, amphibians, and reptiles are ectotherms.

An endotherm is a warm-blooded animal. An *endotherm* has an internal temperature that changes little. Birds and mammals are endotherms. When you go outside on a hot day or cold day, your body temperature does not change much. You are an endotherm.

What fossil records of vertebrates exist?

There are fossils of vertebrates that lived about 420 million years ago (mya). The oldest known amphibian fossils date to about 370 mya. Reptile fossils have been found in deposits that are about 350 million years old. Mammals first appeared about 190 mya.
After You Read

Mini Glossary

cartilage: tough, flexible tissue that joins vertebrae and makes up all or part of the vertebrate endoskeleton

chordate (KOR daryt): an animal that has four characteristics present at some stage of its development—a notochord, postanal tail, nerve cord, and pharyngeal pouches

ectotherm: a cold-blooded animal that has an internal body temperature that changes with the temperature of its surroundings

endoskeleton: an internal framework in all vertebrates

dedotherm: a warm-blooded animal that has an internal body temperature that changes little

nerve cord: a tubelike structure above the notochord and along the length of the developing chordate’s body, which eventually develops into the central nervous system in most chordates

notochord: an internal structure that supports an animal and extends along the upper part of its body

pharyngeal pouches: pairs of openings to the outside of a developing chordate

postanal tail: a muscular structure at the end of the developing chordate

vertebrae: the stack of bones, alternating with cartilage, that form the column of the backbone

1. Review the terms and their definitions in the Mini Glossary. Write a sentence to explain the difference between an ectotherm and an endotherm.

2. Complete the concept map below to show the characteristics of vertebrates.

Chordates

1.

2.

3.

4.

Vertebrates

1.

2.

3.

4.

5.

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Fish, Amphibians, and Reptiles

section 2 Fish

Before You Read

On each line below, write the name of a type of fish. Next to each name, describe some characteristics of that species.

Fish Characteristics

There are more species of fish than species of any other vertebrate group. All fish are ectotherms and live in freshwater or salt water. Some fish, such as salmon, live in both freshwater and salt water. Fish are found at different depths, from shallow pools to deep oceans.

Why can fish move quickly through the water?

A streamlined shape, a muscular tail, and fins allow most fish to move quickly through the water. Fins are fanlike structures attached to the endoskeleton. Fish use fins to steer, balance, and move. Paired fins on the sides allow fish to move right, left, forward, and backward. Fins on the top and bottom of the body give the fish stability. Most fish secrete a slimy mucus that also helps them move through water.

What are scales?

Most fish have scales. Scales are hard, thin plates that cover the skin and protect the body, like shingles on the roof of a house. Most fish scales are made of bone. Scales can be tooth shaped, diamond shaped, cone shaped, or round. The shape of the scales can be used to classify fish.
How do fish sense their surroundings?

All fish have highly developed sensory systems. Most fish have a lateral line system that is made up of a shallow, canal-like structure that runs the length of the fish’s body and is filled with sensory organs. This system allows fish to sense their environment and to detect movement. Some fish, such as sharks, have a strong sense of smell. A fish has a two-chambered heart in which oxygen-filled blood mixes with carbon dioxide-filled blood.

How do fish get oxygen?

Most fish have organs called gills that exchange carbon dioxide and oxygen. Gills are located on both sides of the fish’s head and contain many tiny blood vessels. When a fish takes water into its mouth, the water passes over the gills, where oxygen from the water is exchanged with carbon dioxide in the blood. The water then passes out through openings on each side of the fish.

How do fish feed?

Fish get food in different ways. Some of the largest sharks swim with their mouths open. They take in small fish as they swim. Parrot fish use their hard beaks to bite off pieces of coral. An electric eel produces a powerful electric shock to stun its prey before it eats it. The archerfish shoots down insects by spitting drops of water at them. Some fish have strong teeth, but most do not chew their food. Instead, they use their sharp teeth to catch their food or to tear off chunks of food.

How do fish reproduce?

Fish reproduce sexually. Most female fish release large numbers of eggs into the water. Males then swim over the eggs and release sperm. This way of reproducing is called spawning. The joining of the egg and sperm cells outside the female’s body is called external fertilization. The joining of the egg and sperm cells inside the female’s body is called internal fertilization. Some sharks and rays have internal fertilization and lay fertilized eggs. Some other fish, such as guppies and other sharks, have internal fertilization but the eggs develop and hatch inside the female’s body. After they hatch, they leave her body.

Fish that do not care for their young release hundreds or even millions of eggs. Fish that care for their young lay fewer eggs.
Types of Fish

Fish are different in size, shape, color, living environments, and in many other ways. Even though fish have many differences, there are only three groups of fish—jawless fish, jawed cartilaginous (kar tuh LA juh nuss) fish, and bony fish.

Jawless Fish

Jawless fish have round, toothed mouths. Their long, tubelike bodies are covered with slimy skin but no scales. The endoskeletons of jawless fish are flexible and made of cartilage.

Lampreys and hagfish are jawless fish. Most lampreys attach to other fish with their suckerlike mouths. They are parasites that feed on the blood and body fluids of the host fish. Hagfish feed on dead or dying fish. They also eat other water animals. Some lamprey species live in salt water, while other species live in freshwater. Hagfish live in salt water.

Jawed Cartilaginous Fish

Jawed cartilaginous fish have endoskeletons made of cartilage. They have movable jaws that usually have well-developed teeth. Their bodies are covered with tiny scales. Sharks, skates, and rays are jawed cartilaginous fish.

Bony Fish

The fish you named at the beginning of the section are probably bony fish. About 95 percent of all species of fish are bony fish. Bony fish have skeletons made of bone. A bony flap covers and protects the gills. It closes as water moves into the mouth and over the gills. When the bony flap opens, water leaves the gills. The figure below shows the basic body structure of bony fish.

Foldables

C Describe Make a three-tab Foldable, as shown below, to record descriptions of each of the three groups of fish.

Picture This

4. Compare Highlight the body parts that fish and humans have in common.
5. Explain the main purpose of the swim bladder.

6. Identify When do acanthodians appear in the fossil record?

What is a swim bladder?
Most bony fish have a swim bladder. A swim bladder is an air sac that allows the fish to adjust its density in response to the density of the surrounding water. If a fish is denser than the surrounding water, it will sink. If a fish is less dense than the surrounding water, it will float on top of the water. If a fish is the same density as the surrounding water it will not sink and it will not float to the top of the water.

How does the swim bladder work?
The swim bladder is like a balloon. It inflates and deflates depending on how much gas is in it. The exchange of gases between the swim bladder and the blood causes the swim bladder to inflate and deflate. As the swim bladder fills with gases, the fish’s density decreases and it rises in the water. When the swim bladder deflates, the fish’s density increases and it sinks. Glands in the fish control the amount of gas in the swim bladder, so the fish is able to stay at a certain depth in the water.

What are the three types of bony fish?
The three types of bony fish are the lobe-finned fish, the lungfish, and the ray-finned fish. Lobe-finned fish have fins that are lobelike and fleshy. Scientists hypothesize that fish similar to the lobe-finned fish are the ancestors of amphibians.

Lungfish have one lung and gills. This adaptation allows them to live in shallow waters that have little oxygen.

Most bony fish are ray-finned fish. They have fins made of long, thin bones covered with skin. Salmon, tuna, and swordfish are examples of ray-finned fish.

What do fossils tell us about fish?
The earliest fossils of fish are those of jawless fish that lived about 450 million years ago. Today’s bony fish are most likely related to the first jawed fish called the acanthodians (a kan THOH dee unz). They appear in the fossil record about 410 mya.

Why are fish important?
Fish are food for many animals, including humans. Fish farming and commercial fishing are important to the U.S. economy. Many people enjoy fishing as recreation. Fish also help the environment. They eat large amounts of insect larvae, which helps keep the insect population under control. They also keep the plant growth from blocking waterways.
After You Read

Mini Glossary

fin: a fanlike structure attached to the endoskeleton of fish  
scales: hard, thin plates that cover the skin and protect the body of fish

1. Review the terms and their definitions in the Mini Glossary. Select one term and use it in a sentence to describe a structure of fish.

2. Complete the concept web below to show the characteristics of most fish.

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Fish, Amphibians, and Reptiles

section 2 Amphibians

What You’ll Learn
- the adaptations amphibians have for living in water and living on land
- the characteristics of various kinds of amphibians
- how amphibians reproduce and develop

Before You Read
Describe three characteristics of frogs and toads on the lines below.

Read to Learn

Amphibian Characteristics
Amphibians have characteristics that allow them to live on land and in water. Amphibians include frogs, toads, salamanders, and newts.

Amphibians are ectotherms. Their body temperatures change when the temperature of their surroundings changes. In cold weather, amphibians become inactive. They bury themselves in mud or leaves until the temperature warms. This time of inactivity during cold weather is called hibernation. Amphibians that live in hot, dry climates become inactive and hide in the ground when the temperature becomes too hot. This time of inactivity during hot, dry months is called estivation.

How do amphibians breathe?
Amphibians have moist, thin skin. There are many tiny blood vessels beneath the skin and in the lining of the mouth. This makes it possible for oxygen and carbon dioxide to be exchanged through the skin and the mouth lining. Amphibians also have small, simple, saclike lungs for the exchange of oxygen and carbon dioxide. Some salamanders have no lungs and breathe only through their skin.
What kind of circulatory system do amphibians have?

Amphibians have three-chambered hearts. One chamber receives oxygen-filled blood from the lungs and skin. Another chamber receives carbon dioxide-filled blood from the body tissues. Blood moves from both of these chambers to the third chamber, which pumps oxygen-filled blood to body tissues and carbon-dioxide filled blood back to the lungs. Limited mixing of the two bloods occurs.

How do amphibians reproduce?

Amphibians depend on water for reproduction. Amphibian eggs are fertilized externally. As the eggs come out of the female’s body, the male releases sperm over them. In most amphibian species, the female lays eggs in a pond or other body of water. Some amphibians have adaptations that allow them to reproduce away from water. For example, red-eyed tree frogs lay eggs in thick jellylike material on the underside of leaves that hang over water. After the tadpoles hatch, they fall into the water, where they continue to develop.

How do amphibians develop?

Most amphibians go through a four-stage developmental process called metamorphosis (me tuh MOR fuh sus). The first stage for a frog is laying and fertilizing eggs. Then the fertilized eggs hatch into tadpoles that live in water. Tadpoles have fins, gills, and a two-chambered heart. As tadpoles grow into adults, they develop legs, lungs, and a three-chambered heart. The adult frog can live and move about on land. The figure below shows the stages of this process for frogs.

Picture This

1. Analyze From what two structures do amphibians get oxygen?

2. Infer Circle the stage at which frogs and toads look the most like fish.
Frogs and Toads

Adult frogs and toads have short, wide bodies with four legs. They do not have a neck or tail. They use their strong hind legs for swimming and jumping. Their large eyes and nostrils on top of their heads let frogs and toads see and breathe while the rest of their body is under water. On each side of the head, just behind the eyes, are round membranes that frogs and toads use to hear. These membranes vibrate somewhat like an eardrum in response to sounds.

How do frogs and toads catch their food?

Most frogs and toads have tongues attached at the front of their mouths. When they see prey, their tongues flip out and contact the prey. The prey gets caught in the sticky saliva on the tongue. The tongue flips back into the mouth. Frogs and toads eat mostly insects, worms, and spiders.

Salamanders

Most species of salamanders and newts live in North America. They have long, slender bodies and short legs. Species of salamanders and newts that live on land are usually found near water. They hide under leaves and rocks during the day to stay out of the drying heat of the Sun. They use their well-developed senses of smell and sight to find and eat such things as worms and insects.

Many species of salamanders reproduce on land using internal fertilization. Water species of salamanders and newts release and fertilize their eggs in the water.

Importance of Amphibians

Amphibians eat insects, which helps keep the population of insects down. Amphibians are a source of food for other animals. Some people eat frog legs.

Poison frogs produce a poison that can kill large animals. These frogs secrete a toxin through their skin that affects the muscles and nerves of animals that come in contact with it. Researchers are studying the actions of these toxins to learn more about the human nervous system. Other researchers use amphibians in the study of regeneration. Some amphibians can grow new body parts, such as a tail, if the part breaks off.
How do amphibians tell us about the environment?

Because amphibians live on land and reproduce in the water, they are affected by changes in the environment such as pollution. As a result, amphibians are considered biological indicators. Biological indicators are species whose overall health reflects the health of the ecosystem in which they live. Beginning in 1995, deformed frogs, such as the one below, were found. Scientists hypothesize that an increase in the number of deformed frogs could indicate environmental problems for other organisms.

When did amphibians first live on Earth?

Amphibians probably evolved from lobe-finned fish about 350 million years ago. Few animals competed with amphibians for insects, spiders, and other food. With few predators, amphibians reproduced in large numbers and many species evolved. For about 100 million years, amphibians were the dominant land animals.
After You Read

Mini Glossary

estivation: a time of inactivity during hot, dry months

hibernation: a time of inactivity during cold weather

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that compares hibernation and estivation.

2. Fill in the events-chain concept map below to show the stages of frog metamorphosis. Draw a picture in the box of each stage and write a short description of each picture to explain what is happening in that stage.

Stage 1

Stage 2

Stage 3

Stage 4

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Fish, Amphibians, and Reptiles

section 14 Reptiles

Before You Read
On the lines below, describe how a snake is different from a fish or an amphibian.

What You’ll Learn
- the characteristics of reptiles
- how reptile adaptations enable them to live on land
- the importance of the amniotic egg

Read to Learn

Reptile Characteristics
Reptiles have thick, dry, waterproof skin. Their skin is covered with scales. The scales help reduce water loss and protect them from injury. Even though reptiles are ectotherms, they can change their internal body temperature by changes in their behavior. For example, when the weather is cold, they lie in the Sun, which warms them. When the weather is warm, they move into the shade to stay cool.

How do reptiles move?
Some reptiles, like turtles, crocodiles, and lizards, move on four legs. They use claws to dig, climb, and run. Other reptiles, such as snakes and some lizards, move without legs.

How do reptiles breathe?
Reptiles breathe with lungs. Reptiles that live in water, like turtles and sea snakes, must come to the surface to breathe.

What is the circulatory system of reptiles like?
Most reptiles have a three-chambered heart with a partial wall inside the main chamber. This type of circulatory system provides more oxygen to all parts of the body. Crocodilians have a four-chambered heart that completely separates the oxygen-filled blood and the carbon dioxide-filled blood.

Discuss What You Read
Work with a partner. Read a paragraph to yourselves. Then discuss what you learned in the paragraph. Continue until you and your partner understand the main ideas of this section.

1. Compare How is a reptile heart different from the heart of an amphibian?
Why are reptiles able to lay their eggs on land?

Eggs of reptiles are fertilized internally. Many female reptiles lay eggs that are covered by tough shells. The shells keep the eggs from drying out. This adaptation allows reptiles to lay their eggs on land.

The **amniotic egg** provides a complete environment for the embryo’s development. The figure at the right shows the parts of the amniotic egg. The egg membrane protects and cushions the embryo and helps it get rid of wastes. The yolk gives the embryo a food supply. Tiny holes in the egg’s shell, called pores, allow for the exchange of oxygen and carbon dioxide. When it hatches, the reptile looks like a small adult.

Types of Modern Reptiles

Reptiles live on every continent except Antarctica. They live in all the oceans except those in polar regions. Reptiles are different sizes, shapes, and colors. The three living groups of reptiles are lizards and snakes, turtles, and crocodilians.

What is the largest group of reptiles?

The largest group of reptiles is lizards and snakes. These reptiles have an unusual type of jaw. The jaw has a joint that unhinges and increases the size of their mouths. This lets them swallow their prey whole.

**Lizards** Lizards have movable eyelids. Their ears are on the outside and have legs with clawed toes on each foot. Lizards eat plants, other reptiles, insects, spiders, worms, and mammals.

**Snakes** Snakes move without legs. They have poor hearing and most have poor eyesight. Snakes sense vibrations in the ground through the lower jawbone. These vibrations are interpreted as sound by the snake’s brain. Snakes eat meat. Some snakes wrap around and constrict their prey. Other snakes inject their prey with poison called venom.

Most snakes lay eggs after they are fertilized internally. In some snakes, eggs develop and hatch inside the female’s body and then leave her body soon after.
What are the characteristics of turtles?

Turtles have a two-part shell made of hard, bony plates. The vertebrae and ribs are fused to the inside of the top part of the shell. The muscles attach to the lower and upper part of the inside of the shell. Most turtles can bring the head and legs into the shell for protection.

Turtles have powerful jaws with a beaklike structure to crush food. They eat insects, worms, fish, and plants. Turtles that live on land are called tortoises. Like most reptiles, turtles do not care for their young. The female digs out a nest, lays her eggs, covers the nest, and leaves. Turtles hatch fully formed and live on their own immediately.

What are the characteristics of crocodilians?

Crocodilians are among the largest living reptiles on Earth. They have a lizardlike shape. Their backs have large, deep scales. Crocodiles have a narrow head with a triangular-shaped snout. Alligators have a wide head with a rounded snout. Another kind of crocodilian, called a gavial, has a very slender snout with a rounded growth on the end.

Crocodiles are aggressive. They can attack prey as large as cattle. Alligators are less aggressive than crocodiles. They eat fish, turtles, and waterbirds. Gavials mainly eat fish. Crocodilians care for their young. The female guards the nest and both the male and female protect their young.

The Importance of Reptiles

Reptiles can be important predators. In farming areas, snakes eat rats and mice that destroy grains. Small lizards eat insects. Large lizards eat small animals that are pests. In many parts of the world, humans eat reptiles and their eggs.

The number of reptile species is getting smaller in areas where swamps and other lands are being developed. Coastal nesting sites of sea turtles are being destroyed by development or harmed by pollution. Today, laws protect most species of turtles and their habitats.

What does the fossil record tell us about reptiles?

Fossil records show that the earliest reptiles lived about 345 mya. Dinosaurs, descendants of the early reptiles, lived about 200 mya. Then they died out about 65 mya. Some of today’s reptiles, such as crocodiles and alligators, have not changed much from their ancestors.
After You Read

Mini Glossary

**amniotic egg:** the complete environment for the development of an embryo

1. Review the term and its definition in the Mini Glossary. Write a sentence that explains the importance of the amniotic egg.

2. Complete the concept map below to show the main characteristics of reptiles.

3. Which ideas that you and your partner discussed were hardest to understand? Write a question and the answer on the lines below to show you understand the idea.

End of Section

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Before You Read

Did you ever wish you could fly like a bird? What would you need to be able to fly like a bird?

What You’ll Learn
- the features of birds
- the adaptations birds have for flying
- how birds reproduce and develop

Read to Learn

Bird Characteristics

Birds are versatile animals. They live in some of the warmest and the coldest places on Earth. Some birds fly high in the air. Some swim deep underwater. Some birds are very heavy, while others are very light. Birds eat meat, fish, insects, fruit, seeds, and nectar.

What are birds’ eggs made of?

Birds lay amniotic (am nee AH tik) eggs with hard shells. An amniotic egg provides the developing embryo with a moist environment. The hard shell is made up of calcium carbonate, the same chemical that makes up seashells and marble.

The egg is fertilized before the shell forms around it. The female bird lays one or more eggs in a nest. A group of eggs is called a clutch. One or both parents incubate the eggs, or keep them warm, until they hatch. One or both parents care for the young.

Why can birds fly?

A bird can fly because of its skeleton, wings, and feathers. A bird also has strong muscles and a strong respiratory system. Birds have sharp eyesight and large amounts of energy, which also are needed for flying.
What kind of bones do birds have?

A bird has a skeleton that is different from most other animals. The figure below shows what a bird’s skeleton looks like. A bird’s bones are almost hollow. The hollow spaces are filled with air. Some birds have bones that are joined together, making them strong for flying. A large breastbone supports the chest muscles that are needed for flight. The last bones of the spine support the tail feathers. These feathers help birds steer and balance while flying and landing.

What kinds of feathers do birds have?

Birds are the only animals with feathers. They have two main types. Strong, lightweight **contour feathers** give birds their coloring and shape. They help the birds steer while flying. Soft, fluffy **down feathers** give adult birds a layer of protection next to their skin. Down feathers cover the bodies of young birds. Birds are endotherms. **Endotherms** have a constant body temperature. Feathers help birds keep their body temperature constant no matter what the air or water temperature.

Feathers grow like your hair does. Each feather grows from a small opening in the skin called a follicle (FAH lih kul). When a feather falls out, a new one grows in its place. A bird has an oil gland found just above the base of its tail. A bird uses its beak or bill to rub the oil from the gland over its feathers in a process called **preening**. The oil helps the feathers last longer.
How do wings help birds fly?
Most birds have wings that allow them to fly. The wings are attached to strong chest muscles. When a bird flaps its wings, it gets the power to go forward and the lift to stay in the air. A bird’s wings move up and down, as well as back and forth.

The shape of a bird’s wings helps it fly. As you can see in the figure below, the wings are curved on top and flat or slightly curved on the bottom. When a bird flies, air moves more slowly across the bottom of its wings than across the top. The slow-moving air has greater pressure than the fast-moving air. This causes an upward push called lift.

Not all birds fly, but wings are important for nonflying birds, too. Penguins use their wings to swim underwater. Ostriches use their wings to keep their balance when they walk or run.

Body Systems
Birds are extremely active. They have body systems that help them to be active.

What does the digestive system do?
Because birds use a lot of energy when they fly, they need large amounts of high energy foods. These foods are nuts, seeds, insects, and meat. A bird’s digestive system breaks down food quickly to supply this energy. A bird takes food into its mouth. From there, unchewed food passes into an organ called the crop. There the food takes in moisture to help it move on to the stomach. The food is partly digested in the stomach before it moves to the muscular gizzard. In the gizzard, the food is crushed by small stones that the bird has swallowed. The food then moves to the intestine, where its nutrients move into the bloodstream.

3. Describe to a classmate how the shape of a bird’s wing helps it fly.

4. Explain why a bird’s diet includes large amounts of high-energy foods.
What does the respiratory system do?

Oxygen combines with the energy in food to make body heat. A bird’s respiratory system gets oxygen from the air. Oxygen helps to change food into energy needed to power the flight muscles. A bird has two lungs. Each lung is connected to air sacs. The air a bird inhales passes into the air sacs. When a bird exhales, air with oxygen passes from the air sacs into the lungs. A bird gets air with oxygen both when it inhales and exhales. This gives the flight muscles a constant supply of oxygen.

What is the circulatory system made up of?

A bird’s circulatory system is made up of a heart, arteries, capillaries, and veins. A bird’s heart is large compared to the rest of its body. Blood filled with oxygen is kept separate from blood filled with carbon dioxide as both move through a bird’s heart and blood vessels. A bird’s heart beats rapidly so enough oxygen-filled blood is carried to the bird’s muscles.

The Importance of Birds

Birds have important roles in nature. Some birds are sources of food. Other birds are kept as pets. Some birds help control pests, and others pollinate flowers. Birds can be considered pests when there are too many of them in one place. In cities where there are large numbers of birds, their droppings can damage buildings. Some droppings can contain microorganisms that cause disease in humans.

What are some uses of birds?

For many years, people hunted birds for food and for their colorful feathers. Some wild birds such as chickens and turkeys were tamed to provide humans with eggs and meat. Mattresses, pillows, and clothing are made from birds’ down feathers. Droppings of some birds are used as fertilizer. Birds, such as parakeets, parrots, and canaries, are kept as pets.

How did the first birds develop?

Scientists learn how most living things began by studying their fossils. However, scientists have found very few fossils of birds. Scientists hypothesize that birds developed from reptiles millions of years ago. Some characteristics of birds, such as the scales on their feet and legs, are similar to those of reptiles.
After You Read

Mini Glossary

**contour feathers**: strong, lightweight feathers that give birds their color and shape and help birds steer

**down feathers**: soft, fluffy feathers that give a layer of protection next to the skin of adult birds and cover the bodies of young birds

**endotherms**: animals that have a constant body temperature

**preening**: process in which a bird rubs oil from a gland over its feathers which helps them last longer

1. Review the terms and their definitions in the Mini Glossary. Choose one type of bird feather and describe it in a sentence.

2. Use the web chart below to identify five characteristics that help birds fly.

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ScienceOnline Visit [life.msscience.com](http://life.msscience.com) to access your textbook, interactive games, and projects to help you learn more about birds.
What You’ll Learn
- how the features of mammals have helped them adapt
- the differences among monotremes, marsupials, and placentals
- why some mammals are in trouble today

Before You Read
How many teeth do you have? Are they all the same? Why do you think people have different kinds of teeth?

Read to Learn

Characteristics of Mammals
Mammals have certain characteristics in common. Mammals are endothermic vertebrates that have hair and produce milk to feed their young. Like birds, mammals care for their young. Mammals can be found almost everywhere on Earth. Mammals adapt to the environments in which they live.

What is the purpose of a mammal’s skin?
All mammals have skin to protect their bodies. The skin is an organ that produces hair. In some mammals, the skin also produces horns, claws, nails, or hooves.

What types of glands do mammals have?
A mammal’s skin also has different kinds of glands. Female mammals have mammary glands that produce milk for feeding their young. Some mammal species have oil glands that produce oil to condition the hair and skin. Sweat glands in some species remove wastes and help keep the mammal cool. Some species have scent glands that give off a scent to mark their territory, attract mates, or help the mammals defend themselves.
Why do mammals have different kinds of teeth?

Mammals have different kinds of teeth. Scientists know what a mammal eats by the kind of teeth it has. Incisors are front teeth used for biting and cutting. Canine teeth, next to the incisors, are sometimes used to grip and tear. Premolars and molars, located at the back of the mouth, grind and crush. Some mammals, including humans, have all four kinds of teeth.

Omnivores are animals that eat both plants and animals. Humans are omnivores. Mammals, such as tigers, that are carnivores have large canine teeth because they eat only the flesh of other animals. Herbivores eat only plants. Herbivores such as horses have large premolars and molars to grind the tough fibers of plants. The different kinds of teeth that omnivores, carnivores, and herbivores have are shown in the figure below.

How does hair protect mammals?

All adult mammals have hair on their bodies. The hair can be thick fur or just a few hairs around the mouth. Fur traps air and helps keep the mammal warm. Whiskers near the mouth help some mammals sense their environment. Whales have almost no hair. A thick layer of fat under their skin, called blubber, helps to keep them warm. Porcupine quills are a kind of hair that protects porcupines from other animals.

Body Systems

A mammal’s body systems are important for its activities and its survival. A mammal has a heart with four chambers that pumps oxygen-filled blood throughout the body in blood vessels. A mammal’s lungs are made up of millions of air sacs. These air sacs allow greater exchange of oxygen and carbon dioxide.

Picture This

1. Identify Which mammal has large canine teeth—an omnivore, a carnivore, or a herbivore?

2. Describe What does a four-chambered heart do?
3. Apply Why do mammals have different kinds of digestive systems?

4. Explain How do young monotremes nurse?

Mammal Nervous System A mammal’s nervous system is made up of a brain, spinal cord, and nerves. The brain is involved in learning. It also controls the muscles.

The digestive systems of mammals vary depending on the kinds of food they eat. Herbivores have longer digestive systems than carnivores because plants take longer to digest than meat.

How do mammals reproduce?

All mammals reproduce sexually. Most mammals give birth to live young after they develop in the uterus, the female reproductive organ. Most mammals can not take care of themselves for at least the first several days after they are born. Some can not take care of themselves for several years. Some mammals, such as deer and elephants, are able to stand when they are a few minutes old. They can travel with their constantly moving parents.

While the young mammals depend on their mothers’ milk, they learn many survival skills. Defensive skills are learned while playing with other young of their own kind. In many mammal species only females raise the young. In some mammal species, such as wolves and humans, males help provide food, shelter, and protection for their young.

Types of Mammals

Mammals are classified into three groups based on how their young develop. The three groups are monotremes (MAH nuh treemz), marsupials (mar SEW pee ulz), and placentals (pluh SEN tulz).

What are monotremes?

A mammal that lays eggs with leathery shells is a monotreme. A platypus is a monotreme. The female incubates or keeps the eggs warm for about 10 days. After the young hatch, they nurse by licking the female’s skin and hair where milk comes from the mammary glands. Monotreme mammary glands do not have nipples.

What are marsupials?

A mammal that gives birth to immature young that usually crawl into a pouch on the female’s abdomen is a marsupial. However, not all marsupials have pouches. An immature marsupial crawls to a nipple. It stays attached to the nipple until it is developed. In pouched marsupials, the developed young come back to the pouch for feeding and protection.
Where Marsupials Live  Most marsupials, including kangaroos, wallabies, and koalas, live in Australia, New Guinea, or South America. The opossum is the only marsupial found in North America.

What are placentals?  
A mammal in which an embryo completely develops inside the female’s uterus is a placental. The time it takes for the embryo to develop is the gestation period. The time can range from 16 days for hamsters to 650 days for elephants. Placentals are named for the placenta. The placenta is an organ that develops from tissues of the embryo and tissues that line the inside of the uterus. The placenta takes in oxygen and food from the mother’s blood. An umbilical cord connects the embryo to the placenta. The umbilical cord is made up of blood vessels. The blood in the umbilical cord moves food and oxygen from the placenta to the embryo and removes waste products from the embryo. The blood of the mother and the embryo do not mix.

Importance of Mammals  
Like other living things, mammals help keep a balance in the environment. Carnivores, such as tigers, help control the populations of other animals. Bats help pollinate flowers and control insects. However, some mammals and other animals are in danger today. Many of their habitats are being destroyed for housing, roads, and shopping centers. Many mammals are left without food, shelter, and space to survive.

What were the first kinds of mammals?  
Mammals began branching out into many different species after dinosaurs became extinct about 65 million years ago. Today, more than 4,000 species of mammals have evolved from animals that existed about 200 million years ago. One example of an ancient mammal is shown in the figure below.
After You Read

Mini Glossary

carnivore: animal that eats only the flesh of other animals
gestation period: the time during which the embryo develops in the uterus
herbivore: animal that eats only plants
mammals: animals that are vertebrates, endothermic, have hair, and make milk to feed their young
mammary glands: in female mammals, glands that make milk for feeding their young
marsupials: mammals that give birth to immature young that usually crawl into a pouch on the female's abdomen
monotremes: mammals that lay eggs with leathery shells
omnivore: animal that eats both plants and animals
placenta: organ that develops from tissues of the embryo and tissues that line the inside of the uterus; takes in oxygen and food from the mother's blood
placentals: mammals in which embryos completely develop inside the female's uterus
umbilical cord: made up of blood vessels that transport food and oxygen from the placenta to the embryo and removes waste products from the embryo

1. Review the terms and their definitions in the Mini Glossary. Write a sentence explaining the difference between marsupials and placentals.

2. In the chart below, list four types of glands found in mammals and tell what each one does.

<table>
<thead>
<tr>
<th>Gland</th>
<th>What It Does</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

3. How did previewing the headings before you read help prepare you to read the section?

End of Section

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about mammals.
Animal Behavior

section  ● Types of Behavior

Before You Read
On the lines below, explain how you learned a new skill, such as in-line skating or jumping rope.

Read to Learn

Behavior
Animals are different from one another in their behavior. Behavior is the way an organism interacts with other organisms and its environment. Animals are born with certain behaviors, and they learn other behaviors.

Anything in the environment that causes a reaction is called a stimulus. A stimulus can be external, such as a male dog entering the territory of another male dog. A stimulus can be internal, such as hunger or thirst. The way an animal reacts to a stimulus is called a response. Getting a drink of water is a response to the internal stimulus of thirst.

Innate Behavior
A behavior that an organism is born with is called an innate behavior. These types of behaviors are inherited. They do not have to be learned.

Innate behavior patterns occur the first time an animal reacts to an internal or external stimulus. For birds, building a nest is an innate behavior. Although the first nest a bird builds may be messy, it is built correctly.

What You’ll Learn
- the differences between innate and learned behavior
- how organisms use reflexes and instincts to survive
- examples of different learned behaviors

Identify Main Ideas
Highlight each question head in this section. Then use a different color to highlight the answers to the questions.

Foldables
A Describe Make a two-tab Foldable, as shown below. Describe the innate and learned behaviors of an animal that you have observed.
1. **Explain** Why do insects have mostly innate behavior?

Why are innate behaviors important?

The behavior of animals with short life spans, such as insects, is mostly innate behavior. An insect cannot learn from its parents. By the time the insect hatches, its parents have died or moved on. Innate behavior allows animals to respond quickly. A quick response often means the difference between life and death.

Reflex actions are the simplest innate behaviors. A reflex is an automatic response that does not involve a message from the brain. When something is thrown at you, you blink. Blinking is a reflex action. Your body reacts on its own. You do not think about the behavior.

**What is instinctive behavior?**

An instinct is a complex pattern of innate behavior. Instinctive behavior begins when an animal recognizes a stimulus. It continues until the animal has performed all parts of the behavior. Spinning a web is an instinctive spider behavior. A spider knows how to spin a web as soon as it hatches. Instinctive behaviors take much more time to complete than reflexes. A spider may spend days building a web.

**Learned Behavior**

Animals also have learned behaviors. Learned behavior develops over an animal’s lifetime as a result of experience or practice. Animals with more complex brains have more learned behaviors. Fish, reptiles, amphibians, birds, and mammals all learn.

Learned behavior helps animals respond to changing situations. In changing environments, an animal that can learn a new behavior is more likely to survive than an animal that cannot learn a new behavior. Learned behavior is important for animals with long life spans. The longer an animal lives, the more likely it is that its environment will change.

**Can instincts change?**

Learned behavior can change instincts. Some young birds instinctively crouch and freeze if they see something moving above them. They will crouch and keep still even if the object is only a moving leaf. Older birds have learned that some things that move above them, such as leaves, are not harmful. Learned behavior includes imprinting, trial and error, conditioning, and insight.
How does imprinting occur?

**Imprinting** occurs when an animal forms a social attachment to another organism within a short time after birth or hatching. A gosling follows the first moving object it sees after hatching. The moving object is usually an adult female goose. This behavior is important because adult geese have experience in finding food, protecting themselves, and getting along in the world. Animals that become imprinted toward animals of another species have difficulty recognizing members of their own species.

What is trial-and-error learning?

Behavior that changes with experience is called trial-and-error learning. You learned many skills through trial and error, such as feeding yourself, tying your shoes, and riding a bicycle. Once you learn a skill, you can do it without having to think about it.

How does conditioning change behavior?

Animals often learn new behaviors by conditioning. In **conditioning**, behavior is changed so that a response to one stimulus becomes linked with a different stimulus.

There are two types of conditioning. One type adds a new stimulus before the usual stimulus. Russian scientist Ivan Pavlov performed an experiment to explain how this conditioning works. He knew that hungry dogs salivate when they see and smell food. Pavlov added another stimulus, as seen in the figure below. He rang a bell before he fed the dogs. The dogs connected the sound of the bell with food. The dogs were conditioned to salivate at the sound of a bell even if they were not fed.

<table>
<thead>
<tr>
<th>Before Conditioning</th>
<th>Conditioning</th>
<th>After Conditioning</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Dog" /></td>
<td><img src="image2" alt="Dog" /></td>
<td><img src="image3" alt="Dog" /></td>
</tr>
<tr>
<td><img src="image4" alt="Bowl" /></td>
<td><img src="image5" alt="Bowl" /></td>
<td><img src="image6" alt="Bowl" /></td>
</tr>
</tbody>
</table>

**Foldables**

8 Compare Make a threetab Foldable, as shown below. Use a Venn diagram to compare the two types of conditioning.

**Picture This**

3. Explain Working with a partner, take turns describing how Pavlov conditioned dogs to respond to a bell.
Another Type of Conditioning  In the second kind of conditioning, a new stimulus is given after a behavior has happened. Getting an allowance for doing chores is an example of this type of conditioning. You do the chores because you want to get your allowance. You have learned, or been conditioned, to perform activities that you may not have done if you had not been offered a reward.

How do past experiences help solve problems?

In the problem-solving experiment shown below, bananas were placed out of a chimpanzee’s reach. Instead of giving up, the chimpanzee piled up boxes found in the room, climbed them, and reached the bananas. At some time in the past, the chimpanzee must have solved a similar problem. The chimpanzee used past experiences, or insight, to solve the problem.

Insight is a form of reasoning that allows animals to use past experiences to solve new problems. When you were a baby, you learned to solve problems using trial and error. As you grow older, you use insight more often to solve problems. Much of adult human learning is based on insight.
After You Read

Mini Glossary

behavior: the way an organism interacts with other organisms and its environment
conditioning: a way of changing a learned behavior so that a response to one stimulus becomes associated with a different stimulus
imprinting: a learned behavior that happens when an animal forms a social attachment to another organism within a short time after birth or hatching

innate behavior: a behavior that an organism is born with
insight: a form of reasoning that uses past experiences to solve new problems
instinct: a complex pattern of innate behavior, such as spinning a web
reflex: an automatic response that does not involve a message from the brain

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the difference between instinct and insight.

2. Fill in the graphic organizer below with the different types of animal behavior.

Types of Animal Behavior

Innate behavior

3. How did finding answers to the question heads help you learn about types of behavior?

Science online Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about the types of behavior.
Animal Behavior

section 2 Behavioral Interactions

What You’ll Learn

- the importance of behavioral adaptations
- how courtship behavior improves reproductive success
- the importance of social behavior and cyclic behavior

Before You Read

One way that you communicate with your family and friends is by talking. On the lines below, list three other ways that you communicate.

Study Coach

Make Flash Cards While you are reading this section, write questions on one side of flash cards and answers on the other side. Work with a partner to ask and answer the questions.

Read to Learn

Instinctive Behavior Patterns

Animals inherit, or are born with, instinctive behavior. When an animal interacts with other animals, complex innate behavior patterns can be seen. For example, for most animal groups courtship and mating are instinctive ritual behaviors that help animals recognize possible mates.

Social Behavior

Animals often live in groups. Living in a group provides:

1. safety from predators
2. warmth from other group members
3. security when traveling from place to place

Interactions among organisms of the same species are examples of social behavior. Social behaviors are inherited. Social behaviors include courtship and mating, caring for the young, claiming territories, protecting each other, and getting food. Social behaviors help the species survive. For example, because zebras live in herds, lions are less likely to attack them.

Foldables

Describe Make a three-tab concept map Foldable, as shown below. Describe three behavioral adaptations of animals.

Describe Make a three-tab concept map Foldable, as shown below. Describe three behavioral adaptations of animals.
What is a society?

A society is a group of animals of the same species living and working together in an organized way. Insects, such as ants, live in societies. Each member of the society has a certain role. One female ant lays eggs and a male ant fertilizes the eggs. The workers do all the other jobs in the society.

Some animal societies are organized by dominance. The top animal controls the other members of the society. Wolves live in packs. One female in the pack is dominant. She controls the mating of other females in the pack. This behavior controls the size of the pack and helps the pack survive.

Territorial Behavior

A territory is an area that an animal defends from other members of the same species. Animals may show ownership of territories by making sounds, leaving scent marks, or attacking members of the same species who enter the territory.

Why do animals defend their territories?

Territories contain food, shelter, and possible mates. If an animal has a territory, it will be able to mate and produce offspring. Defending territories is an instinctive behavior. It improves the survival rate of an animal’s offspring.

How do animals defend their territories?

In order to defend their territory, protect their young, or get food, many animals show aggression. Aggression is a forceful behavior used to dominate or control another animal. Animals of the same species rarely fight to the death. An animal that avoids being attacked by another animal is showing submission. In the figure below, one wolf has rolled over and made itself as small as possible to communicate submission to the dominant wolf.

Picture This

2. Draw a circle around the wolf that is showing submissive behavior.
Communication

Communication is important in all social behavior. Communication is an action by a sender that affects the behavior of a receiver. Animals in a group communicate with sounds, scents, and actions. Alarm calls, chemicals, speech, courtship behavior, aggression, and submission are types of communication.

How do animals attract mates?

Courtship behavior allows the male and female members of a species to recognize each other. Courtship behaviors excite males and females so they are ready to mate at the same time. The courtship behavior of a male bird of paradise includes spreading its tail feathers and strutting. This behavior attracts female birds of paradise. Courtship behavior helps increase reproductive success.

In most species, males are more colorful than females. The males perform the courtship activities to attract a mate. Some courtship behaviors allow males and females to find each other across distances.

How do animals use chemicals to communicate?

Ants leave trails that other ants can follow. Male dogs urinate on objects and plants to let other dogs know they have been there. These animals are using chemicals called pheromones (FER uh mohnz) to communicate. A pheromone is a chemical produced by one animal to influence the behavior of another animal of the same species. Pheromones remain in the environment so that the sender and receiver can communicate without being in the same place at the same time.

Males and females use pheromones to set up territories, warn of danger, and attract mates. Some animals release alarm pheromones when hurt or in danger.

How do animals use sounds to communicate?

Male crickets rub one forewing against the other to make a chirping sound. The sound attracts female crickets. Each species of crickets makes a different sound. Rabbits thump the ground, gorillas pound their chests, and beavers slap the water with their flat tails. These sounds are forms of communication to others animals of the same species.
How is light used to communicate?

The ability of certain living things to give off light is called bioluminescence (bi oh lew muh NEH sunts). The light is produced through chemical reactions in the organism's body. A firefly gives off a flash of light to locate a possible mate. Each species has its own pattern of flashing. Certain kinds of flies, marine organisms, and beetles use bioluminescence to communicate.

What are other uses of bioluminescence?

Many bioluminescent animals are found deep in oceans where sunlight does not reach. Bioluminescence helps some animals attract prey. Deep-sea shrimp give off clouds of a luminescent substance that helps them escape their predators.

Cyclic Behavior

Innate behavior that happens in a repeating pattern is called cyclic behavior. This type of behavior is often repeated in response to changes in the environment. Most animals have a 24-hour cycle of sleeping and wakefulness called a circadian rhythm. Animals that are active during the day are diurnal (dy UR nul). Animals that are active at night are nocturnal (nahk TUR nul). Owls are nocturnal.

What is hibernation?

Hibernation is a cyclic behavior in which an animal responds to cold temperatures and a limited food supply. During hibernation, an animal's body temperature drops to near that of its surroundings. The animal’s breathing rate slows. Animals in hibernation survive on their stored body fat and stay inactive until the weather becomes warm in the spring. Some mammals and many amphibians and reptiles hibernate.

In desertlike environments, some animals go into a period of reduced activity called estivation. Desert animals do this as a response to extreme heat, lack of food, or drought.

What is migration?

Many animals move to new locations when the seasons change. This instinctive seasonal movement is called migration. Most animals migrate to find food or to reproduce in environments that give their offspring a better chance for survival.
After You Read

Mini Glossary

aggression: a forceful behavior used to dominate or control another animal
courtship behavior: behaviors that allow male and female members of a species to recognize each other and to excite each other so they are ready to mate at the same time
cyclic behavior: innate behavior that occurs in a repeating pattern
hibernation: a cyclic response to cold temperatures and limited food supplies
migration: instinctive seasonal movement of animals
pheromone (FER uh mohn): a chemical produced by one animal to influence the behavior of another animal of the same species
social behavior: interactions among organisms of the same species
society: a group of animals of the same species living and working together in an organized way

1. Review the terms and their definitions in the Mini Glossary. Write a sentence using one of the terms to explain how innate animal behavior helps species survive.

2. Write one fact you learned about each form of animal communication in the graphic organizer below.

<table>
<thead>
<tr>
<th>Forms of Animal Communication</th>
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<tbody>
<tr>
<td>Courtship behavior</td>
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Chapter 17

Structure and Movement

Section ● The Skeletal System

● Before You Read

What is your favorite sport? On the lines below, name all the body parts you use to play this sport.

● Read to Learn

Living Bones

The bones in your body are very much alive. Each is a living organ made of several different tissues. Like all living tissues, bone tissue is made up of cells that take in nutrients and use energy. Bone cells have the same needs as other body cells.

What are the major functions of the skeletal system?

All 206 bones in your body make up your skeletal system. It is your body’s framework, just like the framework of a building. The skeletal system has five major functions.

1. The skeleton gives shape and support to your body.
2. Bones protect your internal organs. For example, the skull surrounds the brain.
3. Major muscles are attached to bones. These muscles help bones move.
4. Blood cells are formed in the center of many bones in soft tissue called red marrow.
5. Major amounts of calcium and phosphorus compounds are stored in the skeleton for later use. Calcium and phosphorus make bones hard.

What You’ll Learn

- five functions of the skeletal system
- the differences and similarities between the movable and the immovable joints

Mark the Text

Identify the Important Points Write a phrase beside each of the main headings to summarize the main point of that section.

1. Identify Where are blood cells formed?
Bone Structure

Bones are different sizes and shapes. The shapes of your bones are inherited. But, a bone’s shape can change when the attached muscles are used.

As you can see in the figure below, bones are not smooth. They have bumps, edges, round ends, rough spots, and many pits and holes. Muscles and ligaments attach to some of the bumps and pits. The figure below shows that blood vessels and nerves enter and leave the bone through the holes.

The figure above shows that the surface of a living bone is covered with a tough, tight-fitting membrane called the periosteum (per ee AH stee um). Small blood vessels in the periosteum carry nutrients into the bone. Its nerves signal pain. Cells involved in the growth and repair of bone also are found in the periosteum.

What keeps bones from breaking?

Under the periosteum is a hard, strong layer called compact bone. This bone tissue gives bone strength. It has a framework containing deposits of calcium phosphate that makes the bone hard and keeps them from being easily broken. Bone cells and blood vessels are found in compact bone.
Spongy Bone  Spongy bone is tissue found in the ends of long bones such as those in your thigh and upper arm. Spongy bone has many small, open spaces that make bones lightweight. In the centers of long bones are large openings called cavities. These cavities and the spaces in spongy bone are filled with yellow and red marrow. Yellow marrow is made up of fat cells. Red marrow makes 2 million to 3 million red blood cells per second.

**Why is cartilage important in joints?**

The ends of bones are covered with a smooth, slippery, thick layer of tissue called cartilage. Cartilage protects the joints and absorbs shock. It also makes movement easier because it lessens friction between bones. People with damaged cartilage have pain when they move, because the bones rub together.

**Bone Formation**

Before you were born, your skeleton was made of cartilage. Over time, the cartilage was replaced by bone. Bone-forming cells called osteoblasts (AHS tee oh blasts) deposit calcium and phosphorus in bones, making bones hard. Throughout your life, healthy bone tissue is being formed. Osteoblasts build up bone.

Another type of bone cell, called an osteoclast, breaks down bone tissue. Osteoclasts release calcium and phosphorus into your bloodstream. This keeps the amount of calcium and phosphorus in your blood at healthy levels.

**Joints**

You are able to move because your skeleton has joints. Anyplace where two or more of your bones come together is a joint. The bones that make up a joint are kept apart by cartilage and are held in place by a tough band of tissue called a ligament. Muscles move bones by moving joints. The figure below shows the different types of joints in your body.

**Picture This**

5. **Classify** Use the figure to determine which kind of joint you use in each of the following activities.

   a. raise your arm

   b. kneel
What is an immovable joint?
An immovable joint allows little or no movement. The skull has immovable joints.

What are the types of movable joints?
All movements require movable joints. As you can see in the figure on the previous page, there are four types of movable joints—pivot, ball-and-socket, hinge, and gliding.

Pivot Joints
In a pivot joint, one bone rotates in a ring of another bone that does not move. Turning your head is an example of a pivot movement.

Ball-and-socket Joints
Your legs and arms can swing in almost any direction because they have ball-and-socket joints. This kind of joint consists of a bone with a rounded end that fits into a cuplike cavity on another bone. This joint gives you a wide range of motion.

Hinge Joints
A hinge joint has a back-and-forth movement like hinges on a door. Elbows, knees, and fingers have hinge joints. Hinge joints have a smaller range of motion than ball-and-socket joints.

Gliding Joints
Your wrists, ankles, and vertebrae have gliding joints. In a gliding joint, one part of a bone slides over another bone. This joint also moves back and forth.

Why do your bones move smoothly?
If your bones did not have cartilage at the ends, they would wear away at the joints. Cartilage allows bones to slide more easily over each other by reducing friction. Pads of cartilage, called disks, are located between the vertebrae in your back. These disks act as cushions and prevent injury to your spinal cord. A fluid that comes from nearby blood vessels keeps the joint lubricated.

What is arthritis?
Arthritis is the most common joint problem in humans. About one out of every seven people in the United States suffers from arthritis. It causes pain, stiffness, and swelling of the joints. There are more than 100 different forms of arthritis that can damage the joints.
After You Read

Mini Glossary

**cartilage:** a smooth, slippery, thick layer of tissue that covers the ends of bones

**joint:** the place where two or more bones come together

**ligament:** a tough band of tissue that holds bones together at the joint

**periosteum (per ee AH stee um):** a tough, tight-fitting membrane on the surface of a living bone

**skeletal system:** the framework of bones in the body

1. Review the terms and their definitions in the Mini Glossary. Use two terms in the glossary to write a sentence describing some part of the skeletal system.

2. Complete the concept web below by naming the five functions of the skeletal system.
Structure and Movement

section 2 The Muscular System

What You’ll Learn

- the major function of the muscular system
- how the three types of muscles differ
- how muscles move body parts

Before You Read

On the lines below, describe a movement you make that uses muscles.

Read to Learn

Movement of the Human Body

Muscles help make all your movements possible. A muscle is an organ that can relax, contract, and provide the force to move your body parts. In the process, energy is used and work is done.

What are voluntary and involuntary muscles?

Muscles that you are able to control are called voluntary muscles. The muscles in your face, hands, arms, and legs are voluntary muscles. You can choose to move them or not move them.

Muscles that you are not able to consciously control are called involuntary muscles. These muscles are always working. Involuntary muscles pump blood through your blood vessels and move food through your digestive system.

Your Body’s Simple Machines—Levers

A machine, such as a bike, is any device that makes work easier. A simple machine does work with only one movement. The hammer is a type of simple machine called a lever. A lever is a rod or plank that pivots or turns about a point. The point is called a fulcrum.
Types of Levers  The action of bones, joints, and muscles working together is like a lever. In your body, your bones are the rods and your joints are the fulcrums. The relaxation and contraction of muscles provide the force to move body parts. There are three types of levers—first-class, second-class, and third-class. The figure below shows how all three levers are used in the body when serving a tennis ball.

Classification of Muscle Tissue  

There are three types of muscles in your body—skeletal muscle, cardiac muscle, and smooth muscle. The muscles that move bones are skeletal muscles. They are the most common muscle type in your body. They are attached to bones by thick bands of tissue called tendons. Skeletal muscles are voluntary muscles. You choose to use them or not use them, such as when you walk or when you rest. Cardiac muscle is found only in the heart. This involuntary muscle contracts about 70 times per minute. Smooth muscles are found in your intestines, bladder, blood vessels, and other internal organs. They are involuntary muscles that slowly contract and relax.
Working Muscles

You are able to move because skeletal muscles work in pairs, as shown in the figure below. When one muscle of a pair contracts, the other muscle relaxes, or returns to its original length. Muscles always pull. They never push. When the muscles on the back of your upper leg contract, they shorten. This pulls your lower leg back and up. When you straighten your leg, the back muscles lengthen and relax. At the same time, the muscles on the front of your leg contract.

How do muscles change?

Skeletal muscles that do a lot of work become strong and large. Some of this change in muscle size is because of an increase in the number of muscle cells. Most of the change is because individual muscle cells become larger. Muscles that are not exercised become soft, flabby, and weak.

How are muscles fueled?

Your muscles need energy to contract and relax. Your blood carries energy-rich molecules to your muscle cells. As the muscle contracts, part of the chemical energy changes to mechanical energy (movement). Some of the chemical energy changes to thermal energy (heat) as muscles are used. The heat produced by muscle contractions helps keep your body temperature constant. When the supply of energy-rich molecules is used up, the muscle becomes tired and needs to rest. While your muscle rests, your blood supplies more energy-rich molecules to your muscle cells.
After You Read

Mini Glossary

cardiac muscle: muscle found only in the heart
involuntary muscle: a muscle, such as the heart muscle, that cannot be consciously controlled
lever: a rod or plank that pivots or turns about a point; a simple machine
muscle: an organ that can relax, contract, and provide the force to move your body parts

skeletal muscle: a muscle that moves the body
smooth muscle: the muscle found in the intestines, bladder, blood vessels, and other internal organs
tendons: thick bands of tissue that attach muscles to bones
voluntary muscle: a muscle, such as a leg or arm muscle, that can be consciously controlled

1. Review the terms and their definitions in the Mini Glossary. Write a sentence explaining the difference between voluntary muscles and involuntary muscles.

2. Fill in the table below to identify the three types of muscle tissues and explain the functions of each.

<table>
<thead>
<tr>
<th>Types of Muscle Tissue</th>
<th>Function of the Muscle Tissue</th>
</tr>
</thead>
<tbody>
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</table>

2. How did the quiz help you review what you have learned about the muscular system?

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about the muscular system.
Structure and Movement

section The Skin

What You’ll Learn

- the difference between the epidermis and the dermis of the skin
- the functions of the skin
- how skin protects the body from disease
- how skin heals itself

Before You Read

After you scrape your knee or cut your finger, what happens to your skin? On the lines below, describe what happens as your skin heals itself.

Read to Learn

Your Largest Organ

Did you know that your skin is your body’s largest organ? Much of the information you receive about your environment comes through your skin. You can think of your skin as your largest sense organ. Look at the figure below. Notice that your skin is made up of three layers of tissue—the epidermis, the dermis, and a fatty layer. Refer to this figure as you read about the three layers of skin.

Picture This

1. Identify Highlight the three layers of skin. Use a different color for each layer.
Skin Structures

The epidermis is the outer, thinnest layer of skin. The outermost cells of the epidermis are dead. Thousands of these cells rub off your body when you shower, shake hands, or blow your nose. New cells are constantly being made to replace the dead cells.

What causes different skin colors?
Cells in the epidermis make the chemical melanin (MEL uh nun). Melanin is a pigment that protects your skin and gives it color, as shown in the figure below. The different amounts of melanin made by cells cause differences in skin color. When your skin is exposed to ultraviolet (UV) rays, more melanin is made and your skin becomes darker. The lighter a person’s normal skin color, the less protection that person has from the Sun.

What are the dermis and the fatty layer?
The dermis is the layer of skin cells right below the epidermis. The dermis contains many blood vessels, nerves, muscles, oil, and sweat glands. Below the dermis is a fatty layer, which helps keep the body warm.

Skin Functions

The skin is important to the body. Some of its most important functions include protection, sensory response, formation of vitamin D, control of body temperature, and ridding the body of wastes.

Which skin function is the most important?
The most important skin function is protection. The skin is a protective covering over the body. It stops some bacteria and other disease-causing organisms from passing through unbroken skin. The skin slows down water loss from body tissues.
Why do you know a pan is hot?

Special nerve cells in the skin are able to sense things. The cells send this information to the brain. This is why you can sense the softness of a cat or the heat of a hot pan.

How does the skin produce vitamin D?

Another important function of skin is the formation of vitamin D. Ultraviolet light produces small amounts of this vitamin from a fatlike molecule in your epidermis. Vitamin D is needed for good health because it helps your body absorb calcium from food in your digestive tract.

How does skin control body temperature?

Humans can withstand a limited range of body temperatures. The thermometer below shows environmental changes that affect the body. Skin plays an important role in controlling body temperature. Blood vessels in the skin can help release or hold heat. When blood vessels constrict, or get smaller, blood flow slows, and less heat is released. When blood vessels expand, blood flow increases, and more heat is released.

Sweat glands in the skin also help control the body’s temperature. As blood vessels expand, pores open in the skin that lead to the sweat glands. Sweat moves out onto the skin. Heat is transferred from the body to the sweat on the skin. As the sweat evaporates, heat is removed, and the skin is cooled.

Sweat glands also help release wastes. As your cells use nutrients for energy, they produce wastes. Sweat glands release water, salt, and other wastes.
Skin Injuries and Repair

When skin is injured, it responds by producing new cells in the epidermis and repairing tears in the dermis. Injured skin allows disease-causing organisms to enter the body rapidly and an infection may occur.

What are bruises?

When you have a bruise, the tiny blood vessels underneath the skin have burst, releasing red blood cells. These blood cells break down and release hemoglobin. The chemical hemoglobin breaks down into its components, called pigments. The color of the pigments causes the bruised area to turn blue, red, and purple. Swelling also may occur. As the injury heals, the bruise turns yellow as the pigment in the red blood cells is broken down even more and reenters the bloodstream. After all the pigment is absorbed into the bloodstream, the skin looks normal again.

How do cuts heal?

Any tear in the skin is called a cut. Blood flows out of a cut until a clot forms over it. Then a scab forms, stopping bacteria from entering the body. Cells in the surrounding blood vessels fight infection. In time, the scab falls off, and new skin is left behind. If the cut is large, a scar may develop because of the large amounts of thick tissue fibers that form.

What are skin grafts?

When a person has a serious injury to large areas of skin, there may not be enough skin cells left that can divide to replace the skin that has been lost. This can lead to infection and possible death. Skin grafts can be used to replace the lost skin. Skin grafts are pieces of skin that are cut from one part of a person’s body and then moved to the injured or burned area where there is no skin.

Skin grafts are usually taken from the person’s own body. When a person does not have enough healthy skin, doctors may use skin from dead humans, or cadavers, for skin grafts. The cadaver skin is used for a short time to prevent infections. Doctors then grow large sheets of epidermis from small pieces of the burn victim’s own healthy skin. The cadaver skin patch is removed and the new skin is put in place.

Foldables

Describe Make a Foldable from quarter sheets of notebook paper, as shown below, to organize facts and concepts about bruises, cuts, and grafts.

---

6. Explain Why are skin grafts used?
After You Read

Mini Glossary

dermis: the layer of cells directly below the epidermis, which contains blood vessels, nerves, muscles, oil and sweat glands

epidermis: the outer, thinnest layer of skin

melanin: a pigment that protects your skin and gives it color

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that describes one skin structure.

2. Fill in the table below to identify five functions of skin.

<table>
<thead>
<tr>
<th>Functions of Skin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
</tr>
<tr>
<td>2.</td>
</tr>
<tr>
<td>3.</td>
</tr>
<tr>
<td>4.</td>
</tr>
<tr>
<td>5.</td>
</tr>
</tbody>
</table>
Nutrients and Digestion

section Nutrition

Before You Read
List on the lines below five foods that you think are good for you, or are nutritious. Explain what makes them nutritious.

Read to Learn

Why do you eat?
Your body needs energy for every activity that it performs. You need energy to run, blink your eyes, and lift your backpack. This energy comes from the foods you eat. The foods you eat also give your body the nutrients it needs. Nutrients (NEW tree unts) are substances in food that provide the energy and materials cells need to develop, grow, and repair themselves.

How is the energy in food measured?
The amount of energy you need depends on your body mass, age, and how active you are. The amount of energy in food is measured in Calories. A Calorie (Cal) is the amount of heat needed to raise the temperature of 1 kg of water 1°C. The number of calories in a food depends on the kinds of nutrients the food contains.

Classes of Nutrients
Six kinds of nutrients are found in food. The six nutrients are proteins, carbohydrates, fats, vitamins, minerals, and water. Proteins, carbohydrates, vitamins, and fats are organic nutrients because they contain carbon. Minerals and water are inorganic nutrients because they do not contain carbon.

What You’ll Learn
- the six kinds of nutrients
- why each nutrient is important
- how your diet affects your health

Use an Outline As you read, make an outline to summarize the information in the section. Use the main headings in the section as the main headings in the outline. Add information under each heading in the section.

Reading Check
1. Identify three nutrients found in foods.

Reading Essentials 249
Absorption of Nutrients  
Foods with carbohydrates, fats, and proteins have to be digested or broken down before the body can use them. Water, vitamins, and minerals are absorbed directly into the bloodstream.

How does the body use proteins?

Proteins replace and repair body cells and help the body grow. Proteins are large molecules that contain carbon, hydrogen, oxygen, nitrogen, and sometimes sulfur. A protein molecule is made up of many smaller units called amino acids. Different foods have different amounts of protein, as shown in the table below.

### Calories and Protein in Selected Food Items

<table>
<thead>
<tr>
<th>Food</th>
<th>Calories</th>
<th>Protein</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pepperoni pizza (1 slice)</td>
<td>280</td>
<td>16 g</td>
</tr>
<tr>
<td>Large taco</td>
<td>186</td>
<td>15 g</td>
</tr>
<tr>
<td>Banana split</td>
<td>540</td>
<td>10 g</td>
</tr>
</tbody>
</table>

What are essential amino acids?

Your body needs 20 amino acids to make the thousands of proteins that your cells use. Most of the amino acids can be made in the body’s cells. Eight of the amino acids, however, cannot be made by the body. These eight are called essential amino acids. You have to get them from the food you eat. Foods that provide all eight essential amino acids are called complete proteins. Complete proteins are found in eggs, milk, cheese, and meat. Incomplete proteins are missing one or more of the essential amino acids. Vegetarians need to eat a wide variety of protein-rich vegetables, fruits, and grains to get all eight essential amino acids.

Why are carbohydrates important?

Carbohydrates (kar boh HI drayts) are the main sources of energy for your body. A carbohydrate molecule is made up of carbon, hydrogen, and oxygen atoms. Energy holds these atoms together. When carbohydrate molecules break apart in the cells, energy is released for your body to use.

What are the three types of carbohydrates?

The three types of carbohydrates are sugar, starch, and fiber. Sugars are simple carbohydrates. Table sugar is one of these sugars. Fruits, honey, and milk also contain forms of sugar. Your cells break down glucose, which is a simple sugar.
What is the difference between starch and fiber?
Starch and fiber are complex carbohydrates. Starch is found in potatoes and in foods made from grains such as pasta. Starches are made up of simple sugars strung together in long chains. Fiber is found in the cell walls of plant cells. Foods such as whole-grain breads, cereals, beans, and vegetables and fruits are good sources of fiber. You cannot digest fiber, but it is needed to keep your digestive system running smoothly.

How does the body use fats?
Fats, also called lipids, provide the body with energy and help it absorb vitamins. Fat tissue cushions the body’s internal organs. A major part of every cell membrane is made up of fat. Fats release more energy than carbohydrates do. When food is being digested, fat is broken down into smaller molecules called fatty acids and glycerol (GLIH suh rawl). Fat is a good storage unit for energy. Your body takes excess energy from the foods you eat and changes it to fat that is stored for later use.

What are saturated and unsaturated fats?
There are two kinds of fats, unsaturated fats and saturated fats. Unsaturated fats are usually liquid at room temperature. Vegetable oil is an example of an unsaturated fat. Saturated fats are usually solid at room temperature. Saturated fats are found in meats, animal products, and some plants.

Eating too many saturated fats has been linked to high levels of cholesterol in the body. Cholesterol is part of the cell membrane in all of your cells. However, a diet that is high in cholesterol can cause deposits to form on the inside walls of blood vessels. The deposits can keep the blood supply from getting to organs. The deposits also can increase blood pressure and lead to heart disease and strokes.

What are vitamins?
Vitamins are nutrients that the body needs in small amounts. Vitamins help the body grow, help keep the body functioning properly, and help prevent some diseases. Most foods contain some vitamins. However, no single food has all the vitamins you need.
What is the difference between water-soluble and fat-soluble vitamins?

There are two groups of vitamins, water-soluble and fat-soluble. Water-soluble vitamins dissolve easily in water. Your body does not store these vitamins, so you need to get them every day. Fat-soluble vitamins dissolve only in fat. These vitamins are stored in the body.

You get most of your vitamins from food. However, your body makes some vitamins. For example, your body makes vitamin D when your skin is exposed to sunlight.

How do minerals affect the body?

Minerals are inorganic nutrients that take part in many chemical reactions in your body. Minerals build cells, send nerve impulses throughout your body, and carry oxygen to body cells.

Your body uses about 14 minerals. Of the 14 minerals, your body uses calcium and phosphorus in the largest amounts. Calcium and phosphorus help form and maintain bones. Some minerals, such as copper, are trace minerals. The body only needs very small amounts of trace minerals. Review the table below to learn more about some of the minerals your body uses.

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Health Effect</th>
<th>Food Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>builds strong bones and teeth, helps blood clotting and muscle and nerve activity</td>
<td>milk, cheese, eggs, green leafy vegetables, soy</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>builds strong bones and teeth, helps muscles contract, stores energy</td>
<td>cheese, meat, cereal</td>
</tr>
<tr>
<td>Potassium</td>
<td>balances water in cells, conducts nerve impulses, helps muscles contract</td>
<td>bananas, potatoes, nuts, meat, oranges</td>
</tr>
<tr>
<td>Sodium</td>
<td>balances fluid in tissues, conducts nerve impulses</td>
<td>meat, milk, cheese, salt, beets, carrots, nearly all foods</td>
</tr>
<tr>
<td>Iron</td>
<td>moves oxygen in hemoglobin by red blood cells</td>
<td>red meat, raisins, beans, spinach, eggs</td>
</tr>
<tr>
<td>Iodine (trace)</td>
<td>helps thyroid activity, stimulates metabolism</td>
<td>seafood, iodized salt</td>
</tr>
</tbody>
</table>

Why is water an important nutrient?

Next to oxygen, water is the most important thing your body needs for survival. You could live a few weeks without food but only a few days without water. Cells need water to carry out their work. Many other nutrients that the body needs have to be dissolved in water before they can be used.
Water Loss  Water makes up about 60 percent of the weight of your body. Most of the body’s water is located in body cells. Water is also found around cells and in blood. Your body loses water when you perspire and when you exhale. Your body also loses water when it gets rid of wastes. To replace the amount of water your body loses each day, you need to drink about 2 L of liquids. Drinking liquids is not the only way to get water. Many foods, such as apples and meats, are made up of a large amount of water.

Why do you get thirsty?
When your body needs to replace water that it lost, messages are sent to your brain that make you feel thirsty. Drinking water satisfies your thirst. Drinking water also helps to restore the body’s homeostasis (hoh mee oh STAY sus). When your body is in homeostasis, or balance, it has the right amount of water and the right temperature. When homeostasis returns, the messages to the brain stop, and you no longer feel thirsty.

Food Groups
No natural food has all the nutrients your body needs. You need to eat a variety of foods. Nutritionists have set up a system to help people choose foods that supply all the nutrients the body needs for energy and growth. The system is called the food pyramid. It is shown in the figure below.
What are the five food groups?
Foods that have the same type of nutrient belong to a **food group**. There are five food groups: bread and cereal, vegetables, fruits, milk, and meat.

What should you eat from each food group?
The food pyramid on the previous page shows the recommended number of servings from each food group that people should eat every day. Eating the recommended daily amount for each group will give your body the nutrients it needs for good health. The size of a serving is different for different food groups.

Why should you read food labels?
The food labels, such as the one below, on all packaged foods contain nutritional facts about the foods. These facts can help you make healthful food choices. The labels can help you plan meals that include the recommended amounts of nutrients.
After You Read

Mini Glossary

- **amino acid**: one of the small units that make up a protein molecule
- **carbohydrate** (kar boh HI drayt): a molecule made up of carbon, hydrogen, and oxygen atoms; nutrient that is the main source of energy for the body
- **fat**: necessary nutrient that provides the body with energy and helps it absorb vitamins; also known as a lipid
- **food group**: foods that have the same type of nutrient
- **mineral**: inorganic nutrient that takes part in many chemical reactions in the body
- **nutrient** (NEW tree unt): substances in food that provide energy and materials for cells to develop, grow, and repair themselves
- **protein**: large molecules that contain carbon, hydrogen, oxygen, nitrogen, and sometimes sulfur; one of the six kinds of nutrients
- **vitamin**: nutrient that is needed in small amounts to help the body grow, to regulate body functions, and to prevent some diseases

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the relationship between amino acids and proteins.

2. Complete the diagram below by classifying the six kinds of nutrients.

   ![Diagram](image)

3. How does your outline help you understand ideas about nutrition?

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Visit [life.msscience.com](http://life.msscience.com) to access your textbook, interactive games, and projects to help you learn more about nutrition.

End of Section
Nutrients and Digestion

section 2 The Digestive System

Before You Read

Read the title of this chapter above. On the lines below, tell how you think nutrients and digestion are related.


Read to Learn

Functions of the Digestive System

Your body processes food in four stages—ingestion, digestion, absorption, and elimination. Ingestion is when food enters your mouth. Digestion begins immediately.

Digestion is the process that breaks down food into small molecules so that they can move into the blood. Absorption occurs when food molecules move from the blood into the cells. Inside the cell, the food molecules break down even further so their energy and nutrients can be used by the cell. Elimination takes place when unused food molecules pass out of the body as wastes.

Digestion is mechanical and chemical. Mechanical digestion occurs when food is chewed, mixed, and churned. Chemical digestion takes place when chemical reactions occur that break down large molecules of food into smaller molecules.

Enzymes

Enzymes (EN zimez) make chemical digestion possible. An enzyme is a type of protein that speeds up the rate of a chemical reaction in your body. Enzymes reduce the energy needed for a chemical reaction to start.
How do enzymes help digestion?

Enzymes help you digest different nutrients. Amylase (AM uh lays) is an enzyme made by glands near the mouth. Amylase helps speed up the breakdown of complex carbohydrates, such as starch, into simpler carbohydrates—sugars. The enzyme pepsin works in the stomach to help the chemical reactions that break down proteins. Enzymes in the small intestine help to break down proteins into amino acids.

The pancreas, an organ on the back side of the stomach, releases enzymes into the small intestine. Some of these enzymes continue the starch breakdown that started in the mouth. The sugars from this breakdown are turned into glucose and are used by the body's cells. Some enzymes from the pancreas help break down fats into fatty acids. Other enzymes from the pancreas aid the breakdown of proteins.

What else do enzymes do?

Enzymes help speed up chemical reactions that help your body grow. Muscle and nerve cells use enzymes to produce energy. Blood needs enzymes to clot.

Organs of the Digestive System

Your digestive system has two parts—the digestive tract and the accessory organs. The parts of the digestive system are shown on the next page.

What are the parts of the digestive tract?

The digestive tract includes the mouth, esophagus (ih SAH fuh guhs), stomach, small intestine, large intestine, rectum, and anus. Food passes through all of these organs. The accessory organs include the tongue, teeth, salivary glands, liver, gallbladder, and pancreas. Food does not pass through these organs. However, the accessory organs help with mechanical and chemical digestion.

What part does the mouth play in digestion?

Both mechanical and chemical digestion take place in the mouth. Mechanical digestion happens when you chew your food. Chemical digestion happens when the tongue moves food around and mixes it with saliva (suh LI vuh).

Saliva is made by three glands near the mouth. Saliva contains an enzyme that helps break down starch into sugar. After the food is swallowed, it passes into the esophagus.
What does the esophagus do?
Food passes over the epiglottis (ep uh GLAH tus) as it moves into the esophagus. The epiglottis automatically covers the opening to the windpipe to stop food from entering it. Food moves down the esophagus to the stomach, as shown in the figure below. Mucous glands in the esophagus keep the food moist. Smooth muscles in the esophagus move the food downward with a squeezing action. These muscle contractions, called peristalsis (per uh STAHL sus), move food through the entire digestive tract. No digestion happens in the esophagus.

How does the stomach help digestion?
The stomach is a bag of muscle. Both mechanical and chemical digestion take place in the stomach. Mechanical digestion happens when food is mixed in the stomach by peristalsis. Chemical digestion happens when food in the stomach mixes with enzymes and strong digestive acids, such as hydrochloric acid solution.

The acidic solution works with the enzyme pepsin to digest protein. The acidic solution also destroys bacteria present in the food. 

The stomach also produces mucus, which makes food more slippery and protects the stomach from the strong digestive solutions. Food moves through the stomach and is changed into a watery liquid called chyme (KIME). Chyme moves out of the stomach into the small intestine.
What fluids are added in the small intestine?

Chyme enters the first part of the small intestine called the duodenum (doo AH duh num). Most digestion takes place there. Bile, a greenish fluid from the liver, is added in the duodenum. Bile breaks the large fat particles in chyme into smaller particles. Chemical digestion of carbohydrates, proteins, and fats occurs when a digestive solution from the pancreas is mixed in. The solution neutralizes the stomach acid in the chyme.

How is food absorbed in the small intestine?

Food is absorbed from the small intestine into the bloodstream. The wall of the small intestine has many ridges and folds that are covered with fingerlike projections called villi (VIH li). Villi, shown in the figure below, increase the surface area of the small intestine, giving nutrients in the chyme more places to be absorbed. Nutrients move into the blood vessels in the villi. Peristalsis moves undigested and unabsorbed materials into the large intestine.

What happens in the large intestine?

The main job of the large intestine is to absorb water from the undigested materials. This keeps large amounts of water in the body and helps maintain homeostasis. After the water is absorbed, the remaining undigested materials become more solid. Muscles in the rectum and the anus control the release of the wastes from the body in the form of feces (FEE seez).

Bacteria Are Important

Bacteria live in many parts of the digestive tract. Bacteria in the large intestine feed on undigested material like cellulose. Bacteria make Vitamin K and two B vitamins, niacin and thiamine. Vitamin K is needed for blood clotting. The B vitamins help the nervous system and other body functions.
After You Read

Mini Glossary

chemical digestion: digestion that takes place when chemical reactions break down large molecules of food into smaller ones

chyme (KIME): food from the stomach that has been changed into a thin, watery liquid that moves into the small intestine
digestion: the process that breaks down food into small molecules so that they can be moved into the blood and absorbed by the cells

enzyme (EN zime): a type of protein that speeds up the rate of a chemical reaction in the body

mechanical digestion: digestion that takes place when food is chewed, mixed, and churned

peristalsis (per uh STAHL sus): waves of muscle contractions

villi (VIH li): fingerlike projections in the small intestine

1. Review the terms and their definitions in the Mini Glossary. Write a sentence explaining the difference between mechanical digestion and chemical digestion.

2. Complete the web diagram below by listing the major parts of the digestive system and describing the role of each in digestion.

End of Section

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about the digestive system.
Circulation

section ● The Circulatory System

Before You Read

Explain the function of the plumbing system in your home. Describe how it works.

What You’ll Learn

■ the differences among arteries, veins, and capillaries
■ how blood moves through the heart
■ the functions of the pulmonary and systemic circulation systems

Read to Learn

How Materials Move Through the Body

The cardiovascular (kar dee oh VAS kyuhr lur) system supplies materials to and removes wastes from your body cells. This system includes your heart, blood vessels, and blood.

Movement of materials into and out of your cells occurs by diffusion (dih FYEW zuhn) and active transport.

Diffusion occurs when a material moves from an area where there is more of it to an area where there is less of it. Nutrients and oxygen diffuse from your blood into your body’s cells. Active transport is the opposite of diffusion. Active transport needs energy from the cell to occur.

The Heart

Your heart is an organ made of cardiac muscle tissue. Your heart has four compartments called chambers. The two upper chambers are called the right and left atriums (AY tree umz). The two lower chambers are called the right and left ventricles (VEN trih kulz). During one heartbeat, both atriums contract at the same time. Then, both ventricles contract at the same time. A one-way valve separates each atrium from the ventricle below it.
Three Sections of the Circulatory System

Scientists divide the circulatory system into three sections: coronary (KOR uh ner ee) circulation, pulmonary (PUL muh ner ee) circulation, and systemic circulation. The beating of your heart controls blood flow through each section.

What is coronary circulation?

Blood vessels supply the heart with nutrients and oxygen and remove wastes. **Coronary circulation** is the flow of blood to and from the tissues of the heart.

What is pulmonary circulation?

The flow of blood through the heart to the lungs and back to the heart is **pulmonary circulation**. Use the figure below to trace the path blood takes through this part of the circulatory system.

The blood returning from the body through the right side of the heart and to the lungs contains wastes from the body’s cells. Carbon dioxide is one of these wastes.

In the lungs, carbon dioxide and other gaseous wastes diffuse out of the blood, and oxygen diffuses into the blood. Then the blood returns to the left side of the heart.

In the final step of pulmonary circulation, the oxygen-rich blood is pumped from the left ventricle into the aorta (ay OR tuh). The aorta is the largest artery in your body. Next, the oxygen-rich blood flows to all parts of your body.
What is systemic circulation?

Oxygen-rich blood moves to all of your organs and body tissues, except the heart and lungs, by **systemic circulation**. Oxygen-poor blood returns to the heart by systemic circulation. The figure below shows the major arteries and veins (VAYNZ) of the systemic circulation system. Oxygen-rich blood flows from your heart in the arteries. Then nutrients and oxygen are delivered by blood to your body cells and exchanged for carbon dioxide and wastes, as shown below. The blood then returns to your heart in the veins.

**Think it Over**

3. **Infer** Why is systemic circulation important to your muscles?

---

**Blood Vessels**

In the middle 1600s, scientists proved that blood moves in one direction in a blood vessel, like traffic on a one-way street. They discovered that blood moves by the pumping of the heart and flows from arteries to veins. They couldn’t explain how blood got from arteries to veins. With the invention of the microscope, scientists discovered that capillaries (KAP uh ler eez) connect the arteries and veins.

**Picture This**

4. **Identify** Circle the name of the blood vessel in which oxygen and carbon dioxide are exchanged.
5. Describe What does the first number in your blood pressure measure?

What is the function of arteries?
The blood vessels that carry blood away from the heart are called arteries. Arteries have thick, elastic walls made of connective tissue and smooth muscle tissue.

Each ventricle of the heart is connected to an artery. The right ventricle of the heart is connected to the pulmonary artery. The left ventricle of the heart is connected to the aorta. Every time your heart contracts, blood moves from your heart into your arteries.

How does blood flow in the veins?
A blood vessel that carries blood back to the heart is called a vein. Veins have one-way valves that keep blood moving toward the heart. If blood flows backward, the pressure of the blood against the valve causes it to close. Two major veins return blood from your body to your heart. The superior vena cava returns blood from your head and neck. The inferior vena cava returns blood from your abdomen and lower body.

What is the function of capillaries?
Very small blood vessels called capillaries connect arteries and veins. Nutrients and oxygen diffuse into body cells through the thin capillary walls. Waste and carbon dioxide diffuse from body cells into the capillaries.

Blood Pressure
When your heart pumps, the pressure of the push moves through the blood. The force of the blood on the walls of the blood vessels is called blood pressure. Blood pressure is highest in arteries and lowest in veins. When you take your pulse, you can feel the waves of pressure. This rise and fall in pressure occurs with each heartbeat. Normal resting pulse rates are 60 to 100 heartbeats per minute for adults, and 80 to 100 beats per minute for children.

How is blood pressure measured?
Blood pressure is measured in large arteries. Two numbers describe blood pressure, such as 120 over 80. The first number is a measure of the pressure caused when the ventricles contract and blood is pushed out of the heart. The second number is a measure of the pressure that occurs as the ventricles fill with blood just before they contract again.
Blood Pressure and Heart Rate  When blood pressure is higher or lower than normal, messages are sent to the brain by nerve cells in the arteries. One way the brain lowers or raises blood pressure is by speeding up or slowing down the heart rate. When blood pressure stays constant, enough blood reaches all organs and tissues in the body.

Cardiovascular Disease
There are many diseases that affect the cardiovascular system—the heart, blood vessels, and blood. Heart disease is the leading cause of death in the United States.

What is atherosclerosis?
Atherosclerosis (ah thuh roh skluh ROH sus) is a leading cause of heart disease. In this condition, deposits of fat build up on the walls of the arteries. These fat deposits can block an artery. If a coronary artery is blocked, a heart attack can occur.

What happens with hypertension?
Hypertension (HI pur TEN chun) is high blood pressure. When blood pressure is higher than normal most of the time, the heart must work harder to keep blood flowing. Atherosclerosis is one cause of hypertension. 

How does heart failure occur?
Heart failure occurs when the heart cannot pump blood efficiently. When the heart does not pump properly, fluid collects in the arms, legs, and lungs. A person with heart failure is usually short of breath and tired.

Can cardiovascular disease be prevented?
Cardiovascular disease can be prevented by following a diet that is low in salt, sugar, cholesterol, and saturated fats. Large amounts of body fat force the heart to pump faster. Relaxing and exercising help prevent tension and relieve stress. Exercising strengthens the heart and lungs and helps maintain proper weight. Not smoking also helps prevent heart disease.

Reading Check
6. Apply What is another name for high blood pressure?

7. Explain What is one thing you can do to prevent cardiovascular disease?
After You Read

Mini Glossary

artery: a blood vessel that carries blood away from the heart
atriums (AY tree umz): the two upper chambers of the heart
capillaries (KAP uh ler eez): very small blood vessels that connect arteries and veins
coronary (KOR uh ner ee) circulation: the flow of blood to and from the tissues of the heart
pulmonary circulation: the flow of blood through the heart to the lungs and back to the heart
systemic circulation: the system in which oxygen-rich blood moves to all of the organs and body tissues, except the heart and lungs, and oxygen-poor blood returns to the heart
vein: a blood vessel that carries blood back to the heart
ventricles (VEN trih kulz): the two lower chambers of the heart

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the difference between pulmonary circulation and systemic circulation.

2. Complete the concept map below to show the kinds of blood vessels and their functions.

[Diagram of Blood Vessels]

function

function

function

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about the circulatory system.
Before You Read

Have you ever fallen and scraped your knee? What happens to the wounded area? What happens while the wound is healing?

Read to Learn

Functions of Blood

Blood has four important functions.

1. Blood carries oxygen from your lungs to your body cells. Carbon dioxide diffuses from your body cells to your blood. Your blood carries carbon dioxide to your lungs to be exhaled.
2. Blood carries waste from your cells to your kidneys to be removed.
3. Blood carries nutrients and other materials to your body cells.
4. Cells and molecules in blood fight infections and help heal wounds.

Parts of Blood

Blood is a tissue made of plasma (PLAZ muh), platelets (PLAYT luts), and red and white blood cells. Blood makes up about eight percent of your total body mass. If you weigh 45 kg, you have about 3.6 kg of blood.

What is plasma?

The liquid part of blood is mostly water and is called plasma. Nutrients, minerals, and oxygen are dissolved in plasma and carried to cells. Wastes from cells also are carried in plasma.
What is the function of red blood cells?

Red blood cells are different from all other human cells because they have no nuclei. They contain hemoglobin (HEE muh gloh bun), which is a molecule that carries oxygen and carbon dioxide. Hemoglobin is made of an iron compound that gives blood its red color. Hemoglobin carries oxygen from your lungs to your body cells. Then it carries some of the carbon dioxide from your body cells back to your lungs.

How do white blood cells fight invaders?

White blood cells fight bacteria, viruses, and other invaders of your body. Your body reacts to these invaders by increasing the number of white blood cells. These cells leave the blood through capillary walls and go into the tissues that have been invaded. Here, they destroy bacteria and viruses and absorb dead cells.

What are platelets?

Platelets circulate with red and white blood cells. Platelets are irregularly shaped cell fragments that help clot blood.

Blood Clotting

When you cut yourself, platelets stick to the wound and release chemicals. Then materials called clotting factors carry out a series of chemical reactions. These reactions cause threadlike fibers called fibrin (FI brun) to form a sticky net, as shown in the figure below. This net traps escaping blood cells and plasma and forms a clot. The clot becomes hard and skin cells begin the repair process under the scab. After a few days, the scab falls off.
Blood Types

Blood clots stop blood loss quickly in a minor wound. However, a person with a serious wound might lose a lot of blood and need a blood transfusion. During a blood transfusion, a person receives donated blood or parts of blood. The person must get the right type of blood, or the red blood cells will clump together. This causes clots to form in the blood vessels and the person could die.

How are blood types identified?

People can inherit one of four types of blood: A, B, AB, or O. Types A, B, and AB have chemical identification tags called antigens (AN ti junz) on their red blood cells. Type O red blood cells have no antigens, as shown in the table below.

<table>
<thead>
<tr>
<th>Blood Type</th>
<th>Antigen</th>
<th>Antibody</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A</td>
<td>Anti-B</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>Anti-A</td>
</tr>
<tr>
<td>AB</td>
<td>A, B</td>
<td>None</td>
</tr>
<tr>
<td>O</td>
<td>None</td>
<td>Anti-A, Anti-B</td>
</tr>
</tbody>
</table>

Antibodies and Transfusions  Each blood type, except AB, also has specific antibodies in its plasma. Antibodies are proteins that destroy materials that do not belong in or are not part of your body. For example, if type A blood is mixed with type B blood, the type A antibodies cause the type B red blood cells to clump.

Because of these antibodies, certain blood types cannot be mixed. Type AB blood has no antibodies, so people with this blood type can receive blood from A, B, AB, and O types. Type O blood has both A and B antibodies. People with type O blood are sometimes called universal donors because their blood can be transfused into a person with any blood type.

Think it Over

3. Analyze Why would it be important for doctors to check your blood type if you were in a serious accident?

Picture This

4. Identify Highlight the blood type that produces no antibodies. Circle the blood type that has no antigens.
What is the Rh factor in blood?

The Rh factor is another chemical identification tag in blood. The Rh factor is inherited. If the Rh factor is on red blood cells, the person has Rh-positive (Rh+) blood. If it is not present, the person's blood is Rh-negative (Rh−). If an Rh− person receives a blood transfusion from an Rh+ person, he or she will produce antibodies against the Rh factor. These antibodies can cause Rh+ cells to clump. Clots then form in the blood vessels and the person could die.

When an Rh− mother is pregnant with an Rh+ baby, the mother might make antibodies to the child’s Rh factor. Close to the time of birth, Rh antibodies from the mother can pass from her blood into the baby's blood. These antibodies can destroy the baby's red blood cells. If this happens, the baby must receive a blood transfusion before or right after birth.

At 28 weeks of pregnancy and immediately after the birth, an Rh− mother can be given an injection that stops the production of antibodies to the Rh+ factor. This keeps the baby from needing a blood transfusion.

Diseases of Blood

Any disease of the blood is a cause for concern, because blood circulates to all parts of your body and performs many important functions. Anemia (uh NEE mee uh) is a common disease of red blood cells. Body tissues cannot get enough oxygen and are not able to carry out their usual activities. Anemia can be caused by the loss of large amounts of blood. It also can be caused by the lack of iron or certain vitamins in the diet. Anemia can be the result of other diseases. Some types of anemia, such as sickle-cell anemia, are inherited.

Leukemia (lew KEE mee uh) is a disease in which one or more types of white blood cells are made in large numbers. These cells are not able to fight infections well. They crowd out the normal cells. Then not enough red blood cells, normal white blood cells, and platelets can be made. Types of leukemia can affect children or adults. Medicines, blood transfusions, and bone marrow transplants are used to treat this disease. If the treatments are not successful, the person will eventually die from complications related to the disease.
1. Review the terms and their definitions in the Mini Glossary. Choose one term that describes a part of the blood. Write a sentence that explains the function of this part of the blood.

2. Using the phrases below, fill in the boxes in the correct order to explain how a wound heals.

- Clot forms.
- Clot hardens.
- Clotting factors carry out chemical reaction.
- Fibrin forms.
- Net traps blood cells.
- Platelets stick to wound.
- Scab falls off.
- Skin cells repair under scab.

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about blood.
Circulation

section 2 The Lymphatic System

What You’ll Learn
- the functions of the lymphatic system
- where lymph comes from
- how lymph organs help fight infections

Before You Read
When you fill a glass with water from a water faucet, what happens to the water that does not go into your glass?

Functions of the Lymphatic System

When you fill a glass with water from the faucet, some of the water likely runs down the drain. In a similar way, your body’s excess tissue fluid is removed by the lymphatic (lihm FA tihk) system. The nutrient, water, and oxygen molecules in blood diffuse through capillary walls to nearby cells. Water and other substances become part of the tissue fluid that is found between cells. This fluid is collected and returned to the blood by the lymphatic system.

After tissue fluid diffuses into the lymphatic capillaries, it is called lymph (LIHMF). Lymph contains water, other materials, and lymphocytes (LIHM fuh sites), a type of white blood cell.

Your lymphatic system carries lymph through a network of lymph capillaries and larger lymph vessels. Then, the lymph drains into larger veins near the heart. The lymph is moved by the contraction of smooth muscles in lymph vessels and skeletal muscles.

Lymphatic vessels have valves that keep lymph from flowing backward. If the lymphatic system is not working properly, swelling occurs because the tissue fluid cannot get back to the blood.
Lymphatic Organs

Before lymph enters the blood, it passes through lymph nodes. **Lymph nodes** are bean-shaped organs found throughout the body, as shown in the figure below. Lymph nodes filter out microorganisms and foreign materials that have been taken up by the lymphocytes. When your body fights an infection, lymphocytes fill the lymph nodes.

Other important lymphatic organs include the tonsils, the thymus, and the spleen. Tonsils protect you from harmful organisms that enter through your mouth and nose. The thymus makes lymphocytes. The spleen removes worn out and damaged red blood cells from the blood. Cells in the spleen destroy bacteria and other materials that invade your body.

**A Disease of the Lymphatic System**

HIV is a virus. It destroys lymphocytes called helper T cells that help make antibodies to fight infections. This makes it difficult for a person with HIV to fight some diseases. Usually, the person dies from these diseases, not from the HIV infection.
After You Read

Mini Glossary

**lymph (LIHMf):** tissue fluid that passes into the lymphatic capillaries

**lymphatic system:** the system that removes lymph that the body does not need through a network of lymph capillaries and larger lymph vessels

**lymph nodes:** bean-shaped organs found throughout the body, which filter out microorganisms

**lymphocyte (LIHM fuh site):** a type of white blood cell

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that summarizes what lymph nodes do.

2. Complete the concept web below to identify the organs of the lymphatic system.

3. Explain how working with a partner helped you learn about the lymphatic system.

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about the lymphatic system.
Respiration and Excretion

section The Respiratory System

Before You Read
What do people mean when they say they are “out of breath”? What causes them to be out of breath?

What You’ll Learn
- the functions of the respiratory system
- how oxygen and carbon dioxide are exchanged in the body
- how air moves in and out of the lungs
- how smoking affects the respiratory system

Read to Learn

Functions of the Respiratory System
You need to breathe air. Earth is surrounded by a layer of gases called the atmosphere (AT’ muh sfihr). You breathe the gases that are closest to Earth, particularly oxygen.

For thousands of years, people have known that air, food, and water are needed for life. However, people did not know that it is the gas oxygen that is necessary for life until the late 1700s. At that time, a French scientist discovered that animals breathe in oxygen and breathe out carbon dioxide. He then studied the way humans use oxygen. He measured how much oxygen a person uses when resting and when exercising. The measurements showed that the body uses more oxygen during exercise.

What is breathing?
Breathing is the movement of the chest that brings air into the lungs and removes waste gases. When you breathe in, or inhale, the air that comes into the lungs contains oxygen. The oxygen passes from the lungs into the circulatory system. Blood carries the oxygen to individual cells in the body. This process is shown in the figure on the next page.
What is respiration?

As blood is carrying oxygen to cells, the digestive system is providing glucose from digested food to the same cells. The oxygen brought to the cells is used to release energy from the glucose. This chemical reaction is called cellular respiration. Oxygen is necessary for respiration to occur. Carbon dioxide and water molecules are the waste products of cellular respiration. The blood carries the waste products back to the lungs. Breathing out, or exhaling, removes the carbon dioxide and some water molecules.

Organs of the Respiratory System

The respiratory system is made up of structures and organs that help move oxygen into the body and take waste gases out of the body. Air comes into the body through the nostrils in your nose or through the mouth. Hairs in the nostrils trap dust from the air. Air then moves through the nasal cavity. There the air is moistened and warmed by the body’s heat. Glands that produce sticky mucus line the nasal cavity. The mucus traps dust and other materials that were not trapped by the nasal hairs. This process helps clean the air you breathe. Cilia (SIH lee uh), tiny hairlike structures, move the mucus and trapped material to the back of the throat where it can be swallowed.
What does the pharynx do?

The warmed, moistened air enters a tubelike passageway called the pharynx (FER ingks). Food, liquid, and air all use this passage. The epiglottis (eh puh GLAH tus) is a flap of tissue located at the lower end of the pharynx. When you swallow, the epiglottis folds down to prevent food or liquid from entering your airway.

What are the larynx and the trachea?

The air then moves from the pharynx to the larynx (LER ingks). The larynx is the airway to which the vocal cords are attached. Forcing air between the vocal cords causes them to vibrate. The vibration produces sounds. When you speak, muscles tighten or loosen your vocal cords, resulting in different sounds.

From the larynx, the air moves into a tube called the trachea (TRAY kee uh). The trachea has rings of cartilage, a tough, flexible tissue that prevents the trachea from collapsing. Mucus and cilia line the trachea where they trap dust, bacteria, and pollen.

How do the bronchi and the lungs function?

Air is taken into the lungs by two short tubes called bronchi (BRAHN ki). Within the lungs, the bronchi branch into smaller and smaller tubes. The smallest tubes are called bronchioles (BRAHN kee ohlz). At the ends of the bronchioles are clusters of tiny, thin-walled sacs called alveoli (al VEE uh li). Air moves into the bronchi, then into the bronchioles, and finally into the alveoli. Lungs are masses of alveoli arranged in grapelike clusters. Capillaries, or small blood vessels, surround the alveoli.

Oxygen and carbon dioxide are exchanged between the alveoli and the capillaries. Oxygen moves through the cell membranes of the alveoli and then through the cell membranes of the capillaries into the blood. This happens easily because the walls of the alveoli and the walls of the capillaries are only one cell thick.

Hemoglobin (HEE muh gloh bun), a molecule in red blood cells, picks up the oxygen and carries it to all the cells of the body. Carbon dioxide and other cellular wastes leave the cells of the body through the membranes of the capillaries into the blood. In the lungs, the waste gases then move through the cell membranes of the capillaries and the alveoli. The waste gases leave the body when you exhale.
Why do you breathe?

You do not have to think about breathing. Your brain controls your breathing. Signals from your brain tell the muscles in your chest and abdomen to contract and relax. Your brain changes your breathing rate depending on the amount of carbon dioxide that is in your blood. Your breathing rate increases as the amount of carbon dioxide in your blood increases.

How do you inhale and exhale?

Breathing is partly the result of changes in air pressure. Generally, a gas moves from a high-pressure area to a low-pressure area. When you squeeze an empty, soft-plastic bottle, air is pushed out. When you stop squeezing the bottle, the air pressure inside the bottle becomes less than the air pressure outside the bottle. Air comes back in and the bottle returns to its original shape.

Your lungs work much like the squeezed bottle. The diaphragm (DI uh fram) is a muscle below your lungs that contracts and relaxes to help move gases into and out of your lungs. The figure below shows how your lungs inhale and exhale.

Diseases and Disorders of the Respiratory System

Many diseases of the respiratory system are related to smoking. The nicotine and tar in tobacco are poisons that can destroy cells. The high temperatures, smoke, and carbon monoxide produced when tobacco burns also damage a smoker’s cells. The respiratory systems of nonsmokers can be harmed by inhaling secondhand smoke from tobacco products. In addition to smoking, polluted air, coal dust, and asbestos (as BES tus) have been linked to various respiratory diseases.
What causes respiratory infections?

Bacteria and viruses can cause infections of the respiratory system. The common cold virus generally affects the upper part of the respiratory system—from the nose to the pharynx. The cold virus also can affect the larynx, trachea, and bronchi. The cilia that line the trachea and bronchi can be damaged. However, cilia usually heal rapidly.

A virus that causes the flu can affect the organs of the respiratory and other body systems. The virus multiplies in the cells lining the alveoli and damages them. Pneumonia is an infection in the alveoli. It can be caused by bacteria, viruses, or other microorganisms. Antibiotics (an ti bi AH tihks) are used to treat bacterial pneumonia. Before antibiotics were available, many people died from bacterial pneumonia.

What is chronic bronchitis?

Bronchitis (brahn KI tus) develops when bronchial tubes are irritated and swell and too much mucus is produced. Sometimes bronchitis is caused by bacteria and can be treated with antibiotics.

Most cases of bronchitis clear up within a few weeks. Sometimes, however, the disease lasts for a long time. This is called chronic (KRAH nihk) bronchitis. A person with this condition must cough often to clear mucus from the airway. But the more a person coughs, the more the cilia and bronchial tubes can be damaged. When cilia are damaged, they do not move mucus, bacteria, and dirt out of the lungs well. Then harmful substances build up in the airways. Sometimes, scar tissue forms and the respiratory system cannot work properly.

What is emphysema?

A disease in which the alveoli in the lungs enlarge is called emphysema (em fuh SEE muh). When cells in the alveoli are swollen, an enzyme that causes the walls of the alveoli to break down is released. As a result, alveoli cannot push the air out of the lungs and less oxygen moves into the bloodstream from the alveoli. When the blood has too little oxygen and too much carbon dioxide, shortness of breath occurs.

Some people with emphysema need extra oxygen. People with emphysema may develop heart problems because the heart has to work harder to supply oxygen to body cells.
What causes lung cancer?

Cigarette smoking increases the risk of several diseases, as shown in the table below. Cigarette smoking is a major cause of lung cancer. More than 85 percent of all lung cancer is related to smoking.

Tar and other substances found in smoke act as carcinogens (kar SIH nuh junz) in the body. Carcinogens are substances that can cause an uncontrolled growth of cells. In the lungs, this is called lung cancer. Lung cancer is not easy to detect in its early stages. Smoking also has been linked to the development of cancers of the mouth, esophagus, larynx, pancreas, kidneys, and bladder.

<table>
<thead>
<tr>
<th>Disease</th>
<th>Smokers’ Risk Compared to Nonsmokers’ Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lung cancer</td>
<td>23 times higher for males, 11 times higher for females</td>
</tr>
<tr>
<td>Chronic bronchitis and emphysema</td>
<td>5 times higher</td>
</tr>
<tr>
<td>Heart disease</td>
<td>2 times higher</td>
</tr>
</tbody>
</table>

What is asthma?

Asthma (AZ muh) is a lung disorder that can cause shortness of breath, wheezing, or coughing. During an asthma attack, the bronchial tubes contract quickly. To treat an asthma attack, a person inhales medicine that relaxes the bronchial tubes.

Asthma often is an allergic reaction. An allergic reaction occurs when the body overreacts to a foreign substance. An asthma attack can happen when a person breathes certain substances such as cigarette smoke, eats certain foods, or experiences stress.
After You Read

Mini Glossary

- **alveoli**: clusters of thin-walled sacs at the end of each bronchiole that are surrounded with capillaries; where the exchange of oxygen and carbon dioxide takes place
- **asthma**: a lung disorder that results in shortness of breath, wheezing, or coughing
- **bronchi**: two short tubes that carry air into the lungs
- **diaphragm**: muscle beneath the lungs that contracts and relaxes to help move gases into and out of the lungs
- **emphysema**: disease in which the alveoli in the lungs enlarge
- **larynx**: airway to which the vocal cords are attached
- **pharynx**: tubelike passageway that is used by food, liquid, and air
- **trachea**: air-conducting tube lined with mucus membranes and cilia

1. Review the terms and their definitions in the Mini Glossary. Choose one of the organs of the respiratory system and write a sentence that describes the organ and explains its function.

2. Choose one of the question headings in the Read to Learn section. Write the question in the space below. Then write your answer to that question on the lines that follow.

Write your question here.

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about the respiratory system.
Before You Read

On the lines below, write what you know about the job of the body’s kidneys.

The Excretory System

Functions of the Excretory System

It’s your turn to take out trash. You carry the bag outside and put it in the trash can. The next day, you bring out another bag of trash, but the trash can is full. When trash isn’t collected, it piles up. Just as trash needs to be removed from your home to keep the home livable, your body has to get rid of wastes to stay healthy. The digestive system gets rid of undigested material through the large intestine. The respiratory system and the circulatory system work to rid the body of waste gases. These systems work together as part of the excretory system. If wastes are not removed from the body, toxic substances build up and damage organs. Serious illness or death may occur.

The Urinary System

The urinary system rids the blood of wastes produced by the cells. The urinary system controls the volume of blood by removing excess water that the body cells produce during respiration. The urinary system is part of the excretory system. Salts and water that are needed for cell activities are kept in balance by the urinary system.
How are fluid levels in the body regulated?

To stay healthy, the fluid levels in the body have to be balanced. The body also has to keep a normal blood pressure. The hypothalamus (hi poh THA luh mus), an area in the brain, keeps track of the amount of water in the blood. When the brain detects too much water in the blood, the hypothalamus gives off a lesser amount of a specific hormone. This tells the kidneys to return less water to the blood. It also tells the kidneys to increase the amount of urine, or wastewater, that is excreted.

Water in the blood is important for moving gases and getting rid of solid wastes from the body. The urinary system also balances the amounts of certain salts and water that must be present for all cell activities to take place.

What organs make up the urinary system?

The organs of the urinary system are also called excretory organs. They are shown in the figure below. The main organs are two kidneys. They are located on the back wall of the abdomen at about waist level. The kidneys filter blood that contains wastes collected from cells. Blood enters the kidneys through a large artery and leaves through a large vein.

How does a kidney filter blood?

The kidney is a two-stage filtration system. It is made up of about one million tiny filtering units called nephrons (NEF rahnz). Each nephron has a cuplike structure and a tubelike structure called a duct. Blood moves from a renal artery to capillaries in the cuplike structure.

First Stage In the first filtration, water, sugar, salt, and wastes from the blood pass into the cuplike structure. Red blood cells and proteins are left behind in the blood.
Second Stage  Next, liquid in the cuplike structure is squeezed into a narrow tubule. Capillaries that surround the tubule do the second filtration. Most of the water, sugar, and salt are reabsorbed from the tubule and returned to the blood. These capillaries come together to form a renal vein in each kidney. The purified blood is returned to the circulatory system. The liquid left behind flows into collecting tubules in each kidney. This wastewater, or urine, contains excess water, salts, and other wastes that the body did not reabsorb. An average-sized person produces about 1 L of urine per day. Use the figure below to review how the nephrons filter blood.

How is urine collected and released?

The urine that collected in each tubule moves into a funnel-shaped area of each kidney that leads to the ureter (YOO ruh tur). Ureters are narrow tubes that lead from each kidney to the bladder. The bladder is a muscular organ that holds urine until it leaves the body. The bladder has elastic walls that stretch to hold the urine. A narrow tube called the urethra (yoo REE thruh) carries urine from the bladder to the outside of the body.

The body depends on water. Without water, the cells and other body systems could not function. Water is so important to the body that the brain and other body systems are involved in balancing water gain and water loss.
Other Organs of Excretion

Your body loses large amounts of liquid wastes in other ways, such as exhaling and perspiring. The amount of fluid lost each day by exhaling and perspiring is about the volume of a soda can. The liver also filters the blood to remove wastes. Some kinds of wastes are changed to other substances. Excess amino acids are changed to a chemical called urea (yoo REE uh) that passes to the urine. Hemoglobin from broken-down red blood cells becomes part of bile, which is digestive fluid from the liver.

Urinary Diseases and Disorders

When kidneys do not work properly, waste products build up and act as poisons in body cells. Water that kidneys normally remove from body tissues builds up and causes swelling of the ankles and feet. Sometimes the fluids build up around the heart. This causes the heart to work harder to move blood to the lungs.

When the urinary system does not work well, there can be an imbalance of salts. If the balance of salts is not restored, the kidneys and other organs can be damaged or fail. This is always a serious problem because the kidney’s job is so important to the rest of the body.

Microorganisms can cause infections of the urinary system. Usually, the infection starts in the bladder. Sometimes it spreads to the kidneys. The infection can usually be cured with antibiotics.

If the ureters and urethra become blocked, urine cannot flow out of the body properly. If the blockage is not corrected, the kidneys can be damaged.

How can urinary diseases be discovered?

Urine can be tested for signs of a urinary tract disease. A change in the urine’s color suggests kidney or liver problems. High levels of glucose in the urine can be a sign of diabetes. Increased amounts of a protein called albumin (al BYOO mun) can be a sign of kidney disease or heart failure.

What is dialysis?

People can live normally with only one kidney. However, if both kidneys fail, a person will need to have his or her blood filtered by a machine. This process is called dialysis (di AH luh sus). The dialysis machine removes wastes from the blood, just like the kidneys.
After You Read

Mini Glossary

bladder: organ that holds urine until it leaves the body
kidney: urinary system organ made up of about one million nephrons
nephron: tiny filtering unit in the kidney
ureter: one of two tubes that connect a kidney to the bladder

urethra: structure that carries urine from the bladder to the outside of the body
urinary system: body system that rids the blood of wastes made by the body’s cells, controls blood volume, and balances salts and water
urine: wastewater that is excreted by the kidneys

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the role of nephrons.

2. Complete the diagram below to show the effects of a urinary system that is not working properly on different parts of the body.

Effects of Urinary System Not Working Properly

Body cells
Ankles/Feet
Heart
Kidneys

3. How did writing quiz questions help you remember what you read in this section?

End of Section

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about the excretory system.
Control and Coordination

section ● The Nervous System

Before You Read

Do you remember the last time you touched something very hot by mistake? How did you react?

What You’ll Learn

● the basic structure of a neuron
● how an impulse moves across a synapse
● differences between central and peripheral nervous systems
● how drugs affect the body

Read to Learn

How the Nervous System Works

What happens when you hear a sudden, loud noise? Your heart may begin to race and your hands may shake. Once the surprise passes, your breathing returns to normal and your heartbeat is back to its regular rate. The way you react to a sudden, unexpected sound or event is one example of how your body responds to changes in your environment.

What are stimuli?

Any change that brings about a response is called a stimulus (STIHM yuh lus) (plural, stimuli). You respond to thousands of stimuli every day. Noise and light are examples of stimuli from outside your body. Hormones are stimuli from inside your body. Your nervous system helps your body adjust to changing stimuli.

What is homeostasis?

Your body has control systems that handle stimuli. The control systems help keep steady internal conditions. The changing of conditions inside an organism to keep it alive, even though the environment changes, is called homeostasis (hoh mee oh STAY sus). Your nervous system is one of the control systems that your body uses to maintain homeostasis.
Nerve Cells

The basic units of the nervous system are nerve cells, or neurons (NOOR ahnz). The neuron shown in the figure below is made up of a cell body and branches called dendrites and axons. Any message carried by a neuron is called an impulse. Dendrites receive impulses from other neurons and send them to the cell body. Axons (AK sahns) carry impulses away from the cell body and send them to other neurons. Notice the branching at the end of the axon. This allows impulses to move to many other muscles, neurons, or glands.

What are the types of nerve cells?

Your body can detect changes in the environment. Sensory receptors detect such things as temperature, sound, pressure, and light. Sensory receptors respond to stimuli by producing electrical impulses that are carried to the brain. Three types of neurons—sensory neurons, motor neurons, and interneurons—carry impulses. Sensory neurons receive information and send impulses to the brain or spinal cord. For example, when you hear a loud noise, sensory receptors in your ears are stimulated. These sensory neurons produce electrical impulses that travel to the brain. In the brain or spinal cord, interneurons send the impulses to motor neurons. The motor neurons move impulses from the brain or spinal cord to muscles or glands throughout your body. In the example of a loud noise, muscles in your arms contract to jerk your arms in response to the noise.
What is a synapse?

Neurons do not touch each other. Neurons are separated by a small space called a synapse (SIH naps), as shown in the figure below. To move from one neuron to another, the impulse must cross the synapse. When an impulse reaches the end of an axon, the axon releases a chemical. The chemical flows across the synapse and stimulates an impulse in the dendrite of the next neuron. Neurons allow impulses to move in only one direction.

The Central Nervous System

The central nervous system (CNS) is made up of the brain and spinal cord. The peripheral (puh RIH fuh rul) nervous system (PNS) is made up of all the nerves that are not part of the CNS. The PNS includes the nerves in the head, called cranial nerves. The PNS also includes the spinal nerves, which come from the spinal cord. The PNS connects the brain and spinal cord to other body parts.

What does the brain do?

The brain directs all the activities of the body. If someone tickles your feet, your brain directs your reaction. The brain is made up of about 100 billion neurons. That is about ten percent of all the neurons in the human body. The brain is surrounded and protected by a bony skull, three membranes, and a layer of fluid. The brain is divided into three parts: the brain stem, the cerebellum (ser uh BE lum), and the cerebrum (suh REE brum).

What is the role of the cerebrum?

The largest part of the brain is the cerebrum. This is where thinking takes place. The cerebrum interprets the meaning of impulses that come from sensory neurons. The cerebrum also stores memory and controls movements. The outer layer of the cerebrum is the cortex. The cortex has many ridges and grooves that increase its surface area. The greater surface area allows more complex thoughts to be processed.
What does the cerebellum do?

The cerebellum is the part of the brain that interprets stimuli from the eyes and ears and from muscles and tendons. Tendons are tissues that connect muscles to bones. The information received by the cerebellum helps it coordinate voluntary muscle movements, maintain muscle tone, and maintain balance. For example, the cerebellum coordinates muscle movements to help you balance while riding a bike.

What are the three parts of the brain stem?

The brain stem is at the base of the brain. The brain stem extends down from the cerebrum and connects the brain to the spinal cord. It is made up of the midbrain, the pons, and the medulla (muh DUH luh). The midbrain and pons connect various parts of the brain with each other. The medulla controls involuntary actions such as breathing and heartbeat. The medulla is also involved in actions such as coughing and sneezing.

Why is the spinal cord important?

Your spinal cord is an extension of the brain stem. The spinal cord is made up of neurons that carry impulses from all parts of the body to the brain and from the brain to all parts of the body.

The Peripheral Nervous System

Your brain and spinal cord are connected to the rest of the body by the peripheral nervous system (PNS). The PNS is made up of cranial nerves and spinal nerves. Spinal nerves contain bundles of sensory and motor neurons. Because most spinal nerves have these two kinds of neurons, a single spinal nerve can have impulses going to and from the brain at the same time.

What is the difference between the somatic and autonomic systems?

The peripheral nervous system has two major parts, the autonomic system and the somatic system. The somatic system controls voluntary actions, such as raising your hand. It is made up of cranial and spinal nerves that go from your central nervous system to your skeletal muscles. The autonomic system controls involuntary actions. These are actions that you do without making a choice, such as digestion and the beating of your heart.
Safety and the Nervous System

The central and peripheral nervous systems are involved with every mental process and physical action of your body. Therefore, an injury to the brain or the spinal cord can be serious. For example, the back of the brain controls vision. A blow to the back of the head could result in a loss of vision.

The spinal cord is surrounded by the bones of the spine, which protect the spinal cord. However, injuries to the spinal cord do occur. A spinal cord injury can damage nerve pathways and lead to paralysis (puh RA luh suhs). Paralysis is the loss of muscle movement.

**Types of paralysis** Damage to one side of the brain can cause the opposite side of the body to be paralyzed. If the spinal cord is damaged in the neck area, the body can be paralyzed from the neck down. Damage to the middle or lower part of the spinal cord can paralyze the legs and the lower part of the body.

Automobile, motorcycle, and bicycle accidents, as well as sports injuries, are the major causes of head and spinal injuries. You can help protect yourself from serious injury by wearing your seat belt while riding in a car and wearing safety gear while playing sports and riding bicycles.

**How do reflexes work?**

When you accidentally touch something that is very hot, you experience a reflex. A reflex is an involuntary, automatic response to a stimulus. You cannot control a reflex because it occurs before you know what has happened. A reflex involves a simple nerve pathway called a reflex arc.
What is an example of a reflex?

A reflex allows the body to respond without having to think about what action to take. If you step on a sharp object, you experience a shooting pain. Sensory receptors in your foot respond to this sharp object, and an impulse is sent to the spinal cord. The impulse then passes to an interneuron in the spinal cord that immediately sends the impulse to motor neurons. Motor neurons send the impulse to muscles in the leg. Instantly, without thinking, you lift your leg away from the sharp object. This is a withdrawal reflex.

Reflex responses are controlled in your spinal cord, not in your brain. Your brain acts after the reflex to help figure out what to do to make the pain stop. Reflexes also happen if you touch something very cold or when you cough or vomit.

Drugs and the Nervous System

Many drugs, such as alcohol and caffeine, directly affect the nervous system. When alcohol is swallowed, it passes directly through the walls of the stomach and small intestine into the bloodstream. Once in the circulatory system, alcohol can travel throughout the body. When the alcohol reaches neurons, it moves in through their cell membranes and upsets their normal cell functions. Since alcohol slows the activities of the central nervous system, it is called a depressant. Activities such as muscle control, judgment, and memory are reduced, or impaired. Heavy alcohol use destroys brain and liver cells.

A stimulant is a drug that speeds up the activity of the central nervous system. Caffeine is a stimulant found in coffee, tea, and many soft drinks. Too much caffeine can increase heart rate. It can cause increased restlessness in some people and make it difficult to sleep. Caffeine can also stimulate the kidneys to make more urine.

The nervous system controls responses that help keep homeostasis within the body. Drugs make it more difficult for the body to maintain homeostasis.
After You Read

Mini Glossary

axon (AK sahn): the branch of a neuron that carries impulses away from the body of the nerve cell

brain stem: connects the brain to the spinal cord; made up of the midbrain, the pons, and the medulla

central nervous system: the part of the nervous system made up of the brain and spinal cord

cerebellum (ser uh BE lum): the part of the brain that interprets stimuli from the eyes and ears and from muscles

cerebrum (suh REE brum): the largest part of the brain, in which thinking takes place

dendrite: the branch of a neuron that receives impulses from other neurons and sends them to the body of the nerve cell

homeostasis (hoh mee oh STAY sus): the regulation of conditions inside an organism to maintain life, even when the outside environment changes

neuron (NOOR ahn): the basic unit of the nervous system—nerve cell

peripheral (puh RIH fuh rul) nervous system: the part of the nervous system made up of all the nerves outside the central nervous system

reflex: an involuntary, automatic response to a stimulus

synapse (SIH naps): small space between neurons through which an impulse crosses

1. Review the terms and their definitions in the Mini Glossary. Choose one of the parts of the brain and write a sentence that describes the part and explains its function.

2. Complete the chart below to identify the parts of the central nervous system (CNS) and the peripheral nervous system (PNS) and to explain what each part does.

<table>
<thead>
<tr>
<th>Kind of Nervous System (CNS or PNS)</th>
<th>What It Does</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
<td></td>
</tr>
<tr>
<td>Spinal cord</td>
<td></td>
</tr>
<tr>
<td>Somatic system</td>
<td></td>
</tr>
<tr>
<td>Autonomic system</td>
<td></td>
</tr>
</tbody>
</table>

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about the nervous system.
Control and Coordination

section  The Senses

What You’ll Learn
- the sensory receptors in each sense organ
- the type of stimulus each sense organ responds to and how
- why the body needs healthy senses

Before You Read
On the lines below, list which one of your senses you consider the most important. Explain why you think it is the most important.


Read to Learn

The Body’s Alert System
Your sense organs are your body’s alert system. They sense stimuli, such as light rays, sound waves, and heat. Your sense organs convert these stimuli into nerve impulses.

Vision
The eye is the sense organ for vision. Your eyes have adaptations that make it possible for you to see objects, shadows, and colors.

How do you see?
Light travels in a straight line unless something causes it to change direction. Your eyes have structures that refract, or bend, light. Two of these structures are the cornea (KOR nee uh) and the lens. The cornea is the transparent part at the front of the eye. As light passes through the cornea, it is refracted. The lens directs the light onto the retina (RET nuh). The retina is a tissue at the back of the eye that is sensitive to light energy. Cells called cones and rods are found in the retina. Cones respond to bright light and color. Rods respond to dim light. Rods help you distinguish shapes and movement.

Reading Check
1. Determine Which structure of the eye is sensitive to light energy?
How do your eyes sense distance?

The light energy that reaches the retina stimulates the rods and cones to produce impulses. The impulses pass to the optic nerve, which is shown in the figure above. This nerve carries the impulses to the vision part of the cortex, located in your brain's cerebrum. The image that is passed from the retina to the brain is upside down and reversed. The brain interprets the image correctly, and you see what you are looking at. The brain also interprets the images it receives from both eyes. It blends them into one image that gives you a sense of distance. This helps you to tell how close or how far away something is.

Lenses

Light is refracted when it passes through a lens. The way light refracts depends on the kind of lens it passes through. A lens that is thicker in the middle and thinner on the edges is called a convex lens. The lens in your eye is a convex lens. It bends light so that it passes through a point, called a focal point. Convex lenses can be used to make objects appear larger. The light passes through a convex lens and enters the eye in a way that causes your brain to interpret the image as enlarged. [✓]

A lens that is thicker at its edges than in its middle is called a concave lens. A concave lens causes the light to spread out.
How can vision problems be corrected?

In an eye that has normal vision, the cornea, lens, and muscles work together. These three parts focus the light rays onto the retina. But if the eyeball is too long from front to back, the light from objects is focused in front of the retina. This happens because the shape of the eyeball and lens cannot be changed enough by the eye muscles to focus a sharp image on the retina. The image that reaches the retina is blurred. This condition is called nearsightedness, because objects that are near are seen more clearly than objects at a distance. Concave lenses are used to correct nearsightedness by focusing images sharply on the retina as shown in the figure below.

If the eyeball is too short from front to back, then light from objects is focused behind the retina. This condition is called farsightedness, because distant objects are clearer than near objects. Convex lenses are used to correct farsightedness as shown in the figure below.

Hearing

You hear a sound when sound waves reach your ears. Sound waves are made when an object vibrates. Sound waves can travel through liquids, solids, and gases. When sound waves reach the ear, they stimulate nerve cells within the ear. Impulses are sent to the hearing area of your brain’s cortex. The cortex responds and you hear a sound.
How do the outer ear and middle ear work?

The figure below shows the three sections of the ear: the outer ear, the middle ear, and the inner ear. The outer ear intercepts sound waves and funnels them down the ear canal to the middle ear. The sound waves make the eardrum vibrate much like the membrane on a musical drum vibrates when you tap on it. The vibrations then move through three tiny bones called the hammer, anvil, and stirrup. The stirrup bone rests against a membrane on an opening to the inner ear.

How does the inner ear work?

The cochlea (KOH klee uh) is a fluid-filled structure shaped like a snail’s shell. When the stirrup vibrates, fluids in the cochlea begin to vibrate. The vibrations bend hair cells in the cochlea. When a hair cell bends, it sends electrical impulses to the brain. Depending on how the nerves are stimulated, you hear different types of sound.

How does the inner ear control balance?

Some parts of the inner ear also control your balance. These parts are called the cristae ampullaris (KRIHS tee am pyew LEER ihb) and the maculae (MA kyah lee). These parts sense different types of body movement.
The Muscles Respond to the Inner Ear  Both the cristae ampullaris and the maculae have tiny hair cells. As the body moves, the fluid surrounding the hair cells moves. This motion stimulates the nerve cells to send nerve impulses to the brain. The brain interprets the body movements and sends impulses to the skeletal muscles. The impulses cause your muscles to move in a way that helps you keep your balance.

Smell

The sense of smell influences what you eat because you are attracted to some food odors and not others. Some odors can bring to mind strong memories and feelings you may have had the last time you smelled the same odor.

You can smell food because it gives off molecules into the air. The molecules stimulate the olfactory (ohl FAK tree) cells in your nasal passages. The cells are kept moist by mucus. When molecules in the air dissolve in this moisture, the cells become stimulated and produce impulses. Impulses that start in these cells travel to the brain. The brain interprets the stimulus. If you have smelled the odor before, your brain will recognize it and you can identify the odor. If your brain does not recognize the stimulus, it is remembered and may be identified the next time you smell it.

Taste

The major sensory receptors for taste are the taste buds on your tongue. The tongue has about 10,000 taste buds all over it. The taste buds help you to tell one taste from another. The figure below shows the parts of a taste bud.
How are you able to taste food?

Most taste buds respond to several kinds of tastes. However, certain areas of the tongue respond more to one taste than another. The five tastes are sweet, salty, sour, bitter, and the taste of MSG (monosodium glutamate). Before you can taste something, it has to be dissolved in water. Saliva begins this process. The saliva and food wash over the taste buds. Taste buds are made up of a group of sensory cells with tiny taste hairs projecting from them.

When food is taken into the mouth, it is dissolved in saliva. This mixture stimulates taste buds to send impulses to the brain. The brain interprets the impulses, and you identify the tastes.

How do smell and taste work together?

Smell and taste are related. You need the sense of smell to identify some foods such as chocolate. When saliva in the mouth mixes with the chocolate, odors travel up the nasal passage in the back of the throat. The olfactory cells are stimulated, and you taste and smell the chocolate.

When you have a stuffy nose, some foods seem tasteless. It may be because the food’s molecules are blocked from contacting the olfactory cells in your nasal passage.

Other Sensory Receptors in the Body

Your internal organs have several kinds of sensory receptors. These receptors pick up changes in touch, pressure, pain, and temperature and send impulses to the brain or spinal cord. Your body then responds to the new information.

You also have sensory receptors throughout your skin. Your fingertips have many different types of receptors for touch. These receptors help you tell if an object is rough or smooth, hard or soft, hot or cold. Your lips are very sensitive to heat. They keep you from drinking something so hot that it would burn you.

All of the body’s senses work together to maintain homeostasis. Your senses help you enjoy or avoid things around you. You react to your environment because of information that you receive through your senses.
After You Read

Mini Glossary

cochlea (KOH klee uh): fluid-filled structure shaped like a snail’s shell; located in the inner ear
olfactory (ohl FAK tree) cells: nerve cells in the nasal passages
retina (RET nuh): the tissue at the back of the eye that is sensitive to light energy
taste bud: major sensory receptor for taste

1. Review the terms and their definitions in the Mini Glossary. Using one of the terms, write a sentence explaining how it helps you react to your environment.

2. Complete the diagram below to identify the structures of the eye and to name a function of each structure.

<table>
<thead>
<tr>
<th>Structure:</th>
<th>Function:</th>
</tr>
</thead>
<tbody>
<tr>
<td>lens</td>
<td>refracts light</td>
</tr>
<tr>
<td>retina</td>
<td>sends nerve impulses from the rods and cones to the brain</td>
</tr>
</tbody>
</table>

3. How can you use the quiz you created for this section to help you study for a test?

Science online: Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about the senses.
Regulation and Reproduction

section ● The Endocrine System

Before You Read

Have you ever been suddenly frightened? On the lines below, explain how your body reacted.

Read to Learn

Body Controls

Your endocrine system and your nervous system are your body’s control systems. The nervous system sends messages to and from the brain to the rest of your body. The endocrine system sends chemical messages to different parts of your body.

Your body reacts very quickly to messages from the nervous system. Your body reacts more slowly to chemical messages from the endocrine system.

Endocrine Glands

Endocrine glands are tissues that produce hormones. Hormones (HOR mohnz) are chemicals that can speed up or slow down certain cell processes. Each endocrine gland releases its hormones directly into the blood. The blood carries the hormone to other parts of the body.

Endocrine glands produce hormones that control the body in many ways. Some endocrine glands help the body handle stressful situations. Other endocrine glands help the body grow and develop. Endocrine glands coordinate the circulation of the blood and help the body digest and absorb food. The endocrine glands and their functions are listed in the table on the next page.
A Negative-Feedback System

The organs and glands of the endocrine system control the amount of hormones in your body by sending chemical messages back and forth to each other. This process is called a negative-feedback system. Follow each step in the figure below to learn more about how a negative feedback system works.

1. **Identify** Highlight the names of the endocrine glands located in your brain. Then circle the names of the glands and organs that are involved in reproduction. Which gland is both highlighted and circled?

### The Endocrine System

<table>
<thead>
<tr>
<th>Endocrine Glands and Organs</th>
<th>Location in the Body</th>
<th>Major Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pineal</td>
<td>in the brain</td>
<td>produces the hormone melatonin that may help regulate your body clock</td>
</tr>
<tr>
<td>Pituitary</td>
<td>in the brain</td>
<td>produces hormones that regulate various body activities including growth and reproduction</td>
</tr>
<tr>
<td>Thymus</td>
<td>upper chest</td>
<td>produces hormones that help the body fight infections</td>
</tr>
<tr>
<td>Thyroid</td>
<td>below the larynx</td>
<td>produces hormones that regulate metabolism (the chemical reactions in the body)</td>
</tr>
<tr>
<td>Parathyroid</td>
<td>below the larynx</td>
<td>produces hormones that regulate the body's calcium levels</td>
</tr>
<tr>
<td>Adrenals</td>
<td>on top of each kidney</td>
<td>produce several hormones that help your body respond to stress and keep your blood sugar levels stable</td>
</tr>
<tr>
<td>Pancreas</td>
<td>between the kidneys</td>
<td>produces hormones that help control blood sugar levels in the bloodstream</td>
</tr>
<tr>
<td>Testes (male)</td>
<td>in the scrotum</td>
<td>produce testosterone, a male reproductive hormone</td>
</tr>
<tr>
<td>Ovaries (female)</td>
<td>in the pelvic cavity</td>
<td>produce estrogen and progesterone, hormones that regulate the female reproductive cycle</td>
</tr>
</tbody>
</table>

2. **Identify** Circle the name of the organ that produces insulin.

**A** Meal is eaten.

**B** Intestines take in glucose during digestion.

**C** Glucose level in bloodstream increases.

**D** Pancreas responds to high glucose level by producing the hormone insulin.

**E** Insulin is released into bloodstream, causing the liver and other tissues to take up more glucose.
After You Read

Mini Glossary

hormones (HOR mohnz): chemical messages in the body that speed up or slow down certain cell processes

1. Review the term and its definition in the Mini Glossary. Write a sentence that explains the purpose of hormones in your body.

2. Use the terms in the box below to complete the sentences that follow.

<table>
<thead>
<tr>
<th>adrenals</th>
<th>ovaries</th>
<th>parathyroid</th>
<th>pituitary</th>
</tr>
</thead>
<tbody>
<tr>
<td>testes</td>
<td>thymus</td>
<td>thyroid</td>
<td></td>
</tr>
</tbody>
</table>

d. The _____________ gland in the brain controls growth.

e. The _____________ and the _____________ are located below the larynx.
Create a Quiz  As you study the information in this section, create questions about the information you read. The questions can be used to review the section’s content.

What You’ll Learn
- the function of the reproductive system
- the major structures of the male and female reproductive systems
- the stages of the menstrual cycle

Before You Read
On the lines below, describe one way in which a male body differs from a female body.

Read to Learn

Reproduction and the Endocrine System
Most human body systems are the same in males and females, but the reproductive systems are different. As you can see in the figure below, the pituitary gland makes the sex hormones that control the male and female reproductive systems. Sex hormones are needed to develop sexual characteristics. Sex hormones from the pituitary gland begin the process of making eggs in females and sperm in males. Eggs and sperm pass hereditary information from one generation to the next.

Picture This
1. Explain  Use the diagram to explain to a classmate what the pituitary gland does in females and then have the classmate explain what the pituitary gland does in males.
The Male Reproductive System

The male reproductive organs are inside and outside the body. As shown in the figure below, the organs outside the body are the penis and the scrotum (SKROH tum). The scrotum contains two organs called testes (TES teez) (singular, testis). The testes make the male hormone, testosterone (tes TAHS tuh rohn). They also make male reproductive cells, called sperm.

What happens to sperm?

Each sperm cell has a head and tail. The head contains hereditary information. The tail moves back and forth to push the sperm through fluid. Sperm travel out of the testes through sperm ducts that circle the bladder. The seminal vesicle (VEH sih cuhl) provides the sperm with a fluid. The fluid provides energy to the sperm and helps them move. The mixture of sperm and fluid is called semen (SEE mun). Semen leaves the body through the urethra. The urethra is the same tube that carries urine from the body.

The Female Reproductive System

Most of the female reproductive organs are inside the body. The female sex organs are called the ovaries. The ovaries produce eggs. Eggs are the female reproductive cells.
What happens to the eggs?
About once a month, hormones cause one of the ovaries to release an egg. The release of an egg from an ovary is called ovulation (ahv yuh LAY shun). After the egg is released, it enters the oviduct. Short, hairlike structures called cilia (SIH lee uh) help move the egg through the oviduct to the uterus (YEW tuh rus). The uterus is a muscular organ with thick walls. The fertilized egg develops in the uterus.

As you can see in the figure below, at the lower hollow end of the uterus is the cervix. Connected to the cervix is a muscular tube called the vagina (vuh JI nuh). The vagina is also called the birth canal. When a baby is born, it travels through the vagina to the outside of the mother’s body.

The Menstrual Cycle
The menstrual (MEN strul) cycle is the monthly cycle of changes in the female reproductive system. The menstrual cycle lasts about 28 days. During each cycle, an egg matures, female sex hormones are produced, the uterus prepares to receive a fertilized egg, and menstrual flow occurs. The first menstrual period happens between ages nine and 13 for most females.

What controls the menstrual cycle?
The pituitary gland releases several hormones that control the menstrual cycle. These hormones begin the process that results in the release of the egg from the ovary. They also stimulate the production of two other hormones, estrogen (ES truh jun) and progesterone (proh JES tuh rohn). The interaction of all these hormones causes the menstrual cycle. The menstrual cycle has three parts, or phases.
Phase One of the Menstrual Cycle  Phase 1 starts with the menstrual flow, called menstruation (men STRAY shun). This flow is made up of blood and tissue cells released from the thickened lining of the uterus. Menstruation lasts up to six days.

Phase Two of the Menstrual Cycle  During phase 2 of the menstrual cycle, hormones cause the lining of the uterus to thicken. During phase 2, an egg develops in the ovary. The release of the egg, or ovulation, occurs about 14 days before menstruation begins. The egg must be fertilized within 24 hours or it begins to break down. Sperm can live in a female’s body for up to three days, so fertilization can happen soon after ovulation.

Phase Three of the Menstrual Cycle  During phase 3, the lining of the uterus continues to thicken. If a fertilized egg arrives, the thickened lining of the uterus begins to support and feed the developing embryo. If the egg is not fertilized, the lining of the uterus breaks down and the menstrual cycle starts over. The changes to the uterus during the phases of the menstrual cycle are shown in the figure below.

What is menopause?

For most females, the menstrual cycle ends between ages 45 and 60. Menopause occurs when the menstrual cycle ends. During menopause, the ovaries produce fewer and fewer sex hormones. The completion of menopause may take several years.
After You Read

Mini Glossary

menstrual (MEN strul) cycle: the monthly cycle of changes in the female reproductive system

menstruation (men STRAY shun): phase 1 of the menstrual cycle, when blood and tissue cells are released from the thickened lining of the uterus

ovaries: the female sex organs that produce eggs

ovulation (ahv yuh LAY shun): the process that releases an egg from an ovary

semen (SEE mun): a mixture of sperm and fluid

sperm: male reproductive cells

testes (TES teez): male reproductive organs that produce sperm and the male hormone, testosterone

uterus (YEW tuh rus): the female organ in which a fertilized egg develops

vagina (vuh JI nuh): part of the female reproductive system, a muscular tube connected to the cervix

1. Review the terms and their definitions in the Mini Glossary. Use at least two of the terms in a sentence to describe either the male or female reproductive system.

2. Complete the flow chart below by writing a phrase that describes what happens during each phase of the menstrual cycle.

   Phase 1   Phase 2   Phase 3

3. How did writing and answering quiz questions help you better understand what you have read?

End of Section

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Regulation and Reproduction

section 2 Human Life Stages

Before You Read
Describe the changes that you have seen happen in a young child over a year’s time.

Read to Learn

Fertilization
A human develops from an egg that has been fertilized by a sperm. As sperm enter the vagina, they come in contact with chemicals given off in the vagina. These chemicals cause changes in the sperm that make it possible for the sperm to fertilize the egg. A sperm that touches the egg releases an enzyme. This enzyme helps the sperm enter the egg. Fertilization takes place when sperm and egg unite.

How does a zygote form?
Once a sperm enters an egg, the nucleus of the sperm joins with the nucleus of the egg. This joining creates a fertilized cell called the zygote (ZI goht).

Multiple Births
Mothers sometimes give birth to two or more babies at once. These are called multiple births. Multiple births can happen when an ovary releases more than one egg at a time or when a zygote divides into two or more zygotes.

Sometimes an ovary releases two eggs at the same time. If both eggs are fertilized, fraternal twins are born. Fraternal twins do not have the same hereditary information because they came from two different eggs. Fraternal twins can be the same or different sexes.

What You’ll Learn
- how a human egg is fertilized
- how the embryo and fetus develop
- the life stages of infancy, childhood, adolescence, and adulthood

Locate Information
As you read this section, highlight the portions of the text that describe the changes to an embryo and fetus during pregnancy.

1. Explain How many eggs must be fertilized for fraternal twins to be born?
When are twins identical?
Identical twins develop from one egg that has been fertilized by one sperm. The zygote divides into two separate zygotes. Identical twins have the same hereditary information because they come from the same fertilized egg. Identical twins are always the same sex.

Development Before Birth
As you can see in the figure below, the zygote moves along the oviduct to the uterus. During this time, the zygote goes through many cell divisions. After about seven days, the zygote attaches to the wall of the uterus. This is called implantation. A zygote that attaches to the wall of the uterus will develop into a baby in about nine months. The period of development from fertilized egg to birth is called pregnancy.

When does a zygote become an embryo?
After the zygote attaches to the wall of the uterus, it is called an embryo (EM bree oh).

How does an embryo get food and oxygen?
After an embryo attaches to the uterus, a placenta (pluh SEN tuh) develops from tissues of the uterus and the embryo. An umbilical (um BIH lih kul) cord connects the embryo to the placenta. Blood vessels in the umbilical cord carry nutrients and oxygen from the mother’s blood through the placenta to the embryo. Other blood vessels in the umbilical cord carry wastes from the embryo to the mother’s blood.
What protects the embryo?
During the third week of pregnancy, a thin membrane called the amniotic (am nee AH tihk) sac forms around the embryo. The amniotic sac is filled with a clear fluid called amniotic fluid. The amniotic fluid acts as a cushion to protect the embryo. Amniotic fluid also stores nutrients and wastes. ✅

When does the embryo develop body parts?
During the first two months of development, the embryo’s major organs form and the heart begins to beat. At five weeks, the embryo has a head with eyes, nose, and mouth. During the sixth and seventh weeks, fingers and toes develop.

How does a fetus develop?
Pregnancy in humans lasts about 38 to 39 weeks. After the first two months of pregnancy, the developing embryo is called a fetus (FEE tus). The fetus has all its body organs and is about 8 cm to 9 cm long. By the end of the seventh month of pregnancy, the fetus is 30 cm to 38 cm long. By the ninth month, the fetus is about 50 cm long. It weighs from 2.5 kg to 3.5 kg. During the ninth month, the fetus moves to a head-down position within the uterus. This is the best position for delivery.

The Birthing Process
The process of childbirth begins when the muscles of the uterus start to contract. This is called labor. As the contractions increase, the amniotic sac breaks and the fluid comes out. Over a period of hours, the contractions cause the opening of the uterus to get wider. More powerful and more frequent contractions push the baby out through the vagina into the world. After the baby is born, more contractions push the placenta out of the mother’s body. ✅

When are babies delivered through surgery?
Sometimes babies cannot be born through the birth canal. In these cases, a baby is delivered through surgery called a cesarean (suh SEER ee uhn) section. In this surgery, a cut is made in the abdominal wall of the mother, then through the wall of the uterus. The baby is delivered through this opening.

4. Explain What are the functions of the amniotic fluid?

5. Identify two things contractions help push from the mother’s body.
What happens after birth?

After birth, the baby is still attached to the umbilical cord. Two clamps are placed on the umbilical cord and it is cut between the clamps. The scar where the cord was attached is called the navel.

The experiences that a fetus goes through during childbirth can cause **fetal stress**. After it is born, the fetus must adapt from a dark, watery environment with a constant temperature to an environment with more light, less water, and changes in temperature. The first four weeks after birth are known as the neonatal (nee oh NAY tul) period. Neonatal means “newborn.” During this time the baby’s body begins to function normally.

**Stages After Birth**

After birth, four stages of development occur: infancy, childhood, adolescence, and adulthood. Infancy lasts from birth to around 18 months of age. Childhood lasts from the end of infancy to puberty (PYEW bur tee), the time of development when a person becomes physically able to reproduce. Adolescence is the teen years. Adulthood lasts from about the early 20s until death.

**How does a baby develop during infancy?**

Human babies depend on other humans for their survival. During infancy a baby learns how to coordinate the movements of its body, as shown in the figure below. Its mental abilities increase, and it grows rapidly. Many infants triple their weight in the first year of life.

---

**Infant Development**

- **Sit with support**
- **Get on hands and knees; stand with support**
- **Sit alone**
- **Crawl**
- **Pull to standing**
- **Walk around furniture**
- **Stand with no support**
- **Walk**

---

**Reading Check**

6. Explain When do humans become physically able to reproduce?

---

**Picture This**

7. Identify Study the table to answer the following questions.

a. At what age can most infants sit alone?

b. At what age do infants learn to walk?
What developments take place in childhood?

Childhood lasts from the age of about 18 months to about 12 years. Growth during childhood is rapid. Between two and three years of age, the child learns to control his or her bladder and bowels. Most children also can speak in simple sentences at age two or three. Around age four, the child can get dressed and undressed with some help. By age five, many children can read some words. Throughout childhood, children develop their abilities to speak, read, write, and reason.

What happens during adolescence?

Adolescence begins at about age 12 or 13 and ends at about age 20. Puberty is a part of adolescence. For girls, puberty happens between ages nine and 13. For boys, puberty occurs between ages 13 and 16. During puberty, hormones produced in the pituitary gland cause changes in the body. Females develop breasts, pubic and underarm hair, and fatty tissue around the thighs and buttocks. Males develop deeper voices, increased muscle size, and facial, pubic, and underarm hair.

Adolescence is usually when a final growth spurt occurs. Most girls begin this final growth phase around age 11 and end around age 16. For boys, the final growth spurt begins around age 13 and ends around age 18. However, different people have different growth rates.

What happens during adulthood?

Adulthood begins when adolescence ends, at about age 20, and continues through old age. From about age 45 to age 60, middle-aged adults begin to lose physical strength. Their blood circulation and breathing become less efficient. Bones break more easily, and skin becomes wrinkled.

What changes occur in older adults?

After age 60, adults may have an overall decline in their health. Their body systems do not work as well as they once did. Muscles and joints become less flexible. Bones become thinner and break more easily. Older adults may lose some of their ability to hear and see. Their lungs and heart do not work as well as they used to. Eating well and exercising throughout life can help delay these changes.
1. Review the terms and their definitions in the Mini Glossary. Write one or two sentences that explain the relationship of a zygote, an embryo, and a fetus.

2. Fill in the table below to identify and describe the stages of development after birth.

<table>
<thead>
<tr>
<th>Stage of Development</th>
<th>Period of Time</th>
<th>Development Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth to 18 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18 months to 12 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 years to 20 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 years to 60 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After age 60</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about human life stages.
Immunity and Disease

section ● The Immune System

Before You Read

Think about the last time that you had a cold. On the lines below, describe three ways your body reacted to the cold.

---

Lines of Defense

Your body has many ways to defend itself from illness. Your first-line defenses are general. First-line defenses work against harmful substances and all types of disease-causing organisms, called pathogens (PA thuh junz). Your second-line defenses are specific. They work against specific pathogens. The combination of first-line and second-line defenses is called your immune system.

What are your body’s first-line defenses?

Your skin and your respiratory, digestive, and circulatory systems are your first-line defenses against pathogens. Your skin stops many pathogens from entering the body. Sweat and oils produced by your skin cells can slow the growth of some pathogens.

Respiratory System Defenses

The respiratory system traps pathogens with hairlike structures, called cilia (SIH lee uh), and mucus. Mucus has enzymes (EN zimez) that weaken the cell walls of some pathogens. Coughs and sneezes help get rid of pathogens from your lungs and nasal passages.

Read to Learn

What You’ll Learn

- the body’s natural defenses
- the difference between an antigen and an antibody
- the differences between active and passive immunity

Mark the Text

Locate Information

Read all the headings for this section and circle any word you cannot define. Then review the circled words and underline the part of the text that helps you define the words.

1. Explain What do cilia do?

---

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Chapter 23

Reading Essentials

315
Digestive System Defenses
Your digestive system has four defenses against pathogens—saliva, enzymes, hydrochloric acid, and mucus. Saliva contains substances that kill bacteria. Enzymes in your stomach, pancreas, and liver help destroy pathogens. Hydrochloric acid in your stomach kills some bacteria and stops some viruses that enter your body on the food you eat. The mucus in your digestive tract has a chemical that prevents bacteria from attaching to the inner lining of your digestive organs.

Circulatory System Defenses
Your circulatory system contains white blood cells that surround and destroy foreign organisms and chemicals. White blood cells constantly patrol your body, destroying harmful bacteria. If the white blood cells cannot destroy the bacteria fast enough, you may develop a fever. A fever is a slight increase in body temperature that slows the growth of pathogens. A fever speeds up your body’s defenses.

How do you know when tissue is damaged?
When tissue is damaged by injury or infected by pathogens, it becomes inflamed. Signs that tissue is inflamed include redness, an increase in temperature, swelling, and pain. Damaged cells release chemicals that cause nearby blood vessels to widen, allowing more blood to flow into the inflamed area. Other chemicals released by damaged cells attract white blood cells that surround and destroy the pathogens. If pathogens get past these first-line defenses, your body uses its second-line defenses. Second-line defenses work against specific pathogens.

What are antigens?
Molecules that are foreign to your body are called antigens (AN tih junz). Antigens can be separate molecules, or they can be attached to the surface of pathogens. When your immune system recognizes antigens in your body, it releases special kinds of white blood cells that fight infection. White blood cells that fight infections are called lymphocytes.

The first lymphocytes to respond to an antigen are the T cells. There are two kinds of T cells, killer T cells and helper T cells. Killer T cells release enzymes that help destroy foreign matter. Helper T cells cause the body to produce another kind of lymphocyte, called a B cell.
What are antibodies?

B cells form antibodies to specific antigens. An antibody is a protein your body makes to fight a specific antigen. The antibody can attach to the antigen and make the antigen harmless. The antibody can also make it easier for a killer T cell to destroy the antigen.

Other lymphocytes, called memory B cells, also have antibodies against specific pathogens. Memory B cells stay in the blood ready to destroy that same pathogen if it invades your body again. The response of your immune system to a pathogen is summarized in the figure above.

What are active and passive immunity?

Antibodies help your body build defenses in two ways—actively and passively. In active immunity, your body makes its own antibodies in response to an antigen. In passive immunity, the antibodies have been produced in another animal and put into your body. Vaccines are antigens produced in another organism and then placed in your body to build immunity against a disease. Passive immunity does not last as long as active immunity does.
Why do people get vaccines?

The process of giving a vaccine by injection or by mouth is called **vaccination**. For example, when you get a vaccine for measles, your body forms antibodies against the measles antigen. Later, if the measles virus enters your body and begins producing antigens, the antibodies you need to fight the virus are already in your bloodstream. Vaccines have helped reduce cases of childhood diseases as shown in the table below.

### Annual Cases of Disease Before and After Vaccine Availability in the U.S.

<table>
<thead>
<tr>
<th>Disease</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measles</td>
<td>503,282</td>
<td>89</td>
</tr>
<tr>
<td>Diptheria</td>
<td>175,885</td>
<td>1</td>
</tr>
<tr>
<td>Tetanus</td>
<td>1,314</td>
<td>34</td>
</tr>
<tr>
<td>Mumps</td>
<td>152,209</td>
<td>606</td>
</tr>
<tr>
<td>Rubella</td>
<td>47,745</td>
<td>345</td>
</tr>
<tr>
<td>Pertussis (whooping cough)</td>
<td>147,271</td>
<td>6,279</td>
</tr>
</tbody>
</table>

Antibodies that protect you from one virus may not help you fight another virus. Each year a different set of flu viruses causes the flu. As a result, people get a new flu shot each year.

**What is tetanus?**

Tetanus is a disease caused by bacteria in the soil. Bacteria can enter the body through an open wound. The bacteria that causes tetanus produces a chemical that makes muscles unable to move. In early childhood, you received several tetanus vaccines to help you develop immunity to this disease. You need to continue to get tetanus vaccines every 10 years to stay protected.
After You Read

Mini Glossary

**active immunity:** long-lasting immunity that results when the body makes its own antibodies in response to an antigen

**antibody:** a protein made in response to a specific antigen

**antigen (AN tih jun):** any molecule that is foreign to your body

**immune system:** the complex group of defenses against harmful substances and disease-causing organisms

**passive immunity:** immunity that results when antibodies produced in another animal are introduced into your body

**pathogen (PA thuh jun):** a disease-causing organism

**vaccination:** the process of giving a vaccine by injection or mouth to provide active immunity

1. Review the terms and their definitions in the Mini Glossary. Write a sentence or two that explains the difference between an antigen and an antibody.

2. Complete the concept web below to identify four first-line defenses your body has against disease.

   ![Concept Web](image)

3. How did finding definitions of unfamiliar words help you understand the immune system?

---

**ScienceOnline** Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about the immune system.
chapter 23

Immunity and Disease

section 3 Infectious Diseases

What You’ll Learn

- the work done by scientists to discover and prevent disease
- diseases caused by viruses and bacteria
- the causes of sexually transmitted diseases

Before You Read

How do you think washing hands helps prevent disease?

Study Coach

Read-and-Say Work with a partner. Read the information under a heading to yourselves. Then discuss together what you learned. Continue until you both understand the main ideas of this section.

Read to Learn

Disease in History

In the past, there were no treatments for diseases such as the plague, smallpox, and influenza. These diseases killed millions of people worldwide. Today the causes of these diseases are known, and treatments can prevent or cure them. However, some diseases still cannot be cured. Outbreaks of new diseases that have no known cure also occur.

Do microorganisms cause disease?

In the late 1700s, the microscope was invented. Under a microscope, scientists were able to see microorganisms such as bacteria, yeast, and mold spores for the first time. By the late 1800s and early 1900s, scientists understood that microorganisms could cause diseases and carry them from one person to another.

What did Louis Pasteur discover?

The French chemist Louis Pasteur discovered that microorganisms could spoil wine and milk. He then realized that microorganisms could attack the human body in the same way, causing diseases. Pasteur invented pasteurization (pas chuh ruh ZAY shun), which is the process of heating liquid to a specific temperature that kills most bacteria.
Which microorganisms cause diseases?

Many diseases are caused by bacteria, viruses, protists (PROH thists), or fungi. Bacteria can slow the normal growth and activities of body cells and tissues. Some bacteria produce toxins, or poisons, that kill body cells on contact. The table below lists some of the diseases caused by different groups of pathogens.

<table>
<thead>
<tr>
<th>Human Diseases and the Pathogens that Cause Them</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pathogens</strong></td>
</tr>
<tr>
<td>Bacteria</td>
</tr>
<tr>
<td>Protists</td>
</tr>
<tr>
<td>Fungi</td>
</tr>
<tr>
<td>Viruses</td>
</tr>
</tbody>
</table>

**Viruses** A virus is a tiny piece of genetic material surrounded by a protein coating that infects host cells and multiplies inside them. The host cells die when the viruses break out of them. These new viruses infect other cells. Viruses destroy tissues or interrupt important body activities.

**Other Pathogens** Protists can destroy tissues and blood cells. They also can interfere with normal body functions. Fungus infections work in a similar way and can cause athlete’s foot, nonhealing wounds, and chronic lung disease.

**What did Robert Koch develop?**

In the 1880s, Robert Koch developed a way to isolate and grow one type of bacterium at a time. Koch developed rules for identifying which organism causes a particular disease. Koch’s rules are still used by doctors today.

**What did Joseph Lister discover?**

Today we know that washing hands kills bacteria and other organisms that spread disease. But until the late 1800s, people, including doctors, did not know this. Joseph Lister, an English surgeon, saw that infection and cleanliness were related. Lister learned that carbolic (kar BAH lik) acid kills pathogens. He greatly reduced the number of deaths among his patients by washing their skin, his hands, and his surgical instruments with carbolic acid.
What operating procedures are followed today?

Today special soaps are used to kill pathogens on skin. Every person who helps perform surgery must wash his or her hands thoroughly and wear sterile gloves and a covering gown. The patient’s skin is cleaned around the area of the body to be operated on and then covered with sterile cloths. Surgery instruments and all operating equipment are sterilized. The air in the operating room is filtered to keep out pathogens.

How Diseases Are Spread

An infectious disease is a disease that is spread from an infected organism or the environment to another organism. An infectious disease can be caused by a virus, bacterium, protist, or fungus. Infectious diseases are spread in many ways. They can be spread by direct contact with the infected organism, through water and air, on food, or by contact with contaminated objects. They can also be spread by disease-carrying organisms called biological vectors. Rats, birds, and flies are examples of biological vectors.

People also can be carriers of diseases. When you have the flu and sneeze, you send thousands of virus particles into the air. These particles can spread the virus to others. Colds and many other diseases also can be spread by contact. Everything you touch may have disease-causing bacteria or viruses on it. Washing your hands regularly is an important way to avoid disease.

Sexually Transmitted Diseases

Infectious diseases that are passed from person to person during sexual contact are called sexually transmitted diseases (STDs). STDs are caused by bacteria or viruses.

What are bacterial STDs?

STDs caused by bacteria are gonorrhea (gah nuh REE uh), chlamydia (kluh MIH dee uh), and syphilis (SIH fuh lus). The symptoms for gonorrhea and chlamydia may not appear right away, so a person may not know that he or she is infected. The symptoms for these STDs are pain when urinating, genital discharge, and genital sores. Bacterial STDs can be treated with antibiotics. If left untreated, gonorrhea and chlamydia can damage the reproductive system, leaving the person unable to have children.
What are the symptoms for syphilis?

Syphilis has three stages. In stage 1, a sore that lasts 10 to 14 days appears on the mouth or sex organ. Stage 2 may involve a rash, fever, and swollen lymph glands. In stage 3, syphilis may infect the cardiovascular and nervous systems. Syphilis can be treated with antibiotics in all stages. However damage to body organs in stage 3 cannot be reversed and may lead to death.

What is genital herpes?

Genital herpes is a lifelong STD caused by a virus. The symptoms include painful blisters on the sex organs. Genital herpes can be passed from one person to another during sexual contact or from an infected mother to her child during birth. The herpes virus hides in the body for long periods of time without causing symptoms and then reappears suddenly. The symptoms for genital herpes can be treated with medicine, but there is no cure or vaccine for the disease.

HIV and Your Immune System

Human immunodeficiency virus (HIV) can exist in blood and body fluids. This virus can hide in body cells, sometimes for years. HIV can be passed on by an infected person through sexual contact. A person can also be infected by reusing an HIV-contaminated needle for an injection. A sterile needle, however, cannot pass on HIV. The risk of getting HIV through blood transfusion is small because all donated blood is tested for HIV. An HIV-infected pregnant woman can infect her unborn child. A baby can get HIV after birth when nursing from an HIV-infected mother.

What is AIDS?

An HIV infection can lead to Acquired Immune Deficiency Syndrome (AIDS). AIDS is a disease that attacks the body’s immune system.

HIV is different from other viruses. It attacks the helper T cells in the immune system. HIV enters the T cell and multiplies. When the infected T cell bursts open, it releases more HIV that infects more T cells. Soon, so many T cells are destroyed that not enough B cells are formed to produce antibodies. Once HIV has reached this stage, the infected person has AIDS. The immune system can no longer fight HIV or any other pathogen. There is no cure for AIDS, but several kinds of medicines help treat AIDS in some patients.
Fighting Disease

The first step to preventing infections is to wash small wounds with soap and water. Cleaning the wound with an antiseptic and covering it with a bandage also help fight infection.

Washing your hands and body helps prevent body odor. Washing also removes and destroys microorganisms on your skin. Health-care workers, such as the one shown below, wash their hands between patients. This reduces the spread of pathogens from one person to another.

Microorganisms in your mouth cause mouth odor and tooth decay. Brushing and flossing your teeth every day keep these microorganisms under control.

Exercising, eating healthy foods, and getting plenty of rest help keep you healthy. You are less likely to get a cold or the flu if you have good health habits. Having checkups every year and getting the recommended vaccinations also help you stay healthy.
1. Review the terms and their definitions in the Mini Glossary. Choose one term that identifies a way a person gets a disease. Write a sentence about how the term you selected causes infection.

2. Complete the table below to identify the causes, symptoms, and treatments of STDs.

<table>
<thead>
<tr>
<th>Kinds of STDs</th>
<th>Causes (Bacteria or Virus)</th>
<th>Symptoms</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gonorrhea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chlamydia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Syphilis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Genital herpes</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Identify the Main Point
Underline the main point of each paragraph. Review these ideas as you study the section.

What You’ll Learn
- the causes of noninfectious diseases
- what happens during an allergic reaction
- the characteristics of cancer
- how chemicals in the environment can harm humans

Before You Read
Explain on the lines below why it is important to read labels and follow directions when using household products.

Read to Learn

Chronic Disease
Diseases and disorders that are not caused by pathogens are called noninfectious diseases. Allergies, diabetes, asthma, cancer, and heart disease are noninfectious diseases. Many are chronic (KRAH nihk) diseases, or can become chronic diseases if not treated. A chronic disease is an illness that can last a long time. Some chronic diseases can be cured, but others cannot be cured.

Allergies
An allergy is an overly strong reaction of the immune system to a foreign substance. Allergic reactions include itchy rashes, sneezes, and hives. Most allergic reactions do not cause major problems. However, some allergic reactions can cause shock and even death if not treated right away.

What causes allergies?
A substance that causes an allergic reaction is called an allergen. Examples of allergens include dust, chemicals, certain foods, pollen, and some antibiotics. Asthma (AZ muh) is a lung disorder that is caused by allergens. The symptoms of asthma include shortness of breath, wheezing, and coughing.
How does the body react to allergens?

When you come in contact with an allergen, your immune system usually forms antibodies. Your body also reacts to allergens by releasing chemicals called histamines (HIHS tuh meenz) that cause red, swollen tissues. Antihistamines are medications that can be used to treat allergic reactions and asthma.

Diabetes

Diabetes is a chronic disease that has to do with the levels of insulin made by the pancreas. Insulin is a hormone that helps glucose, a form of sugar, pass from the bloodstream into your cells. There are two types of diabetes. Type I diabetes is the result of too little or no insulin production. Type II diabetes happens when your body does not properly use the insulin it produces. Symptoms of diabetes include tiredness, great thirst, the need to urinate often, and tingling feelings in the hands and feet.

People with Type I diabetes often need daily injections of insulin to control their glucose levels. People with Type II diabetes usually can control the disease by watching their diet and their weight.

If diabetes is not treated, health problems can develop. These problems include blurred vision, kidney failure, heart attack, stroke, loss of feeling in the feet, and the loss of consciousness, or a diabetic coma.

Chemicals and Disease

Chemicals are everywhere—in your body, the foods you eat, cosmetics, and cleaning products. Most chemicals used by consumers are safe, but a few are harmful. A chemical that is harmful to living things is called a toxin. Toxins can cause a variety of diseases, as well as birth defects, tissue damage, and death. Some toxins and the damage they cause are shown in the table below.

<table>
<thead>
<tr>
<th>Toxin</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>asbestos</td>
<td>lung disease</td>
</tr>
<tr>
<td>lead-based paints</td>
<td>damage to central nervous system</td>
</tr>
<tr>
<td>alcohol (consumed during pregnancy)</td>
<td>birth defects</td>
</tr>
</tbody>
</table>
Cancer

Cancer is a group of closely related diseases that are caused by uncontrolled cell growth. The table below shows characteristics of cancer cells.

<table>
<thead>
<tr>
<th>Characteristics of Cancer Cells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell growth is out of control.</td>
</tr>
<tr>
<td>Cells do not function as part of the body.</td>
</tr>
<tr>
<td>Cells take up space and cause problems with normal body functions.</td>
</tr>
<tr>
<td>Cells travel throughout the body by way of blood and lymph vessels.</td>
</tr>
<tr>
<td>Cells produce tumors and unusual growths anywhere in the body.</td>
</tr>
</tbody>
</table>

What are some types of cancers?

Leukemia (lew KEE mee uh) is a cancer of white blood cells. The cancerous white blood cells cannot fight diseases. These cancer cells multiply and crowd out normal blood cells. Cancer of the lungs makes breathing difficult. Cancer of the large intestine is a leading cause of death in men and women. Breast cancer causes tumors to grow in the breast. Cancer of the prostate gland, an organ that surrounds the urethra, is the second most common cancer in men.

What are some causes of cancer?

Carcinogens (kar SIH nuh junz) are substances that can cause cancer. Some of these substances are shown in the photograph below. Coming in contact with carcinogens increases your chance of getting cancer. Carcinogens include asbestos, some cleaning products, heavy metals, tobacco, alcohol, and some home and garden products. Smoking has been linked to lung cancer. Exposure to X rays and radiation increase your chances of getting cancer. Some foods, such as smoked or barbecued meats, can give rise to cancers.
**Genetics and Cancer** The genetic makeup of some people increases their risk of developing cancer. That does not mean they will definitely get cancer, but it increases their chances of developing cancer.

**How is cancer treated?**
Finding cancer in its early stages is important for successful treatment. The early warning signs of cancer are listed in the table below.

<table>
<thead>
<tr>
<th>Early Warning Signs of Cancer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changes in bowel movements or urination</td>
</tr>
<tr>
<td>A sore that does not heal</td>
</tr>
<tr>
<td>Unusual bleeding or discharge</td>
</tr>
<tr>
<td>Thickening or lump in the breast or elsewhere</td>
</tr>
<tr>
<td>Difficulty in digesting or swallowing food</td>
</tr>
<tr>
<td>Changes in a wart or mole</td>
</tr>
<tr>
<td>Cough or hoarseness that will not go away</td>
</tr>
</tbody>
</table>

Surgery to remove cancerous tissue is one treatment for cancer. Radiation with X rays may be used to kill cancer cells. In *chemotherapy* (kee moh THER uh pee), chemicals are used to kill cancer cells.

**What can you do to help prevent cancer?**
Knowing the causes of cancer can help you prevent it. One way to help prevent cancer is to follow a healthy lifestyle. Avoiding tobacco and alcohol products can help prevent mouth and lung cancers. Eating a healthy diet that is low in fats, salt, and sugar can help prevent cancer. Using sunscreen and limiting the amount of time you spend in the sunlight are ways to prevent skin cancer. Avoid harmful home and garden chemicals. If you choose to use them, read all the labels and carefully follow the directions for their use.

**Picture This**
5. **Conclude** What should a person do if they notice one of these early warning signs?

**Think it Over**
6. **Identify** one thing that you need to avoid or that you need to start doing to help prevent cancer.
After You Read

Min Glossary

- **allergen**: a substance that causes an allergic response
- **allergy**: an overly strong reaction of the immune system to a foreign substance
- **chemotherapy (kee moh THER uh pee)**: the use of chemicals to destroy cancer cells
- **noninfectious disease**: a disease not caused by pathogens

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that describes an allergy that you have or that someone you know has.

2. Fill in the table below to identify the causes of some noninfectious diseases.

<table>
<thead>
<tr>
<th>Noninfectious Diseases</th>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asthma</td>
<td></td>
</tr>
<tr>
<td>Diabetes Type I</td>
<td></td>
</tr>
<tr>
<td>Diabetes Type II</td>
<td></td>
</tr>
<tr>
<td>Lung cancer</td>
<td></td>
</tr>
<tr>
<td>Skin cancer</td>
<td></td>
</tr>
</tbody>
</table>

3. How did reviewing the main ideas help you study this section?

End of Section

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about noninfectious diseases.
Interactions of Life

section ● Living Earth

Before You Read
On the lines below, list the living things that are part of your neighborhood.

---

What You’ll Learn
- places where life is found on Earth
- what ecology is
- how the environment influences life

Read to Learn

The Biosphere
Earth has many living organisms. The part of Earth that supports life is the **biosphere** (BI uh sfihr). The biosphere includes the top part of Earth’s crust, the waters that cover Earth’s surface, and the atmosphere that surrounds Earth.

The biosphere is made up of different environments. Different kinds of organisms live in each environment. For example, a desert environment gets little rain. Organisms that live in a desert environment include cactus plants, coyotes, and lizards. Tropical rain forest environments get a lot of rain and warm weather. Parrots, monkeys, and tens of thousands of other organisms live in tropical rain forests. Arctic regions near the north pole are covered with ice and snow. Polar bears and walruses are two organisms that live in an arctic environment.

Why is life on Earth possible?
In our solar system, Earth is the third planet from the Sun. The amount of energy that reaches Earth from the Sun helps make the temperature just right for life. Other planets are either too close or too far from the Sun to have the right conditions for life.

---

Study Coach

Two-Column Notes
Organize notes into two columns. On the left, list a main idea about the material in each subheading. On the right, list the details that support the main idea.

1. Describe how the energy from the Sun helps make life on Earth possible.

---

Reading Check

---
Ecosystems

An ecosystem is all the organisms living in an area and the nonliving parts of that environment. In a prairie ecosystem, the living organisms include bison, grass, and birds. Water, sunlight, and soil are nonliving parts of the ecosystem. Ecology is the study of interactions that occur among organisms and their environments. Scientists who study these interactions are ecologists.

Populations

A population is all organisms of the same species that live in an area at the same time. For example, all the bison in a prairie ecosystem make up one population.

Ecologists often study how populations in an ecosystem interact. For example, they might study a prairie ecosystem. How does grazing by bison affect prairie grasses and the insects that live in the grass? By studying the interactions of organisms in a place, ecologists are studying a community.

A community is all the populations of all species living in an ecosystem, as shown in the figure below.

Habitats

The place in which an organism lives is called its habitat. In a forest ecosystem, trees are the habitat of the woodpecker. The forest floor is the habitat of the salamander. An organism’s habitat provides the food, shelter, temperature, and the amount of moisture the organism needs to survive.
1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains how a community is different from an ecosystem.

[Blank]

2. Complete the illustration below to help you understand how scientists organize the living organisms on Earth.

[Diagram]

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End of Section
Interactions of Life

section 2 Populations

What You’ll Learn
■ how population sizes are estimated
■ how competition limits population growth
■ what factors influence changes in population size

Create a Quiz As you study the information in this section, create questions about the information you read. The questions can be used to review the section’s content.

Before You Read
Is the human population in your area getting larger or smaller? What is causing the increase or decrease?

Read to Learn

Competition
Sometimes organisms living in the wild do not have enough food or living space. The Gila woodpecker makes its nest by drilling a hole in a saguaro (suh GWAR oh) cactus. Sometimes Gila woodpeckers have to compete with each other for these living spaces. Competition occurs when two or more organisms are looking for the same resource at the same time.

How can competition limit population growth?
Competition can limit the size of a population. For example, if enough living spaces are not available, some organisms will not be able to raise their young. If there is not enough food, organisms might not live long enough to reproduce. Competition for living space, food, and other resources can limit population growth.

In nature, the most intense competition usually occurs among individuals of the same species. This is because they need the same kinds of food and shelter. Competition also takes place among different species. For example, after a Gila woodpecker has moved from its nest, owls, snakes, and lizards might compete for the empty hole.
Population Size

Ecologists often need to measure the size of a population to find out whether or not the population is healthy and growing. Measuring the size of the population can help ecologists know if a population is in danger of disappearing. One measurement ecologists use is population density. Population density is the number of individuals of one species in a specific area.

How are populations measured?

Imagine having to count all the crickets in an area. They look alike, move a lot, and hide. You might count a cricket more than once. Or you might miss other crickets completely. One method ecologists use to count populations is called trap-mark-release. When ecologists want to count wild rabbits, for example, they set traps that catch the rabbits without hurting them. Each captured rabbit is then marked and let go. Later, another set of rabbits is caught. Some of these rabbits will have marks, but others will not. The ecologists compare the number of marked and unmarked rabbits in the second sample. By doing this, they can estimate the size of the rabbit population.

How are sample counts used?

To estimate the size of large populations, ecologists use sample counts. For example, pretend you wanted to estimate the number of rabbits in an area of 100 acres. You might count the rabbits in one acre and then multiply by 100.

How does a limiting factor affect population?

In an ecosystem, food, water, space, and other resources are limited. A limiting factor is anything that restricts the number of individuals in a population.

A limiting factor can affect more than one population. For example, when the plants in a meadow do not get enough rain, fewer plants survive. Because there are fewer plants, fewer seeds are produced. The seeds are a source of food for the seed-eating mice that live in the meadow. The smaller food supply could become a limiting factor for mice. In turn, a smaller mouse population could be a limiting factor for the hawks and owls that eat the mice. Limiting factors include living and nonliving parts in a community of an ecosystem.
How does carrying capacity affect population?

The largest number of individuals of one species that an ecosystem can support over time is the **carrying capacity**. For example, if the number of robins living in a park increases, nesting space might become difficult to find. Available nesting space limits the robin population. If the population gets larger than its carrying capacity, some individuals of a species will not have enough resources. They could die or have to move somewhere else.

**What is biotic potential?**

If a population had an unlimited supply of food, water, and living space, and was not limited by disease, predators, or competition with other species, the population would continue to grow. The highest rate of reproduction under ideal conditions is a population's biotic potential. The more offspring organisms produce, the higher the species' biotic potential. Tangerines have a higher biotic potential than avocados because tangerines have many seeds in each fruit, while an avocado has only one seed in each fruit.

**Changes in Populations**

A population's birthrate and death rate also influence the size of the population and its rate of growth. A population gets larger when the number of individuals born is greater than the number of individuals that die. A population gets smaller when the number of deaths is greater than the number of births. As the table below shows, countries with a faster population growth have birthrates much higher than death rates. Countries with a slower population growth have only slightly higher birthrates than death rates.

<table>
<thead>
<tr>
<th>Country</th>
<th>Birthrate*</th>
<th>Death Rate*</th>
<th>Population Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Countries with Rapid Growth</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jordan</td>
<td>38.8</td>
<td>5.5</td>
<td>3.3%</td>
</tr>
<tr>
<td>Uganda</td>
<td>50.8</td>
<td>21.8</td>
<td>2.9%</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>34.3</td>
<td>9.4</td>
<td>5.2%</td>
</tr>
<tr>
<td><strong>Countries with Slow Growth</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>9.4</td>
<td>10.8</td>
<td>-1.5%</td>
</tr>
<tr>
<td>Sweden</td>
<td>10.8</td>
<td>10.6</td>
<td>0.1%</td>
</tr>
<tr>
<td>United States</td>
<td>14.8</td>
<td>8.8</td>
<td>0.6%</td>
</tr>
</tbody>
</table>

*Number per 1,000 people
How does moving around affect population size?

When animals move from place to place, the movements can affect population size. For example, a male animal may move many miles to find a mate. After he finds a mate, their offspring might start a completely new population, far from the male’s original population.

Plants and microscopic organisms also can move from place to place. The seeds of dandelions, for example, have special parts that allow them to be carried to other places by the wind. Many kinds of seeds can be moved to new places by water currents. Animals also spread seeds from place to place.

What is exponential growth?

When a species moves to a new area that has plenty of food, living space, and other resources, the population can grow quickly. This pattern of growth is called exponential growth. Exponential growth means that the larger a population gets, the faster it grows. Over time, the population will reach the carrying capacity of the ecosystem for that species.

The figure below shows the exponential growth of the human population. By the year 2050, the population could reach 9 billion people.

---

5. **Identify** three things that move plant seeds from place to place.

---

6. **Estimate** Use the graph to estimate the increase in the human population from 1950 to 2000.
After You Read

Mini Glossary

carrying capacity: the largest number of individuals of one species that an ecosystem can support over time

limiting factor: anything that restricts the number of individuals in a population

1. Review the terms and their definitions in the Mini Glossary. Choose one of the terms and explain how it can affect the population size of a species.

2. Complete the diagram below to help you describe the things that affect changes in population size.

Causes of Changes in Population Size

3. How do the quiz questions and answers help you review what you have learned?
Interactions of Life

section 2 Interactions Within Communities

Before You Read
How do you get the energy you need to do the things you want to do?

What You’ll Learn
- how organisms get energy for life
- how organisms interact
- that every organism occupies a niche

Read to Learn

Obtaining Energy
Living organisms need a constant supply of energy. The Sun provides the energy for most of life on Earth. Some organisms use this energy to make energy-rich molecules through photosynthesis. The energy-rich molecules are food for the organism. They are made up of different combinations of carbon, hydrogen, and oxygen atoms. Chemical bonds hold the atoms of these molecules together. Energy is stored in the chemical bonds. During digestion, the molecules break apart and release energy. The organism uses the energy to grow, develop, and stay alive.

What are producers?
Organisms that use an outside energy source like the Sun to make energy-rich molecules are called producers. Most producers have chlorophyll (KLOH uh fuhl). Chlorophyll is needed for photosynthesis. Green plants are producers.

Not all producers have chlorophyll or use energy from the Sun. Some use chemosynthesis (kee Mohz SIHNUH thuh sus) to make energy-rich molecules. These organisms live near volcanic vents on the ocean floor. Inorganic molecules in the water provide the energy for chemosynthesis.
What are consumers?
Organisms that get energy by eating other organisms are called consumers. There are four kinds of consumers. Herbivores, such as rabbits, eat plants. Carnivores, such as frogs, eat other animals. Omnivores, such as pigs, eat both plants and animals. Decomposers, such as earthworms, consume wastes and dead organisms. Decomposers help recycle once-living matter.

What are food chains?
Ecology includes the study of how organisms depend on each other for food. A food chain is a simple model of the feeding relationships and energy flow in an ecosystem. For example, shrubs are food for deer. Deer are food for mountain lions, as shown in the figure below.

Symbiotic Relationships
Organisms may share food and other resources. Any close relationship between species is called symbiosis.

What is mutualism?
A symbiotic relationship in which both species benefit is called mutualism (MYEW chuh wuh lih zum). Ants and acacia trees illustrate mutualism. The ants protect the tree by attacking any animal that tries to feed on it. The tree provides food and a home for ants.

What is commensalism?
A symbiotic relationship in which one organism benefits and the other one is not affected is called commensalism (kuh MEN suh lih zum). For example, a sea anemone has tentacles that have a mild poison. The clown fish is not harmed by the poison. It swims among the tentacles and is protected from predators. The clown fish benefits, but the sea anemone is not helped or hurt.
What is parasitism?
A symbiotic relationship in which one organism benefits and one is harmed is called parasitism (PAR uh suh tih zum). An example of this relationship is a pet dog and roundworms. A roundworm sometimes attaches itself to the inside of the dog's intestine. It feeds on the nutrients in the dog's blood. The dog may have abdominal pain and diarrhea. Sometimes the dog may die. In this relationship, the roundworm benefits, but the dog is harmed.

Niches
Hundreds of species might live in one habitat. For example, a rotting log is home to many species. Spiders, ants, termites, and worms are some species that live on or under the rotting log. Although many species use the log as their habitat, the species do not compete for resources. This is because each species needs different things to survive. So, each species has its own niche (NICH). An organism's niche is its role in its environment—how it obtains food and shelter, finds a mate, cares for its young, and avoids danger.

Special adaptations that improve survival are often part of an organism's niche. For example, a poison in milkweed plants stops many insects from eating them. Monarch butterfly caterpillars have an adaptation that lets them eat milkweed. When they eat milkweed, the caterpillars become slightly poisonous. Birds avoid eating these caterpillars because they know that the caterpillars and adult butterflies have an awful taste and can make them sick.

How do predator and prey fit in a niche?
An organism's niche includes how it avoids being eaten and how it gets its food. Predators are consumers that capture and eat other consumers. The prey is the organism that is captured by the predator. Having predators in an ecosystem usually increases the number of species that can live in the ecosystem. Predators limit the size of the prey population. So, food and other resources are less likely to become difficult to find. Competition between species is reduced.

How do species in a niche cooperate?
Individual organisms often cooperate, or work together, in ways that improve survival. For example, a white-tailed deer that detects the presence of a wolf will warn other deer in the herd. These cooperative actions are part of the species' niche.
After You Read

Mini Glossary

commensalism (kuh MEN suh lih zum): a symbiotic relationship in which one organism benefits and the other is not affected

consumer: an organism that gets energy by eating other organisms

mutualism (MYEW chuh wuh lih zum): a symbiotic relationship in which both species benefit

niche (NICH): an organism’s role in its environment

parasitism (PER uh suh tih zum): a symbiotic relationship in which one organism benefits but the other is harmed

producer: an organism that uses an outside energy source like the Sun to make energy-rich molecules

symbiosis: any close relationship between species

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the difference between consumers and producers.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

2. Choose one of the question headings in the Read to Learn section. Write the question in the space below. Then write your answer to that question on the lines that follow.

Write your question here.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

End of Section

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about interactions within communities.
The Nonliving Environment

section • Abiotic Factors

Before You Read

How would you describe the climate where you live? How does it affect the plant and animal life around you?

What You’ll Learn

■ the common abiotic factors in most ecosystems
■ the components of air that are needed for life
■ how climate influences life in an ecosystem

Read to Learn

Environmental Factors

Living things depend on one another for food and shelter. The features of the environment that are alive, or were once alive, are called biotic (bi AH tihk) factors.

Biotic factors are not the only things needed for life. Plants and animals cannot survive without the nonliving environment. The nonliving, physical features of the environment are called abiotic (ay bi AH tihk) factors. Abiotic factors include air, water, sunlight, soil, temperature, and climate. These factors often determine the kinds of organisms that live there.

Air

The air that surrounds Earth is called the atmosphere. Air is made up of 78 percent nitrogen, 21 percent oxygen, 0.94 percent argon, 0.03 percent carbon dioxide, and trace amounts of other gases. Some of these gases are important in supporting life.

Carbon dioxide (CO₂) is necessary for photosynthesis. Photosynthesis uses CO₂, water, and energy from sunlight to make sugar molecules. Organisms such as plants use photosynthesis to produce their own food. ☑

Summarize

Write a phrase beside each main heading that summarizes the main point of the section.

1. List What three things are needed for photosynthesis?

Yes
Respiration  Oxygen is released into the atmosphere during photosynthesis. Cells use oxygen to release the chemical energy stored in sugar molecules. This process, called respiration, provides cells with the energy needed for all life processes.

Water

Water is necessary to life on Earth. It is a major part of the fluid inside the cells of all organisms. Most organisms are 50 percent to 95 percent water. Processes such as respiration, digestion, and photosynthesis occur only if water is present. Environments that have plenty of water usually have a greater variety of and a larger number of organisms than environments that have little water.

Soil

Soil is a mixture of mineral and rock particles, the remains of dead organisms, water, and air. Soil is the top layer of Earth’s crust where plants grow. It is formed partly of rock that has been broken down into tiny particles.

Soil is considered an abiotic factor because most of it is made up of nonliving rock and mineral particles. But soil also contains living organisms and the remains of dead organisms. The decaying matter in soil is called humus. Soils contain different combinations of sand, clay, and humus. The kind of soil in a region affects the kinds of plant life that grow there.

Sunlight

Sunlight is the energy source for almost all life on Earth. Plants and other organisms that use photosynthesis are called producers. They use light energy from the Sun to produce their own food. Organisms that cannot make their own food are called consumers. Energy is passed to consumers when they eat producers or other consumers.

Temperature

Sunlight provides the light energy for photosynthesis and the heat energy for warmth. Most organisms can live only if their body temperatures are between the freezing point of water, 0°C, and 50°C. The temperature of a region depends partly on the amount of sunlight it gets. The amount of sunlight depends on the area’s latitude and elevation.
How does latitude affect temperature?
The temperature of a region is affected by its latitude. Places farther from the equator generally have colder temperatures than places at latitudes nearer to the equator. Look at the figure below. Near the equator, sunlight directly hits Earth. Sunlight hits Earth at an angle near the poles. This spreads the energy over a larger area.

How does elevation affect temperature?
A region’s elevation, or distance above sea level, affects its temperature. Earth’s atmosphere traps the Sun’s heat. At higher elevations, the atmosphere is thinner than at lower elevations. Air becomes warmer when sunlight heats the air molecules. Because there are fewer air molecules at higher elevations, the air temperature at higher elevations tends to be cooler.

Trees at higher elevations are usually shorter. The timberline is the elevation above which trees do not grow. Only low-growing plants exist above the timberline. The tops of some mountains are so cold that no plants grow there.

Climate
In Fairbanks, Alaska, winter temperatures may be as low as −52°C. More than one meter of snow might fall in one month. In Key West, Florida, winter temperatures rarely go below 5°C. Snow never falls. These two cities have different climates. The climate of an area is its average weather conditions over time. Climate includes temperature, rainfall or other precipitation, and wind.
How does climate affect life in an area?

Temperature and precipitation are the two most important parts of climate for most living things. They affect the kinds of organisms that live in an area. For example, an area that has an average temperature of 25°C and gets less than 25 cm of rain per year probably has cactus plants growing there. An area with the same average temperature and more than 300 cm of rain every year is probably a tropical rain forest.

How are winds created?

In addition to affecting the temperature of an area, the heat energy from the Sun causes wind. Air is made up of gas molecules. As the temperature increases, the molecules spread farther apart. So, warm air is lighter than cold air. Colder air sinks below warmer air and pushes it upward. This movement creates air currents that are called wind.

What is the rain shadow effect?

Mountains can affect rainfall patterns. As the figure below shows, moist air is carried toward land by the wind. The wind is forced upward by the slope of the mountain. As the air moves to the top, it cools. When air cools, the moisture in it falls as rain or snow. By the time the air crosses over the top of the mountain, it has lost most of its moisture. The drier air warms as it flows down the mountain. The other side of the mountain is in a rain shadow and receives much less precipitation. As a result, one side of the mountain could be covered with forests, while the other side is a desert.

Picture This

7. Explain On the figure below, label the first and fourth arrows to complete the explanation of the rain shadow effect.
1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the difference between abiotic and biotic factors.

2. Complete the chart below to identify a way that each abiotic factor is important to life.

<table>
<thead>
<tr>
<th>Abiotic Factor</th>
<th>Importance to Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td></td>
</tr>
<tr>
<td>Soil</td>
<td></td>
</tr>
<tr>
<td>Sunlight</td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td></td>
</tr>
<tr>
<td>Climate</td>
<td></td>
</tr>
</tbody>
</table>
The Nonliving Environment

section 2 Cycles in Nature

What You’ll Learn
- why Earth’s water cycle is important
- about the carbon cycle
- how nitrogen affects life on Earth

Before You Read
What happens when you boil water in a covered pot? What do you see on the lid of the pot when you remove it?

Read to Learn

The Cycles of Matter

Imagine an aquarium with water, fish, snails, plants, algae, and bacteria. The tank is sealed so that only light can enter. How can the organisms survive without adding food, water, and air? The plants and algae produce their own food through photosynthesis. They also supply oxygen to the tank. The fish and snails eat the plants and algae and take in the oxygen. The wastes from the fish and snails fertilize the plants and algae. Bacteria decompose those organisms that die. The organisms in this closed environment can survive because the materials are recycled.

The environment in the aquarium is similar to Earth’s biosphere. Earth only has a certain amount of water, carbon, nitrogen, oxygen, and other materials needed for life. These materials are constantly being recycled.

Picture This
1. Explain to a partner how the fish in the tank survive without anyone adding food, water, and air.
The Water Cycle

When you leave a glass of water on a sunny windowsill, the water evaporates. Evaporation takes place when liquid water changes into a gas, called water vapor, and enters the atmosphere. Water evaporates from the surfaces of lakes, streams, and oceans. It enters the atmosphere from plants in a process known as transpiration (trans puh RAY shun). Animals release water vapor as they exhale. Water is returned to the environment from animal wastes.

What is condensation?

After water vapor enters the atmosphere, eventually it will come into contact with colder air. The temperature of the water vapor drops. Over time, the water vapor becomes cool enough to change back into liquid water. The process of changing from a gas to a liquid is called condensation.

The water vapor condenses on particles of dust in the air and forms tiny droplets. The droplets join together to form clouds. When the droplets become large and heavy enough, they fall to the ground as rain or other precipitation.

As the figure below shows, the water cycle is a model that describes how water moves from the surface of Earth to the atmosphere and back to the surface again.
How do humans affect the water cycle?
Humans take water from reservoirs, rivers, and lakes to use in their homes, businesses, and farms. Using this water can reduce the amount of water that evaporates into the atmosphere. Humans also influence how much water returns to the atmosphere by limiting the amount of water available to plants and animals.

The Nitrogen Cycle
Nitrogen is important to all living things. It is a necessary part of proteins. Proteins are needed for the life processes that take place in the cells of all organisms. Nitrogen is the most plentiful gas in the atmosphere. However, most organisms cannot use nitrogen directly from the air.

Plants need nitrogen that has been combined with other elements to form nitrogen compounds. Through a process called nitrogen fixation, some types of soil bacteria form the nitrogen compounds that plants need. Plants take in these nitrogen compounds through their roots. Animals get the nitrogen they need by eating plants or other animals. When dead organisms decay, the nitrogen in their bodies returns to the soil or the atmosphere. This transfer of nitrogen from the atmosphere to the soil, to living organisms, and back to the atmosphere is called the nitrogen cycle. The nitrogen cycle is shown in the figure below.
How do human activities affect soil nitrogen?

Humans can affect the part of the nitrogen cycle that takes place in the soil. After crops are harvested, farmers often remove the rest of the plant material. The plants are not left in the field to decay and return their nitrogen compounds to the soil. If the nitrogen compounds are not replaced, the soil could become infertile. Fertilizers can be used to replace soil nitrogen. Compost and animal manure also contain nitrogen compounds that plants can use. They can be added to soil to make it more fertile.

Another way to replace soil nitrogen is by growing nitrogen-fixing crops. Most nitrogen-fixing bacteria live on or in the roots of certain plants. Some plants, such as peas, have roots with nodules that contain nitrogen-fixing bacteria. These bacteria supply nitrogen compounds to the plants and add nitrogen compounds to the soil.

The Carbon Cycle

Carbon atoms are found in the molecules of living organisms. Carbon is part of soil humus and is found in the atmosphere as carbon dioxide gas (CO₂). The carbon cycle describes how carbon molecules move between the living and nonliving world.

The cycle begins when producers take CO₂ from the air during photosynthesis. They use CO₂, water, and sunlight to make energy-rich sugar molecules. Energy is released from these molecules during respiration—the chemical process that provides energy for cells. Respiration uses oxygen and releases CO₂. Photosynthesis uses CO₂ and releases oxygen. The two processes help recycle carbon on Earth.

Human activities also release CO₂ into the atmosphere. For example, when fossil fuels are burned, CO₂ is released into the atmosphere as a waste product. People also use wood for building and for fuel. Trees that are cut down for these purposes cannot remove CO₂ from the atmosphere during photosynthesis. The amount of CO₂ in the atmosphere is increasing. The extra CO₂ could trap more heat from the Sun and cause average temperatures on Earth to rise.
After You Read

Mini Glossary

carbon cycle: a model that describes how carbon molecules move between the living and nonliving world
condensation: process that occurs when a gas changes to a liquid
evaporation: process that occurs when liquid water changes into water vapor and enters the atmosphere
nitrogen cycle: the transfer of nitrogen from the atmosphere to the soil, to living organisms, and back to the atmosphere

nitrogen fixation: process in which some types of soil bacteria form the nitrogen compounds that plants need
water cycle: a model that describes how water moves from the surface of Earth to the atmosphere and back to the surface again

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the difference between condensation and evaporation.

2. In the chart, list the steps in the nitrogen cycle.

<table>
<thead>
<tr>
<th>Steps in the Nitrogen Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>2.</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>3.</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>4.</td>
</tr>
</tbody>
</table>

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The Nonliving Environment

section 2 Energy Flow

Before You Read

Why do you need energy? What is your source of energy?

What You’ll Learn

\begin{itemize}
  \item how organisms make energy-rich compounds
  \item how energy flows through ecosystems
  \item how much energy is available at different levels in a food chain
\end{itemize}

Read to Learn

Converting Energy

All living things are made up of matter, and all living things need energy. Matter can be recycled over and over. Energy is not recycled, but it is converted from one form to another. This conversion is important to all life on Earth.

How is energy converted during photosynthesis?

During photosynthesis, producers convert light energy into the chemical energy in sugar molecules. Some of these sugar molecules are broken down as energy. Some are used to build complex carbohydrate molecules that become part of the producer’s body. Fats and proteins also contain stored energy.

What are hydrothermal vents?

Some producers do not rely on light for energy. These producers live deep underwater in total darkness. They live near powerful hydrothermal vents. Hydrothermal vents are deep cracks in the ocean floor. The water from these vents is very hot from contact with molten rock deep in the Earth’s crust.
What is chemosynthesis?

Because sunlight does not reach deep ocean regions, the organisms that live there cannot get energy from sunlight. Scientists have learned that the hot water has nutrients that bacteria use to make their own food. The production of energy-rich nutrient molecules from chemicals is called chemosynthesis (kee moh SIN thuh sus). Consumers that live in hydrothermal vent communities rely on chemosynthetic bacteria for nutrients and energy.

Energy Transfer

Energy can be converted from one form to another. It also can be transferred from one organism to another. Consumers cannot make their own food. Instead, they obtain energy by eating producers or other consumers. The energy that is stored in the molecules of one organism is transferred to another organism. That organism can release the energy stored in the food. It can use the energy for growth, or it can transform the energy into heat. At the same time, the matter that makes up those molecules is transferred from one organism to another. Throughout nature, energy and matter are transferred from organism to organism.

How does energy flow in food chains?

The food chain in the figure below shows how matter and energy pass from one organism to another. Producers, such as plants, are the first step in a food chain. All producers make their own food using either photosynthesis or chemosynthesis. Animals, such as herbivores, that eat producers are the second step. Animals that eat other consumers are the third and higher steps of food chains.
What are food webs?

There are many feeding relationships in a forest community. For example, bears eat berries, insects, and fish. Berries are eaten by many different organisms. A food web is a model that shows all the possible feeding relationships among the organisms in a community. A food web is made up of many different food chains.

Energy Pyramids

Most food chains have three to five links. The number of links is limited because the amount of available energy is reduced as you move from one level to the next.

How does available energy decline?

When a mouse eats seeds, energy stored in the seeds transfers to the mouse. But most of the energy the plant took in from the Sun was used to help the plant grow. The mouse uses energy from the seed for its own processes, such as digestion and growth. Some of the energy is given off as heat. A hawk that eats the mouse gets even less energy. The amount of available energy is reduced from one level of a food chain to another.

An energy pyramid shows the amount of energy available at each feeding level in an ecosystem. The bottom of the pyramid below includes all producers. It is the first and largest level because it contains the most energy and the largest number of organisms. As the energy is reduced from one level to another, each level becomes smaller. In fact, only about 10 percent of the energy available at each feeding level is transferred to the next higher level.
After You Read

Mini Glossary

**chemosynthesis (kee moh STHOO sus):** the production of energy-rich nutrient molecules from chemicals

**energy pyramid:** a model that shows the amount of energy available at each feeding level in an ecosystem

**food web:** a model that shows all the possible feeding relationships among the organisms in a community

1. Review the terms and their definitions in the Mini Glossary. Choose the term that explains how energy-rich molecules are produced and write a sentence explaining how the process works.

   

2. Place the following organisms in the order of steps in which they would appear in a food chain: mountain lion, plant, bird, insect.

   ![Food Chain Diagram]

3. How did finding definitions of words you did not know help you understand energy flow?

   

End of Section
Before You Read
List two ways the area you live in has changed over time.

What You’ll Learn
- how ecosystems change over time
- how new communities begin in areas
- how pioneer species and climax communities differ

Read to Learn

Ecological Succession

What would happen if the lawn at your home were never cut? The grass would get longer, and it would look like a meadow. Later, larger plants would grow from seeds brought to the area by animals or the wind. Then trees might sprout. In 20 years or less you wouldn’t be able to tell that the land was once a mowed lawn.

An ecologist can tell you what type of ecosystem your lawn would become. Ecosystems are all the organisms that live in an area and the nonliving parts of that environment. Succession is the normal, gradual changes that occur in the types of species that live in an area. Succession occurs differently in different places around the world.

What is primary succession?
The process of succession that begins in a place where no plants grew before is called primary succession. It begins with the arrival of living things such as lichens (LI kunz). The first living things to inhabit an area are called pioneer species. They can survive the harsh conditions of the area, such as drought and extreme heat and cold.
How does soil form?

Pioneer species often start the soil-building process in an area that is made up of rock. Soil begins to form as lichens and the forces of weather and erosion help to break down rocks into smaller pieces. When lichens die, they decay, adding organic matter to the rocks. Moss and ferns can grow in this new soil as shown in the photo. When these plants die, they add more organic material to the soil. Soon there is enough soil for grasses, wildflowers, and other plants to grow. When these plants die, they make the soil richer and deep enough for shrubs and trees to grow. During these changes, insects, small birds, and mammals have begun to move into the area.

Where does secondary succession occur?

Succession that begins in a place that already has soil and was once home to living organisms is called secondary succession. Since the area already has soil, secondary succession is much faster than primary succession. The soil in an area that had a forest fire or a building torn down will not remain lifeless for long. The soil already contains seeds. Wind and birds will carry more seeds to the area. Wildlife will move in.

What are climax communities?

A climax community is a community of plants that is mostly stable and has reached the end stage of succession. New trees grow when larger, older trees die. The individual trees change, but the species does not. For example, a climax community that is a forest of beeches and maples will stay a forest of beeches and maples even though some older trees will die and new trees grow. It can take hundreds or thousands of years for a climax community to develop.
After You Read

Mini Glossary

climax community: a community of plants that is mostly stable and has reached the end stage of succession

pioneer species: the first living things to inhabit an area

succession: the normal, gradual changes that occur in the types of species that live in an area

1. Review the terms and their definitions in the Mini Glossary. Write two or three sentences that explain the difference between pioneer species and climax communities.

![Diagram of soil formation]

2. Fill in the blanks in the graphic organizer below to show how soil is formed.

- 1. ____________ are the first living things to grow.
- 2. ____________ begins to form as pioneer species, erosion, and weathering break down rocks.
- 3. ____________ and ____________ grow in new soil. As they die, they add organic material to the soil.
- 4. ____________ and other plants can now grow. As they die, they make the soil richer and deeper.
- 5. ____________ and ____________ can now grow in the soil.

3. How does the quiz you created help you prepare for a test?
Before You Read

On the lines below, describe the geographic area where you live. Include information about the climate, the landforms, and the kinds of plants and animals that live there.

Read to Learn

Factors That Affect Biomes

Does a desert in Arizona have anything in common with a desert in Africa? Both have heat, little rain, poor soil, water-conserving plants with thorns, and lizards. Large geographic areas that have similar climates and ecosystems are called biomes (BI ohmz).

What climate factors affect biomes?

Deserts are biomes that have little rainfall. Plants and animals living in a desert are adapted to the small amount of rainfall. Climate is the average weather pattern in an area over many years. The two most important factors of climate that affect life are temperature and precipitation.

Major Biomes

The seven types of land biomes are shown on the map on the next page. The major land biomes are tundra, taiga, temperate deciduous forest, temperate rain forest, tropical rain forest, desert, and grassland. Areas with similar climates have similar plants and animals.
What kind of climate does tundra have?

The tundra is a cold, dry, treeless area. The tundra is found in latitudes just south of the North Pole or on high mountains.

Locate the tundra areas on the map below. Notice how far these areas are from the equator. The average amount of precipitation in the tundra is less than 25 cm per year. The average daily temperature is \(-12^\circ\text{C}\). The tundra is covered with ice most of the year. Summers are short and cold. The top part of the soil thaws in summer. Below this thawed surface is a layer of soil called permafrost that is always frozen.

What plants and animals live on the tundra?

Tundra plants include mosses, grasses, small shrubs, and lichens. Since the growing season is so short, it can take many years for the plant life to recover when damaged. During the summer, insects and migratory birds such as ducks and geese live on the tundra. Other animals that live on the tundra include hawks, owls, mice, reindeer, and musk oxen.

Think it Over

1. Infer Would you expect to find few or many species of plants and animals in the tundra? Explain.

Picture This

2. Locate Circle the names of continents on which deserts are found.
What is the world's largest biome?
The taiga (TI guh) is the world's largest biome. The taiga is located between latitudes 50°N and 60°N and stretches across North America, northern Europe, and Asia. The taiga is a cold, forest region. Its climate is warmer and wetter than the tundra's. Precipitation is mostly snow and averages 35 cm to 100 cm a year. Cone-bearing evergreen trees grow in the taiga.

What are temperate deciduous forests like?
The temperate deciduous forests are climax communities of deciduous trees, which lose their leaves every autumn. The yearly precipitation is between 75 cm and 150 cm. Precipitation is received evenly throughout the year. Temperatures range from below freezing during the winter to 30°C or more during the summer. White-tailed deer are one of the many species found in temperate deciduous forests.

Where are temperate rain forests located?
Temperate rain forests are found in places such as New Zealand, southern Chile, and the Pacific Northwest of the United States. This biome receives precipitation ranging from 200 cm to 400 cm throughout the year. The average temperature ranges from 9°C to 12°C. Temperate rain forests do not have the temperature extremes found in the taiga.

Activities in Temperate Rain Forests
Tall trees with needlelike leaves, like fir, cedar, and spruce, grow in temperate rain forests. Lichens and mosses also grow there. Animals that live in temperate rain forests include black bear, bobcats, and many species of amphibians.

The logging industry in the Northwest provides jobs for many people. However, logging removes large parts of the temperate rain forest and destroys the habitat of many organisms. Logging companies in the Pacific Northwest of the United States are required to replant trees to replace the ones they cut down. Some rain forest areas are protected as national parks and forests.

What is the climate in tropical rain forests?
Warm temperatures, wet weather, and dense plant growth are found in tropical rain forests. These forests have warm temperatures that average about 25°C because they are located near the equator. Tropical rain forests receive at least 200 cm and as much as 600 cm of rain per year. This is the most precipitation of any biome.
Zones in Tropical Rain Forests More species of animals are found in tropical rain forests than in any other biome. The variety of species is so large that many have not been discovered. Scientists divide the rain forests into zones based on the types of plants and animals that live there. As shown in the figure below, the zones include forest floor, understory, canopy, and emergents (e MERH gentz).
Determine What keeps forests from developing on grasslands?

Explain why much of the ground in a desert is bare.

Human Impact Farmers clear the land in tropical areas to farm and to sell the wood. After a few years, the crops use up the nutrients in the soil, and more land is cleared. This process destroys the rain forests. Through education, people are learning the value of preserving the species of the rain forest. Logging is not allowed in some areas. In other areas, farmers use new farming methods so they do not need to clear as much rain forest land.

What is the driest biome?
The desert is the driest biome. Deserts receive less than 25 cm of rain each year. The temperatures are extreme heat and cold. Few plants live in desert areas and much of the ground is bare. Most deserts are covered with a thin, sandy, or rocky soil that contains little organic matter. The driest deserts have windblown sand dunes.

Desert Plants and Animals Most desert plants, like cactus, survive the extreme dryness because they are able to store water. Desert plants and animals also are adapted to hot and cold temperatures. Some animals, like the kangaroo rat, never need to drink water. They get the moisture they need from the food they eat. Most animals are active only during the night, late afternoon, or early morning when the temperatures are less extreme. Most animals in the desert are small.

What are grasslands like?
Temperate and tropical regions that receive between 25 cm and 75 cm of precipitation each year and are made up of climax communities of grasses are called grasslands. Most grasslands have a dry season, with little or no rain. This lack of rain prevents the development of forests.

Grassland Plants and Animals The animals in grasslands are mostly mammals that eat the stems, leaves, and seeds of grass plants. Kangaroos are found in the grasslands of Australia. Zebras live in the grasslands of Africa. Many crops, such as wheat, rye, and corn are grown in grasslands. Sheep and cattle are raised on grasslands.
After You Read

Mini Glossary

biomes (BI ohmz): large geographic areas that have similar climates and ecosystems
desert: dry biome with extreme hot and cold temperatures
grasslands: biome of temperate and tropical regions that receive little precipitation and are made up of climax communities of grasses
taiga (TI guh): biome with long, cold winters, moderate precipitation, and forests of evergreen trees
temperate deciduous forests: biome with four seasons and climax forests of deciduous trees, which lose their leaves every autumn
temperate rain forests: biome with warm temperatures, much precipitation, and forests of tall trees that have needlelike leaves

tropical rain forests: biome of warm temperatures, wet weather, and dense plant growth
tundra: a cold, dry, treeless biome that gets little precipitation and is covered with ice most of the year

1. Review the terms and their definitions in the Mini Glossary. Write two sentences that explain the difference between temperate deciduous forests and temperate rain forests.

2. How did underlining the important ideas in this section help you understand biomes?

3. Complete the chart below to help you compare and contrast the seven biomes of the world.

<table>
<thead>
<tr>
<th>Biomes</th>
<th>Climate</th>
<th>Plants and Animals</th>
<th>Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tundra</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taiga</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperate deciduous forests</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Temperate rain forests</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tropical rain forests</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deserts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grasslands</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Ecosystems

section Aquatic Ecosystems

Before You Read
On each line below, name a different body of water. Next to each body of water, classify it as freshwater or salt water.

Describe

Factors That Affect Aquatic Ecosystems
Aquatic ecosystems are places where organisms grow or live in water. There are four factors that affect aquatic ecosystems—water temperature, the amount of sunlight present, dissolved oxygen, and salt in the water.

Freshwater Ecosystems
Earth’s freshwater ecosystems include flowing water such as rivers and streams. Freshwater ecosystems also include standing water such as lakes, ponds, and wetlands. Freshwater ecosystems contain very low amounts of salt.

How are river and stream environments alike?
Rivers and streams that flow fast have clearer water and higher levels of oxygen than slow-flowing rivers and streams. This is because the faster the water moves, the more air mixes in. In flowing-water ecosystems, nutrients that support life are washed in from the land. Plants and animals that live in rivers and streams are adapted to the flowing water.

What You’ll Learn
- the differences between flowing freshwater and standing freshwater ecosystems
- the importance of saltwater ecosystems
- problems that affect aquatic ecosystems

Study Coach

Sticky-Note Discussions
As you read the section, use sticky-note paper to mark at least four paragraphs that you find interesting or that you have a question about. Your teacher can help you better understand what you have read.


Reading Essentials 367
1. Compare What is the difference between a lake and a pond?

2. Graph In the circle below, make and label a circle graph that shows the percent of Earth’s water that is salt water and the percent that is freshwater.

How are lake and pond environments alike?

The water in lakes and ponds hardly moves. These environments have more plants than flowing-water environments. Lakes and ponds contain organisms that are not well adapted to flowing-water environments.

Lakes are larger and deeper than ponds. They have more open water because plant growth is limited to shallow areas along the shoreline. Colder temperatures and lower light levels limit the types of organisms that can live in deep lake waters. Microscopic algae, plants, and other organisms known as plankton live near the surface and the shoreline of freshwater lakes and in ponds where the water is warm and sunlit. Many ponds are filled almost completely with plant material, which make them high in nutrients.

What are wetlands?

Regions that are wet for all or most of the year are called wetlands. These regions, also known as swamps, bogs, and fens, are located between land areas and water. Wetlands are filled with plants and animals that are adapted to water-logged soil. Fish, shellfish, and cranberries are some products that come from wetlands. Wetland animals include beavers, muskrats, alligators, and some species of turtles. Many birds use wetland areas to have their young.

How do humans affect freshwater ecosystems?

Sometimes freshwater ecosystems are used as places to dump waste and other pollutants. Fertilizer from farms and lawns runs off into freshwater. Wetlands were once drained and destroyed because people thought they were useless and full of diseases. The drained land was used for shopping centers and houses.

People are being educated about the damage caused by polluting freshwater ecosystems. Sewage is treated before it is released into the water to prevent problems. People who pollute waterways may be fined. Many developers now are working to restore wetlands.

Saltwater Ecosystems

About 95 percent of Earth’s water contains high amounts of salts. Saltwater ecosystems include oceans, seas, a few inland lakes such as the Great Salt Lake in Utah, coastal inlets, and estuaries.
What are ocean life zones?

Scientists divide the ocean into life zones. There are two zones based on the depth to which sunlight penetrates the water—the lighted zone and the dark zone. The lighted zone of the ocean is about the upper 200 m. Plankton make up the base of the food chain in this zone. Below about 200 m is the dark zone. Animals living in this zone feed on each other or on material that floats down from the lighted zone. A few organisms produce their own food.

How do coral reefs form?

Coral reefs are one of the most varied ecosystems in the world. Coral reefs form in oceans over long periods of time from the calcium carbonate shells of ocean animals called corals. When corals die, their shells remain. Over time the shell deposits form coral reefs. Coral reefs contain colorful fish and many other organisms.

Waste materials easily damage coral reefs. World organizations are helping protect coral reefs from harm.

What are the characteristics of seashores?

The shallow waters along the world’s coastlines have many kinds of saltwater ecosystems. These waters are affected by the tides and by the action of the waves. The height of the tides changes based on the phases of the Moon, the season, and the slope of the shoreline. The part of the shoreline that is covered with water at high tide and exposed to air during low tide is called the intertidal zone. Organisms that live in the intertidal zone must withstand the force of the waves. They must also be adapted to changes in temperature, moisture, and the amount of salt in the water.

What is an estuary?

Almost every river eventually flows into an ocean. The area where they meet contains a mixture of freshwater and salt water and is called an estuary (ES chuh wer ee). Estuaries are located near coastlines and border the land. Other names for estuaries include bays, lagoons, and sounds. An estuary is a very fertile environment. Freshwater streams bring in great amounts of nutrients washed from inland soils. An estuary is an important aquatic ecosystem because many kinds of organisms live there, including algae, grasses, shrimp, crabs, clams, and fish. Estuaries are places where the young of many species of ocean fish grow and develop.
1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the difference between a wetland and an estuary.

2. Complete the graphic organizer below to identify the kinds of aquatic ecosystems.

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**Mini Glossary**

- **coral reefs**: ecosystems in oceans that formed over long time periods from the calcium carbonate shells of corals
- **estuary (ES chuh wer ee)**: the area where a river meets an ocean and contains a mixture of freshwater and salt water
- **intertidal zone**: the part of the shoreline that is covered with water at high tide and exposed to air during low tide
- **wetlands**: regions that are wet for all or most of the year

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**Aquatic Ecosystems**

- **Freshwater**
  - Rivers
  - [ ]
  - [ ]
  - [ ]

- **[ ]**
  - Coral reefs
  - Seashores/intertidal zones
  - [ ]
  - [ ]
  - [ ]

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Conserving Resources

section  Resources

Before You Read

Identify two objects in the room you are in. What products from the environment were used to make them?

Read to Learn

Natural Resources

An earthworm eats decaying plant material. A robin catches the worm and flies to a tree. The leaves of the tree use sunlight during photosynthesis. Leaves fall to the ground and decay. What do these living things have in common? They rely on Earth's natural resources. Natural resources are the parts of the environment that are useful or necessary for the survival of living organisms. Like other organisms, humans need food, air, and water. Humans also use resources to make everything from clothes to cars.

What are renewable resources?

A renewable resource is any natural resource that is recycled or replaced constantly by nature. For example, the Sun provides a constant supply of heat and light. Plants add oxygen to the air when they carry out photosynthesis. Rain fills lakes and streams with water.

Why are some resources in short supply?

Although renewable resources are recycled or replaced, they are sometimes in short supply. Sometimes there may not be enough rain or water provided from melting snow to supply water to people, plants, and animals. In desert regions, water and other resources are often scarce.

What You’ll Learn

- the difference between renewable and nonrenewable resources
- how fossil fuels are used
- alternatives to using fossil fuels

Study Coach

Identify the Main Idea  As you read this section, organize notes into two columns. On the left, list a main idea about the material in each subhead. On the right, list the details that support the main idea.

Foldables®

Identify  Make a vocabulary book using notebook paper. As you read the section, add each boldface underlined term. Write the definitions under the tabs.
What are nonrenewable resources?

Natural resources that are used up more quickly than they can be replaced by natural processes are nonrenewable resources. Earth’s supply of nonrenewable resources is limited. For example, plastics and gasoline are made from a nonrenewable resource called petroleum, or oil. Petroleum is formed mostly from the remains of microscopic marine organisms buried in Earth’s crust. Petroleum is nonrenewable because it takes hundreds of millions of years for it to form.

Fossil Fuels

Coal, oil, and natural gas are nonrenewable resources that supply energy. Most of the energy you use comes from these fossil fuels, as you can see in the figure below. Fossil fuels are fuels formed in Earth’s crust over hundreds of millions of years. Cars are powered by gasoline, which is made from oil. Many power plants use coal to produce electricity. Natural gas is used for heating and cooking.

Sources of Energy in the United States

Why should fossil fuels be conserved?

People all over the world use fossil fuels every day. Earth’s supply of these fuels is limited. In the future, fossil fuels may become more expensive and harder to get.

The use of fossil fuels can cause environmental problems. Layers of soil and rock are often stripped away when mining for coal. This destroys ecosystems. Another problem with fossil fuels is that they have to be burned to release energy. The burning results in waste gases that cause air pollution. Two forms of air pollution are smog and acid rain. To reduce the problems caused by fossil fuels, many people suggest using fossil fuels less and finding other sources of energy.
Reducing the Use of Fossil Fuels  You can turn off the television when you are not watching it. This will reduce the use of electricity. You can ride in a car pool or use public transportation to reduce the use of gasoline. Walking or riding a bicycle also can reduce the use of fossil fuels.

Alternatives to Fossil Fuels
Another way of reducing the use of fossil fuels is to find other sources of energy. Power plants use fossil fuels to power the turbines that produce electricity. Alternative energy sources such as water, wind, and nuclear energy can be used instead of the fossil fuels to turn the turbines. Another alternative is solar cells that use only sunlight to produce electricity.

How can water generate electricity?
Water is a renewable resource that can be used to produce electricity. **Hydroelectric power** is electricity that is made when the energy of falling water is used to turn the turbines of an electric generator. Hydroelectric power does not burn fuel, so it does not cause air pollution. However, this type of power can cause environmental problems. To build a hydroelectric plant, usually a dam needs to be constructed across a river. The dam raises the water level to produce the energy that is needed to make electricity. Many acres of land behind the dam are flooded, destroying land habitats and turning part of the river into a lake.

How can wind be used to produce energy?
Wind power is another renewable energy source that can be used to make electricity. Wind turns the blades of a turbine, which powers an electric generator. Wind power does not cause air pollution. However, electricity can be produced only when the wind is blowing.

Where does geothermal energy come from?
The hot, molten rock that lies beneath Earth’s surface is another energy source. You can see the effects of this energy when a volcano erupts. **Geothermal energy** is the heat energy contained in Earth’s crust. Geothermal power plants use this energy to produce steam to produce electricity. Geothermal energy is available only where there are natural geysers or volcanoes. Iceland, an island nation, was formed by volcanoes. Geothermal energy supplies most of Iceland’s power.
6. **Determine** What do PV cells use to produce electricity?

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What is nuclear power?

Another alternative to fossil fuels is nuclear energy. **Nuclear energy** is released when billions of atomic nuclei from uranium, a radioactive element, are split apart in a nuclear fission reaction as shown below. This energy is used to make the steam that turns the turbines of an electric generator.

Nuclear power does not cause air pollution, but it does cause other problems. Mining uranium can harm ecosystems. Nuclear power plants produce radioactive wastes that can harm living organisms. Disposing of these wastes can be a problem. Accidents also are a danger.

What is solar energy?

Solar energy is another alternative to fossil fuels. Solar energy comes from the Sun. It is an inexhaustible source of energy—it cannot be used up. One use of solar energy is to heat buildings. During winter in the northern hemisphere, the parts of a building that face south receive the most sunlight. Large windows on the south side of the building let in warm sunshine during the day. The floors and walls of solar-heated buildings are made of materials that absorb heat during the day. At night, the heat is slowly released, keeping the building warm.

What are solar cells?

A solar-powered calculator uses photovoltaic (foh toh vohl TAY ihk) cells to turn sunlight into electric current. Photovoltaic (PV) cells, also known as solar cells, are small and easy to use. But they can produce electricity only in sunlight. Batteries are needed to store electricity for use at night or on cloudy days. PV cells are considered too expensive to use to make large amounts of electricity.
After You Read

Mini Glossary

fossil fuel: fuel formed in Earth’s crust over hundreds of millions of years

general energy: heat energy within Earth’s crust that is available only where geysers and volcanoes are found

hydroelectric power: electricity produced when the energy of falling water turns the blades of a turbine that generates electricity

natural resource: part of the environment that is useful or necessary for the survival of living organisms

nonrenewable resource: natural resource that is used up more quickly than it can be replaced by natural processes

nuclear energy: energy released when billions of uranium nuclei are split apart in a nuclear fission reaction

petroleum: nonrenewable resource formed from the remains of microscopic marine organisms buried in Earth’s crust

renewable resource: natural resource that is recycled or replaced constantly by nature

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the difference between renewable and nonrenewable resources.

2. Complete the chart below to compare the advantages and disadvantages of using each of the following forms of energy.

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>fossil fuels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>hydroelectric power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>wind power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>nuclear power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>geothermal power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>solar power</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Conserving Resources

section 2 Pollution

What You’ll Learn
- the types of air pollution
- the causes of water pollution
- how erosion can be prevented

● Before You Read

What do you think are the major causes of pollution in your community?

● Study Coach

Make Flash Cards to help you learn more about the section. Write a quiz question for each paragraph on one side of the flash card and the answer on the other side. Keep quizzing yourself until you know all of the answers.

● Foldables

Describe Make a trifold book using notebook paper, as shown below. Use the Foldable to describe the three types of pollution.

What is smog?

Smog is a form of pollution that is created when sunlight reacts with pollutants produced by burning fuels. Smog can irritate the eyes and make it difficult for people who have lung diseases to breathe. Smog can be reduced if more people take buses or trains instead of driving. Other vehicles, such as electric cars, that produce fewer pollutants also can help reduce smog.
Acid Precipitation

Water vapor condenses on dust particles in the air to form droplets. The droplets create clouds. Eventually, the droplets become large enough to fall as precipitation—mist, rain, snow, sleet, or hail. Air pollutants from the burning of fossil fuels can react with water in the atmosphere to form strong acids. Acidity is measured by a value called pH. **Acid precipitation** has a pH below 5.6, as shown in the figure below.

![pH Scale](image)

**What are the effects of acid rain?**

Acid precipitation, or acid rain, washes nutrients from the soil. This can cause trees and plants to die. Acid rain runs off into lakes and ponds, lowering the pH of the water. If the water is too acidic, it can kill the algae and microscopic organisms in the water. This means that fish and other organisms that depend on them for food also die.

**How can acid rain be prevented?**

When factories burn coal, sulfur is released into the air. Vehicle exhaust contains nitrogen oxide. Sulfur and nitrogen oxide are the main pollutants that cause acid rain. Using low-sulfur fuels, such as low-sulfur coal or natural gas, can reduce acid rain. However, these fuels are more expensive than high-sulfur coal. Smokestacks that remove sulfur dioxide before it enters the air can also help reduce acid rain. Reducing automobile use or using electric cars can help reduce acid rain caused by nitrogen oxide pollution.

**Greenhouse Effect**

When sunlight reaches Earth’s surface, some of it is reflected back into space. The rest is trapped by atmospheric gases. This heat-trapping feature of the atmosphere is the **greenhouse effect**. Without it, temperatures on Earth would probably be too cold to support life.
What are greenhouse gases?

The gases in the atmosphere that trap heat are called greenhouse gases. Carbon dioxide (CO₂) is one of the most important greenhouse gases. CO₂ is a normal part of the atmosphere. It is also a by-product of burning fossil fuels. Over the past century, more fossil fuels have been burned than ever before. This is increasing the percentage of CO₂ in the atmosphere, as you can see in the graph above. The atmosphere might be trapping more of the Sun’s heat, making Earth warmer. A rise in Earth’s average temperature, possibly caused by an increase in greenhouse gases, is known as global warming.

Is Earth’s average temperature changing?

Between 1895 and 1995, Earth’s average temperature increased 1°C. No one is certain whether the rise in temperature was caused by human activities or is a natural part of Earth’s weather cycle.

Global warming might have several effects. It might cause a change in rainfall patterns, which can affect ecosystems. The rate of plant growth and the plants that can be grown in different parts of the world may change. The number of storms might increase. The polar ice caps might begin to melt, raising sea levels and flooding coastal areas. Many people think that the possibility of global warming is a good reason to reduce the use of fossil fuels.

Ozone Depletion

Ozone (OH zohn) is a form of oxygen in the atmosphere. Ozone molecules are made of three oxygen atoms. They are formed in a chemical reaction between sunlight and oxygen. The oxygen you breathe has two oxygen atoms in each molecule.

The ozone layer is found about 20 km above Earth’s surface, as shown in the figure at the top of the next page. The ozone layer in Earth’s atmosphere absorbs some of the Sun’s harmful ultraviolet (UV) radiation. This radiation can damage living cells.
**CFCs** The ozone layer becomes thinner over each polar region during the spring. This thinning of the ozone layer is called **ozone depletion**. It is caused by pollutant gases, especially chlorofluorocarbons (klor oh FLOR oh kar bunz) (CFCs). These gases are sometimes used in the cooling systems of refrigerators and air conditioners. When CFCs leak into the air, they rise in the atmosphere until they reach the ozone layer. CFCs react chemically with ozone, breaking apart the ozone molecules.

![Diagram of atmospheric layers](image)

**Why is ozone depletion a problem?**

Because of ozone depletion, the amount of UV radiation that reaches Earth could be increasing. This radiation may be causing an increase in the number of skin cancer cases in humans. The ozone layer is important to the survival of life on Earth. For this reason, many countries and industries have agreed to stop making and using CFCs.

The ozone that is high in the atmosphere protects life on Earth. However, ozone that is near Earth's surface can be harmful. Ozone is produced when fossil fuels are burned. This ozone stays lower in the atmosphere and pollutes the air. Ozone damages lungs and other tissues of animals and plants.

**Indoor Air Pollution**

Air pollution also can occur indoors. Buildings today are better insulated to conserve energy. The insulation reduces the flow of air into and out of a building, so air pollutants can build up indoors. Burning cigarettes release hazardous particles and gases into the air. Even people who do not smoke can be affected by this secondhand cigarette smoke. For this reason, smoking is not allowed in many buildings. Other dangerous gases in buildings are released by paints, carpets, and photocopiers.
**Carbon Monoxide** Carbon monoxide (CO) is a poisonous gas. It is produced when fuels such as charcoal and natural gas are burned. CO is colorless and odorless, so it is difficult to detect. CO poisoning can cause illness or even death. Today, fuel-burning stoves and heaters have to be designed to prevent CO from building up indoors. Many buildings today have alarms that warn of buildups of CO.

**Radon** Radon is a naturally occurring, radioactive gas that is given off by some types of rock and soil. It has no color or odor. It can seep into basements and lower floors in buildings. Radon exposure is the second leading cause of lung cancer in the United States. Radon detectors sound an alarm if the levels of radon in a building are too high. If radon is present, increasing a building’s ventilation can eliminate any damaging effects.

**Water Pollution**

Pollutants enter water, too. Air pollutants can drift into water or be washed out of the sky by rain. Wastewater from factories and sewage treatment plants is often released into waterways. Pollution also occurs when people dump litter and waste into rivers, lakes, and oceans.

**What happens when surface water is polluted?**

Some water pollutants can poison fish and other animals. People who swim in or drink the polluted water can be harmed. Pesticides used on farms can wash into lakes and streams. The chemicals can harm the insects that fish eat. The fish may die from a lack of food.

Another effect of water pollution is algal blooms. Fertilizers and raw sewage contain large amounts of nitrogen. If they are washed into a lake or pond, they can cause algae to grow quickly. When the algae die, bacteria decompose them. The bacteria use up much of the oxygen in the water during this process. Fish and other organisms can die from a lack of oxygen in the water.

**How is ocean water polluted?**

Rivers and streams flow into oceans, bringing their pollutants along. Ocean water can be polluted by the wastewater from factories and sewage treatment plants along the coast. Oil spills also cause pollution. About 4 billion kg of oil are spilled into ocean waters every year.
How is groundwater polluted?
Groundwater comes from precipitation and runoff that soaks into the soil. This water moves slowly through layers of rock called aquifers. If the water comes in contact with pollutants as it moves through the soil, the aquifer could become polluted. Polluted groundwater is difficult to clean.

Soil Loss
Most plants need fertile topsoil in order to grow. New topsoil takes hundreds or thousands of years to form. Topsoil can be blown away by wind and washed away by rain. The movement of soil from one place to another is called erosion (ih ROH zhun). Eroded soil that washes into a river or stream can block sunlight and slow photosynthesis. It also can harm fish and other organisms. Erosion happens naturally, but human activities increase the rate of erosion. For example, when a farmer plows a field, soil is left bare. Bare soil is more easily carried away by rain and wind. Some methods of farming can help reduce soil erosion.

Soil Pollution
Soil becomes polluted when air pollutants fall to the ground or when water leaves pollutants behind as it flows through the soil. Soil also becomes polluted when people throw litter on the ground or dump trash in landfills.

What happens to solid wastes?
Most of the trash that people throw away every week is dumped in landfills. Most landfills are designed to seal out air and water to keep pollutants from seeping into surrounding soil. However, this also slows normal decay processes. Food scraps and paper, which usually break down quickly, can last for many years in landfills. By reducing the amount of trash that people produce, the need for new landfills can also be reduced.

What happens to hazardous wastes?
Waste materials that are harmful to human health or poisonous to living organisms are hazardous wastes. Pesticides and oil are hazardous wastes. Many household items such as leftover paint and batteries also are hazardous wastes. Hazardous wastes should be treated separately from regular trash to prevent them from polluting the environment.
After You Read

Mini Glossary

- **acid precipitation**: precipitation that has a pH below 5.6
- **erosion**: the movement of soil from one place to another
- **greenhouse effect**: the heat-trapping feature of the atmosphere that keeps Earth warm enough to support life
- **hazardous waste**: waste materials that are harmful to human health or poisonous to living organisms
- **ozone depletion**: the thinning of the ozone layer
- **pollutant**: a substance that contaminates the environment

1. Review the terms and their definitions in the Mini Glossary. Choose one of the terms and write a sentence explaining how it can harm the environment.

2. Choose one of the question headings in the Read to Learn section. Write the question in the space below. Then write your answer to that question on the lines that follow.

   Write your question here.

3. How do flash cards help you remember what you have read?

   Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about pollution.
Conserving Resources

section 3 The Three Rs of Conservation

Before You Read
In what ways do you and your family help to conserve natural resources?

What You’ll Learn
■ how use of natural resources can be reduced
■ how resources can be reused
■ that many materials can be recycled

Read to Learn

Conservation
Conserving resources can help prevent shortages of natural resources. It also can slow the growth of landfills and lower levels of pollution. You can conserve resources in several ways. The three Rs of conservation are reduce, reuse, and recycle.

Reduce
You help conserve natural resources when you reduce your use of them. For example, you use less fossil fuel when you walk instead of ride in a car. You also can reduce your use of natural resources by buying only the things that you need. You can buy products that use less packaging or that use packaging made from recycled materials.

Reuse
Another way to conserve natural resources is to use items more than once. Reusing an item means that it can be used again without changing it or reprocessing it. Bring reusable canvas bags to the grocery store to carry home your purchases. Donate outgrown clothes to charity so that others can reuse them.
Recycle

If you cannot avoid using an item, and if you cannot reuse it, then you may be able to recycle it. Recycling is a form of reuse that requires changing or reprocessing an item or natural resource. Many communities have a curbside recycling program. Items that can be recycled include glass, paper, and plastics. The figure below shows the rates at which some household items are recycled in the United States.

![Recycling Rates of Key Household Items](chart.png)


What makes plastic difficult to recycle?

Plastic is more difficult to recycle than other items because there are several types of plastic. Every plastic container is marked with a code that tells the type of plastic it is made of. Plastic soft-drink bottles are the type of plastic easiest to recycle. Some types of plastics cannot be recycled at all because they are made of a mixture of different plastics. Before plastic can be recycled, it has to be separated carefully. One piece of a different type of plastic can ruin an entire batch.

How are metals recycled?

About one quarter of steel used in cans, appliances, and automobiles is recycled steel. Using recycled steel saves iron ore and coal, the resources needed to make steel. Metals such as iron, copper, and aluminum also can be recycled.

You can conserve metals by recycling food cans, which are mostly steel, and aluminum cans. It takes less energy to make a can from recycled aluminum than from raw materials. Also, a can that is recycled is not taking up space in landfills.
How is glass recycled?
Glas bottles and jars can be sterilized and then reused. They also can be melted and made into new bottles. Glass can be recycled again and again. Most glass bottles today already contain at least 25 percent recycled glass. Recycling glass saves the mineral resources needed to make glass. Recycling glass requires less energy than making new glass.

What are some uses of recycled paper?
Used paper can be recycled to make paper towels, newsprint, and cardboard. Ranchers and farmers sometimes use shredded paper instead of straw for bedding in barns and stables. Used paper can be made into compost. Recycling one metric ton of paper saves 17 trees. It also saves water, oil, and electric energy. You can help by recycling newspapers, notebook paper, and junk mail.

Why is composting useful?
When grass clippings, leaves, and fruit and vegetable scraps are dumped in landfills, they stay there for many years without breaking down. Instead, these items can be turned into compost, which can help to enrich the soil. Many communities distribute compost bins to encourage residents to recycle fruit and vegetable scraps and yard waste.

How are recycled materials used?
Many people have learned to recycle. As a result, many recyclable materials are piling up just waiting to be put to use. When you shop, check labels and buy products that contain recycled materials. Buying products made of recycled material will reduce the backlog of recyclable material.
**After You Read**

**Mini Glossary**

*recycling:* a form of reuse that requires changing or reprocessing an item or natural resource

1. Review the term and its definition in the Mini Glossary. Write a sentence explaining how you can participate in recycling.

2. Use the web diagram below to explain the three Rs of conservation. In the ovals, identify the three Rs and include an example of each.

---

Visit life.msscience.com to access your textbook, interactive games, and projects to help you learn more about the three Rs of conservation.
<table>
<thead>
<tr>
<th>Element</th>
<th>Symbol</th>
<th>Atomic Number</th>
<th>Mass Number</th>
<th>Mass (amu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>Al</td>
<td>13</td>
<td>26.982</td>
<td>6.922</td>
</tr>
<tr>
<td>Silicon</td>
<td>Si</td>
<td>14</td>
<td>28.086</td>
<td>6.028</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>P</td>
<td>15</td>
<td>30.974</td>
<td>5.974</td>
</tr>
<tr>
<td>Sulfur</td>
<td>S</td>
<td>16</td>
<td>32.065</td>
<td>6.065</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Cl</td>
<td>17</td>
<td>35.453</td>
<td>5.453</td>
</tr>
<tr>
<td>Argon</td>
<td>Ar</td>
<td>18</td>
<td>39.948</td>
<td>7.948</td>
</tr>
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<td>Al</td>
<td>13</td>
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<td>Ar</td>
<td>18</td>
<td>39.948</td>
<td>7.948</td>
</tr>
</tbody>
</table>

The color of an element's block tells you if the element is a metal, nonmetal, or metalloid.

Elements 116 and 118 were thought to have been created. The claim was retracted because the experimental results could not be repeated.

The names and symbols for elements 111–114 are temporary. Final names will be selected when the elements' discoveries are verified.

Visit life.msscience.com for updates to the periodic table.
# Periodic Table of the Elements

<table>
<thead>
<tr>
<th>Element</th>
<th>Atomic number</th>
<th>Symbol</th>
<th>Atomic mass</th>
<th>State of matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>1</td>
<td>H</td>
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<tr>
<td>Lithium</td>
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<td>Li</td>
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<td>Sodium</td>
<td>11</td>
<td>Na</td>
<td>22.990</td>
<td>Solid</td>
</tr>
<tr>
<td>Potassium</td>
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<td>K</td>
<td>39.098</td>
<td>Solid</td>
</tr>
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<td>Ti</td>
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<td>Y</td>
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<tr>
<td>Niobium</td>
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<td>Molybdenum</td>
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<td>Mo</td>
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<td>Os</td>
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<td>Francium</td>
<td>87</td>
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<td>Radium</td>
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<tr>
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<td>Meitnerium</td>
<td>109</td>
<td>Mt</td>
<td>(268)</td>
<td>Synthetic</td>
</tr>
</tbody>
</table>

- **Columns of elements are called groups. Elements in the same group have similar chemical properties.**
- **The first three symbols tell you the state of matter of the element at room temperature. The fourth symbol identifies elements that are not present in significant amounts on Earth. Useful amounts are made synthetically.**
- **Rows of elements are called periods. Atomic number increases across a period.**
- **The arrow shows where these elements would fit into the periodic table. They are moved to the bottom of the table to save space.**

### Lanthanide series
- Cerium: 58 (Ce 140.116)
- Praseodymium: 59 (Pr 140.908)
- Neodymium: 60 (Nd 144.24)
- Promethium: 61 (Pm 145)

### Actinide series
- Thorium: 90 (Th 232.038)
- Protactinium: 91 (Pa 231.036)
- Uranium: 92 (U 238.029)
- Neptunium: 93 (Np 237)
- Plutonium: 94 (Pu 244)