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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section 1 What is science?

**Before You Read**

How do you find answers to questions about what is happening around you?

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**Read to Learn**

**Scientific Inquiry**

What do you think of when you hear the word science? Do you think only about your science class or your science book? Is there any connection between what you learn in science class and the rest of your life? When you have problems to solve or questions to answer, you can use science. **Science** is a systematic process that helps you ask questions about the world around you. A **scientist** is a person who works to learn more about the natural world.

**When did people first use science?**

People have always tried to find answers to questions about what was happening around them. Early scientists tried to explain things based on what they observed using their senses—sight, touch, smell, taste, and hearing. But, using only your senses can be misleading. How heavy is heavy? What is cold or hot?

Today, scientists use numbers to describe observations. Tools such as thermometers add numbers to descriptions. Like scientists, you can observe, investigate, and experiment to find answers.

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**What You’ll Learn**

- how science is part of everyday life
- skills and tools used in science

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**Study Coach**

**Ask Questions** Read each subhead. Then work with a partner to write questions about the information in each subhead. Take turns asking and answering the questions. Use the questions as a study guide.

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**Foldables**

**A Describe** Make a two-tab book, as shown below. Use the Foldable to describe tools scientists use and skills they develop.
What causes changes in scientific ideas?

New tools are being invented every year. Some of these tools help scientists make new observations. Scientific ideas change as scientists use new tools and make new observations. Existing theories may be challenged and new theories developed. For example, Antonie van Leeuwenhoek built one of the first microscopes in the 1670s. He used the microscope to observe bacteria. His observation created a new field of scientific study called microbiology. Over time, the study of microbiology led to new ways to study and cure human illnesses.

What do all scientists have in common?

Science has many different fields of study. Each field of study uses different tools and methods to find answers to scientific questions. However, all scientists share similar ways of thinking. All scientists ask questions about the natural world. They look for patterns to help explain the world around us.

Science as a Tool

Suppose two students, Luis and Midori, are working on a history project. Their task is to compare and contrast a past event with something that is happening today. Luis and Midori decide to compare and contrast a cholera outbreak in 1871 with an E. coli outbreak happening now.

Luis and Midori first list what they know about cholera and E. coli. They learned in their science classes that cholera is a disease caused by a bacterium. The bacteria live in contaminated water. When people drink this water, they get sick. Cholera causes bad cases of diarrhea. People quickly become dehydrated and some may die.

E. coli is another type of bacterium. Some types of E. coli do not harm people, but some types cause intestinal problems. E. coli that makes humans ill is found in contaminated food or water.

Luis and Midori know they need to learn more. They decide to find out how people discovered the source of the cholera in 1871. They also want to know how scientists today are tracking down the source of the E. coli. They plan to compare the results as part of their history project. They realize that this will help them complete a history assignment and learn more about science.
Using Science Every Day

You use science in different ways. When you are doing research for your history class, for example, you are using science. In fact, you can use scientific thinking every day to make decisions.

What clues do scientists use?

When you have a project to do for history class, you have a problem to solve. Luis and Midori look for clues that show how two events are similar and different. They will use several skills and tools to find the clues. In many ways, scientists do the same thing. People in 1871 followed clues to track the sources of the cholera outbreak. Today, scientists do the same thing by following clues to find the source of *E. coli*.

Using Prior Knowledge

Luis knows that the project must meet certain requirements. The report must be three pages long and must include maps, pictures, or charts and graphs. Information must come from different sources such as written articles, letters, videotapes, or the Internet.

Luis and Midori discuss the project. Midori reminds Luis that correct grammar and punctuation also are important elements. The teacher did not state this rule on the assignment sheet. However, Luis remembers his last history project on which he lost points for incorrect spelling and grammar. Luis and Midori have learned from experience. Based on their past experiences, they can predict that they will lose points if they use incorrect grammar or punctuation.

How do scientists use prior experience?

Scientists do the same thing. They use prior experience to predict what will occur in investigations. They test their predictions. Scientists then form theories when their predictions have been well tested. A theory is an explanation that is supported by facts. Scientists also form laws. These are rules that describe a pattern in nature, like gravity.

Using Science and Technology

To get information, you need a variety of resource materials. You can use the computer to find books, magazines, newspapers, videos, and web pages that have the necessary information.

3. Explain What is a theory?
Computers

The computer is one tool that modern scientists use to find and analyze data. Computers help scientists collect, sort, and analyze data. Computers also make it easier for scientists to prepare research reports and to share data and ideas with each other.

What is technology?

Modern scientists use computers to find and analyze data. The computer is a kind of technology. Technology is the application of science to make products or tools that people can use. Luis and Midori learn that the use of technology is one big difference between the way diseases were tracked in 1871 and the way they are tracked today.

Computer technology helps scientists in many ways. Scientists use computers to research scientific questions on the Internet. They build spreadsheets and databases to sort and analyze data. Word processing, graphics, and multimedia software help scientists share their research findings with others. The more familiar you become with computer technology, the easier it will be to use computers in your investigations.

What skills do scientists use?

Scientists use skills such as observing, classifying, and interpreting data. You use these skills when you solve problems or run experiments. Luis and Midori learned that scientists in 1871 used these skills to track the source of the cholera outbreak. Likewise, scientists use them today to track the source of *E. coli*.

Why are observation and measurement skills important?

Observing, measuring, comparing, and contrasting are important skills for learning. Scientists often use these skills in their work. Observations are important, but sometimes they do not give a complete picture of what is happening. It is important to take accurate measurements to be sure that your data are useful.

Luis and Midori want to find the similarities and differences between the ways diseases were tracked in the 1870s and the way they are tracked today. They will use their comparing and contrasting skills. They will look for similarities to compare the disease-tracking methods. Contrasting the methods means looking for the differences.

4. Identify three ways scientists use computers.

6. Synthesize Name an observation you have made in the last week.
Communication in Science

The work of scientists is most useful when it is shared with others. After scientists get the results of their observations, experiments, and investigations, they use several methods to share their observations with others. Results and conclusions of experiments often are reported in the many scientific journals or magazines that are published each year.

Scientists use scientific publications to learn about the latest research. Scientists send papers to journals. Other scientists review them before they are published.

What is the purpose of a science journal?

Keeping a science journal is another way of communicating scientific data and results. A journal can be used to record observations and the step-by-step procedures that were followed. The journal can be used to list the materials and equipment that were used. It can include the results of an investigation.

Your journal, like the one below, should include mathematical measurements or formulas that were used to analyze the data. Include any problems that happened during the investigation. You might summarize the data in a paragraph or by using tables, charts, or graphs.
After You Read

Mini Glossary

**science:** a systematic process that helps you ask questions about the world around you

**scientist:** a person who works to learn more about the natural world

**technology:** the application of science to make products or tools that people can use

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that describes a way scientists use technology in their work.

2. Complete the diagram by listing the skills that scientists need to do their work.

   ![Diagram](image)

   **Skills Scientists Need**

3. How did asking and answering questions help you remember what you have learned about science?

   ____________________________________________________________

   ____________________________________________________________

   ____________________________________________________________

End of Section 6

Visit [fl7.mssscience.com](http://fl7.mssscience.com) to access your textbook, interactive games, and projects to help you learn more about what science is.
The Nature of Science and Technology

section 2 Doing Science

Benchmarks—SC.H.1.3.2; SC.H.1.3.4 Annually Assessed: The student knows that accurate record keeping, openness, and replication are essential to maintaining an investigator's credibility with other scientists and society. Also covers: SC.H.1.3.1; SC.H.1.3.5; SC.H.1.3.6; SC.H.1.3.7; SC.H.3.3.5

Before You Read
You need your science book to complete an assignment that is due tomorrow, but you left your book at school. How would you solve this problem?

What You’ll Learn
- the steps used to solve a problem in a scientific way
- how a well-designed investigation is developed

Read to Learn

Solving Problems
You know there is more than one way to solve a problem. This also is true of scientific problems. Every day, scientists work to solve scientific problems. The types of problems are different and require different kinds of investigations. However, scientists use some steps in all investigations.

What is the first step in an investigation?
The first thing scientists do is identify the problem. They have to make sure that everyone working to solve the problem has a clear understanding of the problem. Sometimes one problem must be solved before another one can be addressed. For example, a scientist cannot find a cure for a disease until the source of the disease is known. The first problem, finding the source of the disease, must be answered before the second problem can be investigated.

How can the problem be solved?
Scientific problems can be solved in different ways. Two ways are descriptive research and experimental research design. Descriptive research answers scientific questions through observation.

Foldables

B Define Make a vocabulary book as shown below. Use the Foldable to record the vocabulary words in this section and their definitions.
Descriptive Research

Scientists solve some problems by using descriptive research. Descriptive research is based on observations. Scientists use this method when it would be impossible to do experiments. Descriptive research involves several steps.

Research objective The first step in descriptive research is stating the research objective. A research objective is what you want to find out.

Research design A research design does several things. It tells how the investigation will be carried out. It tells what steps will be used and how the data will be recorded and analyzed. An important part of any research design is safety.

Bias When scientists expect a certain result in an investigation, this is known as bias. A good investigation avoids bias. One way to avoid bias is by keeping accurate records and letting others test your methods. Avoiding bias helps scientists produce valid data. They use the data to draw dependable conclusions.
Equipment, Materials, and Models

When you use descriptive research, the equipment and materials you use are important.

How do scientists select their materials?

Scientists try to use the most up-to-date materials. You should use equipment such as balances, spring scales, microscopes, and metric measurements when performing investigations. Calculators and computers can be used to evaluate and display data. You do not need the latest or most expensive material to run successful investigations.

Your investigations can be completed successfully and the data can be displayed with materials found in your home or classroom. Items such as paper, colored pencils, and markers can be used to create effective displays. Good organization of information, such as the display below, is important.

Why do scientists use models?

Sometimes models are used to carry out investigations. In science, a model represents things that happen too slowly, too quickly, or are too big or too small to observe directly. Models are also used when direct observation would be too dangerous or too expensive. Tables, graphs, and spreadsheets are examples of models. Computers can make three-dimensional models of things such as a bacterium. Models save time and money because they test ideas that might otherwise be too small, too large, or take too long to build.

Think it Over

3. Draw Conclusions
Why is up-to-date material important to scientists?

4. Identify two reasons scientists use models.
What is scientific measurement?

Scientists around the world use a system of measurement called the International System of Units, or SI, to make observations. By using the same system, they can understand each other’s research and compare results. The table below shows some common SI measurements.

<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>Liquid volume</td>
<td>1 milliliter</td>
<td>mL</td>
<td>0.001 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 milligram</td>
<td>mg</td>
<td>0.001 g</td>
</tr>
<tr>
<td></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>

Data

When you do scientific research, you have to collect and organize data. Organized data are easier to interpret and analyze.

How are data tables designed?

One way to record results is to use data tables. Most tables have a title that quickly shows you what the table is about. The table is divided into columns and rows. These are usually trials or characteristics to be compared. You can set up your data tables before beginning the experiment. Then you will have a place to record your data.

How do you analyze data?

Once you finish your investigation, you have to determine what your results mean. You have to review all of the recorded observations and measurements. Charts and graphs are excellent ways to organize data.

Draw Conclusions

After you have organized your data, think about the trends you see in your charts and graphs. You have to decide if the data answered your question and if your prediction was correct. Your experiment can still be successful even if it does not come out the way you originally predicted.
How are results communicated?
Analyzing data and drawing conclusions make up the end of an investigation. However, most scientists do not stop there. They usually share their results. They might share with other scientists, government agencies, or the public. They write reports that show how their experiments were run, the data they obtained, and the conclusions they drew. Scientists usually publish their most important findings.

You also have the chance to communicate the data you obtain from your investigations to members of your class. You can give an oral presentation, display the results on a bulletin board, or make a poster. You can share charts, tables, and graphs that show your data. Analyzing and sharing data are important parts of descriptive and experimental research.

Experimental Research
Another way to solve scientific problems is through experimentation. Experimental research answers scientific questions by observing a controlled situation. It focuses on cause and effect relationships.

How do you form a hypothesis?
A hypothesis (hi PAH thuh sus) is a possible explanation for an observation or event that can be tested scientifically. To form a hypothesis, you use your prior knowledge, new information, and any previous observations.

What are variables?
In a planned experiment, factors called variables are clearly defined. An independent variable is a factor that the scientist changes on purpose. Suppose an experiment is testing the effect of two different antibiotics on the growth of bacteria. The type of antibiotic applied to the bacteria is the independent variable.

A dependent variable is the factor that may change as a result of changes made on purpose to the independent variable. In this experiment, the dependent variable is the growth of bacteria.

To test which antibiotic works best, you have to make sure that every variable is the same except for the type of antibiotic. The variables that stay the same are called constants. For example, you should not run the experiments at two different temperatures, for different lengths of time, or with different amounts of antibiotics.
How are controls identified?

To have a valid experiment, you have to use controls. A **control** is a sample that is treated like the other experimental groups except that the independent variable is not applied to it. In the experiment with antibiotics, the control is a sample of bacteria that is not treated with either antibiotic. The control shows how bacteria grow when they are not treated by an antibiotic.

After you have formed your hypothesis and planned your experiment, you must give a copy of it to your teacher. This is a good way to find out if there are any problems with the setup of your experiment.

Once you start the experiment, you have to carry it out as planned. If you change or skip steps in the middle of the experiment, you will have to start the experiment again. You should record your observations and finish your data tables in a timely manner to ensure accuracy.

Should experiments be repeated?

To make sure that the results of the experiment are valid, you need to do the experiment several times. The more trials you do using the same methods, the more likely it is that your results will be reliable. How many trials you do will depend on how much time, space, and material you have to complete the experiment.

How are results analyzed?

After you complete your experiment and get your data, you should analyze the results. You should see if your data support your hypothesis. Even if your data do not support your hypothesis, the experiment can still provide useful information. Maybe your hypothesis needs to be revised. Or maybe the experiment needs to be run in a different way.

After you analyze the results, you can communicate them to your teacher, as shown here, and your class. By sharing your results, you might get new ideas from other students for improving your research. Your results may contain information that will help other students.
1. Review the terms and their definitions in the Mini Glossary. Write a sentence that compares descriptive research and experimental research design.


2. Imagine that you want to find out whether plants grow better in red or blue light. Decide how you will set up the experiment. Identify the constants. Identify the dependent variable, the independent variable, and the control. Present the information in a summary paragraph.


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The Nature of Science and Technology

section 2 Science, Technology, and Engineering

What You’ll Learn
- how science and technology influence your life
- how modern technology allows scientific discoveries to be communicated worldwide

Before You Read
Name three scientific discoveries that affect your life every day.

Read to Learn

Scientific Discoveries
Science influences your life in many ways. For example, new discoveries have led to new products, such as DVDs, that affect your lifestyle.

Technology helps many people live healthier lives. A disease might be controlled by a skin patch that releases a constant dose of medicine into the body. Miniature instruments help doctors operate on babies to save their lives.

The Concept of Technology
Technology includes a variety of products, tools, and systems. The product can be an object such as a calculator, or a piece of pH paper. The tool can be a conventional tool, such as a microscope, or a new method or technique for doing something. Technology also can be a new system of production, or a social-technical system.

When is technology a product?
Technology can be a product or object that you use every day. One object that you might use is the compact disc. The compact disc is an object that is used to store information. The compact disc is a product of technology.
When is technology a method or technique?
At one time, doctors had to do surgery to see inside the human body. X rays were the first technology that allowed doctors to find some medical problems without surgery. Today, doctors use many other methods and techniques to identify medical problems. All of these methods and techniques are technology because they represent a new way of doing things.

When is technology a system of production?
An assembly line is a system of production. Before assembly lines, one person usually created a product from start to finish. Several workers make a product on an assembly line. Each worker does only one part of the process. Products are made faster and cheaper using assembly lines. The assembly line system is an example of technology.

When is technology a social-technical system?
A hospital is another example of technology. Physicians, technicians, and nurses use many tools to find and treat medical conditions. The collection of people, tools, methods, and systems are a form of technology.

Biotechnology and the Human Body
Technology is used to solve problems in the human body too. When technology is applied to living organisms, it is referred to as biotechnology. An example of using biotechnology in the human body is the hormone insulin.

Insulin is a hormone produced in the pancreas. It controls the amount of sugar in the blood. A person with a particular type of diabetes produces too little or no insulin. In the past, animal insulin was used to treat diabetic patients. Animal insulin is not exactly the same as human insulin. Physicians were not certain about the future effects of using animal insulin in humans. Animals also might not be able to provide enough insulin to meet the growing need for it.

Scientists and engineers worked to find a solution. In 1982, the Federal Drug Administration approved the use of genetically engineered human insulin. The hormone was produced in the laboratory using biotechnology. It was the first drug approved that was manufactured using biotechnology. Engineers planned the equipment and manufacturing processes needed to make human insulin in large amounts.
What is engineering?

Scientists and engineers often work together to find a technological solution. An engineer takes scientific information or a new idea and finds a way to use the information to solve a problem or to mass-produce a product.

For example, scientists developed the genetically engineered human insulin. They made small amounts using common laboratory equipment such as test tubes, beakers, and flasks. After human insulin was approved for use, companies needed to find ways to make large quantities available to diabetic patients. Engineers designed the equipment and processes needed to make large quantities of the insulin.

Engineers work in many areas of science. Types of engineers include aeronautical, aerospace, biomedical, chemical, electrical, and mechanical. Think of the products you use everyday. Engineers have a major role in the manufacturing of these products.

Finding Scientific Solutions

Scientists and engineers use a process to find scientific solutions to problems. They begin by clearly defining the problem or need. Scientists could say that they want to produce a new drug to help people live healthier lives. This goal is too broad. They need to make the definition of the problem or need more specific. For example, a group of scientists may say that they want to find a way to produce insulin that is the same as the insulin produced naturally in the human body. This clear statement helps the team of scientists focus their efforts on the same problem or need.

Likewise, engineers would state their problem or need clearly. Their goal might be to produce enough of the drug to meet the needs of all diabetic patients in the United States.

How do scientists and engineers evaluate possible solutions?

Once the problem or need is clearly defined, scientists and engineers begin searching for possible solutions. A problem might have more than one solution. Scientists and engineers work to find the best solution. They evaluate the advantages and disadvantages of each possible solution. They also determine if each possible solution follows scientific principles. The best solution is likely to be the one with the fewest risks and the most benefits.
Continued Evaluation  After a solution is found, scientists develop the product, such as insulin, in small quantities. They also begin to test the procedures and processes needed to produce more of the product. Then, scientists and engineers work together to design the equipment, procedures, and processes needed to make the product in large quantities.

Business professionals and environmental professionals also evaluate each proposed solution. Business professionals provide information about the cost of the proposed solution. For example, if human insulin is too expensive, diabetic people may not be able to afford to buy it. Environmental professionals study the effect of each proposed solution on the environment. They make certain that the environment is not harmed when a product is produced.

How do scientists and engineers test the solution?

Once everyone agrees on the best solution, a model is built. The model is tested before manufacturing begins. Testing the model helps the team find design flaws. During testing, the team will identify constraints in the design. A constraint is a limiting factor in the design such as maximum speed of the production line, or minimum temperature for operation.

After the model passes all of the design tests, a pilot plant will be built. A pilot plant is a smaller version of the real production equipment that uses actual manufacturing conditions. Testing continues in the pilot plant to make sure the manufacturing process works well. Mistakes and problems can be fixed before a large plant is built. Finally, the large manufacturing plant is built and the manufacturing process begins. Large quantities of the product can now be made.

There are many steps in the technological solution process. Testing and evaluation are done at every step. Scientists and engineers want to find any mistakes in the process as early as possible. The earlier a mistake is found, the less expensive it is to fix.  

Think it Over

5. List four professionals who evaluate solutions.

6. Discuss how a pilot plant saves money.
After You Read

Mini Glossary

biotechnology: technology applied to living organisms
constraint: a limiting factor in a design
engineer: a person who takes scientific information or a new idea and finds a way to use the information to solve a problem or to mass-produce a product

pilot plant: a smaller version of real production equipment that closely models actual manufacturing conditions

1. Review the term and its definition in the Mini Glossary. Write a sentence explaining the purpose of a pilot plant.

__________________________________________________________________________________
__________________________________________________________________________________
__________________________________________________________________________________

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. Describe a problem in the world today that science could help solve.

__________________________________________________________________________________
__________________________________________________________________________________
__________________________________________________________________________________
Before You Read

How would you describe what someone looks like to a friend?

Read to Learn

Physical Properties

Imagine you are visiting the Florida State Fair. You spot the most amazing ride you have ever seen. How will you describe this ride to your friends? What features will you use in your description? Maybe you will tell them it is large, blue, and made of wood. These features are all physical properties, or characteristics, of the ride. A physical property is a characteristic that you can observe without changing or trying to change the substance. How an object looks, smells, sounds, or tastes are examples of physical properties. You can describe matter by its physical properties.

How can your senses help describe matter?

Some physical properties describe what matter looks like. You can use your senses of sight, smell, or taste to describe matter. For example, you can see the color and shape of an object. You also can touch objects and describe what they feel like. You can smell odors and taste flavors of some objects. (You should never taste anything in the laboratory.)

How can matter be described by state?

When you describe matter, you need to describe its state, or form. Is it a solid, a liquid, or a gas? This property is known as state of matter. Your chair, book, and pen are examples of matter in the solid state. Milk, gasoline, and vegetable oil are examples of matter in the liquid state. Helium in a balloon or the air you breathe are matter in the gas state.
Can matter exist in all three states?
Water is one substance that you’ve probably seen or felt in all three states. You drink or swim in liquid water. You might put solid water, or ice, in your soft drink. You might even skate on solid water in the winter. Water in the gas state is in the air you breathe.

What properties depend on size?
Some physical properties, such as volume and mass, depend on the size of the object.

**Volume** Suppose you need to know the volume, or the amount of space inside a box. To find the volume, you multiply its width, height, and depth measurements. Volume is a physical property that depends on size.

**Mass and Weight** Mass is another physical property that depends on size. Mass is the amount of matter in an object. A bowling ball has more mass than a basketball. Weight depends on the mass of the object, but it also depends on gravity. On other planets your weight would change, but not your size or your mass.

What properties do not depend on size?
Some physical properties of materials do not depend on size. Properties like color, density, and solubility do not change whether the amount of material is great or small.

**Density** Density is the amount of mass in a given volume. To find the density of an object, divide the object’s mass by its volume. Water in a drinking glass has the same density as water in a bathtub. The density of an object will change, however, if the mass changes and the volume remains the same.

**Solubility** Another property that does not depend on size is solubility (sahl yuh BIH luh tee). Solubility is the number of grams (g) of one substance that will dissolve in 100 g of another substance at a given temperature. For example, the number of grams of sugar that dissolves in 100 g of water does not change if the water is in a large pitcher or poured into a drinking glass.

**Melting and Boiling Point** Melting and boiling point also do not depend on size. Melting point is the temperature at which a solid changes into a liquid. Boiling point is the temperature at which a liquid changes into a gas.

Think it Over

1. **Identify** Name two properties that depend on size.

Think it Over

2. **Explain** The boiling point of water in a tea kettle is the same as the boiling point in a 20-qt soup pot. Why?
The figure below shows the melting and boiling points of several substances along with other physical properties.

### Physical Properties of Several Substances

<table>
<thead>
<tr>
<th>Substance</th>
<th>State</th>
<th>Density (g/cm³)</th>
<th>Melting point (°C)</th>
<th>Boiling point (°C)</th>
<th>Solubility in cold water (g/100 mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>gas</td>
<td>0.7710</td>
<td>-78</td>
<td>-33</td>
<td>89.9</td>
</tr>
<tr>
<td>Bromine</td>
<td>liquid</td>
<td>3.12</td>
<td>-7</td>
<td>59</td>
<td>4.17</td>
</tr>
<tr>
<td>Calcium carbonate</td>
<td>solid</td>
<td>2.71</td>
<td>1,339</td>
<td>898</td>
<td>0.0014</td>
</tr>
<tr>
<td>Iodine</td>
<td>solid</td>
<td>4.93</td>
<td>113.5</td>
<td>184</td>
<td>0.029</td>
</tr>
<tr>
<td>Potassium hydroxide</td>
<td>solid</td>
<td>2.044</td>
<td>360</td>
<td>1,322</td>
<td>107</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>solid</td>
<td>2.17</td>
<td>801</td>
<td>1,413</td>
<td>35.7</td>
</tr>
<tr>
<td>Water</td>
<td>liquid</td>
<td>1</td>
<td>0</td>
<td>100</td>
<td>—</td>
</tr>
</tbody>
</table>

**Magnetic properties** Some matter can be described by the way it behaves. For example, some materials pull iron toward them. These are called magnetic. Lodestone is a rock that is magnetic. Other materials can be made into magnets like the magnets on your refrigerator. The figure below shows which properties depend on size and which do not.

### Magnetic Properties

- Some matter can be described by the way it behaves.
- Some materials pull iron toward them.
- These are called magnetic.
- Lodestone is a rock that is magnetic.
- Other materials can be made into magnets like the magnets on your refrigerator.

### Chemical Properties

A **chemical property** is a characteristic that cannot be observed without changing the substance. Imagine that you didn’t know what a match was. Could you tell just by looking at it that it would burn? The ability to burn is a chemical property. After a match burns, the match is permanently changed.

### Physical Properties of Matter

<table>
<thead>
<tr>
<th>Depend on size</th>
<th>volume, mass, weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do not depend on size</td>
<td>density, melting/boiling point, solubility, ability to attract a magnet, state of matter, color</td>
</tr>
</tbody>
</table>

---

**Picture This**

3. List the different physical properties shown in the table.

4. Compare and Contrast Do more physical properties depend on size or not depend on size?
1. Review the terms and their definitions in the Mini Glossary. Explain in your own words the difference between chemical properties and physical properties.

2. Fill in the Venn diagram below to compare and contrast physical and chemical properties. Include examples of each type of property.

3. At the beginning of the section, you were asked to make a quiz about the main ideas and vocabulary terms. How did you decide what the main ideas were?
**Before You Read**

A log is cut into boards. Then, the boards are used to make a table. What properties of the log have changed? What has stayed the same?

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**Read to Learn**

**Physical Changes**

What happens when an artist changes a lump of clay into a pot? Does what is in the clay change? No, what is in the clay does not change. Only the way the clay looks changes. The shape of the clay changes from a lump of clay to a pot. This kind of change is a physical change. A **physical change** is a change in the way an object looks, but not in what the object is made of.

For example, a frozen pond in winter looks totally different than the pond in the summer. The water changes state from a solid in the winter to a liquid in the summer because of a change in temperature. Although the physical properties of solid ice are different from the physical properties of liquid water, the chemical makeup, or composition, is the same. The water molecules are still made up of the same elements—hydrogen and oxygen.

**How is changing shape a physical change?**

Have you ever crumpled a piece of paper into a ball? If so, you caused a physical change. The crumpled ball is still the same piece of paper. When you cut a banana, the fruit is still a banana. You change only its form. When you cut, tear, grind, or bend matter, you cause a physical change.
How is dissolving a physical change?

What happens when you add sugar to iced tea? Does the sugar disappear? It may seem to disappear. But, if you taste the tea, it is sweet. The sugar dissolves in the tea. The particles of sugar spread out in the tea. The form of the sugar changes, but the make-up of the sugar stays the same. So, dissolving is a physical change.

How is changing state a physical change?

Matter can change from one state to another. Liquid water that freezes into ice is still water. Both liquid water and solid ice are made up of the same type of molecules. So, changes in state are physical changes.

A liquid also can change into a gas. Vaporization (vay pruh ZAY shun) is a change from a liquid to a gas. Water vaporizes when it boils and turns into steam. Condensation (kahn den SAY shun) occurs when a gas changes into a liquid. What happens to a glass of ice water if it sits at room temperature? Water forms on the outside of the glass. This is an example of condensation.

Sublimation (sub luh MAY shun) is a process in which a solid changes directly to a gas without becoming a liquid first. When dry ice melts, it turns into carbon dioxide gas. You may have seen smoke made from dry ice while watching a play. Deposition (de puh ZIH shun) is a process in which a gas changes directly to a solid without becoming a liquid first. Frost that forms on the ground on a cold, humid night is an example of deposition. The figure below shows these changes in state.

Chemical Changes

Do you enjoy fireworks? The explosions and colors are examples of chemical changes. In a chemical change, substances are changed into different substances. This means the makeup of the substance changes. When fireworks explode, compounds change into different compounds.
How is rusting a chemical change?
Have you ever seen a bike that was left out in the rain? What happened to the bike? You may have noticed that the steel parts of the bike, such as the frame and the chain, can rust after a while. This happens when oxygen and water in the air react with the iron in steel. The iron and oxygen atoms combine to form a reddish, powdery substance called rust. So, rusting is an example of a chemical change.

Signs of Chemical Changes
Physical changes are usually easy to spot. You can see when something changes shape or state. But, how do you know when chemical changes happen? You have probably seen chemical changes before—you just did not know it.

Have you seen the leaves on trees change color in the fall? If so, you have seen a chemical change. The change in the color of the leaves is not caused by a green pigment changing into a red pigment. A pigment is a chemical that makes things certain colors. Paints have pigments in them.

In summer, trees make a green pigment called chlorophyll (KLOHR uh fuhl). This makes the leaves green. In fall, trees stop making chlorophyll. The chlorophyll already in the leaves changes into colorless chemicals. Then you see the yellow, red, and orange pigments that have been in the leaves all along.

How is color a sign of a chemical change?
Have you ever seen an apple slice turn brown? A chemical change occurs when an apple reacts with oxygen in the air. The chemical change makes the apple turn brown. Heat also causes chemical changes in food. Bread turns brown as it cooks because a chemical change occurs.

How is energy a sign of chemical change?
Many substances must absorb energy to have a chemical change. For example, what do you add to pancake batter to make it turn into a pancake? Energy. The energy absorbed by the runny pancake batter as it cooks causes a chemical change. A solid pancake is the result. Many chemical changes require heat.

A release of energy is another sign of a chemical change. Fireworks release energy in the form of light when they undergo a chemical change. Burning is a chemical change that releases energy in the form of heat and light.
How is odor a sign of chemical change?

Have you ever opened a container that has been in the refrigerator too long? Did the food inside smell bad? The bad smell is a sign that the food has spoiled. When foods spoil, they undergo a chemical change. The change in odor is a sign of chemical change. This sign can save lives. A bad odor is a sign that you should not eat the food.

How is the formation of gases or solids a sign of chemical change?

You can see bubbles if you pour vinegar on baking soda. The bubbles in the vinegar are a gas. The gas formed in a chemical reaction. Gas formation is a sign of chemical change.

Sometimes, when you mix two liquids, a solid forms. This solid is called a precipitate (prih SIH puh tut). When a precipitate forms, it is a sign of a chemical change.

Can physical and chemical changes be reversed?

Ice can melt and become water, then freeze again to become ice. Melting and freezing are physical changes. Substances produced by chemical changes cannot be changed back to their original substances. When a log burns, the gases and ash that form cannot be changed back into a log. Pancakes cannot be turned back into batter.

Physical Versus Chemical Change

Here are the important things to remember about physical and chemical changes. In a physical change, the makeup of the substance does not change. However, the substance does change form. In a chemical change, the makeup of the substance changes and the substance changes form.

The table below shows some examples of physical and chemical changes.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Physical Change</th>
<th>Chemical Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>Being cut into pieces</td>
<td>Cut surfaces turning brown</td>
</tr>
<tr>
<td>Egg</td>
<td>Mixing together egg white and yolk</td>
<td>Spoiling and giving off an odor</td>
</tr>
<tr>
<td>Copper</td>
<td>Being pounded and bent</td>
<td>Green patina forming</td>
</tr>
<tr>
<td>Wood</td>
<td>Being cut into lumber</td>
<td>Burning</td>
</tr>
<tr>
<td>Water</td>
<td>Boiling</td>
<td>Mixing with an antacid tablet</td>
</tr>
<tr>
<td>Marble</td>
<td>Carving into a statue</td>
<td>Dissolving in acid rain</td>
</tr>
</tbody>
</table>
**Physical Changes** When a substance such as copper or wood undergoes a physical change, the original substance still remains after the change. To make the Statue of Liberty, copper sheets were bent and pounded into shape. Trees are cut into lumber. After these physical changes, the copper and the wood are still the same substances.

**Chemical Changes** When a substance undergoes a chemical change, the original substance no longer is present after the change. New substances are made during a chemical change. The Statue of Liberty was bright and shiny when it was new. Over time, the copper reacted with air to form a green coating called patina. When wood is burned, it is changed into gases and ash. During these chemical changes, the copper and the wood changed into new substances.

**How are physical and chemical changes used in recycling?**

Recycling is a way to separate used items into their different parts. Then you can reuse the parts. Recycling involves physical and sometimes chemical changes. Rubber tires can be shredded and added to asphalt pavement and playground surfaces. Glass bottles can be smashed and used in asphalt pavement, new containers, and even artwork. Some plastics can be melted and formed into new products. Recycling objects helps keep our landfills from getting too full.

**Conservation of Mass**

In a chemical change, the makeup, or the composition, of the matter changes. Particles in the matter rearrange and new substances are created. When wood burns, the particles in the matter rearrange and turn into gases and ash. The particles are not created or destroyed. The law of conservation of mass states that the total mass of matter is the same before and after physical or chemical changes. Matter cannot be created or destroyed.

Scientist Antoine Lavoisier (AN twan • luh VWAH see ay) proved the law of conservation of mass in the 1700s. This law can sometimes be difficult to understand. When a candle burns, some of it seems to disappear. Lavoisier realized that the mass of a candle doesn’t disappear. The mass changes form into the gases given off when the candle burns.

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7. **Explain** What substance reacts with copper to form patina?

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8. **Apply** A log with a mass of 2 kg is burned. What is the mass of the gases and ash that are produced when the log burns?
1. Review the terms and their definitions in the Mini Glossary. On a sunny winter day, ice and snow sometimes seems to disappear. What term describes this change in state? Explain the term in a sentence.

2. Write physical change or chemical change in the blank after each example to tell what kind of change each example is.
   a. Spoiled food ______________________________
   b. Sublimation ______________________________
   c. Making wood into furniture ______________________________
   d. Fireworks exploding ______________________________
   e. Nails rusting ______________________________
   f. Bending metal sheets ______________________________

3. You were asked to underline ideas about physical and chemical changes and then highlight an example of each kind of change. Did this strategy help you learn about physical and chemical changes? Why or why not?

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Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about physical and chemical changes.
Before You Read

What is the smallest thing you have ever seen? Was this thing made up of smaller parts? Name them.

Read to Learn

First Thoughts

Do you like mysteries? Are you curious? All through history, humans have wondered about things that can’t be seen. One of the things humans have wondered about is what matter is made of. Some early thinkers thought that matter was made of tiny particles. They thought that you could cut matter in half and then in half again many times. Finally, you would have a piece so small that you could not cut it any more. You would have only one particle left. This particle is too small to be seen by human eyes. Early thinkers named this smallest particle the atom. The word atom means “cannot be divided.”

How do you describe something that you can’t see?

Thousands of years ago, people could not prove that atoms existed. In early times, scientists did not do experiments. They discussed their ideas until they agreed on them. Today, scientists will not accept a theory that is not supported by experimental evidence. Even if early scientists wanted to experiment to find out about atoms, they could not have. Long ago, people didn’t know much about what we call chemistry, or the study of matter. Equipment that scientists use today to study matter had not yet been invented. Atoms were still a mystery as recently as 500 years ago.
A Model of the Atom

For a long time, no one had new ideas about the atom. Finally in the 1700s, scientists started thinking about atoms again. Chemists were learning about matter and how it changes. They put substances together to form new substances. They also took substances apart to find out what they were made of. Scientists found that some substances could not be broken down into simpler substances. They called these substances elements. An **element** is matter made up of only one type of atom. For example, iron is an element made of only iron atoms. Silver is an element made of only silver atoms.

**What was Dalton’s concept of the atom?**

John Dalton was an English schoolteacher in the early 1800s. He had these ideas about matter: (1) Matter is made up of atoms. (2) Atoms cannot be divided into smaller pieces. (3) All atoms of an element are exactly alike. (4) Different elements are made of different kinds of atoms. Dalton thought of an atom as a hard sphere, or ball, like a tiny marble.

**How was Dalton’s theory tested?**

In 1870, an English scientist named William Crookes experimented with a glass tube as shown in the figure. The tube had almost all the air removed from it. The tube had two pieces of metal called electrodes inside. The electrodes were connected to a battery by wires.

**What was in Crookes’s tube?**

An electrode is a piece of metal that conducts electricity. An **anode** is an electrode with a positive charge. The anode is connected to the positive side of the battery. The **cathode** is an electrode with a negative charge. The cathode is connected to the negative side of the battery. Crookes’s tube is shown in the figure above. In this tube, the cathode was a small metal disk. The anode was a larger metal disk. In the middle of the tube was an object shaped like a cross.
3. Explain Why couldn’t the cathode rays be light?

When Crookes connected the battery, the tube lit up with a green glow. A shadow of the cross appeared on the anode. Crookes believed that something was flowing from the cathode to the anode. The cross was blocking the flow, causing a shadow. Crookes thought that the glow was caused by rays, or streams of particles. He called the rays cathode rays because they came from the cathode. Crookes’s tube is called a cathode-ray tube, or CRT. Many televisions and computer monitors have a type of CRT.

4. Describe Why did Thomson think all atoms contained electrons?

Some scientists were not sure that cathode rays were streams of particles. They thought the rays were just a form of light. In 1897, an English scientist named J. J. Thomson did an experiment with cathode rays. He placed a magnet beside a CRT. The magnet caused the cathode rays to bend. Light cannot be bent by a magnet. So, the beam could not be light. Thomson concluded that the rays were made of charged particles of matter that came from the cathode.

What are electrons?

Thomson did many more experiments with CRTs. He made cathodes of different metals. He also used different gases in the tube. Each time, the same charged particles were produced. Thomson decided that cathode rays were negatively charged particles of matter. He knew that opposite charges attract each other. He decided the particles in the CRT were negatively charged because they were attracted by the positively charged anode. These particles are now called electrons.

Electrons are negatively charged particles. Thomson thought that electrons were part of every kind of atom because every kind of cathode material produced electrons in his experiment. Thomson’s results showed that particles smaller than atoms do exist.

What did Thomson’s discovery mean?

Thomson’s discovery meant that atoms must have negatively charged particles inside of them. If that is so, why isn’t all matter negatively charged? Thomson believed that atoms also must have some positive charge. That way, the negative and positive charges would neutralize each other, or cancel each other out.
How did Thomson model the atom?
Thomson made a new model of the atom based on his findings. Dalton thought of an atom as a solid ball that was the same throughout. Thomson pictured a sphere of positive charge. Negatively charged electrons were placed evenly in the sphere. The positive charge of the sphere is equal to the negative charge of the electrons. Therefore, the atom is neutral. Later, scientists discovered that not all atoms are neutral because the number of electrons in each atom can change.

Rutherford’s Experiments
A model is not accepted by scientists until it has been tested. In 1906, Ernest Rutherford and his coworkers began an experiment to find out if Thomson’s model of the atom was correct. They fired positively charged bits of matter, called alpha particles, at a thin film of metal. Since alpha particles are positively charged, they would be repelled by matter that is positively charged.

The figure at the top of the next page shows how the experiment was set up. Alpha particles were fired at a sheet of gold foil. The foil was only 400 nanometers thick. There was a fluorescent (floo REH sunt) screen around the foil. The screen gave a flash of light each time it was hit by a charged particle.

What did Rutherford think would happen?
Rutherford predicted that most of the particles would pass straight through the gold and hit the screen on the other side. He didn’t think that the gold foil contained enough matter to stop the speeding alpha particles. He thought that the positive charge in the gold atoms might cause a few minor changes in the path of the alpha particles, but not very often. Rutherford’s hypothesis made sense. Remember that, in Thomson’s model, the positive charge is neutralized by nearby electrons.

Was Thomson’s model wrong?
The figure at the top of the next page also shows the results of Rutherford’s experiments. Rutherford was surprised to find that some of the alpha particles bounced backward off the foil. How could he explain this event? He decided that the positively charged alpha particles were moving so quickly that it would take a large positive charge to make them bounce back. This meant that Thomson’s model of the atom with an equal mix of positive and negative charge was incorrect.
A Model with a Nucleus

Rutherford proposed a new model of the atom, shown in the figure below. The nucleus is a tiny space in the center of an atom that has a positive charge and contains almost all of the atom’s mass. In 1920, Rutherford’s ideas about the nucleus were proven true when scientists identified protons. A proton is a positively charged particle that is in the nucleus of all atoms. The almost-massless electrons move in the empty space around the nucleus.

What did Rutherford’s model explain?

Rutherford’s new model explained what happened in his experiment. Most alpha particles move through the foil with little or no interference because atoms are made up of mostly empty space. But, if an alpha particle hit the nucleus of a gold atom, the strong positive charge in the nucleus repelled the alpha particle. The alpha particle then bounced backward.
What did Rutherford’s model not explain?
Rutherford’s model explained why some alpha particles bounced back. However, his model did not answer all questions about the atom. For instance, an atom’s electrons have almost no mass. In Rutherford’s model, the only other particle in the atom was the proton. So, the mass of an atom should be about equal to the mass of its protons. However, the mass of most atoms is at least twice as great as the mass of its protons. Rutherford’s model did not explain this.

Where does the extra mass come from?
To explain the extra mass in an atom, scientists thought there must be another particle in the nucleus. This particle was called the neutron (NEW trahn). A neutron is a particle that has the same mass as a proton but has no electrical charge, or is neutral. It was hard to prove that neutrons exist. Because neutrons have no charge, they are not attracted by magnets and they do not make fluorescent screens light up. It took 20 more years before more modern experiments were able to show that atoms contain neutrons.

When neutrons were discovered, the model of the atom changed again. The nuclear atom, shown in the figure above, has a tiny nucleus tightly packed with positively charged protons and neutral neutrons. Negatively charged electrons are found in the empty space around the nucleus. The number of electrons in a neutral atom equals the number of protons in the atom.

How big are atoms?
Drawings of the nuclear atom like the one above don’t show how small the nucleus is compared to the rest of the atom. Imagine that the nucleus of an atom is the size of a table-tennis ball. The atom would have a diameter greater than 2.4 km. Most of an atom is empty space.
Further Developments

Scientists first thought electrons orbit, or travel around, the nucleus of an atom like the planets travel around the Sun. They thought that the negatively charged electrons were attracted to the positive charges in the nucleus like the Moon is attracted to Earth. But scientists later learned that electrons are in constant, unpredictable motion. The motion of electrons cannot be easily described by an orbit. It is impossible to know exactly where an electron is at any particular moment. These findings led to even more experiments about atoms.

Can the behavior of electrons be explained?

Scientists continued to struggle with how to explain the unpredictable nature of electrons. New theories and models were needed. One way to explain the movement of electrons is to think of them as waves, not particles. Thinking of electrons in this way helped scientists come up with the current model of the atom.

What is the electron cloud model?

The latest model of the atom is the electron cloud model, shown below. The electron cloud is the area around the nucleus of an atom where electrons travel. The electrons are more likely to be close to the nucleus than far away. That is because the negative electrons are attracted to the positive charge of the protons in the nucleus. Notice that the cloud in the model has a fuzzy outline. There is no clear boundary because electrons could be anywhere within the cloud.

Electron Cloud Model

This may be the latest model of the atom, but it could certainly change. Scientists may find out new things about the atom. They may even decide that this model is incorrect. Science is always changing as long as scientists ask questions and do more experiments.
After You Read

Mini Glossary

anode: an electrode with a positive charge
cathode: an electrode with a negative charge
electron: a negatively charged particle
electron cloud: the area around the nucleus of an atom where electrons travel
element: matter made up of only one type of atom

nucleus: a tiny space in the center of an atom that has a positive charge and contains almost all of the atom’s mass
neutron (NEW trahn): a particle that has the same mass as a proton, but has no electrical charge
proton: the positively charged particle that is in the nucleus of every atom

1. Review the terms and their definitions in the Mini Glossary. What do you know about the atoms of the element gold? Answer in a complete sentence.

2. Look at the figure below. Label the parts of the current model of an atom. Explain what each part is.

3. At the beginning of the section, you were asked to make an outline as you read. How did outlining help you learn about atoms?

End of Section

Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about models of the atom.
Inside the Atom

section 2 The Nucleus

Benchmarks—SC.A.2.3.2: The student knows the general properties of the atom and accepts that single atoms are not visible.
Also covers: SC.H.1.3.1; SC.H.1.3.2; SC.H.1.3.3; SC.H.1.3.4; SC.H.1.3.5; SC.H.1.3.6; SC.H.3.3.1; SC.H.3.3.4; SC.H.3.3.5; SC.H.3.3.6; SC.H.3.3.7

Before You Read

Every person is different. What are some things that make one person look different from another person?

What You’ll Learn

■ about radioactive decay
■ what half-life means
■ how radioactive isotopes are used

Read to Learn

Identifying Numbers

The electron cloud model is an example of what an average nuclear atom looks like. But what makes atoms of different elements different? The atoms of different elements have different numbers of protons. The atomic number of an element is the number of protons in the nucleus of an atom of that element.

The element hydrogen has the smallest atomic number. It has only one proton in its nucleus, so hydrogen’s atomic number is 1. The element uranium has the greatest atomic number of a naturally occurring element. It has 92 protons in its nucleus. Its atomic number is 92.

How many neutrons are in the nucleus?

A certain type of atom can have different numbers of neutrons in its nucleus. For example, most carbon atoms have six protons and six neutrons. But, some have seven or eight neutrons. All of these atoms are carbon atoms because they all have six protons.

These carbon atoms with different numbers of neutrons are called isotopes (I suh tohps). Isotopes are atoms of the same element that have different numbers of neutrons. Carbon-12 is an isotope that has six protons and six neutrons. Carbon-13 has six protons and seven neutrons. Carbon-14 has six protons and eight neutrons. Together, the protons and neutrons make up most of the mass in an atom.

Highlight Main Ideas As you read, highlight the main ideas under each heading. After you finish reading, review the main ideas of the lesson.

Build Vocabulary

Make the following Foldable and write the definitions of each of the terms from this lesson.

Atomic Number
Isotopes
Mass Number
Radioactive Decay
Transmutation
Alpha Particle
Beta Particle
Half Life
What is the mass number?

The **mass number** of an isotope is the number of neutrons plus protons. The figure below shows the mass number and particles for the isotopes of carbon. For example, carbon-12 has six protons and six neutrons, so its mass number is 12. Notice that all isotopes of carbon have six protons. The atomic number of carbon is 6.

<table>
<thead>
<tr>
<th>Isotopes of Carbon</th>
<th>Carbon-12</th>
<th>Carbon-13</th>
<th>Carbon-14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass number</td>
<td>12</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>Number of protons</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Number of neutrons</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Number of electrons</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Atomic number</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

What is the strong nuclear force?

How do you hold things together? You might use tape or glue. What holds the protons and neutrons together in the nucleus of an atom? Remember that protons have a positive charge. You might think that the protons would repel each other. But, when the protons and neutrons are tightly packed together in a nucleus, an even stronger binding force takes over. This force is called the strong nuclear force. The strong nuclear force keeps the protons from repelling each other. This force works only in the nucleus of an atom.

Radioactive Decay

The nuclei of most elements are stable because they have about the same number of protons as neutrons. For example, carbon-12 is stable because its atoms have six protons and six neutrons. Some nuclei are unstable because they have too many or too few neutrons. The particles in the nucleus try to repel each other. The nucleus must eject, or release, a particle to become stable. When a nucleus lets a particle go, it gives off energy. **Radioactive decay** is the release of particles and energy from the nucleus.
Transmutation When protons are released from the nucleus, the atomic number of the atom changes. So one element changes into another. Transmutation is the changing of one element into another through radioactive decay.

What happens when alpha particles are lost? Most smoke detectors contain the element americium-241 (a muh RIH shee um). This element is unstable and undergoes radioactive decay. Americium-241 transmutates into another element by ejecting an alpha particle and energy. An alpha particle is a particle that is made up of two protons and two neutrons. The energy and alpha particle that are ejected are called nuclear radiation.

In a smoke detector, the alpha particles make it possible for the air to conduct an electric current. As long as the electric current flows, the detector is silent. Smoke will interrupt the flow of the electric current and the alarm will go off.

How does an element change its identity? Americium has 95 protons. After transmutation, it only has 93 protons and becomes the element neptunium. Neptunium has an atomic number of 93. Notice in the figure that the mass and atomic numbers of neptunium and the alpha particle add up to the mass and atomic number of americium. No particles were destroyed during transmutation.

What are beta particles? Not all transmutations cause the nucleus to eject an alpha particle. Some eject an electron called a beta particle. A beta particle is a high-energy electron that comes from the nucleus, not the electron cloud. But, the nucleus contains only protons and neutrons. How can it give off an electron? In this kind of transmutation, a neutron becomes unstable. It splits into an electron and a proton. The electron, or beta particle, is ejected with a large amount of energy.

Reading Check

3. Explain What happens to an element if it undergoes transmutation?

4. Calculate The element actinium has an atomic number of 89. How many alpha particles would americium need to lose before it became actinium?
What happens to the proton?

After the electron is ejected, the proton stays in the nucleus. Now there is one more proton in the nucleus and the atomic number increases by one. The figure shows unstable hydrogen-3. One neutron splits into a proton and an electron. The electron (e⁻), or beta particle, is ejected. Now the nucleus has two protons. Hydrogen-3 turns into helium-3. The mass of the atom stays almost the same because the mass of the electron it loses is so small.

Rate of Decay

Have you ever watched popcorn pop? You never know which kernel will pop next. But, if you have popped a lot of popcorn before, you might be able to predict how long it will take for half the kernels to pop. Radioactive decay also is random. That’s why radioactive decay is measured using its half-life. The half-life of a radioactive element is the amount of time it takes for half of a sample of the element to decay.

How do you calculate half-life decay?

The half-lives of radioactive isotopes range from fractions of a second to billions of years. Iodine-131 has a half-life of eight days. If you start with 4 g of iodine-131, after eight days you have only half the amount, or 2 g. After eight more days, you have only 1 g. The radioactive decay of unstable atoms happens at a steady rate that nothing can change.

How are objects dated using half-life?

Scientists use radioactive decay to find the age of fossils. Carbon-14 is a radioactive isotope of carbon. Its half-life is 5,730 years. It is used to find the age of dead animals, plants, and humans. Living things have carbon-14 in them because they take in and release carbon. When a living thing dies, the amount of carbon-14 inside it begins to decrease because of radioactive decay. Scientists can measure the amount of carbon-14 in an ancient item. Using the half-life of carbon-14, scientists can calculate when the animal, plant, or human lived.
8. Infer Why might we want to know what happens to pesticides in the environment?

---

**Why are long half-lives sometimes a problem?**

Some radioactive isotopes have half-lives that are thousands, millions, or billions of years. Waste products that have these isotopes can be dangerous because they still release radiation. These waste products must be kept away from people and the environment. Special disposal sites are used to store this waste for long periods. Many of these sites are deep underground.

**Making Synthetic Elements**

There are only 92 elements found in nature. Other elements are made through transmutation. Scientists can smash alpha and beta particles into the nuclei of existing atoms to make new elements. Since these new elements are made by humans, they are called synthetic. Synthetic elements have greater numbers of protons and neutrons. They have atomic numbers greater than 92.

**What are the uses of radioactive isotopes?**

Scientists have made many useful isotopes. These isotopes, called tracer elements, can be placed in the body or released into the air. Then, scientists can use instruments to look for radiation while the tracer elements decay. Tracer elements have been used to diagnose diseases and study the environment. Tracer elements with short half-lives are the best to use. The short half-lives do not expose living organisms to radiation for long periods of time.

**Diagnose Diseases** Iodine is an element that is used by the thyroid gland. Radioactive iodine-131 can be given to a patient with a thyroid problem. The tracer element is absorbed by the thyroid gland. The radiation can create a picture of the thyroid. Doctors can then find out if the patient’s thyroid is working properly.

**Study the Environment** Tracer elements are used in the environment, too. Scientists inject them into the roots of plants to see how the roots absorb food. Others are put into pesticides. The tracer elements can then be followed to find out what happens to the pesticides in the environment.
1. Review the terms and their definitions in the Mini Glossary. Explain why the mass number and atomic number of an element are different. Use complete sentences.

2. Complete the table to explain what causes radioactive decay and what happens when particles are ejected.

<table>
<thead>
<tr>
<th>Type of Particle Released</th>
<th>Decay Process</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha particle</td>
<td></td>
<td>The atom changes into a different element. The atom now has a lower atomic number.</td>
</tr>
<tr>
<td>Beta particle</td>
<td>A neutron in the nucleus splits into a proton and an electron. The electron, or beta particle, is ejected.</td>
<td></td>
</tr>
</tbody>
</table>
Before You Read

When you walk from one place to another, how do you know that you have moved?

What You’ll Learn

- about distance and displacement
- about speed, velocity, and acceleration
- how to calculate speed and acceleration

Read to Learn

What is motion?

Does Earth move? What is the distance between your home and school? Who is the fastest runner? To answer these questions, you need to be able to describe motion.

What are distance and displacement?

You can describe motion of an object by how it changes position. One way to do this is to describe the path an object travels. The map shows the path traveled by a hiker. She traveled 7 km north, 4 km southeast, and 11 km northeast. The total distance traveled was 22 km.

Another way to describe motion is to give only the starting and stopping points. The hiker’s end position was 12 km northeast of her start position. Displacement is the distance and direction between starting and ending positions. Her displacement was 12 km northeast.

Highlight

Use a highlighter to highlight words and sentences you think are important in this section. When you finish reading, review what you highlighted.

Foldables

Classify

Make the following four-tab Foldable to help you learn definitions and examples of displacement, speed, velocity, and acceleration.
Relative Motion
Something that is in motion changes its position. An object’s position is described in relation to another object, which is assumed to be not moving. The unmoving object is called the reference point. For example, you may look out the window in the morning and see a truck parked under a tree. In the afternoon, you see the truck parked farther down the block. The tree is the reference point, and the truck has moved relative to the position of the tree.

Speed
When you are moving, your position is changing. How quickly your position is changing is your speed. Speed is the distance traveled divided by the time needed to travel that distance. Speed increases if it takes less time to travel the same distance. The sprinter with the greatest speed in the 100-m dash is the sprinter who runs the 100-m in the shortest time.

What is constant speed?
Have you ever been in a car with the cruise control on? The car’s speed does not change. This means the car’s speed is constant. Imagine a car is traveling at a constant speed of 30 m/s. This means that every second the car travels 30 meters. The speed does not change. When an object is traveling at a constant speed, its speed is the same at every instant.

What is average speed?
Does a car moving through the streets of a city have a constant speed? The car slows down or speeds up as traffic lights change. It is not possible to drive at a constant speed in the city. The car’s instantaneous speed tells how fast the car is moving at a certain instant of time. A car’s speedometer shows its instantaneous speed.

Average speed is another way to describe the motion of an object whose speed is always changing. Average speed is represented by the symbol \( \bar{v} \). Use the following equation to find average speed:

\[
\text{average speed (in m/s)} = \frac{\text{distance (in m)}}{\text{time (in s)}}
\]

\[
\bar{v} = \frac{d}{t}
\]
**Velocity**

Sometimes you might want to know the direction you are going as well as your speed. If so, you want to know your velocity. **Velocity** is the displacement divided by time. You can calculate velocity using the following equation:

\[
\text{velocity} = \frac{\text{displacement}}{\text{time}}
\]

Suppose you travel 1 km east in 0.5 hours. What is your velocity?

Velocity = \frac{(1 \text{ km east})}{(0.5 \text{ hours})}

= 2 \text{ km/h east}

Your velocity is 2 km/h east.

Remember that displacement is a distance and a direction. Velocity, like displacement, includes a direction. Airplane pilots need to know velocity. They need to know how fast and in what direction they are flying.

**Acceleration**

Sometimes you need to know how motion changes, such as speeding up or changing direction. **Acceleration** is the change in velocity divided by the time it takes the change to occur. Because velocity includes both speed and direction, so does acceleration. If an object changes its speed, its direction, or both, it is accelerating.

**How can objects accelerate?**

You may think that accelerate means to move faster. But slowing down is also acceleration. Why? Acceleration is a change in velocity. A change in speed is a change in velocity. So, slowing down is accelerating.

**How does turning relate to acceleration?**

Remember that when an object changes direction, its velocity changes. So, when an object changes direction, it is also accelerating. Imagine you are running a race around a track. Every time you follow the turn on the track, your direction changes. You are accelerating. At the end of the race, you slow down and walk. Slowing down is accelerating. Any time velocity changes, acceleration occurs.
After You Read

Mini Glossary

acceleration: a change in the speed, direction, or both
speed: how quickly something’s position changes

velocity: an object’s speed and direction

1. Review the terms and their definitions in the Mini Glossary. Write a sentence using the term velocity that shows your understanding of the term.

   __________________________________________
   __________________________________________
   __________________________________________

2. Match the example of motion in the left column with the term that describes the motion in the right column. Write the letter of the motion in the blank in front of the example.

   Example
   ___ 1. An airplane traveling at 200 km/h north, turns east, but stays at 200 km/h.
   ___ 2. A camper moves to a new campsite 8 km southwest of her first campsite.
   ___ 3. Jaime is riding his bike and looks at his speedometer. He sees that he is traveling 30 km/h.
   ___ 4. Lynn traveled 80 km each hour while driving for a total of 6 hours.
   ___ 5. A sailboat is traveling southeast at 20 km/h.

   Motion
   a. displacement
   b. average speed
   c. instantaneous speed
   d. velocity
   e. acceleration

3. At the beginning of the section, you were asked to highlight words and sentences that you thought were important. Did highlighting help you learn about motion? Why or why not?

   __________________________________________
   __________________________________________
   __________________________________________
Forces and Changes in Motion

section 2 Forces and Motion

Benchmarks—SC.C.1.3.1: The student knows that many forces act at a distance; SC.C.2.3.3 Annually Assessed: The student knows that if more than one force acts on an object, then the forces can reinforce or cancel each other.
Also covers: SC.A.1.3.2; SC.C.2.3.2; SC.C.2.3.6; SC.C.2.3.7; SC.H.1.3.5

● Before You Read

Imagine throwing a ball. What will happen to the ball after you let go of it? How do you know this?

● Read to Learn

Force

Have you ever seen a gymnast flip backward off a balance beam and land perfectly on the floor? Her motion may seem smooth and simple. The gymnast actually makes many different movements to make the flip smooth. What causes these changes in motion to occur? The motion of the gymnast changes because of the forces acting on her.

An object’s motion changes because of a force. A force is a push or a pull that one object exerts on another. Objects like the floor, chairs, and Earth also can exert forces on other objects. For example, Earth pulls the gymnast downward. The balance beam exerts a force on her, pushing her upward.

How is force measured?

Imagine a book is resting on a table in front of you. If you push the book from the side, it will move across the table. But if you push down just as hard on the top of the book, it will not move. The way the book moves depends on the amount of force you apply and the direction of your push. Just like velocity and acceleration, a force has a size and a direction. The direction of a force is the direction of the push or pull. The size of a force is measured in newtons (N). It takes about 3 N of force to lift a can of soft drink.

Creating a Quiz  As you read, write questions about important facts on a sheet of paper. When you finish reading, answer the questions as a quiz to see if you learned the facts.

What You’ll Learn

- what force is
- how forces combine
- how different forces affect motion

Find Main Ideas Make the following half-book Foldable to help you identify different forces that affect motion.
1. **Apply** If two people are pushing at a door from opposite directions, what must one person do to push open the door from his or her side?

---

**How Forces Combine**

Suppose you push on a door to open it. At the same time, someone else pushes on the other side of the door. How will the door move? Will it move in the direction that you are pushing? More than one force is acting on the door. The **net force** is the combination of all the forces acting on an object. The net force on the door comes from the two pushes on the door.

**How do forces in the same direction combine?**

Imagine you and a friend are trying to move a couch. You both push on the same side of the couch. The net force is a combination of both your pushes. You exert a force of 15 N to the left, and your friend exerts a force of 10 N to the left. The net force is 25 N to the left.

**How do forces with opposite directions combine?**

Imagine you are pushing on a door with a force of 5 N to the left. Someone else pushes on the door with a force of 8 N to the right, as in the figure below. The forces combine to form a net force. As you can see, the net force is 3 N to the right. When two forces are in opposite directions, the net force is the difference between the two forces. The net force is in the direction of the larger force.

What would happen if both people pushing on the door exerted 8 N of force, in opposite directions? The two forces have equal strength. If two forces of equal strength act on an object in opposite directions, then the net force is zero.

---

**Picture This**

2. **Label** each set of pictures, showing in which set the box Moves a Lot, Moves a Little, or Does Not Move.
Balanced and Unbalanced Forces

In a game of tug of war, two teams pull on a rope in opposite directions. If both teams pull with the same force, the net force is zero. The motion of the rope does not change. The forces acting on an object are balanced forces if the net force is zero. Balanced forces do not change the motion of an object.

What happens if one team pulls harder on the rope? Then the net force on the rope is not zero. The forces acting on an object are unbalanced forces if the net force is not zero.

The motion of an object will change only if the forces acting on it are unbalanced forces. Unbalanced forces cause an object to speed up, slow down, or change direction.

Contact and Non-contact Forces

A force is exerted when one object pushes or pulls on another. Your fingers exert a force on a pencil when you write. Your fingers have to be touching the pencil to exert a force. A contact force is a force that is exerted only when two objects are touching.

Other forces can be exerted by one object on another even when the objects are not touching. Suppose you rub two balloons on a sweater, and then bring them close together? The balloons push each other away. Each balloon exerts an electric force on the other, even though they are not touching. Electric forces, magnetic forces, and gravity are non-contact forces. Non-contact forces are forces that can be exerted by one object on another even when the objects are not touching.

Gravity

Gravity is a non-contact force that every object exerts on every other object due to their masses. You and Earth exert gravitational forces on each other.

Gravity is an attractive force that pulls objects closer together. If you jump up, gravitational force will pull you down. The size of the force depends on the masses of the objects and the distance between them. The gravitational force between two objects increases if the mass of one or both of the objects increases or if they move closer together.

3. Apply If you hold a magnet near some paper clips, the paper clips will be pulled towards the magnet. Is this an example of a contact force or a non-contact force? Explain
How do mass and weight relate to gravity?

Earth’s gravity exerts a force on an object, pulling it toward Earth. This force is the weight of an object. Because weight is a force, it is measured in units called newtons. Mass is the amount of matter an object contains, so mass is measured in kilograms. The mass of an object may not change, but its weight does change if its distance from Earth changes or if it’s on a planet with a force of gravity different from Earth’s.

The gravitational force Earth exerts on an object is the weight of the object. Because weight is a force, it is measured in newtons. Weight is not the same as mass. Mass is the amount of matter an object contains and is measured in kilograms. The mass of an object doesn’t change. The weight of an object will change if its distance from Earth changes.

Friction

Push your hand across a desk top. Is it hard to move your hand across the desk? Maybe there is some resistance, and it feels like something is pushing back. That resistance is the force of friction between your hand and the desk. Friction is a contact force that resists the sliding motion of two surfaces that are touching. Friction causes a sliding object to slow down and stop. Friction also can prevent surfaces from sliding past each other.

What is static friction?

Imagine you are trying to push a box filled with books. You apply a force to the box, but the box still does not move. Because there is no change in the box’s motion, the net force must be zero. The figure below shows this. The force you are exerting on the box is balanced by another force on the box in the opposite direction. Static friction is the force between two surfaces in contact that keeps them from sliding when a force is applied.

![Diagram of static friction](https://www.example.com/diagram.png)
What is sliding friction?
If you push hard enough on the box of books, it will start to slide. If you stopped pushing the box, it would slide a little more and then come to a stop. Sliding friction is a force that opposes the motion of two sliding surfaces in contact.

Sliding friction exists between any sliding surfaces that are touching. There is sliding friction as a book moves across a table. There is sliding friction between the moving parts in a car’s engine.

What causes friction?
All surfaces are covered with tiny dips and bumps. When two surfaces meet, they stick together where these dips and bumps come into contact. Friction is caused by the sticking of two surfaces at these dips and bumps.

Static friction happens when the force on an object cannot overcome this sticking. Once enough force is applied, the sticking connections are broken and the object can be moved over the surface.

The Buoyant Force
The force that is exerted by a fluid on an object that is in the fluid is called the buoyant force. The buoyant force is always an upward force. When you float in a pool of water, the buoyant force is large enough to balance your weight.

Air Resistance
If you drop a flat sheet of paper and a crumpled sheet of paper at the same time, the crumpled paper falls faster. Air resistance is a contact force that opposes the motion of objects moving in air. Air resistance is a force that pushes up on a falling object. Like friction, it acts in the direction opposite to the object’s motion.

The air resistance on a flat sheet of paper is larger than the force of air resistance on a crumpled sheet. The size of the air resistance force depends on the shape and speed of the object. Air resistance is greater on a wide, flat object than on a narrow, pointed one.

Parachutes increase the amount of air resistance on a skydiver. Air resistance on the parachute becomes large enough to balance the gravitational force on the skydiver. Air resistance reduces the skydiver’s speed so that he can land safely.
1. Review the terms and their definitions in the Mini Glossary. Explain the difference between contact and non-contact forces.

2. On the lines, label each figure below with the terms balanced forces or unbalanced forces to show whether the forces acting on each object are balanced or unbalanced. If the forces are unbalanced, use an arrow to show the direction of the greatest force.

   a. ___________________
   b. ___________________
   c. ___________________
   d. ___________________

3. How could you use a shopping cart to show balanced and unbalanced forces to a group of elementary students?

   ______________________
   ______________________
   ______________________
   ______________________
Identifying the Main Point
As you read, write down the main point or idea of each paragraph. After you finish reading, make sure you understand each main point.

Before You Read
How do you know how hard to kick a ball to get it to a friend?

What You’ll Learn
■ how net force, mass, and acceleration are related
■ what action and reaction forces are

Read to Learn
Newton’s Laws of Motion
Changes in motion of all objects are caused by forces. Forces act on galaxies, planets, and cars on the street. How do the forces that act on an object change an object’s motion? There are three rules that can help you understand changes in motion. These rules are known as Newton’s laws of motion. Isaac Newton presented these laws in 1687. These laws apply to all objects. They can predict the motion of planets in the solar system and describe the motion of a skateboard.

First Law of Motion
How can an object move if the forces acting on it are balanced? The first law of motion states that if the forces acting on an object are balanced, then an object at rest remains at rest and an object in motion keeps moving in a straight line with constant speed. In other words, when forces acting on an object are balanced, the object’s motion doesn’t change.

For an object to change speed or direction, the net force acting on it must not be zero. For example, if you throw a ball, it eventually changes direction after it leaves your hand. When it leaves your hand, the net force on the ball is not zero. Gravity exerts a force on the ball. The force of gravity is the unbalanced force that changes the ball’s direction, pulling it toward the ground.
Why do objects change speed?

You make a skateboard speed up by pushing it in the direction it is moving. If the net force acting on an object is in the same direction the object is moving, the object will speed up.

If the net force acts in the direction opposite to an object’s motion, the object slows down and moves in a straight line.

Why do objects change direction?

In the figure below, the basketball player expects the ball to go up, then curve down and through the hoop. He throws the ball up, but after the ball leaves his hands, it does not go up forever. It changes direction. An unbalanced net force, gravity, acts on the ball. Because of the force of gravity, the path of the basketball curves downward and goes through the hoop.

The Second Law of Motion

You have learned that an object is accelerating when it speeds up, slows down, or changes direction. Newton’s second law of motion describes how the net force on an object, the mass of an object and the acceleration of the object are related. When you lift your backpack, you cause the backpack to speed up and accelerate. The second law of motion states that the acceleration of an object depends on the net force acting on the object and the object’s mass.
How are acceleration and mass related?

It is easier to throw a baseball than a basketball because the baseball has a smaller mass. If you apply the same amount of force to the baseball and the basketball, the baseball will have more speed. Acceleration is larger when the speed of an object changes more quickly.

The same net force affects a baseball and a basketball differently. If the net force is the same as the mass of an object increases, acceleration decreases. If you lift an empty backpack and one that is full of books with the same force, the empty one will accelerate more quickly.

The same applies to lifting a backpack. If your backpack is empty, you can lift it easily and quickly with little force. But suppose your backpack is filled with textbooks. Then you will have to apply a lot of force to lift the backpack. The book-filled backpack has more mass than an empty backpack. If you lift a full backpack with the same force as you would an empty backpack, you will not be able to lift it very quickly, if at all. The mass of the backpack determines how much force you must apply to lift it.

How does direction of net force affect acceleration?

The second law of motion states that an object’s acceleration is in the same direction as the force applied to it. When you pull on a wagon, it moves in the same direction as your pull. When a tennis player serves a ball, the ball changes direction and moves in the direction of the force from the racket.

If a soccer ball rolls toward you, you can stop it with your foot. The force of your foot is opposite to the motion of the ball, so the ball slows and stops. When an object slows down, the direction of its acceleration is opposite to its direction of motion. The acceleration of the ball is still in the direction of the net force on the ball.

How does the size of force affect an object’s acceleration?

When you apply enough force to lift your backpack, the backpack accelerates. Its speed depends on its mass and also on the force you exert on the backpack. If you apply more force, the speed of the backpack changes more quickly. The greater the force, the larger the acceleration of the backpack. The second law of motion explains that the acceleration of an object increases when the net force on the object increases.
The Third Law of Motion

How high can you jump? Think about the forces acting on you when you jump. Gravity is pulling you downward. Where does the upward force come from? Part of the upward force comes from your legs and feet pushing you up. Part of the force also comes from the ground, which pushes you up.

Newton’s **third law of motion** states that when one object exerts a force on a second object, the second object exerts an equal force in the opposite direction on the first object. In the figure below, the person’s feet are pushing down on the ground. The ground is pushing up on her. This upward force the ground exerts allows the jumper to leave the ground for an instant.

What are force pairs?

Force pairs are the forces two objects exert on each other. In the figure above the girl is pushing down on Earth when she jumps, and Earth is pushing up on her. These two forces are a force pair. They are equal even though they push in opposite directions. What if the girl wants to jump higher? She has to push harder on the ground. Then the ground will push up harder on her.

You might think that the forces in a force pair cancel out because they are equal and in opposite directions. But remember that the two forces are acting on different objects. One force is acting on the girl, and the other force is acting on Earth. Force pairs don’t cancel out because they act on different objects. Equal and opposite forces cancel out only if they act on the same object.
What are action and reaction forces?

The third law of motion says that forces act in pairs. When you push on a wall, the wall pushes back on you. One force is called the action force. The other force is the reaction force. Your push on the wall is the action force. The wall pushing back is the reaction force. Every action force has a reaction force that is equal in size, but in the opposite direction.

Newton’s third law explains how a swimmer moves through the water. The swimmer’s hands exert a backward force on the water creating an action force. The water then exerts a forward reaction force pushing the swimmer forward.

Combining the Laws

The laws of motion describe how the motion of any object changes when forces act on it. This is true of the space shuttle. Newton’s third law states that every action has an equal and opposite reaction. That is why a huge force from its rocket engines is required to lift the space shuttle into the atmosphere. The rocket engines give off gasses that push down against the ground with tremendous force. The reaction is that the shuttle lifts off, or moves away from Earth and its gravitational force.

Basketball Application When a basketball player pushes down on the ground, the third law of motion states that the ground pushes up on the basketball player. If the basketball player pushes hard enough, the downward force of gravity and the upward push from the ground combine to produce a net force on him or her that is upward. According to the second law of motion, the basketball player accelerates upward.

When the basketball player is in the air the downward force of gravity is acting in a direction opposite to the player’s direction of motion. This causes the basketball player to slow down until he or she reaches the top of the jump. Then, as the basketball player starts moving downward, gravity is working in the same direction as the player’s motion, so the basketball player speeds up as he or she falls.

When the basketball player hits the ground, the upward force exerted by the ground brings the player to a stop. Then the forces acting on the basketball player are balanced, and the player remains at rest.
1. Review the terms and their definitions in the Mini Glossary. State each of the laws of motion in your own words.

First Law: an object will remain at rest, or keep moving in a straight line with constant speed, unless an unbalanced force acts on it.

Second Law: the acceleration of an object depends on the net force acting on an object, and the object’s mass.

Third Law: when one object exerts a force on a second object, the second object exerts an equal force in the opposite direction on the first object.

2. Look at the figure. Using the third law of motion, identify and label the action and reaction forces that are applied to each object as the bowling ball hits the pin.

   a. ______________________  b. ______________________

3. At the beginning of this section, you identified the main point of each paragraph. How did this help you understand the information in this section?

   ______________________

   ______________________

Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about Newton’s laws of motion.
What You’ll Learn

- when work is done
- how to calculate how much work is done
- how work and power are related

Before You Read

When you think of work, you might think of household chores, homework, or an after school job. Describe the work you have done today.

Read to Learn

What is work?

In science, there is a special definition of work. Work is done when a force makes an object move in the same direction as the force that is applied. You do work when you lift your books, turn a doorknob, or write with a pen.

What does motion have to do with work?

Suppose your teacher asks you to move a box of books. You try, but the box will not move. It is too heavy. You are tired because you tried to force the box to move. But you have not done any work. Two things must happen for you to do work. First, you must apply a force on an object. Second, the object must move in the same direction as the force that you applied. Imagine a girl standing still and holding two bags of groceries. Is she doing work? No, she is not moving or causing anything to move.

How does the direction of force affect work?

Your arms apply a force upward when you lift a box. Your arms did work because the basket moved in the same direction as the force your arms applied. If you walk with the box, your arms are still applying an upward force on it. But you and the box are moving. The box is not moving in the same direction as the upward force your arms applied. So, no work is done by your arms.
Does all of a force do work?
Sometimes only part of a force moves an object. Think about what happens when you push a lawn mower. Look at the figure below. You push at an angle to the ground. Part of the force is forward. Part of the force is downward. Which part of the force does work? Only the part of the force that is forward does work because it is in the same direction as the motion of the mower.

Calculating Work
Work is done when a force makes an object move. More work is done if the force is increased or if the object moves farther. You can calculate how much work is done by using the work equation below. The SI unit for work is the joule (JEWL). The joule is named for the nineteenth-century scientist James Prescott Joule.

Work Equation
\[ \text{work (joules)} = \text{force (newtons)} \times \text{distance (meters)} \]
\[ W = Fd \]

What distance is used for the work equation?
Suppose you give a book a push and it slides across a table. You use the distance an object moves while a force is acting on it to calculate work, not the total distance the object moved. So, the distance in the work equation is the distance the book moved while you were pushing it.
What is power?
What does it mean to be powerful? Imagine two weightlifters lifting the same amount of weight. They lift the weight the same distance above the floor. They both do the same amount of work. But the amount of power they use depends on how long it took to do the work. Power is how quickly work is done. The weightlifter who lifted the weight in less time is more powerful.

How do you calculate power?
You can calculate power by dividing the amount of work done by the time needed to do the work.

\[
power \ (\text{watts}) = \frac{\text{work} \ (\text{joules})}{\text{time} \ (\text{seconds})}
\]

\[
P = \frac{W}{t}
\]

The SI unit of power is the watt. The watt is named for James Watt, a nineteenth-century British scientist.

How can doing work change energy?
Remember that when something moves, it has kinetic energy. If you push a chair and make it move, you do work on the chair. You also change the chair’s energy. By making the chair move, you increase the chair’s kinetic energy.

If you lift an object higher, you also change the energy of the object. The potential energy of an object increases when it is higher above Earth’s surface. When you lift an object, you do work on the object and increase its potential energy.

How are power and energy related?
You increase the energy of an object when you do work on it. Because energy cannot be created or destroyed, the object gains energy while you lose energy. When you do work on an object, you move, or transfer, energy to the object and your energy decreases. The amount of work done is the amount of energy transferred to the object. So, power is also equal to the amount of energy transferred in a certain amount of time.

Sometimes energy can be transferred even when no work is done. This happens when heat flows from a warm object to a cold one. Energy can be transferred in many ways, even when no work is done. Power is always the rate, or speed, at which energy is transferred. The rate is the amount of energy transferred divided by the time needed to transfer it.
1. Read the key terms and definitions in the Mini Glossary above. Describe work in your own words.

2. Complete the table.

<table>
<thead>
<tr>
<th>Action</th>
<th>Was work done on the book?</th>
<th>In which direction was work done?</th>
<th>How did the action change the energy of the object?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifting your books from the bottom of your locker</td>
<td>yes</td>
<td>up</td>
<td>Increases the potential and kinetic energy as they are lifted.</td>
</tr>
<tr>
<td>Carrying your books from your locker to class</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pushing your book across your desk for a friend to see</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. You were asked to make two flash cards for every page of the section. How did this help you learn the material in the section?

---

Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about work and power.
Before You Read
Describe a machine you used today and tell what it does.

What You’ll Learn
■ how a machine makes work easier
■ about mechanical advantage and efficiency
■ how friction reduces efficiency

Read to Learn
What is a machine?
You may think of a machine as a car or an appliance. Scissors, brooms, and knives are all machines, too. A machine is a device that makes doing work easier. Even a sloping surface can be a machine.

Mechanical Advantage
Machines change the way you do work. When you use a machine, you apply a force over a distance. You use force to move a rake or lift the handles of a wheelbarrow. **Input force** is the force that you apply on a machine. The work you do on a machine is equal to the input force times the distance over which your force moves the machine. The work that you do on the machine is the input work.

The machine also does work. It applies a force to move an object over a certain distance. **Output force** is the force that the machine applies. A rake, for example, applies a force to move leaves. The work that the machine does is the output work.

When you use a machine, the output work can never be greater than the input work. So why use a machine? A machine can make work easier in three ways because it can:

• change the amount of force you need to apply.
• change the distance over which the force is applied.
• change the direction in which the force is applied.
How does changing force make work easier?

Some machines make work easier by reducing the force you need to apply. This kind of machine increases the input force so the output force is greater than the input force. You need less force to do the work. The **mechanical advantage** (MA) of the machine is the number of times that a machine increases the input force. You can calculate mechanical advantage using this equation:

\[
\text{mechanical advantage} = \frac{\text{output force (newtons)}}{\text{input force (newtons)}}
\]

\[
MA = \frac{F_{\text{out}}}{F_{\text{in}}}
\]

How does changing distance make work easier?

Some machines let you apply force over a shorter distance. In these machines, the output force is less than the input force. A rake is an example of this kind of machine. You move your hands a small distance at the top of the handle. But, the bottom of the rake moves a greater distance. The mechanical advantage of this kind of machine is less than one because the output force is less than the input force.

Does changing direction make work easier?

Sometimes it is easier to apply a force in a certain direction. Imagine putting a flag up on a flagpole. It is easier to pull down on the rope on the flagpole than to pull up on it. Some machines let you change the direction of the input force. In these machines, the distance and the force do not change. The mechanical advantage of this kind of machine is equal to one. The output force is equal to the input force. The figures show the three ways machines make doing work easier.

**Applying Math**

1. **Calculate** Suppose you use a machine to move a large rock. You apply a force of 100 N to the machine. The machine applies a force of 2,000 N to the rock. What is the mechanical advantage of the machine? Show your work.

2. **Describe** Write the words that make the sentence true: When a machine increases

   a. ________, it is applied over a shorter b. ________.

   a. ___________________
   b. ___________________

**Picture This**

2. **Describe** Write the words that make the sentence true: When a machine increases

   a. ________, it is applied over a shorter b. ________.

   a. ___________________
   b. ___________________
Efficiency

A machine can make the output force greater than the input force, but it can’t make the output work greater than the input work. There is friction when parts of the machine move. Friction always changes some of the input work into thermal energy. So, the output work is less than the input work. If friction in the machine decreases, the efficiency of the machine increases. The efficiency of a machine is the ratio of the output work to the input work. You can find efficiency by using this equation:

\[
\text{efficiency (in percent)} = \frac{\text{output work (joules)}}{\text{input work (joules)}} \times 100%
\]

\[
\text{eff} = \frac{W_{\text{out}}}{W_{\text{in}}} \times 100%
\]

How does friction affect a machine?

Imagine pushing a heavy box up a ramp. The bottom surface of the box slides across the top surface of the ramp. Neither the box nor the ramp is perfectly smooth. Each surface has high spots and low spots.

As the two surfaces slide past each other, high spots on the two surfaces touch each other. The places that they touch are called contact points. At these contact points, atoms and molecules can bond together. This makes the contact points stick together. The attractive forces between all of the bonds added together is the frictional force. The frictional force tries to keep the two surfaces from sliding past each other.

To keep the box moving, a force must be applied. The force has to break the bonds between the contact points. Even after these bonds are broken and the box moves, new bonds form as different parts of the two surfaces touch.

How can friction be reduced?

One way to reduce friction between two surfaces is to add oil to the surfaces. Oil can fill the gaps between the surfaces. Oil keeps many of the high spots from touching each other. There are fewer contact points between the surfaces. So, the force of friction is less. This means more of the input work is changed to output work by the machine.

Applying Math

3. Calculate Workers use a ramp to load a piano into a truck. The output work, or the amount of work needed to move the piano, is 12,000 J. The workers do 15,000 J of work. What is the efficiency of the ramp? Show your work.

4. Identify What causes friction?
1. Review the terms and their definitions in the Mini Glossary. Describe one of the ways a machine makes work easier.

2. In the figure below, write how each machine makes doing a job easier. Write the terms increases force, changes direction of force, and increases distance in the correct locations.

3. How did highlighting the answers to the headings that were questions help you make sure you understood the material in the section?
Work and Simple Machines

section 3 Simple Machines

Before You Read
Suppose you need to put a heavy box into a truck. Would you rather push the box up a ramp or lift it straight into the air? Explain.

What You’ll Learn
- what the different simple machines are
- how to find the mechanical advantage of each simple machine

Read to Learn

What is a simple machine?
In the last section you learned that machines make work easier. Some machines like cars, elevators, or computers are very complicated. But machines can be very simple. A hammer, a shovel, and a ramp are all machines. A simple machine is a machine that does work with only one movement. The six simple machines are the inclined plane, lever, wheel and axle, screw, wedge, and pulley. A compound machine is a machine made up of more than one simple machine. A bicycle and a can opener are compound machines.

Inclined Plane
Ramps have been used for thousands of years. Ancient Egyptians might have used them to build their pyramids. Archaeologists hypothesize that the Egyptians built huge ramps to move limestone blocks. The blocks each weighed more than 1,000 kg.
A ramp is a simple machine known as an inclined plane. An inclined plane is a flat, sloped surface. You might need a lot of force if you have to lift an object. An inclined plane lets you use less force to move an object from one height to another. The longer the inclined plane, the smaller the force needed to move the object.
How are inclined planes used?

Suppose you have to lift a box weighing 1,500 N into a truck that is 1 m off the ground. Could you do that? The force (1,500 N) times the distance (1 m) equals 1,500 J of work. Look at the figure. Suppose you use a 5-m-long ramp to move the box into the truck. The amount of work you need to do is still 1,500 J of work. But, the distance over which you apply the force is now 5 m. When you divide both sides of the work equation by distance, you have an equation for finding force.

\[
\text{Force} = \frac{\text{work (joules)}}{\text{distance (meters)}}
\]

\[
\text{Force} = \frac{1,500 \text{ J}}{5 \text{ m}} = 300 \text{ N}
\]

When you use the ramp, you need to apply a force of only 300 N. A force of 300 N is much less than a force of 1,500 N. With the ramp, you apply the force over a distance that is five times longer. So, the force is five times less.

The mechanical advantage of an inclined plane is the length of the inclined plane divided by its height. In this example, the ramp has a mechanical advantage of 5.

What is a wedge?

A **wedge** is an inclined plane that moves. A wedge can have one or two sloping sides. A knife is an example of a wedge. An axe and certain kinds of doorstops also are wedges. The mechanical advantage of a wedge increases as the wedge becomes longer and thinner.
Are there wedges in your body?
You have wedges in your body. Think of biting into an apple. The bite marks on the apple show that your front teeth are wedge-shaped. A wedge changes the direction of the applied force. The downward force of your bite is changed into a sideways force. The sideways force pushes the skin of the apple apart.

Is a screw an inclined plane?
The screw is another form of inclined plane. A **screw** is an inclined plane wrapped around a cylinder or post. The inclined plane on a screw forms the threads of the screw. A screw changes the direction of the applied force. The applied force pulls the screw into the material. Friction between the threads and the material holds the screw tightly in place. The mechanical advantage of the screw is the length of the inclined plane wrapped around the screw divided by the length of the screw. The more tightly wrapped the threads are, the easier it is to turn the screw.

Lever
A **lever** is any rigid rod or plank that pivots, or rotates, around a point. The **fulcrum** is the point that the lever pivots around. You can find the mechanical advantage of a lever by dividing the distance from the input force to the fulcrum by the distance from the fulcrum to the output force. This is shown in the figure below.

![Diagram of a lever with input force, fulcrum, and output force showing mechanical advantage calculations.]

The fulcrum of a lever can be in different positions. When the fulcrum is closer to the output force than the input force, the mechanical advantage is greater than 1. Scissors, a wheelbarrow, and a baseball bat are all levers.

---

**Picture This**

3. **Calculate** The distance from the input force to the fulcrum is 60 cm. The distance from the fulcrum to the output force is 20 cm. What is the mechanical advantage of this lever? Show your work.

---

**SC.C.2.3.4**

2. **Explain** What holds a screw into an object?

---

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5. Calculate

A wheel has a diameter of 15 cm. The axle has a diameter of 3 cm. What is the mechanical advantage of the wheel and axle? Show your work.

Wheel and Axle

Imagine a doorknob the size of a pencil. Would it be easy to turn? No, it would be hard to turn. A doorknob is a simple machine that makes opening a door easier. A doorknob is a wheel and axle. A wheel and axle is two circular objects of different diameters attached so that they rotate together. The larger object is the wheel and the smaller object is the axle.

If the input force is applied to the wheel, the output force is exerted by the axle. In this case, the mechanical advantage is equal to the diameter of the wheel divided by the diameter of the axle. The handle on the water faucet in the figure below is a wheel and axle. The faucet handle has a large diameter and is the wheel. The axle is the shaft the handle is attached to.

How are wheel and axles used?

In some wheel and axles, the input force turns the wheel. The wheel turns the axle. The turning axle exerts the output force. The mechanical advantage is greater than 1 because the wheel is bigger than the axle. This means the output force is greater than the input force. A doorknob, a steering wheel, and a screwdriver are examples of this type of wheel and axle.

In other wheel and axles, the input force is applied to turn the axle and the output force is exerted by the wheel. The mechanical advantage is less than 1. The output force is less than the input force. A fan and a Ferris wheel are examples of this type of wheel and axle.
**Pulley**

To raise a sail, a sailor pulls down on a rope. The rope uses a simple machine called a pulley to change the direction of the force used. A **pulley** is a grooved wheel with a rope or cable wrapped over it.

**What is a fixed pulley?**

Think about the pulley on a sail. The pulley is attached to something above your head. This kind of pulley is called a fixed pulley. When you pull down on the rope, the sail is pulled up. Look at the figure of the fixed pulley below. A fixed pulley does not change the force you apply. It also does not change the distance over which you apply a force. A fixed pulley does change the direction in which you apply your force. The mechanical advantage of a fixed pulley is 1.

**What is a movable pulley?**

You can also attach a pulley to the object you need to lift. This is called a movable pulley. A movable pulley lets you apply a smaller force to lift the object. The mechanical advantage of a movable pulley is always 2. The middle pulley in the figure below is a movable pulley.

You often will see movable and fixed pulleys used together. This is called a pulley system. The mechanical advantage of a pulley system is equal to the number of sections of rope pulling up on the object. The mechanical advantage for the pulley system in the figure is 3.

---

**Picture This**

6. **Explain** How does a movable pulley change the input force?

---

A fixed pulley changes the direction of the input force.

A movable pulley multiplies the input force.

A pulley system uses more than one pulley to increase the mechanical advantage.
1. Review the terms and their definitions in the Mini Glossary. Write a sentence describing how a screw and a wedge are related.

________________________________________________________________________

________________________________________________________________________

2. Match each simple machine with the correct example. Write the letter of each simple machine in Column 2 on the line in front of the example it is or uses in Column 1.

<table>
<thead>
<tr>
<th>Column 1</th>
<th>Column 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>_____ 1. tooth</td>
<td>a. inclined plane</td>
</tr>
<tr>
<td>_____ 2. doorknob</td>
<td>b. wheel and axle</td>
</tr>
<tr>
<td>_____ 3. threads of a lightbulb</td>
<td>c. wedge</td>
</tr>
<tr>
<td>_____ 4. wheelbarrow</td>
<td>d. screw</td>
</tr>
<tr>
<td>_____ 5. ramp</td>
<td>e. pulley</td>
</tr>
<tr>
<td>_____ 6. flagpole</td>
<td>f. lever</td>
</tr>
</tbody>
</table>

3. What would be a good way to teach an elementary science class about simple machines?

________________________________________________________________________

________________________________________________________________________
Before You Read
What does the phrase “She has a lot of energy” mean to you?

Read to Learn

The Nature of Energy

Energy is the ability to do work. An object that has energy can make things happen or make things change.

Look around you and notice the changes that are happening. Sunshine might be warming your desk. Maybe you can see the wind moving the leaves on a tree.

When is energy noticed?
You have a lot of energy. So does everything around you. But you only notice this energy when a change takes place. When a change happens, energy is transferred, or moved, from one object to another. Energy from sunlight transfers to the spot on the desktop and makes it warm. Energy from the wind is transferred to the leaves. All objects, including desktops and leaves, have energy.

Kinetic Energy

When an object is moving, it can do work and cause change. Suppose a bowling ball rolls down the alley and knocks down some bowling pins. A change happens when the pins fall over. The bowling ball causes this change. Because energy is the ability to do work or cause change, the bowling ball has energy. The energy in the moving ball makes the pins fall. The energy an object has because of its motion is kinetic energy. So as a bowling ball moves, it has kinetic energy. If an object is not moving, it does not have kinetic energy.
How are kinetic energy and speed related?

What would happen to the bowling pins if the bowling ball rolls faster? More of the pins might fall down or they might move farther. A faster bowling ball causes more change to happen than a slower bowling ball. The faster the bowling ball goes, the more kinetic energy it has. This is true for all moving objects. Kinetic energy increases as the speed of an object increases.

How are kinetic energy and mass related?

Suppose you roll a volleyball down the alley at the same speed as a bowling ball. The volleyball will not move the pins as far as the bowling ball will.

The volleyball has less kinetic energy than the bowling ball because it has less mass. Kinetic energy increases as the mass of an object increases.

Potential Energy

An object has energy even if it is not moving. Look at the vase on top of the bookcase in the figure below. The vase does not have any kinetic energy because it is not moving.

When the vase is sitting on the shelf, however, it has potential (puh TEN chul) energy. Potential energy is the energy stored in an object because of its position. The position of the vase is its height above the floor. If the vase falls, the potential energy will be transformed, or changed, from one form to another. It will be transformed into kinetic energy. A vase has more potential energy if it is higher above the floor. Potential energy also depends on mass. The more mass an object has, the more potential energy it has.

All objects on Earth’s surface have stored potential energy, called gravitational potential energy. The higher above Earth’s surface an object is, the more gravitational potential energy it has.

Picture This

1. Determine Which vase on the shelves has the most potential energy?
Forms of Energy

Food, sunlight, and wind have different forms of energy. The energy in food is different from the energy in wind. Most forms of energy are types of kinetic energy or potential energy. All forms of energy are measured using the same unit of measurement—the joule (J).

What is thermal energy?

When you heat a pot of water, energy from the burner is transferred to the water. This causes the energy of the water to increase. The energy transferred to the water is thermal energy.

What is thermal energy? All materials are made of extremely small particles—atoms and molecules. These particles are in constant motion, bumping into each other and moving in all directions. This motion is called random motion. Thermal energy is the sum of the kinetic and potential energy of the particles in an object due to their random motion. All materials have thermal energy because their particles are always moving.

How is thermal energy related to temperature?

Heating water on the stove causes the temperature of the water to increase. The temperature of a material is not the same as the amount of thermal energy in the material. Temperature is related to the kinetic energy of a material’s particles due to their random motion. Temperature is a measure of the average kinetic energy of the particles in a material. When the particles move faster, the material’s temperature increases. When the particles move more slowly, the material’s temperature decreases.

Thermal energy also increases when the particles in matter have more kinetic energy. The temperature of a material increases when the thermal energy of the material increases.

What is chemical energy?

Chemical energy is the energy stored in chemical bonds. Chemical energy is a type of potential energy. Some of this energy is released when chemicals are broken apart and new chemicals are formed.

Food has chemical energy that your body uses. Food, such as sugar, has chemicals compounds whose molecules can be broken down in your body to release energy.

3. Explain Where does your body get the chemical energy that it uses?
What is radiant energy?

Earth is warmed by the energy it gets from the Sun. The Sun’s energy travels almost 150 million km through space before it reaches Earth. The sunlight that reaches Earth is radiant energy. Radiant energy is energy that travels in the form of waves. Sunlight travels to Earth as electromagnetic waves. Radio waves, microwaves, and light are also electromagnetic waves which transfer radiant energy from one place to another. In a microwave oven, radiant energy is transferred by microwaves to the food and is changed into thermal energy that makes food hotter.

What is electrical energy?

Electrical energy is used in many ways every day. Electrical energy is the energy carried by an electric current. Electrical lighting uses electrical energy. Look around at all the devices that use electrical energy.

All electrical devices change electrical energy to other types of energy, such as thermal energy (a toaster) or radiant energy (a lightbulb). The electrical energy that runs these devices comes from the electric current that flows in these appliances when they are being used. Some devices, such as portable CD players, may use batteries that provide the electrical energy the device uses.

What is nuclear energy?

At the center of every atom is a nucleus. Nuclear energy is the energy that is stored in the nucleus of an atom. Nuclear energy is released when changes occur in an atom’s nucleus. In the Sun, the nuclei of atoms are joined together, or fused, in a process called nuclear fusion that releases a huge amount of energy.

Nuclear power plants use the energy stored in the nucleus of an atom to make electricity. In a nuclear power plant, the nuclei of uranium atoms are split apart to release energy. This energy is used to produce electrical energy.
After You Read

Mini Glossary

chemical energy: energy stored in chemical bonds; a type of potential energy
electrical energy: energy carried by an electric current
energy: the ability to do work
kinetic energy: energy an object has because of its motion

potential energy: the energy stored in an object because of its position
radiant energy: energy that travels in the form of waves
thermal energy: the sum of kinetic and potential energy of the particles in an object due to their random motion

nuclear energy: energy stored in the nucleus of an atom

1. Read the key terms and definitions in the Mini Glossary above. On the lines below, explain the difference between potential energy and kinetic energy.

2. Match the forms of energy with the correct examples. Write the letter the example in Column 2 on the line in front of the form of energy it matches in Column 1.

<table>
<thead>
<tr>
<th>Column 1</th>
<th>Column 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. potential energy</td>
<td>a. the energy that a television uses</td>
</tr>
<tr>
<td>2. kinetic energy</td>
<td>b. the energy a lamp gives off</td>
</tr>
<tr>
<td>3. electrical energy</td>
<td>c. the energy in food</td>
</tr>
<tr>
<td>4. thermal energy</td>
<td>d. the energy in a ball rolling</td>
</tr>
<tr>
<td>5. chemical energy</td>
<td>e. the energy of a book sitting on a shelf</td>
</tr>
<tr>
<td>6. nuclear energy</td>
<td>f. the energy in a cup of hot tea</td>
</tr>
<tr>
<td>7. radiant energy</td>
<td>g. the energy in an atom’s nucleus</td>
</tr>
</tbody>
</table>

3. You were asked to highlight the different forms of energy in this section. What do you think would be another way to help you remember the different forms of energy?

ScienceOnline Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about energy.
What You’ll Learn

■ to apply the law of conservation of energy
■ how energy changes form
■ how electric power plants make energy

Identify Main Ideas

Highlight the main point in each paragraph as you read this section. Study the main points, then state each point in your own words.

Before You Read

Explain how you used one kind of energy today.

Read to Learn

Changing Forms of Energy

Energy can have different forms such as chemical, thermal, radiant, and electrical. Any time energy is being used, it is changed from one form to another form. These changes from one form of energy to another are called energy transformations. Work is done and changes occur when energy changes form.

How can you track energy transformations?

When a mountain biker peddles his legs transform chemical energy into kinetic energy. The kinetic energy of his legs is transferred to the bicycle as he pedals. As he moves up the hill, some of this energy is transformed into potential energy. The biker’s body becomes warmer as chemical energy is transformed into thermal energy by his muscles. The parts of the bicycle are warmer because kinetic energy is transferred to the bike and transformed into thermal energy by friction. Thermal energy is always produced during an energy transformation.

The Law of Conservation of Energy

The law of conservation of energy states that energy is never created or destroyed. The only thing that changes is the form of the energy. In any energy transformation, the total amount of energy before the transformation is the same as the total amount of energy after the after transformation.
Changing Kinetic and Potential Energy

The figure below shows the energy transformations that occur when you toss a ball into the air. As the ball leaves your hand, most of its energy is kinetic. As it rises, it loses kinetic energy. The kinetic energy is changed into potential energy. The amount of kinetic energy that it loses equals the amount of potential energy that it gains. The total amount of energy stays the same. The **mechanical energy** of an object is the sum of the object’s potential and kinetic energy. The mechanical energy of the thrown ball stays the same as the ball rises and falls.

Friction can cause the mechanical energy of an object to decrease. When you slide a book across a table, friction changes the book’s kinetic energy into thermal energy.

Using Energy

Energy changes form all the time all around you. Many machines transform energy from one kind to another. For example, an automobile engine transforms the chemical energy in gasoline into kinetic energy. Some of the chemical energy also is transformed into thermal energy, which makes the engine hot. Some of this thermal energy also spreads out into the air.

**How efficient are energy changes?**

The thermal energy that spreads out from the car is no longer useful energy. It does not help the car move, so it is wasted. In energy transformations, some energy is always changed into thermal energy that is no longer useful. So, in any energy transformation, some useful energy is produced plus some waste thermal energy is produced. This means that no energy transformation is 100 percent efficient in converting a form of energy into useful energy.

1. **Draw Conclusions**

   At what point does the ball have the most potential energy?
   
   a. when it reaches its highest point  
   b. when it leaves your hand  
   c. just before you catch the ball  
   d. halfway up in the air

2. **Trace** the changes from kinetic energy to potential energy and back again as the ball is tossed in the air.

3. **Identify** What is waste thermal energy?
How is chemical energy used?

Chemical energy can be transformed into kinetic energy inside your body. This happens in muscle cells. Chemical reactions take place and cause certain molecules to change shape. Your muscles contract and a part of your body moves.

The energy stored in food originally came from the Sun. Plants use photosynthesis to change the radiant energy in sunlight into chemical compounds. Some of these compounds are eaten by humans and other organisms as food.

How is thermal energy used?

All forms of energy can be transformed into thermal energy. When something burns, chemical energy is transformed into thermal energy. Electrical energy is transformed into thermal energy when an electrical current flows in a wire. Thermal energy is used to heat buildings and keep you warm.

How does thermal energy move?

Thermal energy moves from a warmer material to a colder material and then spreads out. Thermal energy can move in three ways. It can move by conduction, which happens when the particles in a material transfer energy by colliding with each other. It can move by convection, as when particles in a liquid or gas move from a warmer place to a cooler place. Thermal energy can also move by radiation, which transfers energy as waves.

How is radiant energy used?

Visible light provides the radiant energy that allows you to see. Radiant energy from the Sun can be converted into electrical energy. X rays and gamma rays are forms of radiant energy used in medicine. These rays help doctors make images of the inside of the body and so help them treat disease.

How is electrical energy used?

A huge amount of electrical energy is used every day in the United States. Some of this electrical energy is changed into radiant energy to provide light. Some is changed into thermal energy to heat buildings or water. Electric motors convert electrical energy into kinetic energy by making objects, such as the blades of a fan, move.
Generating Electrical Energy

Where does the electrical energy in an electrical outlet come from? It must be made all the time by power plants. In fossil fuel power plants, coal, oil, or natural gas is burned to boil water. Steam from the boiling water rushes through a turbine, a machine that has a set of fan blades that are close together. The steam pushes on the blades and turns the turbine. The turbine rotates a shaft in the generator. A generator is a device that transforms kinetic energy into electrical energy. All power plants, like the one in the figure below, work in a similar way—they use energy to turn a generator.

Organized Energy and Disorganized Energy

In energy transformations, the amount of useful energy always decreases. How is useful energy different from energy that cannot be used? Useful energy is energy that is organized in a certain way and does not spread out. The electrical energy in a battery is organized energy. Energy that can’t be used is disorganized, and it spreads out to where it is not needed. The extra heat produced by a car engine spreads out into the air and is not used to help move the car.

Useful energy is organized energy. Whenever an energy transformation occurs, some organized energy becomes disorganized energy. This means that the total amount of disorganized energy in the universe is always increasing.

Why does disorder always increase?

Just as energy becomes more disorganized over time, matter also becomes more disorganized and disordered. For example, when a drop of food coloring is placed into a glass of water, the food coloring becomes more disordered as it spreads. In fact, events that occur in the universe always cause disorder to increase.
1. Review the terms and their definitions in the Mini Glossary. Explain how a generator makes electrical energy.

2. Fill in the blanks to tell what type of energy is being transformed as a biker rides a bicycle.

A biker eats food. Food contains ___________ energy.

When a biker’s muscles move, the energy in food is turned into ___________ energy.

The biker’s working muscles make him hot. Some of the energy in his muscles is turned into ___________ energy.

The biker’s muscles turn the pedals on the bike. This makes the bike move. So his muscle energy is transformed into ___________ energy in the bike.

Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about energy transformations.
Before You Read

You must plug in most appliances before they will work. Where does the energy in an electrical outlet come from?

What You’ll Learn

■ what renewable, nonrenewable, and alternative resources are
■ about the advantages and disadvantages of using different energy sources

Read to Learn

Energy Only Changes Form

Energy is used every day to provide light and heat to homes, schools, and workplaces. The law of conservation of energy states that energy cannot be created or destroyed. It only can change form. If a car or refrigerator cannot create the energy they use, where does the energy come from?

Energy Resources

Energy must come from the natural world. The surface of Earth gets energy from two sources—the Sun and radioactive atoms in Earth’s interior, as shown in the figure below. Earth gets far more energy from the Sun than is made in Earth’s interior. Almost all the energy you use today can be traced to the Sun. Even the gasoline used to power a car can be traced to the Sun.

Identify Details As you read this section, highlight the text each time you read about an energy source.

Organize Information

Make the following Foldable to organize information about the fossil fuels, nuclear energy, hydroelectric energy, and alternative sources of energy.
Fossil Fuels

Fossil fuels are coal, oil, and natural gas. Oil and natural gas were made from the remains of microscopic organisms that lived in Earth’s oceans millions of years ago. Heat and pressure slowly turned these organisms into oil and natural gas. Coal was formed in a similar way.

As shown in the figures below, coal was made from the remains of plants that once lived on land. Through photosynthesis (foh toh SIHN thuh sus), ancient plants transformed the radiant energy from sunlight into chemical energy. The chemical energy is stored in molecules. Over time, heat and pressure changed these molecules into fossil fuel. Chemical energy stored in fossil fuels is released when the fossil fuels are burned.

How are fossil fuels used?

Most of the energy you use comes from fossil fuels. Fossil fuels are used to make electricity, to heat homes, to power cars and trucks. It takes millions of years to replace each drop of gasoline and each lump of coal that is burned. This means that the amount of fossil fuels on Earth will keep decreasing as it is used. Fossil fuels are nonrenewable resources. A nonrenewable resource is an energy source that is used up much faster than it can be replaced.

What are some disadvantages of fossil fuels?

Burning fossil fuels for energy produces chemical compounds that cause pollution. Each year billions of kilograms of air pollutants are produced by burning fossil fuels. These pollutants cause respiratory illnesses and acid rain. The carbon dioxide gas that forms when fossil fuels are burned might cause Earth’s climate to warm.
Nuclear Energy

Can you imagine 1 kg of fuel that releases as much energy as almost 3 million liters of gas? What could supply so much energy? The answer is in the nuclei of uranium atoms. When these nuclei break apart, they release huge amounts of nuclear energy. This energy is used to make electricity by heating water to produce steam that spins an electric generator. The generator produces electricity. The figure below shows this process.

**What are the advantages of nuclear energy?**

Generating electricity by using nuclear energy helps make the supply of fossil fuels last longer. Nuclear power plants also produce almost no air pollution. In one year, a typical nuclear power plant makes enough energy to supply 600,000 homes with power. To do this, it produces only 1 m³ of waste.

**What are the disadvantages of nuclear energy?**

One disadvantage of nuclear energy is that uranium is a nonrenewable resource. It comes from Earth’s crust. Another disadvantage is that nuclear waste is radioactive and can be dangerous to living things. Some of the materials in nuclear waste will remain radioactive for many thousands of years. This means that nuclear waste must be carefully and safely stored so no radioactivity will be released into the environment for a long time.
How can nuclear waste be stored?

One way to store nuclear waste is to seal it in a ceramic material that is put in protective containers. Then the containers are buried far underground. The place to bury them has to be chosen carefully. It cannot be near underground water supplies. It also has to be safe from earthquakes and other natural disasters. Earthquakes and other natural disasters could cause the radioactive material to leak.

Hydroelectricity

The potential energy of water trapped behind a dam can be transformed into electrical energy. Energy made this way is called hydroelectricity. This process is shown in the figure below. About 20 percent of the world’s electrical energy comes from water. Hydroelectricity is the largest renewable source of energy. A **renewable resource** is an energy source that is replaced continually. As long as rivers flow, hydroelectric power plants can make electricity.

Hydroelectricity makes little pollution. This is an advantage over some other sources of electricity. However, the production of hydroelectricity does have a major disadvantage. Dams upset the life cycle of some animals that live in the water. River dams have caused problems for salmon in the Northwest. Salmon return to the spot upriver where they were hatched to lay their eggs. Many salmon cannot reach these places because of dams. There are plans to remove some dams and build fish ladders to help fish go around other dams.
Alternative Sources of Energy

There are many ways to make electrical energy. Each has disadvantages that can affect the environment and humans. Alternative resources are being researched. Alternative resources are new sources of energy that are safer and less harmful to the environment. Alternative resources include solar energy, wind, and geothermal energy.

Solar Energy

The Sun is an inexhaustible resource. An inexhaustible resource is an energy source that cannot be used up by humans. The amount of solar energy that hits the United States in one day is more than the total amount of energy used by the country in one year. But less than 0.1 percent of the energy used in the United States comes directly from solar energy. One reason is that solar energy is more expensive to use than fossil fuels. However, as the supply of fossil fuels decreases, it might become more expensive to find and mine fossil fuels. Then, it might be cheaper to use solar energy or other energy sources to make electricity.

How is the Sun’s energy collected?

Two types of collectors take in the Sun’s rays. Have you ever seen large rectangular panels on the roofs of houses or buildings? These are collectors for solar energy.

Thermal Collector If the panels had pipes coming out of them, they were thermal collectors. A thermal collector uses a black surface to absorb the Sun’s radiant energy. Black absorbs more radiant energy than any other color. The thermal collector uses the Sun’s radiant energy to heat water. The water can be heated to about 70°C. The hot water can be pumped through a house to provide heat. It can also be used for washing and bathing.

Photovoltaic If the panel has no pipes, it is a photovoltaic (foh toh vohl TAY ihk) collector. A photovoltaic is a device that transforms radiant energy directly into electrical energy. Photovoltaics are used in calculators and satellites. They also are used on the International Space Station.

Reading Check

5. Identify What type of resource is the Sun?
Geothermal Energy

Imagine you could go to the center of Earth, about 6,400 km below the surface. As you went deeper and deeper, the temperature would increase. After going only about 3 km, the temperature would be warm enough to boil water. At a depth of 100 km, the temperature could be over 900°C.

The heat generated inside Earth is called geothermal energy. Some geothermal energy is made when unstable radioactive atoms inside Earth decay. This transforms nuclear energy into thermal energy. At some places deep within Earth, the temperature is hot enough to melt rock. Melted, or molten, rock is called magma. Magma rises up close to the surface through cracks in Earth’s crust. Magma reaches the surface when a volcano erupts. In other places, magma gets close to the surface and heats the rock around it.

What are geothermal reservoirs?

In some places, magma is very close to Earth’s surface. Rainwater and water from melted snow can seep down to the magma through the cracks and openings in Earth’s surface. The magma heats the water and it can become steam. The hot water and steam can be trapped under high pressure in cracks and pockets. These are called geothermal reservoirs. Geothermal reservoirs are sometimes close enough to the surface to make hot springs and geysers.
How is geothermal power made?
Wells can be drilled to reach geothermal reservoirs in places where the reservoirs are less than several kilometers deep. Hot water and steam from geothermal energy is used by geothermal power plants to make electricity.

The figure above shows how geothermal reservoirs make electricity. Geothermal power is an inexhaustible resource. But geothermal power plants can be built only where geothermal reservoirs are close to Earth’s surface, such as in the western United States.

How are heat pumps used?
Geothermal heat helps keep the temperature of the ground at a depth of several meters at about 10° to 20°C. This constant temperature can be used to heat or cool buildings by using a heat pump.
During the summer, the air is warmer than the ground below. A heat pump sends warm water from the building through the cooler ground. The water cools and then is pumped back to the building to absorb heat. In the winter, the air is cooler than the ground below. Then, the cool water absorbs heat from the ground and releases it from the heat pump into the building.
Energy from the Oceans

The ocean is constantly moving. If you have been to the seashore, you have seen the waves roll in. If you spent the day at the beach, you may have also seen the level of the ocean rise and fall. The rise and fall in the ocean level is called a tide. The movement of the ocean is an inexhaustible source of mechanical energy. Mechanical energy can be transformed into electric energy. Several electric power plants that use the motion in ocean waves, or tidal energy, have been built.

How much change in water level is needed?

A high tide and a low tide each happen about twice a day. In most places, the level of the ocean changes by only a few meters. In some places, it changes by much more. In the Bay of Fundy in Eastern Canada, the ocean level changes by 16 m between high tide and low tide. Almost 14 trillion kg of water move into or out of the bay between high tide and low tide. This tidal energy makes enough electricity to power about 12,000 homes.

How is tidal energy used to make electricity?

The figures below show how the power plant that has been built along the Bay of Fundy works. The first figure shows that as the tide rises, water flows through a turbine. The turbine causes a generator to spin, which makes electricity. The water is then trapped behind a dam. The second figure shows that when the tide goes out, the trapped water is released. It again flows through the turbine making the generator spin. This makes more electricity. Electric power is made each day for about 10 hours.

Tidal energy is a clean, inexhaustible resource. But only a few places have a large enough difference between high and low tide to build an electric power plant.

Picture This

11. Highlight Use a highlighter to trace the flow of water into and out of the tidal power plant.
Wind

Wind is another inexhaustible supply of energy. Modern windmills, like the ones in the figure below, transform the kinetic energy of the wind into electrical energy. Electrical energy is made when wind spins the propeller. The propeller is connected to a generator, which makes electricity. These windmills produce almost no pollution. But windmills do make noise. You also need a large area of land on which to place a lot of windmills. Also, studies have shown that birds sometimes are killed by windmills.

Conserving Energy

Fossil fuels are a valuable resource. They are burned to provide energy. Oil and coal can be used to make plastics and other materials. To make the supply of fossil fuels last longer, people need to use less energy. Using less energy is called conserving energy.

You can save money by conserving energy. You should turn off appliances like televisions when you are not using them to conserve energy. Keep doors and windows closed tightly when it is hot or cold outside. This will keep heat from leaking out of or into your house. If cars were used less or were made more efficient, they would use less gas and oil, and therefore less energy. You also help conserve energy when you recycle aluminum cans and glass.

Picture This

12. Infer Why do you think the windmills shown in the figure are placed on top of mountains instead of between hills or mountains?

13. Describe What is another way you can conserve energy?
1. Review the terms and their definitions in the Mini Glossary. What is the difference between a renewable resource and a nonrenewable resource?

2. Write as many examples of renewable, nonrenewable, and inexhaustible resources in the chart as you can.

<table>
<thead>
<tr>
<th>Renewable Resources</th>
<th>Nonrenewable Resources</th>
<th>Inexhaustible Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. You were asked to highlight the text each time you read about an energy source. How did this help you learn about energy sources?
Waves, Sound, and Light

section 1 Waves

Benchmarks—SC.A.2.3.1: The student describes and compares the properties of particles and waves; SC.B.1.3.6 Annually Assessed: The student knows the properties of waves; S.C.C.1.3.2 Annually Assessed: The student knows that vibrations in materials set up wave disturbances that spread away from the source.
Also covers: SC.H.1.3.4; SC.H.1.3.5; SC.H.2.3.1

Before You Read

Have you ever seen a crowd of people do a wave at a sporting event? Describe what people doing a wave looks like.

What You’ll Learn

- how waves carry energy
- the differences among types of waves
- the properties of waves
- what happens during the reflection, refraction, and diffraction of waves

Read to Learn

What are waves?

When you float in the ocean, waves move past you. The waves move you up and down. Waves can be so strong they knock you over or they gently rock you. You know there are waves in the water because you can see them and feel them. Did you know there are other types of waves? Sound waves make it possible for you to hear. Light waves make it possible for you to see. Other waves carry signals to radios and televisions. Waves even cause the damage from earthquakes.

What do waves transfer?

A wave is a disturbance that moves through matter or through empty space. Waves do not transfer matter. They transfer energy from one place to another.

Imagine throwing a stone in a pond. When the stone hits the water, it causes a disturbance. It makes waves. The waves look like they carry water with them as they move. But that is not what really happens. When the stone hits the water, the energy is transferred to water molecules nearby. These water molecules move energy to other water molecules. The energy is passed from water molecule to water molecule. You see this movement of energy as the waves spread out farther and farther. The waves move away, transferring energy. But, the water molecules barely move from their places.

 Locate Information
Underline every heading in this section that asks a question. Then, use a different color to highlight the answers to those questions.

Build Vocabulary

Make the Foldable shown below. Use it to define some terms in this section.

Foldables

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Types of Waves

Waves usually are produced by an object moving back and forth, or vibrating. Waves carry the energy of the vibrating object. This energy can spread out from the vibrating object in different types of waves. One type of wave is a mechanical wave. Mechanical waves can travel only in matter and not through space. Another type of wave, an electromagnetic wave, can travel through matter or through empty space.

What are transverse waves?

What happens if you tie a rope to a door handle and shake the rope up and down? You have made a mechanical wave called a transverse wave, like the one in the figure below. A transverse wave causes the particles in matter to move back and forth at right angles to the direction that the wave is traveling.

Crests and Troughs

The points where the wave is highest are called crests. The points where the wave is lowest are called troughs. A series of crests and troughs forms a transverse wave. The crests and troughs move along the rope. But, the particles in the rope move only up and down.
What are compressional waves?
Imagine you and a friend are each holding an end of a spring. When you pull and push on your end of the spring, you make another kind of mechanical wave. It is called a compressional wave. A compressional wave makes the particles in matter move back and forth in the same direction the wave is traveling.

The figure below shows a compressional wave moving along a spring. The places where the coils are squeezed together are called compressions. The places where the coils are spread apart are called rarefactions (rare FAK shunz). The repeating compressions and rarefactions make a compressional wave. The compressions and rarefactions travel along the spring. But the coils move only back and forth.

What are electromagnetic waves?
Light, radio waves, and X rays are examples of electromagnetic waves. Just like waves on a rope, they are transverse waves. However, electromagnetic waves have electric and magnetic parts. These parts vibrate up and down at right angles to the direction the wave travels.

Properties of Waves
The properties of waves depend on the vibrations that produce them. The faster you shake the end of a rope up and down, the closer the crests and troughs will be. If you shake the end of a rope by moving it up and down a greater distance, the crests will become higher, and the troughs will become deeper. You changed the properties of the waves by changing the movement of the rope.
What is the wavelength of a wave?

**Wavelength** is the distance between any point on a wave and the nearest point just like it. The figure above on the left shows the wavelengths of a transverse wave. It is the distance from one crest to the next crest or from one trough to the next trough. The figure above on the right shows the wavelengths of a compressional wave. A wavelength of a compressional wave is the distance between two adjoining compressions or rarefactions. Wavelength is measured in units of meters (m).

What is the frequency of a wave?

The **frequency** of a wave is the number of wavelengths that pass by a point each second. The SI unit for frequency is hertz (Hz). One hertz equals one vibration per second or one wavelength passing a point in one second. If five wavelengths pass by a point in one second, the frequency of the wave would be 5 Hz. The unit Hz is the same as the unit 1/s.

What is amplitude and how is it measured on a transverse wave?

Suppose you shake the end of a rope by moving your hand up and down a large distance. You make a transverse wave with high crests and deep troughs. The wave you have made has a large amplitude. The **amplitude** of a wave is the greatest distance that matter moves as the wave passes.

The amplitude of a transverse wave is the distance from the top of the crest or the bottom of a trough to the rest position of the material. You can see this in the figure at the top of the next page. As the distance between crests and troughs increases, the amplitude of a transverse wave becomes larger.
How is amplitude measured on a compressional wave?
The amplitude of a compressional wave depends on how close together the material is at the compressions and rarefactions. Compressional waves with greater amplitude have compressions that are closer together. Their rarefactions are farther apart. Think about a spring. When you squeeze some parts of the spring together tightly, other parts of the spring spread apart more.

How are amplitude and energy of a wave related?
The vibrations that produce a wave transfer energy to the wave. The more energy a wave carries, the larger its amplitude. Think about making a transverse wave on a rope again. If you move your hand up very high then down very low, you transfer a lot of energy to the rope. You make a wave with a large amplitude. If you move your hand up and down only a little, you transfer a small amount of energy. You make a wave with a small amplitude.

What are seismic waves?
Waves that are formed in Earth’s crust during an earthquake are called seismic waves. Some of these waves are compressional. Others are transverse. The seismic waves that cause the most damage to buildings are a kind of rolling wave. These rolling waves are a combination of compressional and transverse waves. The larger the amplitude, the more energy these waves carry. Seismic waves with large amplitudes carry a great amount of energy. The larger the amplitude of a seismic wave, the more damage it causes as it moves along Earth’s surface.
How fast do waves travel?

The wavelength, frequency, and speed of a wave are related. The faster a wave travels, the more wavelengths pass you by each second. You can calculate the wavelength of a wave if the wave speed and frequency of the wave are known. Use the equation below.

\[ \text{wavelength (in m)} = \frac{\text{wave speed (in m/s)}}{\text{frequency (in Hz)}} \]

\[ \lambda = \frac{v}{f} \]

In this equation, \( v \) is the symbol for wave speed, and \( f \) is the symbol for frequency. The Greek letter lambda, \( \lambda \), is the symbol for wavelength.

Waves Can Change Direction

Waves do not always travel in a straight line. You see your reflection in the mirror because the mirror makes light waves change direction. Waves can bounce off a surface, or reflect. They can change direction, or refract. Waves also can bend around an object, or diffract.

How do waves reflect?

When waves reflect off a surface, they always obey the law of reflection. A line that makes a 90 degree angle with a surface is called the normal to the surface. The law of reflection states that the angle the incoming wave makes with the normal equals the angle the outgoing wave makes with the normal. The figure below shows the normal and the two angles made when a flashlight reflects off a surface.
What makes a wave change direction?

The speed of a wave depends on the properties of the material through which it travels. For example, a light wave travels faster through air than through water.

The figure below shows a light wave that travels through air and then through water. The wave does not travel in a straight line. It changes direction. When the wave moves from the air to the water, it slows down. Waves change direction when they slow down or when they speed up. When a light wave changes speed, it bends. **Refraction** is the change in direction of a wave when it changes its speed as it travels from one material to another.

What causes diffraction?

When waves hit an object they cannot go through, the waves bend around the object. **Diffraction** is the bending of waves around an object. Waves can diffract a small amount or a large amount. If the object is much larger than the wavelength, the wave diffracts only a small amount. If the wavelength is larger than the object, the wave diffracts a greater amount. As the wavelength gets larger compared to the object, the amount of diffraction increases.

How do waves compare to particles?

Waves are different from particles of matter. Particles have mass and take up space. Particles have a positive or negative electric charge. Waves do not have any of these properties. However, waves and particles are both in constant motion. Moving particles and waves both transfer energy from one place to another.
After You Read

Mini Glossary

**amplitude:** the greatest distance that matters move as a wave passes.

**diffraction:** the bending of waves around an object

**frequency:** the number of wavelengths that pass by a point in one second

**law of reflection:** the angle the incoming wave makes with the normal equals the angle the outgoing wave makes with the normal

**refraction:** the change in direction of a wave when it changes its speed as it travels from one material to another

**wave:** a disturbance that moves through matter or through empty space; carries energy, not matter

**wavelength:** the distance between one point on a wave and the nearest point that is moving with the same speed and direction

---

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that describes how frequency relates to wavelength.

---

2. Complete the table below to help you review what you have read about waves.

<table>
<thead>
<tr>
<th></th>
<th>Transverse Waves</th>
<th>Compressional Waves</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Motion of Particles</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Wavelength</strong></td>
<td>the distance between two crests or two troughs that are next to each other</td>
<td></td>
</tr>
<tr>
<td><strong>Frequency</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Amplitude</strong></td>
<td></td>
<td>depends on how close together the material is at the compression and rarefaction</td>
</tr>
</tbody>
</table>

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Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about waves.
Before You Read

Think about the sounds you hear everyday. On the lines below, write at least three words that describe sounds.

---

Read to Learn

Making Sound Waves

How does hitting the head of a drum produce sound waves? When you hit the head of a drum, you make it vibrate. The vibrations transfer energy to air particles near the drum head. This produces sound waves in the air. When the sound waves reach your ear, you hear the drum. Every sound you hear is made by something vibrating. For example, when you talk, tissues in your throat vibrate in different ways. These vibrations form sounds.

What type of wave are sound waves?

The sound waves produced when an object vibrates are compressional waves. When you hit the head of a drum, it vibrates. The air particles near the drum start to vibrate. When the drum head moves outward, it compresses the air particles nearby. The compressed particles form the compression in a compressional wave. When the drum head moves inward, it causes rarefactions in the nearby air particles. The inward and outward movement of the drum head makes the same pattern of compressions and rarefactions in the air particles. The particles of air vibrate with the same frequency as the frequency of vibrations in the drum head.

The energy carried by a sound wave is transferred by particles bumping into other particles. This means that sound waves can only travel through matter. They cannot travel through empty space.
The Speed of Sound

Sound waves travel at different speeds through different materials. Sound waves travel faster through solids and liquids. They travel slower through gases. The table below shows the speeds of sound waves traveling through a solid, a liquid, and a gas. Sound waves also travel faster in warmer materials than they do in cooler ones.

<table>
<thead>
<tr>
<th>Material</th>
<th>Speed (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass</td>
<td>5,640</td>
</tr>
<tr>
<td>Water (25°C)</td>
<td>1,493</td>
</tr>
<tr>
<td>Air (20°C)</td>
<td>343</td>
</tr>
</tbody>
</table>

The Loudness of Sound

What makes one sound loud and another soft? The amount of energy carried by the sound waves makes the sound loud or soft. Loud sounds have more energy than soft sounds.

What is the intensity of a sound?

The intensity of a sound is the amount of energy a wave carries past a unit area each second. The intensity of a sound decreases with distance.

When you clap your hands, sound waves spread out as they move away from you. The energy the waves carry also spreads out. Someone standing close to you hears an intense sound. Someone standing farther away hears a less intense sound. The intensity of sound waves is related to the amplitude. Sound waves with greater amplitude also have greater intensity.

How is the intensity of a sound measured?

The intensity of a sound wave is measured in units called decibels (dB). The softest sound a person can hear has an intensity of 0 dB. Normal speech has an intensity of about 50 dB. Sounds with intensities of around 120 dB or higher are painful to people.

Loudness is how humans hear the intensity of sound waves. Each increase of 10 dB in intensity multiplies the energy of the sound wave ten times. To most people, a sound that has an intensity 10 dB higher than another sound is twice as loud. An intensity increase of 20 dB is an increase in energy of 100 times. The loudness of the sound increases by about four times.
**Frequency and Pitch**

**Frequency** The frequency of sound waves depends on the frequency of the vibrations that produce the sound. Recall that wave frequency is the number of vibrations per second. Frequency is measured in hertz (Hz).

If you play an instrument or sing, you know about notes and the musical scale. On the musical scale, the note C has a frequency of 262 Hz. The note E has a frequency of 330 Hz. People usually are able to hear sounds with frequencies between about 20 Hz and 20,000 Hz.

**Pitch** How can you describe the frequency of a sound? **Pitch** describes how humans hear the frequency of a sound. Sounds with low frequencies have low pitch. Sounds with high frequencies have high pitch. The sounds from a tuba have a low pitch. The sounds from a flute have a high pitch.

**Hearing and the Ear**

Your ear is an organ that allows you to hear many different sounds. There is more to your ear than the part you can see. The ear is divided into three parts—the outer ear, the middle ear, and the inner ear.

**The Outer Ear** The outer ear collects sound waves. It is made up of the part you can see and also the ear canal. The part you see is shaped somewhat like a funnel. This shape helps collect the sound waves and send them into the ear canal.

**The Middle Ear** The middle ear makes sounds louder. It is made of the eardrum and three tiny bones. The bones are called the hammer, the anvil, and the stirrup. When sound waves move down the ear canal, they press against the eardrum and make it vibrate. The vibrations move from the eardrum to the three small bones. These bones make the vibrations stronger.

**The Inner Ear** The inner ear contains the cochlea (KO klee uh). The cochlea is shaped like a small snail. It is filled with fluid and lined with tiny hair-like cells. Vibrations move from the stirrup bone in the middle ear to the hair cells in the cochlea. The movement of the hair cells produces signals that travel to the brain. The brain understands these signals as sounds.

**Think it Over**

1. **3. Explain** What kind of frequency does a sound with a low pitch have?
   
   ________________
   
   ________________

2. **4. Think Critically** Think about how fast sound moves through different materials. What is the advantage of the cochlea being filled with fluid instead of air?
   
   ________________
   
   ________________
How do the parts work together?
The figure below shows the different parts of the ear. The outer ear is the sound collector. The middle ear is the sound amplifier. It makes the sounds louder. The inner ear is the sound interpreter. The inner ear sends signals to the brain so you hear sounds.

The Reflection of Sound

Have you ever heard an echo? Echoes are sounds reflected off surfaces. A reverberation (ree ver buh RAY shun) is a repeated echo. Concert halls and movie theaters try to lessen reverberation. They have soft materials on the ceilings and walls to keep sound from reverberating too much. The soft materials absorb the energy of the sound waves.

Echolocation

The reflection of sound can be used to locate objects. Echolocation is the process of finding objects by bouncing sounds off them. Bats, dolphins, and other animals give off high-frequency sound waves. The waves reflect off of objects and back to the animal. The animal can locate and identify objects from the reflected waves.

Medicine

Doctors also use reflected sound waves in medicine. Ultrasonic waves can be reflected off of body parts. Computers use the waves to produce pictures of the inside of the body.
After You Read

Mini Glossary

intensity: the amount of energy a sound wave carries past a certain area each second

loudness: how humans hear the intensity of a sound

pitch: describes how humans hear the frequency of a sound

1. Review the terms and their definitions in the Mini Glossary. Write a sentence using one of the terms above.

___________________________________________________________________________________________

___________________________________________________________________________________________

2. Complete the flow chart to show the path taken by a sound wave from the time it enters your ear until you hear the sound.

   Outer ear → [ ] → [ ] → [ ] → Hammer

   [ ] ← Brain ← [ ] ← [ ] ← [ ] ← [ ] ← [ ] ← [ ] ← [ ] ← [ ]

3. How can you use the quiz questions you created to help you study for a test about sound waves?

___________________________________________________________________________________________

___________________________________________________________________________________________

Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about sound waves.

End of Section

Reading Essentials 105
Waves, Sound, and Light

section 3 Light

What You’ll Learn
- the properties of light waves
- about the electromagnetic spectrum
- how humans see

Before You Read

What would life be like without light? On the lines below, describe two things for which you need light.

Read to Learn

Waves in Empty Space

You see the Moon when you look up in the sky because of light waves. Light is an electromagnetic wave that can be seen by the human eye. Like sound waves and waves in water, light waves can travel through matter. But, light waves can do something these other waves can’t. Light waves can travel through space that contains almost no matter. Electromagnetic waves are waves that can travel through matter and through empty space.

How fast can light travel?

Have you ever seen a movie in which spaceships travel faster than the speed of light? That is impossible, because nothing travels faster than the speed of light. In empty space, light travels at about 300,000 km/s. That means that light from the Sun can travel 150 million km to Earth in only eight and a half minutes. Light travels fastest through empty space and slowest through solids. Matter has atoms and molecules in the material that slow down light.

How long is a wavelength of light?

Wavelengths of light are so short they are usually measured in a unit called the nanometer (nm). One nanometer is extremely small. It is one billionth of a meter. For example, green light has a wavelength of about 500 nm, or 500 billionths of a meter.
Properties of Light Waves

Light waves, like all electromagnetic waves, are transverse waves. Remember the transverse wave on a rope? The transverse wave made the rope move at right angles to the direction the wave moved. Electromagnetic waves also make matter move at right angles to the direction the wave is moving.

An electromagnetic wave has an electric part and a magnetic part. Both parts are called fields. They are shown in the diagram of a light wave in the figure above. Both fields vibrate at right angles to the direction the wave moves. The frequency of an electromagnetic wave is the number of times the electric and magnetic fields vibrate in one second. The wavelength of an electromagnetic wave is the distance between the crests or troughs of the vibrating electric or magnetic fields.

How is the intensity of a light wave measured?

The intensity of waves is a measure of the amount of energy that the waves carry. The intensity of light waves tells about the brightness of a light. A dim light has lower intensity. Its waves carry less energy. A bright light has higher intensity. Its waves carry more energy. As you move away from a light source, the energy spreads out and the intensity decreases.

The Electromagnetic Spectrum

There are many kinds of electromagnetic wave other than light waves. Together, all these waves make up what is called the electromagnetic spectrum. The electromagnetic spectrum is the complete range of electromagnetic wave frequencies and wavelengths.
How is the electromagnetic spectrum organized?

Look at the figure above. At one end of the spectrum are the waves that have the lowest frequency. They have the lowest energy and the longest wavelength. At the other end of the spectrum are the waves that have the highest frequency. They have the highest energy and the shortest wavelength. All of the waves are the same kind of waves. They only have different frequencies, wavelengths, and energy.

How are radio waves and microwaves used?

Radio waves have the lowest frequency on the electromagnetic spectrum. They are on the left side of the electromagnetic spectrum in the figure above. They carry television and radio signals into your home. These waves have the longest wavelength. The wavelength of radio waves can range from 0.3 meters to thousands of meters long. The shortest radio waves are called microwaves. Microwaves have a wavelength of between 0.3 meters and 0.001 meters. Microwaves are used to cook food in microwave ovens. They also carry information to and from cell phones.

How are infrared waves used?

You use infrared waves when you use a remote control to change the channel on your television. Infrared waves carry information from the remote control to the television. **Infrared waves** have wavelengths between 0.001 meters and 700 billionths of a meter. All warm bodies give off infrared waves. Special night goggles that pick up infrared waves can be used to locate people in the dark.
Can people see electromagnetic waves?
The part of the electromagnetic spectrum that people can see is called visible light. Visible light has wavelengths between 700 and 400 billionths of a meter. Find visible light on the electromagnetic spectrum on the previous page.
The color of the light you see depends on the wavelength of the light wave. Violet light has the shortest wavelength. Red light has the longest wavelength. The light from the Sun or from a flashlight is white light. White light is a combination of different colors. You can see this if you shine white light into a prism. When the light passes through the prism, each wavelength bends a different amount. You see this as a rainbow of different colors coming from the prism.

What are ultraviolet waves?
The next type of wave in the electromagnetic spectrum is ultraviolet waves. Ultraviolet waves are electromagnetic waves with wavelengths measuring between 400 billionths and 10 billionths of a meter. These wavelengths are shorter than those of visible light. Ultraviolet waves carry more energy than visible light waves.

There are ultraviolet waves in sunlight that reaches Earth’s surface. Some exposure to ultraviolet waves is good for you. Ultraviolet waves help your body make vitamin D. You need vitamin D to keep your teeth and bones healthy. But, ultraviolet waves can give you a sunburn if you stay out in the sunlight too long. Too much exposure to ultraviolet waves can damage skin and even in some cases cause skin cancer.

How are X rays and gamma rays used?
X rays and gamma rays have the highest energy, highest frequency, and shortest wavelengths of all the waves in the electromagnetic spectrum.

X Rays Have you ever had an X ray taken after an accident or a sports injury? Doctors use X rays to see broken bones. X rays have enough energy to go right through your skin. But, they cannot pass through dense objects, such as bones. This allows X rays to produce an image of the inside of your body. X rays are also used to kill cancer cells.

Gamma Rays Gamma rays have even more energy than X rays. Gamma rays are used on some foods to kill bacteria that make food spoil quickly.
What kind of electromagnetic waves come from the Sun?

Most of the energy from the Sun is in the form of ultraviolet, visible, and infrared waves. These waves spread out over our entire solar system. Only a small number of them reach Earth. Earth’s atmosphere keeps most of the ultraviolet waves from reaching Earth’s surface. As a result, almost all the energy from the Sun that reaches Earth is transferred by infrared and visible electromagnetic waves.

The Eye and Seeing Light

Objects you see either reflect light or give off light. When this light reaches your eye, you see the object. The figure below shows what happens to light that enters your eye.

First, light waves pass through a clear layer called the cornea (KOR nee uh). Then, the light goes through the lens, which is also clear. From the lens, the light shines on the back part of your eye called the retina.

Why do some objects have color?

When visible light waves hit an object, some of the waves are reflected. The wavelengths of the light waves that are reflected determine the object’s color. For example, a red rose reflects light waves that have the wavelengths in the red part of the visible spectrum. A green leaf reflects the wavelengths that make green light.

Some objects give off light. The color of objects that give off light is determined by the wavelengths they give off. For example, a neon sign looks red because it gives off red light waves.
How does the eye focus on objects?
The cornea and the lens help focus the light waves that come into your eye. This lets you see a clear picture instead of a blurry one. The lens of the eye is flexible. It changes shape to let you focus on objects that are nearby and far away, as shown in the figure below.

Sometimes people need to wear glasses to correct their vision. Many people are nearsighted or farsighted. A person that is nearsighted can see nearby objects clearly. But objects that are far away are blurry. Nearsightedness results if the eyeball is too long.

A farsighted person can see objects that are far away clearly. But they cannot focus on nearby objects. Farsightedness results if the eyeball is too short.

What happens when light reaches the retina?
When the light reaches the retina, special cells there send signals to your brain and you see objects. But how? The retina has millions of special cells called rods and cones. Rods help you see when there is not much light. Cones help you see colors. There are three types of cone cells. One type helps you see red and yellow light. Another type helps you see green and yellow light. The third type helps you see blue and violet light. Together, the cone cells help you see all the colors in an object.
1. Review the terms and their definitions in the Mini Glossary. Write a sentence that tells how the electromagnetic spectrum and electromagnetic waves are related.

2. Complete the diagram with the information you learned from reading this section.

3. You highlighted the main idea of each paragraph as you read this section. How did you decide what to highlight each time?

Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about light.
Rocks and Minerals

section 1 Minerals—Earth’s Jewels

Before You Read

Think about a gem, such as a diamond, and a rock that you have seen. How are gems and rocks the same and how are they different?

What You’ll Learn

- how rocks and minerals are different
- what are properties of minerals

Read to Learn

What is a mineral?

Suppose you wanted to look for minerals (MIH nuh rulz). Would you have to crawl into a cave or go down into a mine to find them? No. You could find minerals just walking around outdoors. You can even find minerals in your home. Many things you use every day, such as metal pots, glasses, and the salt you sprinkle on food, are made from minerals. Minerals and products made from them are all around you.

How are minerals defined?

A mineral is a solid, inorganic material found in nature. Inorganic means that minerals usually are not made of living things, such as plants or animals. You can find minerals in nature that formed as large, beautiful crystals. Minerals can also be as small as the grains in an ordinary rock.

Every mineral has its own particular chemical makeup and its own unique arrangement of atoms. An X ray of a mineral shows the orderly arrangement of its atoms, this orderly arrangement is often seen in the mineral’s crystal shape. Every mineral’s distinct crystal structure gives it unique properties. These properties can be used to identify minerals. So far, more than 4,000 minerals have been identified. Rocks usually are made up of two or more minerals.
How do minerals form?

Minerals form in several ways. Some minerals form from melted rock inside Earth called magma. As magma cools, atoms combine in orderly patterns to form minerals. Minerals also form when magma reaches Earth’s surface. Magma at Earth’s surface is called lava.

Some minerals form from evaporation of water. For example, ocean water has salt dissolved in it. If the water evaporates, salt crystals remain. Many kinds of minerals are dissolved in water. When the water evaporates, the minerals form crystals.

Minerals also form from a process called precipitation (prih sih puh TAY shun). Water can hold only a certain amount of dissolved minerals. Any extra minerals separate from the water and fall out of solution. The extra minerals are deposited as crystals. For example, large areas of the ocean floor are covered with manganese nodules that formed in this way. The manganese fell out of solution and formed round deposits of manganese crystals.

What are some clues to mineral formation?

Sometimes just by looking at a mineral you can tell how it formed. Some minerals have large grains that fit together like the pieces of a puzzle. These large mineral grains formed as magma cooled slowly. Large, perfectly formed crystals means the mineral had plenty of space in which to grow. They probably formed in open spaces within the rocks.

Some clusters of crystals grow from solutions rich in dissolved minerals. To figure out how a mineral was formed, look at the size of the mineral crystal and how the crystals fit together.

Properties of Minerals

Imagine you are walking down the street. You think you see a friend walking ahead of you. The person is the same height and weight and has the same hair color as your friend. Is it your friend? Then the person turns around and you see her face and recognize her features right away. You’ve identified your friend by physical properties that set her apart from other people.

Each mineral also has unique physical properties. You can identify minerals by their properties in the same way you identify friends by their physical properties.
What are crystals?

All minerals have an orderly pattern of atoms. These atoms are arranged in a repeating pattern. A crystal is a solid material that has an orderly, repeating pattern of atoms. Sometimes crystals have smooth growth surfaces called crystal faces.

What are cleavage and fracture?

One clue to a mineral’s identity is the way it breaks. Some minerals split into pieces with smooth, flat planes that reflect light. Minerals that break this way have cleavage (KLEE vihj). The mica in the figure below shows cleavage because it splits into thin sheets.

Some minerals do not show cleavage when they break. These minerals break into uneven pieces with rough edges. Minerals that break into uneven chunks have fracture (FRAK chur). The figure below shows the fracture of the mineral flint.

How does color help identify minerals?

Copper is a mineral that has a reddish-gold color. The reddish-gold color of a penny tells you it is made of copper. Sometimes a mineral’s color helps you identify it.

Sometimes, though, a mineral’s color can fool you. The common mineral pyrite (PI rite) has a shiny gold color similar to the color of the mineral gold. During the California Gold Rush of the 1800s, miners sometimes thought pyrite was gold. Pyrite has little value, while gold is extremely valuable.

While different minerals may look similar in color, the same mineral may be found in several different colors. For example, the mineral calcite can occur in different colors depending on what other materials are mixed in with it.
What are streak and luster?
Scraping a mineral across an unglazed white tile, called a streak plate, produces a streak of color. The color of a mineral’s streak is another way to identify it. Oddly, a mineral’s streak is not always the same color as the mineral itself. Yet a mineral’s streak color is a more accurate way of identifying a mineral. For example, pyrite has a green-black or brown-black streak. Gold has a yellow streak. If the gold miners had used streak tests to identify the minerals they found, they might not have confused pyrite with gold.

Some minerals are shiny. Others are dull. Another property of minerals is luster. A mineral’s luster describes how light reflects off its surface. If a mineral shines like metal, the mineral has a metallic (muh TA lihk) luster. A mineral with a nonmetallic luster looks dull, glassy, pearly, or earthy. Together, a mineral’s color, streak, and luster help identify it.

How is a mineral’s hardness measured?
Some minerals are harder than others. Talc is a mineral that is so soft, it can be scratched with a fingernail. Diamond is the hardest mineral. Diamond can be used to scratch or cut almost anything else.

In 1822, Austrian geologist Friedrich Mohs developed a way to classify mineral hardness. The Mohs scale is shown in the figure below.

<table>
<thead>
<tr>
<th>Mohs Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mineral</strong></td>
</tr>
<tr>
<td>Talc</td>
</tr>
<tr>
<td>Gypsum</td>
</tr>
<tr>
<td>Calcite</td>
</tr>
<tr>
<td>Fluorite</td>
</tr>
<tr>
<td>Apatite</td>
</tr>
<tr>
<td>Feldspar</td>
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<tr>
<td>Quartz</td>
</tr>
<tr>
<td>Topaz</td>
</tr>
<tr>
<td>Corundum</td>
</tr>
<tr>
<td>Diamond</td>
</tr>
</tbody>
</table>
How is the Mohs scale used?

A mineral with the number 1 on the Mohs scale is the softest mineral, talc. A mineral with the number 10 is the hardest mineral, diamond.

A mineral’s hardness is determined by scratching it with other minerals. For example, fluorite (number 4 on the Mohs scale) will scratch calcite (number 3 on the Mohs scale). But fluorite cannot scratch apatite (number 5 on the Mohs scale). You can use objects you have at home to determine a mineral’s hardness. Look at the table on the previous page. The hardness of several common objects is listed. Using common objects can help you determine the hardness of the mineral. Knowing a mineral’s hardness will help you identify that mineral.

What is specific gravity?

Imagine two cubes that are the same size. One is made out of wood and the other is made out of lead. Which one is heavier? Though both cubes are the same size, the lead cube is much heavier than the wooden cube. Some minerals are much heavier for their size than others. Specific gravity compares the weight of a mineral with the weight of an equal volume of water. For example, pyrite is about five times heavier than water. Pure gold is more than 19 times heavier than water. You could feel the difference by holding each one in your hand. Measuring specific gravity is another way you can identify minerals.

What other properties help identify minerals?

Some minerals have other unusual properties that can help identify them. For example, the mineral magnetite acts like a magnet. A piece of magnetite will attract metal paper clips just like a magnet.

The mineral calcite has two unusual properties. When it comes into contact with an acid like dilute HCl, calcite begins to fizz. Calcite also changes a single ray of light into a double ray of light. If you look through a piece of calcite, you will see a double image.

Halite is a mineral that has a salty taste. Scientists sometimes use taste to identify a mineral. You should not do this because some minerals are harmful to the body.

Together, all the properties you have read about are used to identify minerals. Learn to use them and you can identify most minerals you find.

7. Determine Specific gravity compares the weight of a mineral to what?

8. Identify What unusual property does the mineral halite have?
Common Minerals

Rocks that make up huge mountain ranges are made of minerals. But of the 4,000 known minerals, only a few make up most of the rocks. These minerals are known as the rock-forming minerals. If you learn to recognize these common minerals, you will be able to identify most rocks.

What are rock-forming minerals?

Most rock-forming minerals are silicates (SIH luh kaytz). Silicates contain the elements silicon and oxygen. Quartz is a mineral that is pure silica (SiO2). Feldspar is a silicate mineral in which silica combines with other elements. More than half of the minerals in Earth’s crust are types of feldspar.

Other important rock-forming minerals are carbonates. Carbonates are compounds containing the elements carbon and oxygen. The carbonate mineral calcite makes up most of the common rock limestone.

What are some other common minerals?

Other common minerals can be found in rocks formed on the bottom of ancient seas. When these seas evaporated, the mineral gypsum remained. Rock that contains the mineral gypsum is found in many places.

The mineral halite, or rock salt, is found beneath the surface of much of the Midwest. The mineral halite formed when the ancient seas that covered the Midwest evaporated.

What are gems?

Which type of ring would you rather have—a quartz ring or a diamond ring? Of course, you would rather have a diamond ring. A diamond is a gem that is often used in jewelry. A gem is a rare, valuable mineral that can be cut and polished, giving it a beautiful appearance. To have the quality of a gem, a mineral must be clear. It should not have any flaws, defects, or cracks. A gem must also have a beautiful luster or color. Few minerals meet these high standards. That is why the ones that do are rare and valuable.

Why are gems so rare?

Gems are rare because they are made under special conditions. Scientists have learned to make synthetic diamonds by using very high pressure. This pressure is greater than any found in Earth’s crust. For this reason, scientists think diamonds form deep inside Earth’s mantle.
What are ores?

An ore is a mineral that contains enough of a useful substance that it can be mined and sold for a profit. Many metals that humans use every day come from ores. For example, the lead used in batteries comes from galena, and the magnesium in vitamins comes from dolomite. Ores of these useful metals must be removed from Earth in a process called mining.

How can minerals be conserved?

There are limited amounts of minerals in Earth’s crust. As a result, minerals are considered a nonrenewable resource. For this reason, scrap metal is often reused or recycled. Old, used metal products are melted down and made into new products. Conserving metal in this way decreases the need for mining and saves mineral resources. Recycling also limits the amount of land that is disturbed by mining. The figure below shows some common items collected and recycled.

How are ores processed?

After an ore is mined, it must be processed to remove the useful mineral or element. Smelting is the process used to obtain copper. In the smelting process, the ore is melted and unwanted materials are removed. After smelting, the copper is refined, or purified. Then it is made into many types of products used in homes, businesses, and industry. Copper products include electrical wiring, pots and pans, and most electronics.

What minerals are around you?

Central Florida is the world’s leading producer of phosphate, which is processed, mainly to make fertilizer. The phosphate industry brings money into Florida, but it also creates problems.

The process that buried phosphate also buried dangerous materials, such as uranium and arsenic, with it. These harmful metals are mixed with phosphate and are mined with it.
After You Read

Mini Glossary

crystal: solid material with atoms arranged in an orderly, repeating pattern

gem: rare, valuable mineral that can be cut and polished

mineral: solid, inorganic material found in nature that always has the same chemical makeup, atoms arranged in an orderly pattern, and unique properties

ore: material that contains enough of a useful metal that it can be mined and sold for a profit

rock: solid inorganic material that is usually made up of two or more minerals

1. Review the terms and their definitions in the Mini Glossary. Write one sentence about minerals. Use at least two terms in your sentence.

2. Compare minerals and gems using this Venn diagram.

3. As you read, you used sticky notes to mark interesting pages or questions. How did this strategy help you understand the information you learned about minerals?

End of Section

Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about minerals.
Rocks and Minerals

section 2 Igneous and Sedimentary Rocks

Benchmarks—SC.D.1.3.3: The student knows how conditions that exist in one system influence the conditions that exist in other systems.
Also covers: SC.D.1.3.1; SC.D.1.3.2; SC.D.1.3.5; SC.H.3.3.6

Before You Read

Think about an erupting volcano. Often, there is red-hot material exploding out of it. What do you think happens to the material when it cools?

What You’ll Learn

- how intrusive and extrusive igneous rocks are different
- how different types of sedimentary rocks form

Read to Learn

Igneous Rock

Rocks are constantly changing. Slowly, over time, rocks are worn away and new rocks form. These processes produce the three main kinds of rocks—igneous, sedimentary, and metamorphic.

Deep inside Earth, it is hot enough to melt rock. **Igneous** (IHG nee us) rock forms when melted rock from inside Earth cools and hardens. Sometimes, melted rock reaches Earth’s surface and erupts from volcanoes. When melted rock material cools on Earth’s surface, it is called **extrusive** (ehk STREW sihv) igneous rock. When melted rock material cools beneath Earth’s surface, it is called **intrusive** (ihn TREW sihv) igneous rock.

What determines the color of igneous rock?

The chemicals in the melted rock determine the color of the rock that forms. Melted rock that contains a lot of silica will produce an igneous rock with a light color. Light-colored igneous rocks are call granitic (gra NIH tihk) rocks. Melted rock that contains more iron, magnesium, or calcium, will produce an igneous rock that has a dark color. Dark-colored igneous rocks are called basaltic (buh SAWL tihk) rocks. Intrusive igneous rocks are often granitic. Extrusive igneous rocks are often basaltic. These two categories are important in classifying igneous rock.
How do rocks form from lava?

When melted rock reaches Earth’s surface, it is called lava. Extrusive igneous rocks form from lava that cools on Earth’s surface. Since lava cools quickly, large mineral crystals, or grains, do not have time to form. As a result, extrusive igneous rocks usually have small mineral crystals that are hard to see and a smooth, sometimes glassy, appearance.

Extrusive igneous rocks can form in two ways. They may form when a volcano erupts and shoots lava and ash into the air or onto the surface. Extrusive igneous rocks also may form from cracks in Earth’s crust called fissures (FIH shurz). When a fissure opens, lava oozes out onto the ground or into water. This is called a lava flow. The fastest-cooling lava flows have no grains at all. They form volcanic glass. Sometimes lava traps gas and forms rocks filled with holes.

How do rocks form from magma?

Melted rock inside Earth is called magma. Intrusive igneous rock forms when magma cools below the surface of Earth. They form when a huge glob of magma inside Earth is forced upward but never reaches the surface. It can take millions of years for the magma to cool and harden into igneous rock. The cooling process is so slow, minerals in the magma have time to form large crystals. The figure below shows where intrusive and extrusive igneous rocks form around a volcano.

Think it Over

1. Describe What would you look for to determine if a rock is an intrusive or an extrusive igneous rock?

Picture This

2. Identify Use a blue pencil to trace the path of the magma to the area where the extrusive igneous rock forms. Use a red pencil to circle the area where the intrusive igneous rock forms.
Sedimentary Rocks

Tiny pieces of rock, shells, mineral grains, and other materials are called sediment (SE duh munt). For example, the sand at the beach is a type of sediment.

Sediment is made and transported in several ways. Wind, water, and ice break down pieces of rock or rock mineral grains. Wind, water, and ice can also carry these sediments from one place to another. When the sediments settle, they form a thin layer. Sedimentary (sed uh MEN tuh ree) rock is made from sediment that collected in layers to form rock. It takes many thousands or even millions of years for sedimentary rock to form. Rock is always being worn away on Earth's surface. This means that sediments and sedimentary rocks are continuously forming. There are three main categories of sedimentary rock—detrital (dih TRI tuhl), chemical, and organic.

How are detrital rocks formed?

Some sedimentary rocks are made of mineral grains or tiny pieces of rocks that have been worn away by wind, water, or ice. Sedimentary rocks that form from tiny mineral grains or other rock particles are called detrital sedimentary rocks. Wind, gravity, ice, or water carry these tiny particles of sediment and deposit them in layers. Layer upon layer of mineral grain sediment is deposited. As the layers pile up, top layers press down, or compact, lower layers. Other minerals dissolved in water act like cement to bind the layers of sediment together into rock. Sandstone is a common detrital sedimentary rock.

How are detrital rocks identified?

To identify detrital sedimentary rock, you use the size of the grains that make up the rock. The smallest, clay-sized grains feel slippery when they are wet. These clay-sized grains make up a rock called shale.

Silt-sized grains are slightly larger than clay-sized grains and feel rough. Siltstone is a detrital sedimentary rock made up of silt-sized grains.

Sand-sized grains are even larger. Rough sedimentary rocks, such as sandstone, are made of sand-sized grains. You can see the separate grains in a piece of sandstone.

The roughest detrital sedimentary rock is made up of pebbles. Pebbles that are mixed and cemented together with other sediments form detrital rocks called conglomerates (kun GLAHM ruts).
How do chemical sedimentary rocks form?

Some chemical sedimentary rocks form from ocean water that is rich in minerals. When the water evaporates, mineral layers are left behind. Over time, the layers form chemical sedimentary rock.

Some chemical rocks form from geysers or hot springs when hot, mineral-rich water reaches the surface from deep underground. As the hot water evaporates on the surface, layers of minerals are left behind.

Have you ever sat in the Sun after swimming in the ocean? You may have noticed tiny crystals forming on your skin as the Sun warms and dries you. When the ocean water on your skin evaporated, it left behind crystals of salt, or halite. The halite was dissolved in the ocean water. Chemical rocks form this way when the water evaporates.

How do organic sedimentary rocks form?

Did you know that the chalk your teacher uses on the chalkboard may also be a sedimentary rock? Another sedimentary rock is the coal that is used as a fuel to produce electricity.

Chalk and coal are examples of organic sedimentary rocks. When living matter dies, the remains pile up in layers. Over millions of years, the layers are pressed together to form rock. If the rock is formed from layers of dead plant material, then coal forms. Organic sedimentary rocks also form in the ocean and are usually classified as limestone.

Are fossils found in sedimentary rocks?

Chalk and other types of limestone are made from fossils. Fossils are the remains or traces of once-living plants and animals. Often, the fossils in organic sedimentary rock are extremely small. But sometimes, the fossils are large and reveal much of the body of the once-living plant or animal. For example, dinosaur bones and footprints are fossils that have been found in sedimentary rocks.

Fossils are found in all three types of sedimentary rocks—detritus, chemical, and organic. Scientists use fossils to study organisms that lived long ago and to compare them with those living today.
1. Review the terms and their definitions in the Mini Glossary. Then write one sentence about igneous rock and one sentence about sedimentary rock.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

2. Fill in the blanks in the boxes below.

   **TWO TYPES OF ROCK**

<table>
<thead>
<tr>
<th>rock forms from magma deep inside Earth.</th>
</tr>
</thead>
<tbody>
<tr>
<td>forms from cooling lava on the surface.</td>
</tr>
<tr>
<td>forms from cooling magma underground.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>rock forms from layers of sediment.</th>
</tr>
</thead>
<tbody>
<tr>
<td>forms from mineral grains or tiny parts of rock.</td>
</tr>
<tr>
<td>forms from mineral dissolved in water that evaporates.</td>
</tr>
<tr>
<td>forms from the remains of once-living plants and animals.</td>
</tr>
</tbody>
</table>

3. Did the two-column notes you made help you understand the information about sedimentary rock? Would you use this strategy again to learn new information?

________________________________________________________________________

________________________________________________________________________
Before You Read

Imagine that someone leaves a hat on a chair and you accidentally sit on it. Describe how the pressure of your body changes the hat.

Read to Learn

New Rock from Old Rock

Rocks on Earth are constantly changing because of different physical processes. Sedimentary rocks are formed by low temperature processes that break down and wear away bits of rock. Igneous rocks are formed by high temperature conditions that form molten rock material. There are conditions in between these that form igneous and sedimentary rocks that produce new rocks.

How do pressure and temperature change rock?

Deep inside Earth, rock is under great pressure. Just as the pressure of your body can change a hat you sit on, pressure inside Earth can cause certain changes in rock. Pressure and temperature increase with depth inside Earth. Changes in pressure and temperature can change the chemicals that make up rock and the size of the mineral grains in rock.

It can take millions of years for rocks to change. It may take that long for pressure to build up while rocks are buried deeply or continents collide. Sometimes rocks are cooked by magma moving up into Earth’s crust. The heat of the magma doesn’t melt the rock, but it does change the rock’s mineral crystals. All these events make new rock out of old rock.
How do metamorphic rocks form?

Do you recycle your plastic milk jugs? Have you ever thought about what happens to these jugs after you put them in the recycling bin? First the jugs are collected, sorted, and cleaned. Then they are heated and squeezed into pellets. The pellets later can be made into useful new products.

Rocks are recycled too, in a process that takes millions of years. Most rocks are recycled deep inside Earth, where great pressure and high temperatures process them into new rocks. Metamorphic (me tuh MOR fihk) rock is new rock that forms when existing rock is heated or squeezed, but not melted. The new rock that forms not only looks different, but it might be chemically changed, too. Sometimes the minerals in the new rock line up in a distinct way.

The word metamorphic means “change of form.” This is a good word for rocks that get a new look when they are under great pressure and high temperature.

How are metamorphic rocks grouped?

New metamorphic rocks can form from any other type of rock—sedimentary, igneous, or even other metamorphic rock. One way to identify and group rock is by its texture. A rock’s texture is a physical property that refers to how the rock looks. Texture helps to divide metamorphic rock into two main groups—foliated (FOH lee ay tud) and nonfoliated.

What are foliated rocks?

Foliated rocks have visible layers of minerals. The word foliated comes from a Latin word that means “leafy.” Foliated minerals have been heated and squeezed into layers, like the pages, or leaves, of a book. Many foliated rocks have bands of different-colored minerals. Slate, gneiss (NISE), phyllite (FIH lite), and schist (SHIHST) are examples of foliated rocks. Some walkways and roofs are made of slate, a foliated metamorphic rock.

What are nonfoliated rocks?

Nonfoliated rocks do not have distinct layers or bands. They are usually more evenly colored than foliated rocks. Often mineral grains can’t be seen in nonfoliated rocks. If the mineral grains are visible at all, they are not lined up in any particular way. Soapstone and marble are nonfoliated rocks. Quartzite is a nonfoliated rock made from quartz sand grains. When the sand grains are squeezed and heated, they form the new kind of crystals found in quartzite.
The Rock Cycle

Rocks are constantly changing from one type to another. Scientists have made a model to show how all rocks are related to one another and how different processes constantly change rocks. The rock cycle is the model that shows the slow continuing process of rocks changing from one type to another. Every rock on Earth is on an endless journey through the rock cycle. A rock’s trip through the rock cycle can take millions of years. The rock cycle is shown below.
What is the journey of a rock?
Look at the figure of the rock cycle on the previous page. Pick any spot on the rock cycle model. What form of rock is on the spot you chose? From that spot, follow the rock through the rock cycle. Notice the processes that act on the rock and change it. These processes include heat and pressure, wearing away, moving, melting, cooling, compacting, and cementing together. Look at the types of rock it becomes through these different processes. You can see that any rock can turn into any other type of rock.

What forms from magma?
Now start tracing the rock cycle from the magma at the bottom of the figure. The magma rises to the surface as a glob of lava. The lava cools and forms an igneous rock.

What changes igneous rock?
Wind, rain, and ice slowly wear away bits of the igneous rock, breaking off some of its tiny mineral grains, or sediment. The sediment is carried by the wind or by a river or maybe even by ice. Eventually, the sediment is deposited in thin layers. Over time, the layers build up. The weight of the top layers presses down on lower layers, compacting them. The pressure acts like glue, cementing the layers together to form a sedimentary rock.

What other changes occur?
Deep inside Earth, the sedimentary rock is under great pressure and high temperature. Slowly, over millions of years, the sedimentary rock is changed into metamorphic rock. The metamorphic rock may eventually be melted to form magma. When magma cools below Earth’s surface, intrusive igneous rock forms. When magma explodes out of a volcano and lava flows onto Earth’s surface, extrusive igneous rock forms.

The cycle of change continues. The processes that are part of the rock cycle change rocks slowly over time. These processes are taking place right now.
1. Review the terms and their definitions in the Mini Glossary. Then write one sentence about metamorphic rocks. Use at least two vocabulary words in your sentences.

2. Fill in the blanks in the chart below to show how rocks change.

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**After You Read**

**Mini Glossary**

- foliated: metamorphic rocks that have visible layers of mineral
- metamorphic rock: new rock that forms when existing rock is heated or squeezed
- nonfoliated: metamorphic rocks that do not have distinct layers or bands
- rock cycle: model that shows the slow continuing process of rocks changing from one type to another

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Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about metamorphic rocks and the rock cycle.
Clues to Earth’s Past

section 1 Fossils

Benchmarks—SC.D.1.3.2 Annually Assessed: The student knows that over the whole Earth, organisms are growing, dying, and decaying as new organisms are produced by the old ones.
Also covers: SC.B.2.3.2; SC.D.1.3.1; SC.D.1.3.3; SC.D.1.3.5

Before You Read

You can learn about a person’s history by looking at photos, letters, and other things they own. Earth has a history, too. What things might be used as a record of Earth’s history?

What You’ll Learn

■ how fossils form
■ how fossils are used to tell rock ages
■ how fossils explain changes in Earth’s life forms and environments

Read to Learn

Traces of the Distant Past

It’s likely that you’ve read about dinosaurs and other animals that lived on Earth in the past. But how do you know that they were real? How do you know what they were like? The answer is fossils. Paleontologists, scientists who study fossils, can learn about extinct animals from their fossil remains. They can use fossils to study organisms that lived in the past and compare them with organisms living today.

Formation of Fossils

Sedimentary rock may contain fossils of plants, animals, and even microbes. **Fossils** are the remains, imprints, or traces of organisms that died long ago. Scientists have used fossils to determine when life first appeared, when plants and animals first lived on land, and when organisms became extinct.

Most animals and plants decay soon after they die. Some animals may eat and scatter the remains of dead organisms. Fungi and bacteria may cause the remains to rot. In time, no trace is left. But some dead organisms do become fossils. Why do they become fossils? Which organisms are more likely to become fossils?

Two-Column Notes

As you read, organize your notes in two columns. In the left column, write the main idea of each paragraph. Next to it, in the right column, write details about it.

Compare and Contrast

**A Compare and Contrast**

Make a Foldable as shown below to compare and contrast the ways that fossils are preserved.
How do fossils form?

In order for a dead organism to become a fossil, its remains must be protected. One way a dead organism can be protected is for sediment to bury the body quickly. For example, a dead fish might sink to the bottom of a lake. If it is quickly buried by sediment dropped from a stream, no animals or waves could get to it and tear it apart. Over time, the fish may become a fossil in a layer of rock. But quick burial alone isn’t always enough to make a fossil.

Organisms with hard parts, such as bones, shells, or teeth, have a better chance of becoming fossils. These hard parts are less likely to be eaten than soft parts. Hard parts also decay more slowly than soft parts do. Most fossils are the hard parts of organisms.

Types of Preservation

You may have seen the bones of a dinosaur in a museum. You may have seen drawings of dinosaurs in books. Artists who draw dinosaurs study their fossilized bones. How are bones and other parts of organisms preserved as fossils?

How do minerals help form fossils?

The hard parts of living things, such as bones, teeth, and shells, have tiny spaces in them. When organisms are alive, the spaces can be filled with cells, blood vessels, nerves, or air. When organisms die, the soft parts decay and leave empty spaces. If the hard part is buried, groundwater can seep into these spaces and deposit minerals. The result is a type of fossil. Permineralized remains are fossils in which the spaces inside are filled with minerals from groundwater. Some original material from the organism’s body might also be preserved. It is enclosed in the minerals from the groundwater. At times, some DNA can be found in the original materials. DNA is the chemical that carries the genetic code of the organism. Sometimes minerals replace the hard parts of fossil organisms. Water with dissolved minerals might flow through the shell of a dead organism. After the weather dissolves the shell, the mineral is left in its place. Silica (SiO₂) dissolved in water is one chemical compound that replaces the hard parts of fossil organisms.

Bones, wood, and other materials can become permineralized remains. People can learn about the past by looking at these remains.
What are carbon films?
The tissues of living organisms contain carbon. Some fossils contain only carbon. Fossils usually form when sediments bury a dead organism. As sediment builds up, heat and pressure force all the gases and liquids out of the organism. A thin layer, or film, of carbon is left, like an outline of the organism’s body. A **carbon film** is a thin film of carbon left from an organism and preserved as a fossil.

What is coal?
Large amounts of dead plant material may build up in swamps. Over millions of years, heat and pressure change the carbon in thick layers of plant material into coal. Coal is a kind of fossil, but it doesn’t show much about the past. The structure of the original plant is usually lost.

What are molds and casts?
Sometimes the hard parts of a dead organism fall into a soft sediment and get buried. In time, the sediment turns into rock. There may be small spaces in the rock. Air and water can flow through these spaces and break down the organism’s hard parts. This leaves a hole, or cavity, in the rock that is shaped like the body part. A **mold** is a fossil that forms when an organism decays, or dissolves, leaving a cavity in the rock.

Later, water and minerals may enter the mold and form new rock. This produces a copy, or cast, of the original object. A **cast** is a type of fossil that forms when minerals fill a mold and harden into rock. The figure below shows how a cast forms when a mold fills with minerals.

3. Describe What does a mold in a rock look like?

4. Explain What is the key difference between the shell on the left and the cast fossil on the right?
How are original remains preserved?
From time to time, conditions are just right for the soft parts of an organism to be preserved. Insects can be trapped in amber, a tree sap that turns into a solid. The amber surrounds and protects the insect’s original parts. Some organisms, such as the mammoth, have been found preserved in frozen ground in Siberia. Some original remains have been found in natural tar deposits.

What are trace fossils?
Animals that walked on Earth long ago left tracks in soft mud. Some of those tracks have been preserved. They are trace fossils. Trace fossils may be footprints, trails, burrows, or any marks that tell something about how an animal moved and lived. These fossils give scientists clues about an animal’s way of life.

Tracks can tell how herds of dinosaurs traveled or how one type of dinosaur might have stalked another. Fossil burrows can reveal how firm the sediment was that the animal lived in. From this information, scientists can learn more about the animal who dug the burrow.

Index Fossils
Species have changed over time. Fossils show the differences and similarities of organisms that lived in the past and those living today. Some species lived on Earth for a long time without changing. Other species changed a lot in a short time. Scientists can learn about the past from the fossils of organisms that existed for a short time. They are called index fossils.

What do index fossils reveal?
Index fossils are the remains of species that existed on Earth for a short time, were numerous, and were found in many places. Organisms that became index fossils lived only during a specific time. Because of this, scientists can estimate the ages of rock layers based on the index fossils they contain.

But not all rocks have index fossils. There is another way to estimate when these rocks formed. It is done by comparing time spans in which more than one fossil appears. Look at the figure at the top of the next page which shows the time spans of three different fossils in sedimentary rock. The estimated age of the rock layer is the time period where the fossil ranges overlap.
Fossils and Ancient Environments

Scientists can use fossils to learn what an area was like long ago. Using fossils, they can determine whether an area was land or covered by an ocean. If the area was covered by ocean, it might even be possible to learn how deep the water was.

Fossils also can give clues about the past climate of an area. For example, rocks in parts of the eastern United States contain fossils of tropical plants. But today the environment of this area isn’t tropical. Because of these fossils, scientists know that the climate was tropical when these plants were living.

Why might fossils of sea animals be found in a desert?

Crinoids are animals with many arms that usually live in warm, shallow waters. But fossils of crinoids have been found in deserts in parts of western and central North America. What do scientists learn from these fossils? When the fossil crinoids were living, a shallow sea must have covered this area of North America.

Fossils give clues about past life on Earth. Fossils give information about plants and animals that are now extinct. They provide information about the rock layers that contain them and about the ages of the rock layers. By studying fossils, scientists learn about the climate and environment that existed when the rocks formed.
1. Review the terms and their definitions in the Mini Glossary. Then write a sentence that explains why a mold and a cast fossil may be found in the same area.

2. Complete the concept map below. Identify each type of fossil and write one clue it provides about the past.

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**After You Read**

**Mini Glossary**

- **carbon film**: thin film of carbon left from an organism and preserved as a fossil
- **cast**: a fossil that forms when a mold fills with sediment or minerals and then hardens into rock
- **fossil**: the remains, imprints, or traces of animals or plants that died long ago
- **index fossil**: the remains of species that lived for a short time, were numerous, and were found in many places
- **mold**: a fossil that forms when an organism decays or dissolves and leaves a cavity in the rock
- **permineralized remains**: fossils in which the spaces are filled with minerals from groundwater

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**Types of fossils**

- Original remains: Shows the complete structure of an organism from the past
- Carbon films

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Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about fossils.
Before You Read

Suppose you want to make a timeline of your life. What units would be best for this timeline—minutes, years, or decades? Explain your answer.

Read to Learn

Geologic Time

A group of students is searching for fossils. By looking in rocks that are hundreds of millions of years old, they hope to find fossils of organisms called trilobites (TRI loh bites). Trilobites are small, hard-shelled animals that lived in ancient seas. Trilobites are considered to be index fossils because they lived over vast regions of the world during specific periods of geologic time. The students hope that by studying trilobite fossils, they can help piece together a puzzle. They want to know what caused the trilobites to disappear from Earth.

What is the geologic time scale?

The appearance or disappearance of types of organisms throughout Earth's history marks important events in geologic time. Paleontologists divide Earth's history into time units based on life-forms that existed only during certain periods. The geologic time scale is made up of divisions of time in Earth's history. Sometimes few fossils remain from a period. Then paleontologists use other methods to define a division of geologic time.

What You’ll Learn

- how geologic time is divided
- how changes in organisms can show divisions in geologic time
- how plate tectonics affects species

Communicate

Work with a partner. As you read each paragraph of the text, take turns saying something about the main idea of the paragraph. Help each other understand the information in the text.

Classify

Make the following Foldable to help you organize geologic time periods and events into groups based on their characteristics.
What are major subdivisions of geologic time?

The oldest rocks on Earth contain no fossils. Fossils began to form when organisms began to appear on Earth. Scientists can use rocks containing fossils to subdivide geologic time. The figure below shows the major subdivisions of geologic time. Eons are the longest subdivision and are based on the abundance of certain fossils.

Eons are divided into smaller time periods called eras. An era is marked by major worldwide changes in the types of organisms present. For example, at the end of the Mesozoic Era, many kinds of invertebrates, birds, mammals and reptiles became extinct. This can be seen in the fossils present in rocks.

Eras are subdivided into periods. A period is a unit of geologic time during which certain types of life-forms existed all over the world.

Geologic periods are divided into epochs. An epoch is also characterized by differences in life-forms, but these may vary from continent to continent. Epochs may be given names, like those in the Cenozoic Era, or may be called simply early, middle, or late.

What limits the divisions of geologic time?

There is a limit to how finely geologic time can be subdivided. It depends on the kind of rock record that is being studied. Sometimes it is possible to distinguish different layers of rock that formed during a single year. In other cases, there is little information to help scientists subdivide geologic time.
Trilobites

Remember the trilobites you read about earlier? A trilobite is an ancient organism with a three-lobed exoskeleton. An exoskeleton is a hard outer skeleton. These ancient animals were given the name trilobite because they have a three-part shell. The figure below shows the three parts of the trilobite shell. The three parts, called lobes, run the length of its body.

The bodies of trilobites also can be described as having three parts in a different way. The bodies have a head (cephalon). They have a middle that is segmented or divided into sections (thorax). They also have a tail (pygidium).

What do the changing characteristics of trilobites tell scientists?

Trilobites lived in Earth’s oceans for more than 200 million years. All through the Paleozoic Era, some species of trilobites became extinct and other new species of trilobites evolved. Different periods of the Paleozoic Era had different species of trilobites. Each species of trilobites had its own particular characteristics that were different from all other species.

Paleontologists use the differences in trilobite species to explain how trilobites evolved over geologic time. These changes tell how different trilobites from different periods lived. The changes also tell how trilobites responded to changes in their environment.

The figure at the top of the next page shows the different kinds of trilobites that lived during different periods.
What do trilobite eyes reveal?

Trilobites may have been the first organisms on Earth with complex eyes. Trilobite eyes show the result of natural selection. The position of an organism’s eyes give clues about how it lived. If its eyes are in the front of its head, it likely swam actively through the sea. If its eyes are located toward the back of its head, it likely lived on the bottom of the ocean. Most species of trilobites had eyes that were midway between the front and the back of the head. This clue shows that trilobites were adapted to both active swimming and crawling on the ocean floor.

What changes occurred in trilobite eyes?

Over time, the eyes in trilobites changed. Gradually, the eyes of many trilobite species became smaller and smaller. Eventually, their eyes disappeared completely. These blind trilobites might have burrowed into sediments on the ocean floor. They might have lived in a part of the deep ocean where there was no light.

Not all trilobite species lost their eyes. Some trilobite species developed highly complex eyes. One species of trilobite had compound eyes—eyes with many individual lenses. These trilobites had excellent vision. Still other trilobite species developed complex eyes on stalks that extended from their head. They also could see their world very well.

What changes occurred in trilobite bodies?

The trilobite body also changed over geologic time. Some early trilobite species had many segments in the middle part of the body. Later trilobites had fewer segments.
1. Review the terms and their definitions in the Mini Glossary. Then write two sentences explaining how the geologic time scale relates to what you learned about trilobites.

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2. Fill in the correct term to show how the Geologic Time Scale is divided.

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What You’ll Learn

- how to tell the relative ages of rock layers
- how to interpret gaps in the rock record

Before You Read

Think of two friends. You want to know who is older. Without knowing their birthdays, how could you figure out who’s older?

Read to Learn

Superposition

Imagine that you see an interesting car drive by. Then you remember seeing a picture of the car in the January edition of a magazine you have at home. In your room is a pile of magazines from the past year. As you dig down through the pile, you find magazines from March, then February. January must be next. How did you know that the January issue would be at the bottom?

Where are the oldest rock layers?

To find the older magazine under newer ones, you used the principle of superposition. How does this principle apply to rocks? The principle of superposition states that in layers of rock that have not been disturbed, the oldest rocks are on the bottom and the rocks become younger toward the top. Scientists use this principle to help find the ages of layers of rock.

How do rocks layers form?

Sediments build up, forming layers of sedimentary rock. The first layer to form is on the bottom. A new layer forms on top of the first one. A third layer forms on top of the second layer. The bottom layer is the oldest, because it was formed first. Sometimes, the layers of rock are disturbed. When layers have been turned upside down, other clues are needed to tell which rock layer is oldest.
Relative Ages

Remember the old magazine you were trying to find? What if you want to find another magazine? You don’t know how old it is, but you know it came after the January issue. You can find it in the stack by using the principal of relative age. The relative age of something is its age in comparison to the ages of other things.

Geologists figure out the relative ages of rocks by studying their places in a sequence. For example, if layers of sedimentary rock have been moved by a fault, or a break in Earth’s surface, the rock layers had to be there before the fault cut through them. So, the relative age of the rocks is older than the relative age of the fault. Relative age doesn’t tell you how old the rock is in actual years. The rock layer could be 10,000 years old or one million years old. The relative age only tells you that the rock layer is younger than the layers below it and older than the fault cutting through it.

How do other clues help?

It’s easy to figure out relative age if the rocks haven’t been moved. Look at the figure below on the left showing rock layers that haven’t been disturbed. Which layer is the oldest? According to the principle of superposition, the bottom layer is oldest.

Now look at the figure on the right where the rock layers have been disturbed. If a fossil is found in the top layer that is older than a fossil in a lower layer, it shows that the layers have been turned upside down. This could have been caused by folding during mountain building.

Reading Check

1. Identify  What term describes the age of something compared with the ages of other things?

   ________________

2. Interpret  Highlight the layer of limestone in both figures. Which rock layer probably has the oldest fossils?

   ________________
Unconformities

Layers of rock form a record of the past. But the record may not be whole. Layers or parts of layers might be missing. These gaps in the rock layers are called **unconformities** (un kun FOR muh teez). Unconformities develop when erosion removes rock layers by washing or scraping them away. There are three types of unconformities.

**What are angular unconformities?**

Forces below Earth’s surface can lift and tilt layers of sedimentary rock as shown in the figure below. Over time, erosion and weathering wear down the tilted rock layers. Later, new layers of sedimentary rock are deposited on top of the tilted and eroded layers. The unconformity that results when new layers form on tilted layers is called an angular unconformity.

**Why would a layer of rock be missing?**

Sometimes flat layers of rock can be missing from a stack of horizontal sedimentary rock layers. Careful study reveals an old surface of erosion. At one time the rocks were exposed and eroded. Later, younger rocks formed above the erosion surface when sediments were deposited again. Even though all the layers are parallel, the rock record still has a gap.
Disconformity When a flat rock layer is missing, this type of unconformity is called a disconformity, shown in the figure below. A disconformity also forms when a long period of time passes without any new layers of rock forming.

What are nonconformities?

Another type of unconformity is shown in the figure below. A nonconformity occurs when metamorphic or igneous rocks are uplifted and eroded. Sedimentary rocks are then deposited on top of the erosion surface. The surface between the two rock types is a nonconformity.

Matching Up Rock Layers

Suppose scientists are studying a layer of sandstone. Later, at an area 250 km away, they observe a layer of sandstone that looks like the sandstone they studied in the first location. Above the sandstone is a layer of limestone and then another layer of sandstone. They return to the first area and find the same sequence—sandstone, limestone, sandstone. Based on their observations, they theorize that the same layers of rock are in both locations. Often, layers of rocks that are far apart can be matched up, or correlated.

What evidence can correlate rock layers?

One way to correlate rock layers from two places that are far apart is to walk along the layer from one place to the next. Walking along a layer can prove it is unbroken. The layers can also be matched using fossil evidence. If the same types of fossils are found in the rock layers in both places, it can show that the rock in each place is the same age and, therefore, part of the same deposit.
After You Read

Mini Glossary

**principle of superposition:** states that in undisturbed rock layers, the oldest rock is at the bottom and the rocks are younger toward the top

**relative age:** age of something compared to the age of other things

**unconformity:** a gap in the rock layers due to erosion or a period without rock deposit

1. Review the terms and their definitions in the Mini Glossary. Choose one term and explain in your own words what it means.

2. Look back at the question you answered for the “Before You Read” at the beginning of this section. Explain how figuring out which of your friends is older is connected to finding relative age.

3. Complete the table about unconformities.

<table>
<thead>
<tr>
<th>Unconformities</th>
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<tbody>
<tr>
<td><strong>Type</strong></td>
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<tr>
<td>Angular unconformity</td>
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</table>
| Sedimentary rock layers over igneous or metamorphic rock | }
4. The diagram below shows rock layers in two different locations: Bryce Canyon and Canyonlands National Park.

![Diagram of rock layers]

**Date deposited (millions of years ago)**

- 2–65
- 65–136
- 136–190
- 190–225
- 225–280
- 280–320

**Bryce Canyon National Park**
- Morrison Fm
- Entrada Ss
- Navajo Ss
- Wingate Ss
- Chinle Fm
- Moenkopi Fm
- Older rocks
- Not exposed

**Canyonlands National Park**
- Kaiparowits Fm
- Straight Cliffs Ss
- Dakota Ss
- Winsor Fm
- Entrada Ss
- Carmel Fm
- Navajo Ss

a) What are the names of the rock layers that are the same in both of these locations?

b) Suppose you found a fossil in the top layer of the Canyonlands rock formation. It is the fossil of an organism that only existed on Earth for a short time. In which rock layer of Bryce Canyon could you look in to find a similar fossil? Explain your answer.

5. As you read this section, you made flash cards to help you learn. How did the flash cards help you learn about how layers can be correlated?
What You’ll Learn

- how absolute age differs from relative age
- how the half-lives of isotopes are used to tell a rock’s age

Before You Read

How old are you? How do you know what your exact age is? On the lines below, tell different ways you could prove your exact age.

---

Read to Learn

Absolute Ages

After you sort through your stack of magazines looking for that article about the car you saw, you decide that you need to get your magazines back into a neat pile. By now, they are all in a jumble. They are no longer in order according to their relative age.

How can you stack the magazines so the oldest are on the bottom and the newest are on the top? Luckily, all the magazines have dates on their covers. The dates make your job easy. By using the dates as your guide, you can put the magazines back in order.

What is absolute age?

Rocks don’t have dates stamped on them. Or do they? Absolute age is the age, in years, of a rock or other object. Scientists who study rocks, or geologists, are able to figure out the absolute age of rocks. Geologists use the properties of atoms in rock material to determine absolute age. The properties of some atoms give good clues about how much time has passed since the rock was formed. Knowing the absolute age of rocks leads to a better understanding of events in Earth’s history.
Radioactive Decay

Every atom has a dense center called the nucleus, which is surrounded by a cloud of particles negatively charged called electrons. The nucleus is made up of protons, which have a positive charge, and neutrons, which have no electric charge. The number of protons determines the identity of the element. The number of neutrons determines the form of the element, or isotope. For example, every atom with just one proton is a hydrogen atom. Hydrogen atoms can have no neutrons, one neutron, or two neutrons. This means that there are three isotopes of hydrogen.

Some isotopes break down into other isotopes, giving off a lot of energy. **Radioactive decay** is the process in which the nucleus of an atom breaks down.

**What are alpha and beta decay?**

In some isotopes, a neutron breaks down into a proton and an electron. This type of radioactive decay is called beta decay because the electron leaves the atom as a beta particle. The nucleus loses a neutron but gains a proton. Other isotopes give off two protons and two neutrons in the form of an alpha particle. This is called alpha decay. Alpha and beta decay are shown in the figure below.

**Beta decay**

Unstable parent isotope

![Beta decay diagram](image)

Daughter product

![Unstable parent isotope](image)

Proton

Beta particle (electron)

**Alpha decay**

Unstable parent isotope

![Alpha decay diagram](image)

Daughter product

![Unstable parent isotope](image)

Neutron

Proton

Alpha particle

**Reading Check**

1. **Identify** What is the process in which the nucleus of an atom breaks down?

2. **Determine** Circle the beta particle that is given off during beta decay and the alpha particle given off during alpha decay.
What is a half-life?

In radioactive decay, the parent isotope breaks down. The daughter product is formed. Each parent isotope decays to its daughter product at a certain rate. Based on its decay rate, it takes a certain period of time for one half of the parent isotope to decay to its daughter product. The **half-life** of an isotope is the time it takes for half of the atoms in the isotope to decay.

The figure below shows how during each half-life, one half of the parent material decays to the daughter product. For example, the half life of carbon-14 is 5,730 years. So, it will take 5,730 years for half of the carbon-14 atoms to change into nitrogen-14 atoms. You might think that in another 5,730 years, all the remaining carbon-14 atoms will decay into nitrogen-14 atoms. But they won’t. Only half the remaining atoms will decay during the next 5,730 years. So, after two half-lives, one fourth of the original carbon-14 atoms will remain. After many half-lives, such a small amount of isotope remains that it is not measurable.

**Radiometric Ages**

Decay of radioactive isotopes is like a clock keeping track of time that has passed since rocks have formed. As time passes, the amount of parent isotope in a rock decreases and the amount of daughter product increases. Scientists can use this information to figure out the absolute age of the rock. **Radiometric dating** is the process used to calculate the absolute age of rock by measuring the ratio of parent isotope to daughter product in a mineral and knowing the half-life of the parent. To do radiometric dating, scientists choose an isotope to look for based on its half-life, and its availability in a certain rock.
What does radiocarbon dating show?
Carbon-14 is useful for dating bones, wood, and charcoal up to 75,000 years old. Living organisms take in carbon from the environment to build their bodies. Most of the carbon is carbon-12, but some is carbon-14. The ratio of these two isotopes in the environment is always the same. After the organism dies, the carbon-14 slowly decays. Scientists can compare the isotope ratio in the sample to the isotope ratio in the environment. Once scientists know the amount of carbon-14 in a sample, they can determine the age of bones, wood, or charcoal.

Can radiometric dating be used on all rocks?
Rocks that can be radiometrically dated are usually igneous and metamorphic rocks. Most sedimentary rocks can’t be dated this way. Why? Many sedimentary rocks are made up of particles that eroded from older rocks. Dating these pieces only gives the age of the original rocks they came from.

What are the oldest known rocks?
Radiometric dating has been used to date the oldest rocks on Earth. These rocks are about 3.96 billion years old. Scientists estimate Earth is about 4.5 billion years old. Rocks older than 3.96 billion years probably were eroded or changed by heat and pressure.

Uniformitarianism
Before radiometric dating was used, many people thought Earth was only a few thousand years old. But in the 1700s, Scottish scientist James Hutton estimated Earth to be much older. He used the principle of uniformitarianism. Uniformitarianism states that Earth processes occurring today are similar to those that occurred in the past.
Hutton observed that the processes that changed the landscape around him were slow. He inferred that they were just as slow all through Earth’s history. Hutton hypothesized that it took much longer than a few thousand years to form rock layers and erode mountains.
Today, scientists agree that Earth has been shaped by two types of change. There are slow, everyday processes that take place over millions of years. There are also sudden, violent events such as the collision of a comet that might have caused the dinosaurs to become extinct.

5. Explain Why doesn’t radiometric dating work on sedimentary rock?

6. Describe What are the two types of change that have shaped Earth?
After You Read

Mini Glossary

absolute age: age, in years, of a rock or other object
half-life: time it takes for half of the atoms in an isotope to decay
radioactive decay: process in which the nucleus of an atom breaks down
radiometric dating: process used to calculate the absolute age of rock by measuring the ratio of parent isotope to daughter product in a mineral and knowing the half-life of the parent
uniformitarianism: principle stating that Earth processes occurring today are similar to those that occurred in the past

1. Review the terms and their definitions in the Mini Glossary. Then explain the difference between absolute age and relative age.

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

2. Fill in the half-life chart to show the decay of carbon-14 over time.

<table>
<thead>
<tr>
<th>Percent Carbon-14</th>
<th>Years Passed</th>
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<tbody>
<tr>
<td>100</td>
<td>0</td>
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<tr>
<td>6.25</td>
<td>5,730</td>
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<tr>
<td>3.125</td>
<td>11,460</td>
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<tr>
<td>12.5</td>
<td>11,460</td>
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</tbody>
</table>

3. In this section you highlighted vocabulary terms. Was this strategy helpful? Explain why or why not.

____________________________________________________________________

____________________________________________________________________

Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about the absolute ages of rocks.
Before You Read

Every day the Sun rises and sets. Seasons change throughout the year. What causes these changes? Write your ideas below.

What You’ll Learn

■ about Earth’s shape and physical properties
■ about Earth’s rotation and revolution
■ why Earth has seasons

Read to Learn

Earth’s Physical Data

Think about the last time you saw a sunset. The Sun seemed to be sinking lower and lower in the sky. Then it disappeared. Maybe it looked like the Sun was actually moving. A long time ago, when people observed the sky, they thought the Sun and the Moon moved around Earth each day. But now it is known these objects seem to move because Earth is moving.

What is Earth’s shape?

Pictures from space show that Earth is shaped like a giant ball, or sphere (SFIHR). A sphere is a three-dimensional object whose surface at all points is the same distance from its center. Earth’s spherical shape is not perfect. It bulges slightly at the equator and is somewhat flattened around the poles.

What is the evidence of Earth’s shape?

Have you ever stood on a dock and watched a sailboat come in? If so, you may have noticed that the first thing you see is the top of the boat’s sail. This occurs because Earth’s curved shape hides the rest of the boat from view until it is closer to you. As the boat slowly comes closer to you, more and more of its sail is visible. Finally, the entire boat is in view. This is proof that Earth is a sphere.
How does gravity affect Earth’s shape?

Earth’s spherical shape is caused by gravity. Gravity is a force that attracts all objects toward each other. When objects are apart, the gravitational pull between them is weak. The larger an object is, the stronger its gravitational pull.

Large objects in space, such as planets and moons, often are spherical because of how they formed. At first, particles collide and stick together without any particular shape. However, as the object grows larger, its mass and gravitational pull increase. Particles are pulled to the center of the object, giving it the shape of a ball.

What are some of Earth’s physical properties?

Scientists have measured the distance around Earth (circumference), the distance through the center of Earth (diameter), and other properties of Earth. Some of these properties are shown in the table below.

<table>
<thead>
<tr>
<th>Physical Properties of Earth</th>
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<tbody>
<tr>
<td>Diameter (pole to pole)</td>
<td>12,714 km</td>
</tr>
<tr>
<td>Diameter (equator)</td>
<td>12,756 km</td>
</tr>
<tr>
<td>Circumference (poles)</td>
<td>40,008 km</td>
</tr>
<tr>
<td>(distance around Earth through N and S poles)</td>
<td></td>
</tr>
<tr>
<td>Circumference (equator)</td>
<td>40,075 km</td>
</tr>
<tr>
<td>(distance around Earth at the equator)</td>
<td></td>
</tr>
<tr>
<td>Mass</td>
<td>$5.98 \times 10^{24}$ kg</td>
</tr>
<tr>
<td>Average density (average mass per unit volume)</td>
<td>5.52 g/cm$^3$</td>
</tr>
<tr>
<td>Average distance from the Sun</td>
<td>149,600,000 km</td>
</tr>
<tr>
<td>Period of rotation relative to stars (1 day)</td>
<td>23h, 56 min</td>
</tr>
<tr>
<td>Solar day</td>
<td>24 h</td>
</tr>
<tr>
<td>Period of revolution (1 year) (path around the Sun)</td>
<td>365 days, 6 h, 9 min</td>
</tr>
</tbody>
</table>
Is Earth a perfect sphere?

Earth is not a perfect sphere. It bulges slightly at the equator and is somewhat flattened around the poles. This causes the distance around the equator to be greater than the distance around the poles.

Motions of Earth

Have you ever wondered why the Sun appears to rise and set each day or why the Moon and other objects in the sky appear to move from east to west? The answer is shown in the figure above. Earth’s geographic poles are located at the north and south ends of Earth’s axis. The axis is an imaginary line drawn from the north geographic pole through Earth to the south geographic pole. Earth spins around this imaginary line. Rotation is the spinning of Earth on its axis. This is what causes you to experience day and night.

What is Earth’s revolution?

Earth has another type of motion. As it spins on its axis each day, Earth also moves along a path around the Sun. Revolution is the motion of Earth around the Sun. It takes Earth about one year to travel around the Sun, so Earth rotates on its axis approximately 365 times during one complete revolution of the Sun. Earth’s revolution around the Sun is shown in the figure above.
How does Earth’s orbit relate to seasons?

A new year begins. As the weeks pass, you notice that the Sun remains in the sky later each day. When spring comes, the weather is warmer, and the number of daylight hours gradually increases. What causes these changes?

You learned earlier that Earth’s rotation causes day and night. Earth also moves around the Sun, completing one revolution each year. Earth’s orbit, or curved path around the Sun, forms an ellipse, or oval shape.

Earth’s elliptical orbit causes it to be closer to the Sun in January and farther from it in July. But the total amount of energy Earth receives from the Sun does not change much throughout the year. However, the amount of energy that specific places on Earth receive varies.

How does Earth’s tilt cause seasons?

Earth has seasons because it is tilted on its axis. The angle of the tilt is about 23.5 degrees. The figure below shows that during part of Earth’s orbit, the northern hemisphere is tilted toward the Sun and tilted away from the Sun during another part. 

The hemisphere that is tilted toward the Sun has more daylight hours than the hemisphere that is tilted away. When Earth’s northern hemisphere is tilted toward the Sun, that half of the planet has longer daylight hours. Also, sunlight strikes the hemisphere tilted toward the Sun at a higher angle during the summer. The Sun’s rays are more direct, and they bring more heat. In winter, the opposite happens. Sunlight strikes the hemisphere tilted away from the Sun at a lower angle. Less direct sunlight reaches the surface. There are fewer daylight hours, and the temperatures are colder during winter.
What causes the solstices?

Because of the tilt of Earth’s axis, the Sun’s position relative to Earth’s equator changes. Twice a year there is a solstice. The **solstice** is the time when the Sun reaches its greatest distance north or south of the equator, and is directly over the Tropic of Cancer or the tropic of Capricorn. These times are known as the summer and winter solstices.

In the northern hemisphere, summer solstice happens on June 21 or 22, when the Sun is highest in the sky at noon. Winter solstice happens in the northern hemisphere on December 21 or 22, when the Sun is lowest at noon. In the southern hemisphere, the summer solstice is in December; the winter solstice is in June. The solstices are shown in the figure below.

![Diagram of solstices and equinoxes](image)

What causes equinoxes?

At an **equinox** (EE kwuh nahks), the Sun is directly above Earth’s equator, and the lengths of day and night are nearly equal all over the world. During equinox, Earth’s tilt is neither toward nor away from the Sun. You can see this in the figure above. In the northern hemisphere, spring equinox is March 21 or 22. The fall equinox is September 21 or 22. The dates for solstices and equinoxes change over time.

What is Earth’s place in space?

Earth is shaped much like a sphere. As Earth rotates on its axis, the Sun appears to rise and set in the sky. Earth’s tilt and revolution around the Sun cause seasons to occur. Later you will learn about motion of the Moon and planets other than Earth.
**After You Read**

### Mini Glossary

- **axis**: imaginary line around which Earth spins; drawn from the north geographic pole through Earth to the south geographic pole
- **equinox (EE kwuh nahks)**: twice-yearly time when the Sun is directly above Earth’s equator and there are equal hours of day and night
- **orbit**: a curved path followed by Earth as it moves around the Sun
- **revolution**: the motion of Earth around the Sun, which takes about $365\frac{1}{4}$ days, or one year, to complete
- **rotation**: the spinning of Earth on its axis every 24 hours, which causes day and night
- **solstice**: time when the Sun reaches its greatest distance north or south of Earth’s equator

1. Review the terms and their definitions in the Mini Glossary above. Choose two of the terms that are related and write a sentence using both terms.

2. Complete the sentences to compare and contrast Earth’s revolution and rotation.

   Earth’s _____ takes _____ days.

   Earth revolves around the _________.

   Earth rotates on its _________.

   Earth’s _____ takes _____ hours.

3. As you read this section, you outlined the facts about Earth’s properties and how Earth moves through space. Did your outline help you understand more about Earth and how it moves? What other strategies did you use to help you read and understand this section?

---

Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about Earth’s motion and seasons.
Before You Read

The Moon is Earth’s only natural satellite. It orbits Earth and is our closest neighbor in space. What do you know about the Moon? List what you know below.

What You’ll Learn

- about the Moon’s surface features and interior
- about the Moon’s phases
- the causes of eclipses
- about the origin of the Moon

Read to Learn

The Moon’s Surface and Interior

Suppose that on a clear night you take a good look at the full moon. If you use binoculars or a telescope, you can see dark- and light-colored areas on the Moon’s surface. The dark areas are maria (MAR ee uh). Galileo named the dark-colored areas *maria*, the Latin word for seas, because they reminded Galileo of the oceans.

What are maria?

Maria probably formed when lava from inside the Moon flowed into large, bowl-like regions on the Moon’s surface. These depressions may have formed early in the Moon’s history. During the Apollo moon missions, astronauts collected moon rocks from the maria. These rocks were analyzed on Earth. The rocks were about 3.2 billion to 3.7 billion years old. They are the youngest rocks found on the Moon so far.

What are lunar highlands?

The light-colored areas on the Moon are lunar highlands. They are several kilometers higher than the maria. The oldest moon rocks analyzed so far were found in the lunar highlands. They are about 4.6 billion years old.

Make Flash Cards

Think of a quiz question for each main point. Write the question on one side of a flash card and the answer on the other side. Quiz yourself until you know all the answers.

1. Identify Where have the oldest moon rocks been found?
What are craters?
As you look at the Moon’s surface features, you will see craters. **Craters** are depressions formed by large meteorites. Meteorites are space objects that strike the surface. When meteorites struck the Moon, cracks could have formed in its crust, allowing lava flows to fill in the large depressions. Craters help scientists find out how old parts of a moon’s or a planet’s surface are compared to other parts. The more craters there are in a region, the older the surface is.

**What is the inside of the Moon like?**
During the Apollo space program, astronauts left several seismographs (SIZE muh grafs) on the Moon. A seismograph is an instrument that measures tremors, or seismic vibrations. On Earth, these instruments are used to measure earthquake activity. On the Moon, seismographs are used to measure moonquakes. Based on the study of moonquakes, a model of the Moon’s interior has been developed, as shown in the figure below.

The first layer of the Moon is the crust, which is about 60 km thick on the side facing Earth and about 150 km thick on the far side. Below the crust is a solid layer called the mantle, which may extend 900 km to 950 km farther down. A soft layer of mantle may continue another 500 km down. The innermost layer may be an iron-rich, solid core with a radius of about 300–450 km.
How is the Moon like Earth?

Like the Moon, Earth also has a dense, iron core. However, the Moon’s core is small compared to its total volume. The Moon is most like Earth’s outer two layers—the mantle and the crust—in density. This supports the idea that the Moon may have formed mostly from material ejected from Earth’s mantle and crust.

Motions of the Moon

The same side of the Moon always faces Earth. You can prove this by looking at the Moon for several nights in a row. You’ll see that its bright and dark features stay in the same positions. Does this mean that the Moon doesn’t spin on its axis as it orbits Earth? Read on to explore why the same side of the Moon always faces Earth.

What are the Moon’s cycles?

The Moon is an average distance of 384,000 km from Earth. It takes 27.3 days for the Moon to complete one orbit around Earth. The Moon also takes 27.3 days to rotate once on its axis. Because these two motions of the Moon take the same amount of time, the same side of the Moon is always facing Earth, as shown in the illustration below.

The Moon’s orbit is an ellipse. When the Moon is closer to Earth, it moves faster, and it moves slower when it is farther away. This means the rotation and revolution of the Moon are not exactly the same during a 27.3-day period. So during the Moon’s orbit, observers can first see a little more of the western side of the Moon, then a little more of the eastern side.
What causes the Moon’s phases?

If you watch the Moon for several days in a row, you may notice how its shape and position in the sky change. You learned that the Moon rotates on its axis and revolves around Earth. These motions cause the regular cycle of change in the way the Moon looks to an observer on Earth.

How does the Sun light the Moon?

You see the Moon because it reflects sunlight. As the Moon revolves around Earth, the Sun always lights one half of the Moon. However, you don’t always see the entire lighted part of the Moon. Sometimes you just see half, or even less, of the lighted part. What you see are phases of the moon. **Moon phases** are the changing views of the Moon as seen from Earth.

![Diagram of Moon Phases]

What is the new moon?

The Moon phases are illustrated in the figure below. New moon occurs when the Moon is between Earth and the Sun. You can’t see a new moon because the lighted half of the Moon is facing the Sun.

When is the Moon waxing?

Shortly after the new moon, more and more of the side facing Earth is lighted. The phases are said to be waxing, or growing in size. About 24 hours after new moon, a thin sliver on the side facing Earth is lighted. This phase is called waxing crescent. As the Moon continues its trip around Earth, half of that side is lighted. This phase is first quarter. The next phase is called waxing gibbous (GIH bus).
**What is the full Moon?**

Sometimes, when you look at the Moon from Earth, it looks like a complete circle. This is the full moon, when all of the facing Earth is lighted. It comes after the waxing gibbous phase. At full Moon, Earth is between the Sun and the Moon.

**When is the Moon waning?**

After passing full moon, the amount of the side facing Earth that is lighted begins to decrease.

Now the phases are said to be waning. Waning gibbous takes place just after full moon. Next comes third quarter, when only half of the side facing Earth is lighted. This is followed by waning crescent, the final phase before the next new moon. The Moon continues to wane until it is time for the new moon again.

**What is the time difference between the Moon’s phases and revolution?**

The complete cycle of the Moon’s phases takes about 29.5 days. However, you will recall that the Moon takes only 27.3 days to revolve once around Earth. Earth’s revolution around the Sun cause the time difference. It takes the Moon about two days longer to align itself again between Earth and the Sun at new moon. You can see the time difference between the Moon’s phases and revolution in the figure below.

---

**Picture This**

8. **Identify** On the figure, circle the phase that comes after waning crescent.

---

Earth’s orbit

Day 1
New moon

Day 14 1/4
Full moon

Day 29 1/2
New moon again

2 days

Day 27 1/4
Earth, Moon, and distant star are once again aligned.

Distant star

Reading Essentials 163
Eclipses

When the Moon lines up directly with the Sun, it can cast its shadow on Earth. Earth also can cast its shadow onto the Moon during a full moon. When shadows are cast in these ways, eclipses can occur.

Eclipses occur only when the Sun, the Moon, and Earth are lined up perfectly. Eclipses happen only a few times each year because the Moon’s orbit is tilted at an angle from Earth’s orbit. This most often causes the Moon’s shadow to miss Earth.

What is a solar eclipse?

Sometimes the Moon blocks sunlight from reaching a portion of Earth’s surface. During new moon, a solar eclipse occurs if Earth moves into the Moon’s shadow. Look at the figure below. It shows how the Moon blocks sunlight from reaching part of Earth’s surface. Only areas on Earth in the Moon’s umbra, or the darkest part of its shadow, experience a total solar eclipse. The sky becomes dark and stars can be seen easily.

Areas that are in the penumbra, or lighter part of the shadow, have a partial solar eclipse. Because Earth rotates and the Moon is moving in its orbit, a solar eclipse lasts only a few minutes in any one location. WARNING: To avoid harming your eyes, never look directly at a solar eclipse.

Picture This

9. Identify Circle the area of Earth in the Moon’s umbra, or darkest part of the Moon’s shadow.
What is a lunar eclipse?

A *lunar eclipse* occurs when the Sun, Earth, and the Moon are lined up. The full moon moves into Earth’s shadow. Earth blocks sunlight from reaching the Moon. When the Moon is in the darkest part of Earth’s shadow, a total lunar eclipse occurs.

During a total lunar eclipse, the full moon darkens. The Moon appears to be deep red because some sunlight refracts, or bends, through Earth’s atmosphere. As the Moon moves out of the umbra and into the penumbra, or lighter shadow, you can see the curved shadow of Earth move across the Moon’s surface. When the Moon passes partly through Earth’s umbra, a partial lunar eclipse occurs.

Origin of the Moon

Before the *Apollo* space program, scientists had hypotheses to explain the origin of the Moon.

The co-formation hypothesis states that Earth and the Moon formed at the same time and out of the same material. According to the capture hypothesis, Earth and the Moon formed at different locations in the solar system. Then Earth’s gravity captured the Moon as it passed close to Earth. The fission hypothesis states that the Moon formed from material thrown off of a rapidly spinning Earth.

What is the collision hypothesis?

The collection and study of moon rocks brought evidence to support the collision hypothesis. When Earth was about 100 million years old, a Mars-sized space object may have collided with Earth. Such an object would have broken through Earth’s crust and plunged toward the core. Large amounts of gas and debris would have been thrown into orbit around Earth. Within about 1,000 years, the gas and debris could have condensed to form the Moon. The collision theory is strengthened by the fact that Earth and the Moon have different densities. The Moon’s density is similar to material that would have been thrown off Earth’s mantle and crust.

10. **Compare and Contrast** Why do you think a lunar eclipse lasts longer than a solar eclipse?

11. **Identify** Which hypothesis about the origin of the Moon suggests that the Moon formed from gas and debris thrown into orbit around Earth?
After You Read

Mini Glossary

- **crater**: depression formed by impact of meteorites or comets; the more craters in a region, the older the surface
- **lunar eclipse**: occurs during a full moon when the Sun, the Moon, and Earth line up in such a way that the Moon moves into Earth’s shadow
- **moon phase**: changing view of the Moon as seen from Earth, which is caused by the Moon’s revolution around Earth
- **solar eclipse**: occurs during a new moon when the Sun, the Moon, and Earth are lined up in a specific way and Earth moves into the Moon’s shadow

1. Review the terms and their definitions in the Mini Glossary. Choose a term and write a definition of the term in your own words.

2. Complete the concept map to name the four major phases of the Moon.

3. Think about what you learned. How did making flash cards help you? Describe another study strategy you could use for this section.

Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about Earth’s moon.
Earth’s Place in Space

section 2 Earth and the Solar System

Benchmarks—SC.E.1.3.1 Annually Assessed: The student understands the vast size of our Solar System and the relationship of the planets and their satellites.
Also covers: SC.D.1.3.5; SC.E.1.3.2; SC.E.1.3.3; SC.E.1.3.4; SC.E.2.3.1; SC.H.1.3.6; SC.H.2.3.1; SC.H.3.3.5

Before You Read

Earth is the third planet from the Sun. Eight other planets also orbit the Sun. How many of the planets can you name? List them below.

---

Read to Learn

Size of the Solar System

Our solar system is extremely large. Our solar system is made up of the Sun, planets, asteroids, comets, and other objects that orbit the Sun. How would you measure something this large? Distances in space are measured by astronomical units, not kilometers. This is because the distances are so huge, it is not practical to use kilometers. Earth, for example, is about 150,000,000 km from the Sun. This distance is referred to as one astronomical unit, or 1 AU. The astronomical unit, is a unit used to measure distances in the solar system. Jupiter, the largest planet in the solar system, is more than 5 AU from the Sun. Other units are used to measure the larger distances between the stars.

At the center of the solar system is a star you know as the Sun. The Sun is an enormous ball of gas that produces energy by fusing hydrogen into helium in its core. More than 99 percent of all matter in the solar system is contained in the Sun.

What kind of star is the Sun?

Although the Sun is important to life on Earth, it is much like many other stars. The Sun is one of billions of stars in our galaxy—the Milky Way galaxy. The Sun is middle-aged and about average in the amount of light it gives off. Other galaxies exist and have the same forces and forms of energy found in our solar system.

---

What You’ll Learn

- about the characteristics of inner planets
- about how other inner planets compare and contrast with Earth
- about the characteristics of outer planets

---

Create-a-Quiz

As you read the text, create a quiz question for each subject. When you have finished reading, see if you can answer your own question correctly.

---

Compare and Contrast

Make the following two-tab Foldable to help you compare and contrast the inner planets and outer planets.
The Planets

The planets in our solar system can be classified as inner planets or outer planets. Inner planets have orbits that lie inside the orbit of the asteroid belt as shown in the figure below. The inner planets are mostly solid and rocky. They have thin atmospheres compared to the atmospheres of outer planets.

Outer planets have orbits that lie outside the orbit of the asteroid belt. Four of these are known as gas giants. One is a small ice/rock planet that seems to be out of place.

Inner Planets

The inner planets are Mercury, Venus, Earth, and Mars. They are known as the terrestrial planets, after the Latin word *terra* (earth). The inner planets are similar in size to Earth and are made up mainly of rock.

What is Mercury like?

The closest planet to the Sun is Mercury. It is covered by craters formed when meteorites crashed into its surface. The surface of Mercury has cliffs, some of which are 3 km high. These cliffs may have formed when Mercury’s molten, iron-rich core cooled and contracted, causing the outer solid crust to shrink. The planet seems to have shrunk about 2 km in diameter. Mercury has almost no atmosphere.
What is Venus like?
The second planet from the Sun, Venus, is similar in size and mass to Earth. It is often referred to as Earth’s twin. However, the atmosphere of Venus is very different from that of Earth. Thick clouds surround Venus and trap energy from the Sun causing the surface temperature on the planet to reach about 472°C. The process is similar to what occurs in a greenhouse.

What is planet Earth like?
The third planet from the Sun is Earth. It is unique because temperatures on Earth’s surface allow water to exist in three states—solid, liquid, and gas. Ozone, a molecule of three oxygen atoms bound together, exists in the layer of Earth’s atmosphere known as the stratosphere. This ozone protects life on Earth from the Sun’s harmful ultraviolet radiation.

What is Mars like?
The fourth inner planet from the Sun is Mars. It is often called the red planet. Iron oxide, the material found in rust, is found in weathered surface rocks on Mars. This gives the planet a reddish color. These rocks are similar to some volcanic rocks found on Earth. A section of the surface of Mars is shown in the figure below. The largest volcano in the solar system, Olympus Mons, is found on Mars.

3. Explain why Earth’s surface temperatures are unique.

4. Describe What does the surface of Mars look like?
Is there water on Mars?

Mars has two polar ice caps made of frozen water covered by a layer of frozen carbon dioxide. These ice caps change in size between Martian winter and summer.

There are long channels on Mars. These channels may have been carved by flowing water sometime in the past. The atmosphere of Mars, made up mostly of carbon dioxide with some nitrogen and argon, is much thinner than the atmosphere of Earth.

Outer Planets

The five outer planets are Jupiter, Saturn, Uranus, Neptune, and Pluto. Except for Pluto, they are all gaseous giant planets with dense atmospheres. They are mainly made up of light elements such as hydrogen and helium.

What is Jupiter like?

The largest planet in the solar system, Jupiter, is about twice the width of Earth. It is the fifth planet from the Sun and rotates once every six days. Its atmosphere is made mostly of hydrogen and helium and has many huge storms. The largest storm, the Great Red Spot, has raged for more than 300 years.

With its 63 moons, Jupiter is like a miniature solar system. The four largest moons of Jupiter are Io, Europa, Ganymede, and Callisto. They are called the Galilean satellites after Galileo Galilei, who discovered them in 1610. The moon Io is the most volcanically active body in the solar system. An ocean of liquid water is thought to exist beneath the ice crust on the moon Europa. Does that mean life may exist on Europa? The National Aeronautics and Space Administration (NASA) is preparing a mission to launch an orbiting spacecraft in 2008 to study this moon and search for signs of life.

What is Saturn like?

The sixth planet from the Sun is Saturn. The gases in Saturn’s atmosphere are made up mostly of hydrogen and helium. Saturn is often called the ringed planet because of its seven major ring divisions. The rings are made up of pieces of ice and rock, and can be seen in the figure on the next page.
Saturn has at least 33 moons. The largest, Titan, has an atmosphere denser than the atmospheres of Earth or Mars. The environment on Titan might be similar to that on Earth before oxygen became a major atmospheric gas.

**What is Uranus like?**

Uranus is the seventh planet from the Sun. Its atmosphere, made up mostly of hydrogen, also contains helium and methane. Methane reflects blue light and absorbs red light giving the planet a bluish-green color. Uranus is thought to have 27 moons.

**What is Neptune like?**

The eighth planet from the Sun is Neptune. Its atmosphere of hydrogen, helium, and methane gradually changes into a slushlike layer. This layer is comprised partially of water and other melted ices. This material is thought to change into an icy solid toward the interior. The icy layer may surround a central, rocky core about the size of Earth.

As with Uranus, the methane in Neptune’s atmosphere gives its bluish color. Winds in the gaseous portion of Neptune exceed 2,400 km/h, faster than winds on any other planet. Thirteen moons have been discovered. The largest moon, Triton, has geysers that shoot gaseous nitrogen into space. A lack of craters on Triton’s surface suggests that the surface of Triton is fairly young.

**How is Pluto different from other planets?**

Pluto is so far from the Sun that it has completed less than 20 percent of one revolution since its discovery in 1930. It is thought to be made partly of ice and partly of rock. A frozen layer of methane, nitrogen, and carbon monoxide sometimes covers Pluto’s surface. But when Pluto is closest to the Sun, these materials thaw and become gases rising to form a temporary atmosphere.
9. Draw Conclusions
Why did it take so long to discover Charon?

--

Does Pluto have a Moon?
The surface of Charon, Pluto’s moon, appears to be covered by water ice. Charon is so close to Pluto that it usually can’t be detected using ground-based telescopes. Because of this, Charon was discovered nearly 50 years after Pluto.

Other Objects in the Solar System
Other objects in the solar system are asteroids, comets, and meteoroids. **Asteroids** are small, rocky objects that are most often found in a belt between Mars and Jupiter. The asteroid belt is used by astronomers as a dividing line that separates the inner and outer planets. Jupiter’s tremendous gravity probably kept a planet from forming from the material in the asteroid belt.

**Comets** are made mainly of rocky particles and water ice. As their orbits approach the Sun, parts of comets turn to vapor and form tails. A comet, with its tail, is shown in the figure below. Comet tails always point away from the Sun. Almost all of the solar system’s comets are located in the Kuiper Belt and the Oort Cloud. The Kuiper Belt is located beyond Neptune’s orbit, and the Oort Cloud is located far beyond Pluto’s orbit.

When comets break up, some of the particles remain in orbit. When asteroids collide, small pieces break off. Both of these processes produce small objects in the solar system known as meteoroids. If meteoroids enter Earth’s atmosphere, they are called meteors. If they fall to Earth, they are called meteorites.

Picture This
10. **Identify** If the meteor in the picture falls to Earth, what will it be called?
Origin of the Solar System

How did the solar system begin? One hypothesis is that the Sun and all the planets and other objects formed from a large cloud of gas, ice, and dust about 5 billion years ago. This large nebul (NEB yuuh luh), or cloud of material, was rotating slowly in space. Shock waves, perhaps from a nearby exploding star, might have caused the cloud to start condensing, or pulling together. As it condensed, it started rotating faster and flattened into a disk.

How might the planets have formed?

Most of the condensing material was pulled by gravity toward the center to form an early Sun. The rest of the gas, ice, and dust in the outer areas of the nebula condensed, collided, and stuck together. This material formed the planets, moons, and other objects in the solar system.

Conditions in the inner part of the cloud caused small, solid planets to form. Conditions in the outer part of the cloud were better for the formation of giant, gaseous planets. Comets are thought to be made up of material left over from the original cloud. You can see how the solar system is thought to have formed in the figures below.

Formation of the Solar System

11. Compare and Contrast How did conditions in the inner part of the cloud differ from conditions in the outer part?

12. Interpret Scientific Illustrations Describe how the stage of the solar system shown in the top diagram is different from the stage shown in the bottom diagram.
**After You Read**

**Mini Glossary**

- **asteroid**: small, rocky object found in the asteroid belt between the orbits of Jupiter and Mars
- **astronomical unit**: unit used to measure distances in the solar system; 1 AU equals 150,000,000 km
- **comet**: space object made of rocky particles and ice that forms a tail when orbiting near the Sun
- **nebula**: cloud of gas and dust particles in interstellar space
- **solar system**: the sun, planets, asteroids, comets, and other objects in orbit around the Sun

1. Review the terms and their definitions in the Mini Glossary above. Then write a sentence comparing two of the objects described.

   ____________________________________________________________

   ____________________________________________________________

2. Complete the concept map to show the formation of the solar system.

   ![Concept Map]

3. As you read this section, you wrote a quiz question for each subject. After reading, could you answer your questions? If not, did you go back and review the part of the section that you did not understand?

   ____________________________________________________________

   ____________________________________________________________

Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about our solar system.
Cells

section 1 Cell Structure

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.

---

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** (S1 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 cell’s shape may tell you something about its function. 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.

---

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

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?

---

Reading Check
What types of cells are there?

Scientists separate cells into two groups, as shown in the figure above. 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 cell wall is outside the cell membrane. Cells of plants, algae, fungi, and most bacteria are each enclosed in a cell wall.

A plant cell wall is mostly made up of a substance 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.

3. List three things found in the cell wall of a plant.

_________________________
_________________________
_________________________
What is the function of the cell membrane?
The protective layer around every cell is the cell membrane. 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 a 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 a chemical that has 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.

6. **Identify** Where are ribosomes made?

**Picture This**
7. **Compare** Circle the organelles that direct cell activities in each cell. Highlight the organelle that contains chlorophyll.
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 a 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. Use 1 as the simplest level of organization and 5 as the most complex level of organization.
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 ______________

Visit fl7.mssscience.com to access your textbook, interactive games, and projects to help you learn more about cell structure.
Cells

section 2 Viewing Cells

Benchmarks—SC.H.1.3.3: The student knows that science disciplines differ from one another...but that they share a common purpose, philosophy, and enterprise; SC.H.3.3.5: The student understands that contributions to...science, mathematics, and technology have been made by different kinds of people, in different cultures, at different times...
Also covers: SC.H.1.3.1; SC.H.1.3.4; SC.H.1.3.5; SC.H.1.3.6

Before You Read

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

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. Most 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 $270 \times$. 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.

What You’ll Learn

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

Study Coach

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.

Foldables

Compare Make a three-tab Foldable, as shown below. Compare compound light microscopes and electron microscopes.
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× and the objective lens has a power of 43×, then the total magnification is 430× (10× times 43×). A 430× 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>Most plants and animals have many cells.</td>
</tr>
<tr>
<td>2. The cell is the basic unit of organization in organisms.</td>
</tr>
<tr>
<td>Even in complex organisms such as humans, the cell is the basic unit of life.</td>
</tr>
<tr>
<td>3. All cells come from cells.</td>
</tr>
<tr>
<td>Most cells can divide to form two new cells that are exactly the same.</td>
</tr>
</tbody>
</table>

Picture This
1. Identify Highlight Rudolf Virchow’s contribution to cell theory in the table.
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?

Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about viewing cells.
Cells

section 3 Viruses

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 at your doctor’s office or at a health clinic. On the lines below, list the kinds of diseases these shots will help prevent.

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?
A virus doesn’t have a nucleus or other organelles. It also lacks a cell membrane. Viruses have a variety of shapes.

Viruses are too small to be seen with a light microscope. They were discovered when scientists began using electron microscopes. Before that time, scientists only hypothesized about viruses.

How do viruses multiply?
A virus can make a copy of itself. A virus, however, must have the help of a living cell called a host cell. Crystallized 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.

The virus attaches to a specific host cell.

Host cell  Virus

The virus's hereditary material enters the host cell.

Nucleus

Viral hereditary material

Viral proteins

The hereditary material of the virus causes the cell to make viral hereditary material and proteins.

New viruses are released as the host cell bursts open and is destroyed.

New viruses form inside the host cell.

What happens when a virus is latent?

Some viruses can be latent, or inactive. When a latent virus enters a host cell, its hereditary material can become part of the cell’s hereditary material. Unlike an active virus, 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.
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, 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. A bacteriophage attaches to a bacterium and injects its 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.

Picture This
3. Identify  Circle each of the places where the virus is attached to the cell.

4. Define  the term vaccine.
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

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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 discovered and 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, including cold, icy regions and 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 a green pigment, or coloring, called chlorophyll (KLOR uh fihl). Chlorophyll traps light energy that is used to make food. 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 can carry out photosynthesis. 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 plant fossils 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. They 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 cell walls even stronger. Trees, such as oaks and pines, could not grow without these 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 and dissolved nutrients that can move into the cell. Through adaptations, structures developed in many plants 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 named Carolus Linnaeus developed a system to classify plants. He also developed a way to name plants called binomial nomenclature (bi NOH mee ul • NOH mun klay chur).
1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the difference between vascular and nonvascular plants.

nonvascular plants: plants without tubelike structures; move water and other substances through the plant in other ways
cellular plant: plants that have tubelike structures to carry water, nutrients, and other substances to the cells of the plant

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

Plant Adaptations for Life on Land

- cuticle: a waxy, protective layer on the surface of the plant
- cellulose: a chemical compound that forms the walls of plants; plants make it out of sugar
- 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

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Before You Read

Ferns are a type of seedless plant that is often grown as a house plant. 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 have flowers or cones, and they 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 usually are only a few cells thick. They are not very tall, only 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 anchor the plants where they grow. Most nonvascular plants grow in damp places. They absorb water through their cell membranes and cell walls.

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.

1. Identify How do rhizoids help a plant?
Mosses The largest group of nonvascular plants is the mosses. Mosses have green, leaflike growths on a stalk. Their rhizoids are made of many cells. Like all nonvascular plants, mosses reproduce by forming spores. In many moss species, a stalk with caps grows from the plant when it is ready to reproduce. Spores are produced in the cap. Mosses often grow on tree trunks, rocks, or the ground. Most mosses live in damp places, but some can live in deserts.

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 these plants are carried by the wind. When a spore lands on the ground, it can 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. 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

Vascular tissue is made up of tubelike cells that carry water, minerals, and food 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 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 below. 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 both cold and hot areas. Ground pines are endangered in some places because they have been over-collected by humans.
Spike Mosses  Spike mosses resemble ground pines. One species, 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 from 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 decaying. 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 to use as a low-cost fuel in places such as Ireland and Russia. Scientists hypothesize that over time peat that remains in a bog will become coal.

How are seedless vascular plants used?
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. Peat is used to enrich garden soil. 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 compare nonvascular and vascular seedless plants. Include phrases that describe how the plants get nutrients and how they reproduce.

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

section 3 Seed Plants

What You’ll Learn
■ the characteristics of seed plants
■ how roots, stems, and leaves function
■ the characteristics of gymnosperms and angiosperms
■ how monocots and dicots are different

Before You Read
What are your favorite fruits? What type of plant 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.
**Palisade Layer** 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 petunia. Woody stems are hard and rigid, like those of trees and shrubs. The trunk of a tree is a stem.

**Why are plant roots important?**

The root system of most plants is the largest part of the plant. Roots contain vascular tissue. Water and dissolved substances from the soil move into the roots and 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.

---

**Picture This**

1. **Identify** Color in blue the plant layer that contains the chloroplasts. Color in red the plant layer that protects the leaf. Finally, underline the name of the part of the leaf that allows carbon dioxide, water, and oxygen to enter and exit the leaf.

---

**FeAT Focus**

**Annually Assessed Benchmark Check**

2. **Identify** two things roots do for a plant.

   __________________________

   __________________________

   __________________________
Functions of Roots  Roots can store food and water. They can take in oxygen that the plant needs for the process of cellular 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 on the female cone but not on the male cone.

Angiosperms  
An angiosperm is a vascular plant that flowers and produces fruit with one or more seeds. 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 have 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 a life cycle—all the events in an organism’s growth and development. 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 seeds to maturity. A plant that completes its life cycle in one year is called an annual. 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. Some desks and chairs are made from wood.
After You Read

Mini Glossary

angiosperm: vascular plant that flowers and produces one or more seeds inside a fruit

 cambium: plant tissue that produces most of the new xylem and phloem cells
dicot: angiosperm that has two cotyledons inside its seeds
guard cells: cells that surround a stoma and open and close it
gymnosperm: vascular plant that produces seeds that are not protected by fruit
life cycle: all the events in an organism’s growth and development

monocot: angiosperm that has one cotyledon inside its seeds
phloem: plant tissue made up of tubelike cells that are stacked to form tubes; tubes move food from where it is made to parts of the plant where it is used
stomata: small openings in the epidermis of the leaf
xylem: plant tissue made up of hollow, tubelike cells that are stacked one on top of the other to form vessels; vessels transport water and dissolved substances from the roots to all other parts of the plant

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>
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</tbody>
</table>

Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about seed plants.
**Before You Read**

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

---

**Read to Learn**

**Taking in Raw Materials**

Plants can make their own food using water, carbon dioxide, and inorganic chemicals from the soil. Plants also produce waste products.

**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**

As you read the section, write down the main ideas. Take notes on the facts that support the main ideas. Then use your notes to summarize the main ideas of this section.

**Picture This**

1. **Identify** Circle the names of 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 that enters roots of a plant exits the plant through its leaves. Carbon dioxide, oxygen, and water vapor enter and exit a plant through openings in its 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 light, which is used during food production, 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 (KLOH rufihl). Chlorophyll is important to plants because the light energy that plants absorb is used during food production. Photosynthesis (foh toh SIHN thuh suhs), a food-making process, happens in the chloroplasts.
The Food-Making Process

**Photosynthesis** is the process during which a plant’s chlorophyll traps light energy and uses it to produce sugar. 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 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.

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

**What are light-dependent reactions?**

Some chemical reactions that occur during photosynthesis need light. These are called light-dependent reactions. During light-dependent reactions, chlorophyll and other pigments trap light energy that will be changed and stored in sugar molecules. Light energy causes water molecules in chloroplasts to split into oxygen and hydrogen. The oxygen exits the plant through the stomata. The hydrogen produced when water is split is used in reactions that do not need light.

**What are light-independent reactions?**

Other chemical reactions that occur during photosynthesis do not need light. These are called light-independent reactions. The light energy trapped during the light-dependent reactions is used to combine carbon dioxide and hydrogen. This process creates 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?**

Glucose is the main form of food for plant cells. A plant usually produces more glucose than it can use and stores it as other sugars and starches. When you eat carrots or potatoes, you are eating the stored product of photosynthesis.

Oxygen is produced during photosynthesis. Most of the oxygen is released as waste through the stomata.

4. **List** two foods other than carrots and potatoes that are stored products of photosynthesis.
How does a plant use glucose?

Glucose also is important to 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

Cellular respiration is the process of breaking down food and releasing energy that occurs inside cells. It occurs in many organisms. In many-celled organisms it usually occurs in the mitochondria. The overall chemical equation for cellular respiration is shown below.

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

How does cellular respiration occur?

Before cellular respiration begins, glucose molecules in the cytoplasm are broken down into two smaller molecules. These molecules move into a mitochondrion. Oxygen breaks down the molecules into water and carbon dioxide and to release energy. The figure below shows cellular respiration in a plant cell.
**Why is cellular respiration important?**

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

Plants cells use energy produced by cellular respiration to transport sugars, to open and close stomata, and to produce chlorophyll. When seeds sprout, energy released from stored food is used. The figure below shows some uses of energy in plants.

The waste product carbon dioxide also is important. Cellular respiration returns carbon dioxide to the atmosphere, where plants and some other organisms use it for photosynthesis.

**Comparison of Photosynthesis and Cellular Respiration**

Cellular respiration is almost the reverse of photosynthesis. Photosynthesis combines carbon dioxide and water by using light energy. This produces glucose (food) and oxygen. Cellular respiration combines oxygen and food to release the energy in the chemical bonds of the food. This produces energy, carbon dioxide, and water. Look at the table below to compare the differences between photosynthesis and cellular respiration.

| Comparing Photosynthesis and Cellular Respiration |
|------------------------------------|-----------------|
| **Photosynthesis** | **Cellular Respiration** |
| Energy | stored | released |
| Raw materials | water and carbon dioxide | glucose and oxygen |
| End products | glucose and oxygen | water and carbon dioxide |
| Where | cells with chlorophyll | cells with mitochondria |

---

**Picture This**

7. List **two uses of the 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.
1. Review the terms and their definitions in the Mini Glossary. Write one or two sentences that explain the difference between photosynthesis and cellular 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?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
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. Often plants respond to stimuli by moving toward or away from the stimulus. Plants respond to touch, light, and gravity. Most plant responses are slow and involve growth.

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 grow longer than the cells facing the light. Because of this, the plant bends toward the light. The leaves move 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.

How does auxin affect plants?

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 plants?
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. This stimulates 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 plants?
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, the hours of daylight and darkness change with the seasons. These changes in the number of hours of daylight and darkness affect plant growth.

How does darkness affect flowers?
Many plants must have a certain number of hours of darkness to flower. Plants that need less than 10 to 12 hours of darkness to flower are called long-day plants. These plants include spinach, lettuce, and beets. Plants that need 12 hours or more 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.

2. Complete the cause-and-effect chart below to show how plant hormones affect plant growth.

---

**After You Read**

**Mini Glossary**

**auxin** (AWK sun): a plant hormone that causes plant stems and leaves to exhibit positive response to light

**day-neutral plant**: a plant that does not have a specific photoperiod to flower

**long-day plant**: a plant that needs less than 10 to 12 hours of darkness to flower

**photoperiodism** (foh toh PIHR ee uh dih zum): a plant’s response to the number of hours of daylight and darkness it receives daily

**short-day plant**: a plant that needs 12 hours or more of darkness to flower

**tropism** (TROH pih zum): a response of a plant to an external stimulus

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Classifying Animals

section 1 What is an animal?

Before You Read

List the names of five animals on the lines below. Then write one thing that these animals have in common.

Animal Characteristics

If you asked ten people what all animals have in common, you would get many different answers. Animals come in many different shapes and sizes. All animals, however, have five common characteristics.

1. All animals are many-celled organisms that are made of different kinds of cells.
2. Most animal cells have a nucleus and organelles. The nucleus and many of the organelles are surrounded by a membrane. A cell that contains a nucleus and organelles surrounded by membranes is called a eukaryotic (yew ker ee AH thik) cell.
3. Animals cannot make their own food.
4. Animals digest their food. Large food particles are broken down into substances cells can use.
5. Most animals can move from place to place.

What is symmetry?

As you study different groups of animals, you will look at their symmetry (SIH muh tree). Symmetry refers to the way parts of an object are arranged. If the parts are arranged in a way that allows the object to be divided into similar halves, it is symmetrical.
What kind of symmetry do most animals have?

Most animals have either radial symmetry or bilateral symmetry. An animal with body parts arranged in a circle around a central point has radial symmetry. As you can see in the figure below, a sea anemone has radial symmetry. An animal with radial symmetry can find food and gather information from all directions. Other animals that have radial symmetry are jellyfish and sea urchins.

An animal with bilateral symmetry has parts that are nearly mirror images of each other. You can draw a line down the center of its body to divide it into two similar parts. The figure below shows that a lobster has bilateral symmetry. A human also has bilateral symmetry.

What is an asymmetrical animal like?

An animal with an uneven shape is called asymmetrical (AY suh meh trih kul). Its body cannot be divided into halves that are similar. Look at the sponge in the figure below. Notice that you cannot draw a line down the center of its body to divide it into two halves that are similar. As you learn more about invertebrates, think about their body symmetry. Notice how body symmetry affects the way they gather food and do other things. Most animals have radial or bilateral symmetry. Only a few animals are asymmetrical.

Picture This

3. Classify Draw a simple human figure beside the animal with the type of symmetry that humans have.

Sea anemones have radial symmetry.

Lobsters have bilateral symmetry.

Many sponges are asymmetrical.
**Animal Classification**

Animals have many characteristics in common. But when you think about the variety of animals you can name, you know that there are many different kinds of animals. Some animals have legs, others have wings. Some live on land, others live in water. Scientists use a classification system to place all animals into related groups.

Scientists separate animals into two groups—vertebrates (VUR tuh bruts) and invertebrates (ihn VUR tuh bruts). These two groups are shown in the figure below.

**Vertebrates** are animals that have a backbone. **Invertebrates** are animals that do not have a backbone. About 97 percent of all animals are invertebrates.

In the circle below, draw a circle graph showing the percent of invertebrates and the percent of vertebrates.

*Picture This*

5. **Identify** Circle any words in the diagram that you do not know. When you have finished reading this chapter, review the words you circled and state a characteristic of each one.
1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the difference between an animal that has symmetry and one that is asymmetrical.

2. Fill in the table below to describe the common characteristics of animals.

<table>
<thead>
<tr>
<th>Common Characteristics of All Animals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
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<tr>
<td>2.</td>
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<tr>
<td>3.</td>
</tr>
<tr>
<td>4.</td>
</tr>
<tr>
<td>5.</td>
</tr>
</tbody>
</table>

3. How did writing and answering quiz questions help you remember what you read about animal characteristics and classification?
Before You Read

On the lines below, list a difference between the way plants and animals get food.

Read to Learn

Sponges

Scientist have identified about 15,000 species of sponges. Most sponges live in the ocean, although some live in freshwater. Adult sponges remain attached to one place for their lifetime.

How does a sponge eat?

Sponge bodies are made of two layers of cells. Water containing tiny food particles and oxygen flows through the pores of the sponge. The inner part of a sponge’s body is lined with collar cells. Thin, whiplike structures called flagella (flah JEH luh) are attached to the collar cells. The whiplike movements of the flagella keep water moving through the sponge. Other cells digest the food, carry nutrients to all parts of the sponge, and remove wastes from the sponge.

How does a sponge protect itself?

Many sponges have soft bodies that are supported by sharp, glass-like structures called spicules (SPIHK yewlz). Other sponges have a material called spongian. Spongian is like foam rubber. It makes sponges soft and stretchable. Some sponges have both spicules and spongian to protect their soft bodies.
How do sponges reproduce?
Sponges can reproduce asexually and sexually. A sponge reproduces asexually when a bud on the side of the parent sponge develops into a small sponge. The small sponge breaks off, floats away, and attaches itself to a new surface. New sponges also can grow from pieces of a sponge.

Cnidarians
Jellyfish, sea anemones, hydra, and coral are cnidarians (nih DAR ee unz). Cnidarians are hollowed-bodied animals with two cell layers that are organized into tissues. Cnidarians have tentacles surrounding their mouths. The tentacles shoot out harpoon-like stinging cells to capture prey. Cnidarians have radial symmetry, so they can locate food that floats by from any direction. The inner cell layer digests the food. Nerve cells work together as a nerve net throughout the cnidarian’s whole body.

How do cnidarians reproduce?
Cnidarians reproduce both sexually and asexually. Some cnidarians, such as hydras, reproduce asexually by budding. Some can reproduce sexually by releasing eggs or sperm into the water. The eggs from one cnidarian are fertilized by the sperm from another cnidarian.

Flatworms and Roundworms
Unlike sponges and cnidarians, flatworms search for food. Flatworms are invertebrates with long, flattened bodies and bilateral symmetry. A flatworm’s body is soft and has three layers of tissue organized into organs and organ systems. Some kinds of flatworms can move around and search for food. These flatworms have a digestive system with one opening. Most flatworms are parasites that live in or on their hosts. A parasite gets its food and shelter from its host.

Roundworms are the most widespread animal on Earth. There are thousands of kinds of roundworms. Billions of roundworms can live in an acre of soil.

A roundworm’s body is a tube inside a tube. Between the two tubes is a cavity full of fluid. The fluid-filled cavity separates the digestive tract from the body wall. The digestive tract of a roundworm has two openings. Food enters the roundworm through the mouth, it is digested in a digestive tract, and wastes exit through the anus.
Mollusks

A mollusk is a soft-bodied invertebrate that usually has a shell. A mollusk also has a mantle and a large, muscular foot. The mantle is a thin layer of tissue that covers the mollusk’s soft body. The foot is used for moving or for holding the animal in one place. Snails, mussels, and octopuses are mollusks.

Mollusks that live in water have gills. Gills are organs in which carbon dioxide from the animal is exchanged for oxygen from the water. Mollusks that live on land have lungs in which carbon dioxide from the animal is exchanged for oxygen from the air.

What body systems does a mollusk have?

A mollusk has a digestive system with two openings. Many mollusks have a scratchy, tonguelike organ called the radula (RA juh luh). The radula has rows of tiny, sharp teeth that the mollusk uses to scrape small bits of food off rocks and other surfaces.

Some mollusks have an open circulatory system, which means they do not have blood vessels. Instead, the blood washes over the organs, which are grouped together in a fluid-filled cavity inside the animal’s body. Others have a closed circulatory system in which blood is carried through blood vessels.

Segmented Worms

Earthworms, leeches, and marine worms are segmented worms. Segmented worms are also called annelids (A nul idz). A segmented worm’s body is made up of repeating rings that make the worm flexible. Each ring or segment has nerve cells, blood vessels, part of the digestive tract, and the coelom (SEE lum). The coelom is a body cavity that separates the internal organs from the inside of the body wall. A segmented worm has a closed circulatory system and a complete digestive system with two body openings.

What do earthworms eat?

Earthworms are important in shaping the landscape. They move through soil by eating the soil. The earthworm uses the organic matter in the soil for food. The undigested wastes and soil that leave the earthworm make the soil better. Earthworms add nutrients to the soil and loosen it. This increases the fertility of the soil.
Scientists have discovered more than a million species of arthropods (AR thruh pahdz). An arthropod is an invertebrate animal with jointed appendages (uh PEN dih juz). Appendages are structures such as claws, legs, or antennae that grow from the body.

Arthropods have bilateral symmetry and segmented bodies similar to annelids. Most arthropods have fewer and more specialized segments. They have an open circulatory system. Oxygen enters the animal’s tissues through spiracles. Fertilization in most arthropods is internal.

**How does an arthropod protect itself?**

Arthropods have hard body coverings called exoskeletons. The exoskeleton protects and supports the animal’s body and reduces water loss. As the animal grows, it sheds the exoskeleton, which does not grow with the animal.

**What is metamorphosis?**

The young of many arthropods don’t look anything like the adults. Many arthropods completely change their body form as they grow. This change in body form is called metamorphosis (met uh MOR fuh sus).

Butterflies, bees, and beetles are arthropods that go through a complete metamorphosis. Complete metamorphosis has four stages—egg, larva, pupa (PYEW puh), and adult. At each stage, the arthropod looks completely different.

Some insects such as grasshoppers and dragonflies go through incomplete metamorphosis. They have only three stages—egg, nymph, and adult. The nymph looks similar to its parents, only smaller. A nymph sheds its exoskeleton by a process called molting as it grows. The two types of metamorphosis are shown in the figure below.
Echinoderms

Echinoderms (ih KI nuh durmz) are animals that have radial symmetry. Sea stars and sand dollars are echinoderms. Echinoderms have spines of different lengths that cover the outside of their bodies. Most echinoderms have an internal skeleton made up of bonelike plates that supports and protects the animal. Echinoderms have a simple nervous system, but no head or brain. Some echinoderms are predators, some are filter feeders, and some feed on decaying matter.

What is a water-vascular system?

An echinoderm has a water-vascular system, which is a network of water-filled canals and thousands of tube feet. The tube feet work like suction cups to help the animal move and capture prey. The figure below shows the parts of a sea star. A sea star eats by pushing its stomach out of its mouth and into the opened shell of its prey. After the prey’s body is digested, the sea star pulls in its stomach. Like some other invertebrates, sea stars can regrow lost or damaged parts.

7. List two examples of echinoderms.

7. List two examples of echinoderms.

8. Explain Highlight the name of the body structure a sea star uses to capture prey.

- Tube feet
- Stomach
- Mouth
- Radial canal
- Ray
- Anus
After You Read

Mini Glossary

appendage (uh PEN dihj): a structure such as a claw, leg, or antennae that grows from the body

closed circulatory system: a circulatory system in which blood is carried through blood vessels

exoskeleton: a hard body covering that protects and supports the body and reduces water loss

metamorphosis (met uh MOR fuh sus): a change in body form

open circulatory system: a circulatory system without blood vessels in which blood washes over the organs

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that describes how an arthropod might use an appendage.

2. Complete the flowcharts to compare complete and incomplete metamorphosis.

Complete Metamorphosis

1.  

2.  

3.  

4.  

Incomplete Metamorphosis

1.  

2.  

3.  

3. How do the sticky-notes help you remember what you have read?

Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about arthropods and echinoderms.
List three animals on the lines below. Then write one thing that all these animals have in common with humans.

What is a chordate?

Familiar animals such as birds, fish, cats, and dogs belong to a large group of animals called chordates. **Chordates** (KOR dayts) are animals that have the following three characteristics—a notochord (NOH tuh cord), a nerve cord, and pharyngeal (fur RIN jee uhl) pouches at some time during their development.

The notochord is a flexible rod that runs the length of the developing organism. The nerve cord is made of nerve tissue. In most chordates, one end of the nerve cord develops into the organism’s brain.

Pharyngeal pouches are slitlike openings between the inside of the body and the outside of the body. They are present only in the early stages of the organism’s development. In some chordates, like the lancelet in the figure below, the pharyngeal pouches develop into gill slits.
What are the characteristics of vertebrates?
Chordates are classified into several smaller groups. The largest group of chordates is made up of the vertebrates, which include humans. All vertebrates have an internal system of bones called an endoskeleton. The endoskeleton supports and protects the body’s internal organs. For example, the skull is the part of the endoskeleton that surrounds and protects the brain.

How do vertebrates control body temperature?
Vertebrates are either ectotherms or endotherms. Ectotherms (EK tuh thurmz) are cold-blooded animals. Their body temperature changes as the temperature of their surroundings changes. Fish and reptiles are ectotherms.

Endotherms (EN duh thurmz) are warm-blooded animals. Their body temperature does not change with the surrounding temperature. Humans are endotherms. Your body temperature is usually about 37°C, but can vary by about 1°C, depending on the time of day.

Fish
Fish are the largest group of vertebrates. Scientists classify fish into three groups—bony, jawless, and jawed cartilaginous (kar tuh LA juh nuhs). All fish are ectotherms and live in water. Some species of fish are adapted to live in freshwater and other species are adapted to live in salt water.

Fish have gills. Gills are fleshy filaments where carbon dioxide and oxygen are exchanged. Water that contains oxygen passes over the gills. When blood is pumped into the gills, the oxygen in the water moves into the blood. At the same time, carbon dioxide moves out of the blood in the gills and into the water. 

Most fish have pairs of fanlike fins. Fish use fins to steer, balance, and move. The motion of the tail fin pushes the fish through the water.

Most fish have scales. Scales are thin structures made of a bony material that overlap to cover the skin.

Amphibians
Amphibians (am FIH bee unz) are animals that spend part of their lives in water and part on land. They have many adaptations that allow for life both on land and in the water. Amphibians include frogs, toads, salamanders, and newts.
What are characteristics of amphibians?

Amphibians are vertebrates with a strong endoskeleton made of bones. The skeleton helps support their body while on land.

Adult amphibians use lungs instead of gills to exchange oxygen and carbon dioxide. Lungs are an important adaptation for living on land. Amphibians have three-chambered hearts, in which blood carrying oxygen mixes with blood carrying carbon dioxide. This mixing makes less oxygen available to the amphibian. Adult amphibians also exchange oxygen and carbon dioxide through their moist skin, which increases their oxygen supply. Amphibians can live on land, but they must stay moist for the exchange of oxygen and carbon dioxide to occur.

Amphibian hearing and vision also are adapted to life on land. Amphibians have tympanums (TIHM puh nuhmz), or eardrums, that vibrate in response to sound waves. Large eyes help some amphibians catch their prey. Land environments provide many insects as food for adult amphibians. They have long, sticky tongues used to capture the insects.

How do amphibians develop?

Most amphibians go through a series of body changes called metamorphosis (me tuh MOR fuh sus). Eggs are most often laid in water and hatch into larvae. Young larval forms of amphibians live in water. They have no legs and breathe through gills. Over time, they develop the body structures needed for life on land including legs and lungs. The rate of metamorphosis depends on the species, the water temperature, and the amount of available food. The figure below shows the stages of development for one amphibian—the frog.

Stage 1: Frog eggs are laid and fertilized.

Stage 2: Fertilized frog eggs are hatched into tadpoles. Tadpoles live in water. They use their gills for gas exchange.

Stage 3: Tadpoles begin to grow into adults. They develop legs and lungs.

Stage 4: The adult frog can live and move about on land.

Think it Over

2. Describe two characteristics that allow amphibians to live on land.

Picture This

3. Compare Circle the stage of metamorphosis in which frogs are most like fish.
Reptiles

Snakes, lizards, turtles, and crocodilians are reptiles. Reptiles are vertebrates and ectotherms. Most reptiles live their entire lives on land and do not depend on water for reproduction.

What are some types of reptiles?

A turtle is covered with a hard shell. Most turtles can bring their heads and legs into the shell for protection. Alligators and crocodiles are large reptiles that live in or near water. Alligators and crocodiles are predators that live in warmer climates.

Lizards and snakes make up the largest group of reptiles. Snakes and lizards have an organ in the roof of the mouth that senses molecules collected by the tongue. The constant in-and-out motion of the tongue allows a snake or lizard to smell its surroundings. Lizards have movable eyelids and external ears. Most lizards have legs with clawed toes on each foot. Snakes move without legs. They don’t have eyelids or ears. Snakes feel vibrations in the ground instead of hearing sounds.

What are some reptile adaptations?

A thick, dry waterproof skin is an adaptation that allows reptiles to live on land. Reptile skin is covered with scales to reduce water loss and help prevent injury. Reptiles breathe with lungs. Reptiles that live in water, like sea turtles, must come to the surface to breathe.

Two adaptations allow reptiles to reproduce on land—internal fertilization and laying shell-covered eggs. Sperm are deposited directly into the female’s body. Female reptiles lay fertilized eggs that are covered by tough shells. These eggs are called amniotic (am nee AH tihk) eggs. An amniotic egg supplies the embryo with everything it needs to develop. A leathery shell protects the embryo and yolk. The yolk is the embryo’s food supply. When a reptile hatches, it is fully developed.

Birds

Birds are vertebrates that have two wings, two legs, and a bill or beak. Birds are covered mostly with feathers. They lay eggs with hard shells and sit on their eggs to keep them warm until they hatch. All birds are endotherms.
How do bird species differ?
There are more than 8,600 species of birds. Different species have different adaptations. For example, ostriches have strong legs for running. Penguins can't fly, but they are excellent swimmers. Wrens have feet that allow them to perch on branches.

How are birds adapted for flight?
The bodies of most birds are designed for flight. They are streamlined and have light, strong skeletons. The inside of a bird’s bones is almost hollow. Special structures make the bones strong, but lightweight. A bird’s tail is designed to provide the stiffness, strength, and stability needed for flight. Birds use their tail to steer.

Birds need a lot of energy and oxygen to fly. They eat high-energy foods like nectar, insects, and meat. They have a large, efficient heart. A bird’s lungs connect to air sacs that provide a constant supply of oxygen to the blood and make the bird more lightweight.

Birds beat their wings up and down as well as forward and backward. A combination of wing shape, surface area, wind speed, and angle of the wing provide the upward push needed for flight.

What is the function of feathers?
Birds are the only animals with feathers. They have two main types of feathers—contour feathers and down feathers. Contour feathers are strong and lightweight. They give adult birds their streamlined shape and coloring. Contour feathers have parallel strands, called barbs, that extend from the main shaft. Outer contour feathers on the wings and tail help a bird move, steer, and keep from spinning out of control. Feather color and patterns help attract mates. The color patterns also protect birds from predators by helping the birds blend into their surroundings.

Birds have down feathers that trap and keep warm air next to their bodies. In adult birds, down feathers provide a layer of insulation under the contour feathers. Down feathers cover the bodies of some young birds.

Birds care for their feathers by preening. Birds preen, or use their bills, to clean and rearrange their feathers. During preening, birds also spread oil over their bodies and feathers. The oil keeps the bird’s skin soft and keeps feathers and scales from becoming brittle.
Mammals

Moles, dogs, bats, and humans are some examples of mammals. Mammals are vertebrates and endotherms. They live in water and in many different climates on land. They burrow through the ground and fly through the air. Mammals have mammary glands in their skin.

A mammal’s skin usually is covered with hair that keeps the body from being too hot or too cold. The hair also protects mammals from wind and water. Some mammals, like bears, have thick fur. Other mammals, like humans, have a few patches of thick hair while the rest of the body has little hair. Dolphins have little hair. Porcupines have quills, which are a kind of modified hair.

Why do mammals have mammary glands?

In females, the mammary glands produce and release milk for the young. For the first few weeks or months of life, the milk provides all the nutrients the young mammal needs.

What kinds of teeth do mammals have?

Plant-eating animals are called herbivores. Animals that eat meat are called carnivores. Animals that eat plants and meat are called omnivores.

Mammals have four types of teeth—incisors, canines, premolars, and molars. As the figure below shows, you usually can tell from the kind of teeth a mammal has whether it eats plants, meat, or both.

Mountain lions are carnivores. They have sharp canines that are used to rip and tear flesh.

Humans are omnivores. They have incisors that cut vegetables, premolars that are sharp enough to chew meat, and molars that grind food.

Herbivores, like this beaver, have incisors that cut vegetation and large, flat molars that grind it.
What body systems do mammals have?
Mammals have well-developed lungs made of millions of small sacs called alveoli. Alveoli allow the exchange of carbon dioxide and oxygen during breathing. Mammals also have a complex nervous system that lets them learn and remember more than many other animals. Mammals have larger brains than other animals of similar size.

All mammals have internal fertilization. After an egg is fertilized, the developing mammal is called an embryo. Most mammal embryos develop inside the female in an organ called the uterus.

Monotremes make up the smallest group of mammals. They lay eggs instead of having live births. The female monotreme sits on the eggs for about ten days before they hatch. The mammary glands of monotremes do not have nipples. The milk seeps through the skin onto their fur. The young monotremes lick the milk off the fur. Duck-billed platypuses are an example of monotremes.

How do young marsupials develop?
Most marsupials, such as kangaroos and koalas, live in Australia. The opossum is the only marsupial native to North America. A marsupial embryo develops for only a few weeks within the uterus. When a marsupial is born, it is not fully formed. It has no hair and is blind. The young marsupial uses its sense of smell to find its way to a nipple usually within the mother’s pouch. It attaches to the nipple to feed and finishes developing in the pouch.

How do placental embryos develop?
Most mammals belong to a group called placentals. Placentals are named for the placenta, which is a saclike organ that develops from tissues of the embryo in the uterus.

An umbilical cord connects the embryo to the placenta. Food and oxygen are absorbed from the mother’s blood. Blood vessels in the umbilical cord carry food and oxygen to the developing young. The blood vessels also take away wastes. In the placenta, the mother’s blood absorbs wastes from the developing young. The blood of the mother and the embryo do not mix.

The time of development from fertilization to birth is called the gestation period. Gestation periods vary widely, from about 21 days in rats to about 616 days in elephants. Human gestation lasts about 280 days.

Reading Check
8. Apply What kind of fertilization do all mammals have in common?

9. Define What is the gestation period?
1. Review the terms and their definitions in the Mini Glossary. Write one or more sentences to explain how herbivores, carnivores, and omnivores are different.

2. Complete the table below to list the adaptations birds have for flight.

<table>
<thead>
<tr>
<th>Adaptations for Flight</th>
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<tbody>
<tr>
<td>1.</td>
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<td>5.</td>
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<td>6.</td>
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</tbody>
</table>

3. Complete the diagram below to identify the three types of mammals.

Mammal Types

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Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about mammals.
section 1 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.

What is a stimulus?

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. Your dog wagging its tail is a response to your greeting.

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

Mark the Text

Identify Main Ideas

Highlight each question head in this section. Then use a different color to highlight the answers to the questions.

Foldables®

**Describe** Make a two-tab Foldable, as shown below. Describe the innate and learned behaviors of an animal that you have observed.
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. Key deer instinctively stay away from humans. If humans feed the deer, the deer learn that humans give food. They learn to approach humans for food. More deer-car crashes could happen as deer walk up to cars. Florida wildlife officials post signs to warn people not to feed deer. They want deer to keep their instinctive fear of humans.
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 usually is 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>
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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 have 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.
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.

   ![Graphic Organizer]

3. How did finding answers to the question heads help you learn about 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.

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, lions are less likely to attack a herd of zebras than a lone zebra. Animals that migrate travel in groups. A group is less likely to get lost than animals that travel alone.
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, frogs croak, and beavers slap the water with their flat tails. These sounds are forms of communication to other 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 suns). 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.
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>Courtship behavior</th>
<th>Chemical communication</th>
<th>Sound communication</th>
<th>Light communication</th>
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Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about behavioral interactions.
The Nonliving Environment

section 1 Abiotic Factors

Benchmarks—SC.G.1.3.4 Annually Assessed: The student knows that the interactions of organisms with each other and with the non-living parts of their environments result in the flow of energy and the cycling of matter throughout the system; SC.H.2.3.1: The student recognizes that patterns exist within and across systems.

Also covers: SC.B.1.3.1; SC.D.1.3.4; SC.G.2.3.2; SC.H.1.3.4

Before You Read

How would you describe the climate where you live? How does it affect the plant and animal life around you?

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 for 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.

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

Mark the Text

Summarize Write a phrase beside each main heading that summarizes the main point of the section.

Reading Check

1. List What three things are needed for photosynthesis?

________________________

________________________

________________________
Cellular Respiration  Oxygen is released into the atmosphere during photosynthesis. Cells use oxygen to release the chemical energy stored in sugar molecules. This process, called cellular 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 cellular 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, an abiotic factor, is made mostly 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 plants 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.

Think it Over

2. Recognizing Cause and Effect  How does soil affect plant life in an area?

3. Identify  What are two types of energy the Sun provides?

Reading Check

242  The Nonliving Environment
How does latitude affect temperature?
Scientists use an imaginary grid on Earth to locate points. The parallel lines that circle Earth between poles are lines of latitude. The equator is halfway between the poles.
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 hits Earth directly. 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. The atmosphere is thinner at higher 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.
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.

Reading Check
5. Explain Why is the air temperature at higher elevations usually cooler than the air temperature at lower elevations?

Picture This
4. Identify Use one color to highlight the sunlight hitting Earth directly at the equator. Use another color to highlight the sunlight hitting Earth near the poles.
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.
After You Read

Mini Glossary

abiotic (ay bi AH tihk): nonliving, physical features of the environment, including air, water, sunlight, soil, temperature, and climate

atmosphere: the air that surrounds Earth

biotic (bi AH tihk): features of the environment that are alive or were once alive

climate: an area’s average weather conditions over time, including temperature, rainfall or other precipitation, and wind

soil: a mixture of mineral and rock particles, the remains of dead organisms, water, and air

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>

Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about abiotic factors.
The Nonliving Environment

section 3 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 has only 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.

Foldables
A Describe Make a three-tab book Foldable, as shown below. Use the Foldable to describe the water, carbon, and nitrogen cycles.

Picture This
2. Identify Complete the figure by labeling the missing processes in the water cycle.
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.

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 cellular respiration—the chemical process that releases energy in cells. Cellular 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 diagram, list the processes in the nitrogen cycle in the order in which they occur.

Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about the cycles in nature.
The Nonliving Environment

section 2 Energy Flow

Before You Read

Why do you need energy? What is your source of energy?

Read to Learn

Converting Energy

All living things are made of matter, and all living things need energy. Matter and energy move through the natural world in different ways. Matter can be recycled over and over. The recycling of matter requires energy. 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 extremely hot from contact with molten magma that lies deep in Earth’s crust.

What You’ll Learn

- how organisms make energy-rich compounds
- how energy flows through ecosystems
- how much energy is available at different levels in a food chain

Mark the Text

Locate Information 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.

Foldables

Compare Make a two-tab Foldable, as shown below, to compare how producers use photosynthesis and chemosynthesis to convert energy.
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 SIHN 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 wetlands community. For example, alligators eat herons, frogs, and fish. Bladderwort is 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 cellular respiration, 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.

Think it Over
3. **Synthesize** Why are there more producers than consumers?
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.

3. How did finding definitions of words you did not know help you understand energy flow?

---

**Mini Glossary**

- **chemosynthesis (kee moh SIN thuh 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
Benchmarks—SC.D.2.3.1: The student understands that the quality of life is relevant to personal experience; SC.D.2.3.2 Annually Assessed: The student knows the positive and negative consequences of human action on the Earth’s systems; SC.G.2.3.4 Annually Assessed: The student understands that humans…may deliberately or inadvertently alter the equilibrium in ecosystems.

Also covers: SC.G.2.3.2; SC.G.2.3.3; SC.H.1.3.4; SC.H.1.3.5; SC.H.1.3.7

Before You Read
On the lines below, explain what happened to the dinosaurs. Tell why you think it happened.

---

Read to Learn

The Variety of Life
When you walk through a forest, you see different kinds of trees, shrubs, and animals. Hundreds of species live in the forest. When you walk through a wheat field, you see wheat plants, insects, and weeds. Only a few species live in the wheat field. The forest has a higher biodiversity than the wheat field. Biodiversity refers to the variety of life in an ecosystem.

How is biodiversity measured?
The common measure of biodiversity is the number of species that live in an area. For example, a coral reef can be home to thousands of species including corals, fish, algae, sponges, crabs, and worms. The biodiversity of a coral reef is greater than that of the shallow waters around it.

Scientists once thought that biodiversity of dark deep-sea waters was low. Deep-sea exploration has helped scientists discover that species biodiversity is great.

What explains differences in biodiversity?
Biodiversity tends to increase the closer you move toward the equator, where temperatures tend to be warmer. Ecosystems that have the highest biodiversity are usually located in warm, moist climates. The tropical regions of the world are home to two-thirds of Earth’s land species.

---

Identify the Main Point
Underline the main idea in each paragraph. Then circle the details that support the main idea.

---

What You’ll Learn
- about biodiversity
- why biodiversity is important in an ecosystem
- factors that limit biodiversity in an ecosystem

---

Mark the Text

---

Reading Check

1. Explain What are the characteristics of climates that have the highest biodiversity?

---

Reading Essentials 255
Why is biodiversity important?
Biodiversity is important for many reasons. It provides people with food, medicines, building products, and fiber for clothing. Every species on Earth plays a certain role in the cycling of matter. As a result of biodiversity, soils are richer, pollutants break down, and climates are stable.

Why do humans need biodiversity?
Eating a variety of foods is a good way for people to stay healthy. Hundreds of species help feed the human population all around the world.

Biodiversity can help improve food crops. Crossbreeding food crops with wild species helps develop plant strains that are resistant to many diseases. In the 1970s, American farmers began using a new strain of crossbred corn that resists fungal disease.

Most medicines used today originally came from wild plants. Scientists are still discovering new species. The next plant species discovered could be the cure for cancer.

Biodiversity strengthens an ecosystem. For example, if a disease infects a grapevine in a vineyard, it can easily move from one plant to the next because vines grow close together. Soon, the whole vineyard can become infected with the disease. Farmers may plant one row of grapevines and the next row of another crop. By alternating rows, farmers may help prevent a disease from spreading.

Why is stability important to biodiversity?
If one type of plant in a forest disappears, the forest still exists. Imagine that a forest had only one plant species, one herbivore species that ate the plant, and one carnivore species that ate the herbivore. What would happen if the plant species died out? Biodiversity helps keep the stability of an ecosystem.

What changes biodiversity?
About 100 years ago, passenger pigeons flew across North America. Today, however, the passenger pigeon is extinct. An extinct species is a species that was once present on Earth but has died out.

Extinction is a normal part of nature. Fossil records show that many species have become extinct since life appeared on Earth. Species can become extinct because of competition from other species. They can become extinct because of changes in the environment.
**Mass Extinction** A mass extinction happens when a disaster causes many species to die out. One occurred on Earth about 65 million years ago. That extinction, shown on the graph below, occurred in the Mesozoic Era. It wiped out almost two-thirds of all species living on Earth at that time, including dinosaurs.

This extinction might have happened because a huge meteorite crashed into Earth’s surface. The impact may have caused dust to block sunlight from reaching Earth’s surface leading to climate changes that many species could not survive. After a mass extinction, new species eventually appear. After the dinosaurs disappeared, many new species of mammals appeared on Earth.

### Mass Extinctions in Earth’s History

<table>
<thead>
<tr>
<th>Extinction Rate (Families of Species per Million Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paleozoic</td>
</tr>
<tr>
<td>438</td>
</tr>
<tr>
<td>360</td>
</tr>
<tr>
<td>245</td>
</tr>
<tr>
<td>208</td>
</tr>
<tr>
<td>65</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

**What causes species to die out?**

Humans did not have anything to do with the dinosaurs becoming extinct. Today, however, human activities probably contribute to the extinction of many species. The rate of extinctions appears to be rising. About 40 species of plants and animals in the United States became extinct between 1980 and 2000. Hundreds of tropical species became extinct during that same period of time. As the human population increases, more species could be lost.

**What are endangered species?**

To prevent species from becoming extinct, it is important to know which species could soon disappear. A species in danger of becoming extinct is an **endangered species**.
Human Impact The Florida panther is the most endangered species in the world. This species originally lived in all parts of Florida, as far west as Louisiana, and as far north as Tennessee. Now they are only found in a small part of southwest Florida, as shown on the map below. Human actions have led to the decline in the Florida panther population. Much of their habitat has been lost as cities have expanded to fill the land. Pollutants have entered their food chain and diseases have greatly reduced their numbers. Now, only a small breeding population exists in national and state parks.

Present Range of the Florida Panther

What are threatened species?

Species that are likely to become endangered in the near future are threatened species. The Godfrey’s butterwort is a species of carnivorous plant. It can be found near the Gulf coast between Tallahassee and Panama City. The plant already had a limited range. Now, the pine grown for logging has blocked the sunlight from these plants. This has reduced their population even more.

What causes habitat loss?

When people change an ecosystem, such as replacing a forest with a parking lot, the habitats of many species that lived in the forest may become smaller or disappear. Biodiversity can be reduced if many species lose their habitats.

The loss of habitat is a major reason why many species become endangered, threatened, or extinct. For example, the Key Largo cotton mouse lived on all the northern Florida Keys. The keys have become popular tourist destinations. The increase in buildings and people has led to a decrease in habitat available for the Key Largo cotton mouse.
**Protecting Habitats** The Key Largo cotton mouse has become a threatened species because of habitat loss. At first, scientists tried to introduce the Key Largo cotton mouse to a new habitat in the Keys. This effort did not succeed. A new strategy limits building in North Key Largo’s forests.

**How can a divided habitat reduce biodiversity?**

Biodiversity can be reduced when a habitat is divided by roads, cities, or farms. Small areas of habitat usually have less biodiversity than large areas of habitat. Divided habitats are a problem for large animals that need large hunting territories. If their habitats are divided, the animals are forced to move somewhere else.

Small habitat areas make it difficult for species to recover from a disaster. If a fire destroys a small part of a forest, the salamanders living in that part are destroyed. After new trees have grown in that part of the forest, salamanders from the part of the forest that was not damaged move in to replace those that had died. However, if a fire destroys a grove of trees surrounded by paved parking lots, salamanders might never return. No salamanders live nearby to move into the area.

**How can introduced species affect ecosystems?**

An *introduced species* is a species that moves into an ecosystem as a result of human actions. These species usually have no predators or competitors in the new area, so the population of this species grows quickly. Introduced species can crowd out native species. *Native species* are the original organisms in an ecosystem.

In the early 1900s, much of southern Florida was swampland. People wanted to drain the swamps and build on the land. They brought the melaleuca tree from Australia to “dry up” the swamps. The trees quickly took over. Native species died, and animals that ate those native species lost their food source. The trees have reduced biodiversity in southern Florida.

**Pollution**

Pollution of land, water, or air also affects biodiversity. Soil that is contaminated with chemicals or other pollutants can harm plants or limit their growth. Plants provide habitats for many species. Any change in plant growth can limit biodiversity.
What causes water pollution?

Pollutants that contaminate the water harm organisms that live in the water. These pollutants come from factories, ships, or runoff from lawns and farms. The pollutants can kill aquatic plants, fish, insects, and the organisms they depend on for food.

What causes air pollution?

A form of water pollution known as acid rain is caused by air pollution. Acid rain forms when sulfur dioxide and nitrogen oxide released by industries and automobiles combine with water vapor in the air. Acid rain damages trees. It washes away calcium and other nutrients from the soil, making the soil less fertile. Acid rain also harms fish and other organisms that live in lakes and streams. Acid rain makes the water too acidic for many species of fish.

Air pollution from factories, power plants, and automobiles can harm tissues of many organisms. Air pollution can damage the leaves or needles of some trees. This can weaken the trees and make them less able to survive diseases or environmental disasters such as drought or flooding.

What is global warming?

Carbon dioxide (CO$_2$) is released into the air when wood, coal, gas, or any other fuel is burned. Humans burn large amounts of fuel. This contributes to an increase in the percentage of CO$_2$ in the atmosphere. An increase in CO$_2$ may raise Earth’s average temperature. This rise in temperature, called global warming, can lead to changes in climate that could affect biodiversity.

What is ozone depletion?

The ozone layer is the part of the atmosphere that is made up of ozone gas. It is about 15 km to 30 km above Earth’s surface. The ozone layer protects life on Earth by preventing damaging amounts of the Sun’s ultraviolet (UV) radiation from reaching Earth’s surface.

The ozone layer is becoming thinner. This thinning is called ozone depletion. The thinning ozone layer allows more of the UV radiation that can harm organisms to reach Earth’s surface. Increased amounts of UV radiation can lead to more cases of skin cancer in humans.
After You Read

Mini Glossary

**acid rain:** results when sulfur dioxide and nitrogen oxide released by industries and automobiles combine with water vapor in the air

**biodiversity:** the variety of life in an ecosystem

**endangered species:** species that is in danger of becoming extinct

**extinct species:** species that was once present on Earth but has died out

**introduced species:** species that moves into an ecosystem as a result of human actions

**native species:** the original organisms in an ecosystem

**ozone depletion:** the thinning of the ozone layer

**threatened species:** species that is likely to become endangered in the near future

---

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the difference between introduced species and native species.

2. Complete this diagram by listing three things that reduce biodiversity.

<table>
<thead>
<tr>
<th>Causes</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Biodiversity is reduced.</td>
</tr>
</tbody>
</table>

3. How did highlighting the main idea and circling supporting details help you remember what you read about biodiversity?

---

Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about biodiversity.
Conserving Life

section 3 Conservation Biology

What You’ll Learn
■ the goals of conservation biology
■ ways to prevent the extinction of species
■ how an endangered species can be reintroduced into its original habitat

● Before You Read

On the lines below, tell why you think zoos exist.

________________________________________

________________________________________

● Read to Learn

Protecting Biodiversity

The study of methods for protecting biodiversity is called conservation biology. Conservation biologists develop strategies to stop the continuing loss of members of a species. Their strategies are based on the principles of ecology. Because human activities have much to do with this loss, the strategies have to consider the needs of the human population. However, because the needs of humans and other species are often different, it is difficult to make conservation plans to satisfy all needs.

Conservation Biology at Work

Most conservation plans have two goals. One goal is to protect the species from harm. The other goal is to protect the species’ habitats.

How can laws protect a species?

Laws can be passed to protect both the species and its habitat. One such law is the U.S. Endangered Species Act of 1973. This law makes it illegal to harm, collect, harass, or disturb the habitat of any species on the endangered or threatened species lists. The law also prevents the U.S. government from spending money on projects that might harm these species or their habitats.
**Enforcement** The U.S. Endangered Species Act is enforced by the United States Fish and Wildlife Service. The Florida Department of Environmental Protection enforces the law in Florida. The Act has helped several species come back from near extinction.

**What is CITES?**
The United States works with other countries to protect endangered or threatened species. In 1975, The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) was set up. One of its goals is to protect certain species by controlling international trade in these species or any part of the species, such as elephant ivory tusks. Under this agreement about 5,000 animal species and 25,000 plant species are protected.

**How are habitats being protected?**
A species that is protected by law cannot survive unless its habitat also is protected. Conservation biology works to protect habitats. One way is to set up nature preserves. Nature preserves include national parks and protected wildlife areas.

**Protecting the Florida Everglades** For many years, a group of conservationists worked hard to find ways to protect the Florida Everglades. In 1947, President Harry S Truman dedicated the Everglades National Park. It was the first national park set aside for biological reasons. Without national parks and wildlife areas, some animals would be closer to extinction. Visitors to the Everglades National Park can view a mix of tropical and temperate species. Its rare mix of freshwater and saltwater habitats are now protected by law.

**What is the purpose of wildlife corridors?**
Some large-animal species, such as the Florida panther, need large amounts of land to survive. However, it is not always possible to create large nature preserves. One way to solve this land problem is to link smaller parks together with wildlife corridors.

Wildlife corridors are part of a strategy for saving the endangered Florida panther. A male panther needs a territory of at least 712 km². This area is larger than many of the protected panther habitats. Wildlife corridors allow panthers to move from one preserve to another without crossing roads or entering areas where humans live.

---

**Reading Essentials**

**D Identify** Make a three-tab Foldable, as shown below. Use the Foldable to identify the importance of habitat preservation, habitat restoration, and wildlife corridors.

1. **Explain** What is the purpose of a wildlife corridor?
How are habitats being restored?

Habitats that have been harmed by human activities can be restored. **Habitat restoration** is the process of taking action to bring a damaged habitat back to a healthy condition.

Project Greenshores, shown below, began in 2001 as a habitat restoration effort. Its goal is to return an oyster reef and salt marsh to the Pensacola Bay ecosystem. Workers placed 20,000 tons of recycled concrete and limestone rock in the salt marsh off the coast. The materials formed a man-made reef, which protects aquatic plants from the waves and gives oysters a habitat. The reef also provides a place for bird and marine wildlife.

Project Greenshores is managed by the Florida Department of Environmental Protection. Students and volunteers have been important to the success of the project.

![Project Greenshores](Cheryl Bunch/Project Greenshores/Florida Dept. of Environmental Protection)

What is the purpose of wildlife management?

Wildlife parks and preserves do not automatically protect species living there from harm. People are needed to manage the areas. For example, in South Africa, guards patrol wildlife parks to prevent poachers from killing elephants for their ivory tusks. Some wildlife preserves do not allow visitors other than biologists who are studying the area.

Wildlife managers and hunters often work together to protect certain animal species. People usually are not allowed to hunt or fish in a park unless they buy a license. The sale of licenses provides money for taking care of the wildlife area. It also helps prevent overhunting. Licenses usually limit the number of animals a hunter is allowed. Hunting rules also can help prevent a population from becoming too large for an area.
How can keeping animals in captivity preserve biodiversity?

Sometimes endangered or threatened animals are placed in zoos. Often these animals are no longer found in the wild. A captive population is a population of organisms that is cared for by humans. Often, with human care, the numbers of the species increase.

Keeping endangered or threatened animals in captivity can help preserve biodiversity. However, it is not an ideal solution. Providing food, space, and care can be expensive. Sometimes captive animals lose their wild behaviors. If that happens, these animals might not survive if they are returned to their habitats.

What is the purpose of reintroduction programs?

Sometimes members of captive populations can be put back into the wild to help restore biodiversity. Reintroduction programs return captive organisms to an area where the species once lived. Once reintroduced, researchers may observe the animals from a distance. These programs can be successful only if the reasons that caused the species to become endangered are removed. Plants also can be reintroduced into their original habitats. Often this is done by replanting seedlings in the original habitats.

How are seed banks used?

Seed banks store the seeds of many endangered plants species. There are seed banks throughout the world. If a species becomes extinct in the wild, the stored seeds can be planted to reintroduce the plants to their original habitats.

Why are some species relocated?

Reintroduction programs do not always involve captive populations. The most successful reintroduction programs happen when wild organisms are moved to a suitable new habitat. The brown pelican relocation is an example of this.

The pelican was once common along the Gulf of Mexico. In the mid-1900s, a pesticide known as DDT ended up in the food that pelicans ate. Because of DDT, the pelican’s eggshells became so thin that they broke before the chicks could hatch. Soon, pelicans disappeared from Louisiana and most of Texas. In 1971, pelicans were reintroduced to the area. By the year 2000, more than 7,000 brown pelicans lived in Louisiana and Texas. The United States banned the use of DDT in 1972.
1. Review the terms and their definitions in the Mini Glossary. Using two of the terms, write a sentence explaining what is being done to protect biodiversity.


2. Use the web diagram below to identify different strategies used to protect biodiversity.

---

**Mini Glossary**

- **captive population**: a population of organisms that is cared for by humans
- **conservation biology**: the study of methods for protecting biodiversity
- **habitat restoration**: the process of taking action to bring a damaged habitat back to a healthy condition
- **reintroduction program**: a program that returns captive organisms to an area where the species once lived

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Our Impact on Land

section 1 Population Impact on the Environment

Before You Read

How do you think the total number of people on Earth in 1900 compares to the human population in 2000? How will the population change in the next 100 years?

What You’ll Learn

- how fast the human population is increasing
- why the human population is increasing rapidly
- ways you can affect the environment

Read to Learn

Population and Carrying Capacity

Humans share Earth with many other living things. Look around and you might see fish in a tank, squirrels in a tree, or plants in the yard. These are examples of populations. A population is the total number of individuals of one species occupying the same area. That area can be large or small. A human population can be of one community, such as Tampa, or the entire planet.

Is Earth’s population increasing?

In 2000, there were 6.1 billion humans on Earth. Each day, approximately 200,000 more humans are born. Earth is experiencing a population explosion. The word explosion is used because the rate at which the population is growing is rapidly increasing.

How much has the human population grown?

Many years ago, few people lived on Earth. Look at the graph of population growth on the next page. It took thousands of years for the population to reach 1 billion humans. After the mid-1800s, the population grew much faster. This type of growth is called exponential. The growth rate multiplies as the population increases.
1. **Use Graphs** What was the approximate human population in 1950?
   a. 2 billion
   b. 2.2 billion
   c. 2.8 billion
   d. 3.1 billion

![Population Growth of Modern Humans Graph]

**Why has the human population grown?**

The human population has increased because modern medicine, clean water, and better nutrition have decreased the death rate. This means that more people are living longer. Also, more babies are being born because more people reach the age at which they can reproduce.

By 2050, the population is predicted to be about 9 billion, or one and a half times what it is now. What effect will this population increase have on the environment? Will Earth have enough natural resources to support such a large population? What will become of the things that have helped the population grow, such as health care and clean water?

**What are population limits?**

Each person uses space and resources. Population size depends on the amount of resources that are available. It also depends on how members of a population use their resources. For example, if an area has a long drought, the amount of freshwater resources will decrease. If members of a population pollute their drinking water reservoirs, the result is the same. The population will suffer and the population size could decrease.

Humans once thought that Earth had an endless supply of natural resources, such as fossil fuels, clean water, rich soils, and metals. It’s now known that Earth’s resources are limited. The planet has a carrying capacity. **Carrying capacity** is the largest number of individuals of a particular species that the environment can support. If people waste or pollute Earth’s resources, they could disappear, and the human population could reach its carrying capacity.
People and the Environment

How will you affect the environment over your lifetime? If you are like most Americans, by the time you're 75 years old, you will have produced 53,000 kg of garbage. That is equal to the mass of 11 African elephants. You will have consumed 18 million liters of water. That's enough water to fill 68,000 bathtubs. A person living in the United States uses many times more resources than a person living elsewhere in the world.

How do daily activities affect the environment?

Every day, the environment is affected by human activity. The energy for electricity often comes from fossil fuels. Fossil fuels must be mined and then burned to create energy. Each of these steps changes the environment.

Water that is used must be treated to make it as clean as possible before being returned to the environment. You eat food, which needs soil to grow. Many vegetables are grown using chemical substances, such as pesticides to kill insects and herbicides to kill weeds. These chemicals can get into water supplies. If the concentration of chemicals is too great, it can threaten the health of living things.

What are pollutants?

Many of the products humans use are made of plastic and paper. Plastic is made from oil. The process of refining oil can produce pollutants. Pollutants are substances that contaminate the environment. Several of the steps used in making paper can damage the environment. Trees are cut down. Trucks use oil to transport trees to the paper mill. Water and air pollutants are given off in the papermaking process.

After many products are made and used, they are thrown away as garbage. Unnecessary packaging and disposable items create additional waste. As the population increases, more resources will be used and more waste will be created. Humans must think carefully before using natural resources and products that come from natural resources. If you conserve resources, you can lessen the impact on the environment.
After You Read

Mini Glossary

carrying capacity: the largest number of individuals of a given species that the environment can support

pollutant: substance that contaminates the environment

population: total number of individuals of one species occupying the same area

1. Review the terms and their definitions in the Mini Glossary above. Then write a sentence using one of the terms to show how humans can or should take care of the environment.

2. Complete the concept map to show you understand Earth’s carrying capacity.

3. Review the questions you wrote as you read this section. What resources could you use to find answers to your questions? Did the questions you wrote help you understand the information in this section?

End of Section
Our Impact on Land

section 2 Using Land

Before You Read

Think of one way that humans use land. Describe how this particular use of land might harm the environment.

What You’ll Learn

- ways that land is used
- how land use creates environmental problems
- things you can do to help protect the environment

Read to Learn

Land Usage

Many people do not think of land as a natural resource. Yet it is as important to humans as clean air and fresh water. Land is used to grow food and harvest forest products. It is used to build cities and to dispose of garbage. All of these activities can affect Earth’s land resources.

How does agriculture affect the land?

About 16 million km$^2$ of Earth’s total land surface is used for farming. To feed a growing population, more food needs to be produced. Farmers use chemical fertilizers to increase the amount of food grown on each km$^2$ of land. Herbicides and pesticides are also used to reduce weeds, insects, and other pests that can damage crops.

Organic farming techniques include the use of natural fertilizers, crop rotation, and biological pest controls. These methods help crops grow without using chemicals. However, organic farming cannot currently produce enough food to feed all of the humans on Earth.

When farmland is tilled, soil is exposed. Without plant roots to hold soil in place, the soil can be carried away by running water and wind. Several centimeters of topsoil may be lost in one year. In some places, it takes more than 1,000 years for new topsoil to develop.
How can soil erosion be reduced?

Some farmers till, or turn over, the soil before planting a new crop. However, other farmers practice no-till farming. They don’t plow the soil from harvest until planting. Instead of tilling, they simply plant seeds between the stubble of last year’s vegetation.

Another method of reducing soil loss is contour plowing. Rows are tilled across hills and valleys. When it rains, water and soil are trapped in the plowed rows, reducing soil erosion. Other techniques include planting trees in rows along fields. The trees slow the wind, reducing the amount of soil that can be blown away. Cover crops—crops that are not harvested—also can be planted to reduce erosion.

How is land used to feed livestock?

Land also is used for feeding livestock. Animals such as cattle eat the vegetation growing on the land. Then the animals are used as food for humans. Many farmers grow corn and hay just for feeding their livestock. These crops provide cattle with a variety of nutrients and can improve the quality of the meat.

What are forest resources?

According to the Food and Agriculture Organization of the United Nations, about one-fourth of the land on Earth is covered by forest. About 55 percent of this forest is found in developing countries. The other 45 percent occurs in developed countries.

Deforestation is the clearing of forested land for agriculture, grazing, development, or logging. It is estimated that the amount of forested land in the world decreased by 0.24% (94,000 km²) each year between 1990 and 2000. Most of this deforestation occurred in tropical regions.

How does deforestation affect the environment?

Many plants and animals that live in tropical rain forests cannot survive in other places. If their homes are destroyed, they may become extinct. Many of these plants might be important for developing new medicines.

Cutting trees can affect climate as well. Water from tree leaves evaporates into the atmosphere where it can condense to form rain. If many trees are cut down, less water enters the atmosphere and that region receives less rainfall. This is one way humans can affect the water cycle.
How does development affect land?

Between 1990 and 2000, the number of kilometers of roadways in the United States increased by more than 13 percent. Building highways often leads to more paving as office buildings, stores, and parking lots are constructed.

Paving land prevents water from soaking into the soil. Instead, it runs into sewers and streams. Streams are forced to move a larger volume of water. Stream discharge is the volume of water flowing past a certain point per unit of time. If enough rainwater flows into streams, it increases stream discharge. Then streams may flood.

Many communities get their drinking water from underground sources. When land is covered with roads, sidewalks, and parking lots, less rainwater soaks into the ground to refill underground water supplies.

Some communities and businesses have begun to preserve areas rather than pave them. Land is being set aside for environmental protection.

What are sanitary landfills?

Land also is used to dispose of garbage. About 60 percent of our trash is put into sanitary landfills like the one illustrated below. A sanitary landfill is an area where each day’s garbage is deposited and covered. Covering the garbage keeps it from blowing away. It also reduces the odor that comes from decaying waste.

The figure below shows how sanitary landfills are designed to prevent liquid wastes from seeping into the soil and groundwater below. New sanitary landfills are lined with plastic, concrete, or clay-rich soils that trap the liquid waste. These linings greatly reduce the chance that pollutants will soak into the surrounding soil and groundwater.

Think it Over

3. Think Critically Why do you think that building a highway in an area leads to more construction in that area?

4. Identify Highlight the part of the landfill that prevents liquid waste from polluting the soil and groundwater.
How do landfills use up a land resource?

Many materials do not decompose in landfills or decompose very slowly. When landfills are filled with garbage, new ones must be built. Locating an acceptable area to build a landfill can be difficult. Type of soil, the depth to groundwater, and neighborhood concerns must be considered.

Hazardous Wastes

Some of the wastes thrown away are dangerous to organisms. Wastes that are poisonous, cause cancer, or can catch fire are called hazardous wastes. Hazardous wastes once were put in landfills with regular household garbage. In the 1980s, new laws made it illegal for industries to put hazardous wastes into sanitary landfills. New technologies have since developed to help recycle hazardous wastes. Now there is less need to dispose of them.

How can household hazardous wastes be disposed of properly?

Most individuals throw hazardous materials such as insect sprays, batteries, drain cleaners, bleaches, medicines, and paints in the trash. These substances take hundreds of years to decay. You can help by disposing of hazardous wastes at special hazardous waste-collection sites. Contact your local government to find out about collection sites in your area.

What is phytoremediation?

Hazardous substances from leaking landfills or nearby industries can pollute soil and water. One method for cleaning polluted soil is called phytoremediation (FI toh ruh mee dee AY shun). Phyto means “plant” and remediation means “to fix a problem.” The roots of certain plants, such as alfalfa, grasses, and pine trees, can absorb harmful metals from contaminated soils just as they absorb other nutrients. People can grow these plants in polluted areas to remove the harmful metals from the soil.

Plants that absorb too much of these metals eventually must be harvested and either composted to recycle the metals or burned. If these plants are destroyed by burning, the ashes left behind still contain hazardous waste and must be disposed of at a site.
**How are organic pollutants broken down?**

Living things can clean up pollutants other than metals. Substances that contain carbon and other elements, such as hydrogen, oxygen, and nitrogen, are called organic compounds. Some pollutants, such as gasoline and oil, are made of organic compounds.

These organic pollutants can be broken down into simpler, harmless substances. Plants use some of these harmless substances as nutrients to grow. Some plant roots release enzymes (EN-zymes) into the soil. An **enzyme** is a substance that makes a chemical reaction go faster. The enzymes these plants release cause organic pollutants to break down more quickly. Then the plant can use these substances for growth.

**Natural Preserves**

Not all land on Earth is being used to store waste or produce something humans can use. Some land remains mostly uninhabited by humans. National forestlands, grasslands, and national parks in the United States are protected from development. The map below shows some areas of the country that are used for national parks and preserves. Many other countries also set aside land for natural preserves. As the world population continues to grow, the strain on the environment may worsen. Preserving some land in its natural state will benefit future generations.

**Picture This**

8. **Identify** Circle the Natural Preserve found in Florida.
After You Read

Mini Glossary

enzyme: substance that makes a chemical reaction go faster

hazardous waste: wastes that are poisonous, cause cancer, or can catch fire

sanitary landfill: area where garbage is deposited and covered

stream discharge: volume of water flowing past a certain point per unit of time

1. Review the terms and their definitions in the Mini Glossary above. Then write a sentence using one of the terms to explain how humans affect the environment.

2. Complete the following cause-and-effect chart to show that you understand some of the effects pollutants and overuse of soil can have on land.

<table>
<thead>
<tr>
<th>CAUSE OR ACTION</th>
<th>POSSIBLE EFFECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmers till soil.</td>
<td></td>
</tr>
<tr>
<td>Crops harvested or vegetation dug up for construction</td>
<td></td>
</tr>
<tr>
<td>Sanitary landfills leak.</td>
<td></td>
</tr>
<tr>
<td>Hazardous wastes are improperly thrown away.</td>
<td></td>
</tr>
</tbody>
</table>

3. As you read, you marked pages where you had questions. How did discussing your questions with other students help you understand the material presented?

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Our Impact on Land

section 3 Conserving Resources

Before You Read
Do you think humans need to conserve resources? Why or why not? What might you do to help conserve resources?

Read to Learn

Resource Use
Earth’s natural resources are important for making everyday products. Minerals are used to make cars and bikes. Petroleum is used to produce plastics and fuel. If these resources are not used carefully, the environment can be damaged. Conservation is the careful use of Earth materials to reduce damage to the environment. Conservation can keep humans from running out of materials, such as certain metals.

Reduce, Reuse, Recycle
The graph on the next page shows that developed countries, such as the United States, use more natural resources than other regions. Resources can be conserved if people use fewer disposable materials in their everyday lives. Resources can also be conserved if people reuse and recycle materials instead of throwing them away. You can help conserve resources in simple ways. Using both sides of notebook paper and carrying your lunch to school in a nondisposable container help reduce the use of materials. Reusing an item means finding another way to use it instead of throwing it away. Old clothes can be given away or cut into rags for use around your home.

What You’ll Learn
- three ways to conserve resources
- the advantages of recycling

Highlight
As you read, highlight the new vocabulary words and definitions to help you organize and understand the information in this section.

Foldables
Find Main Ideas
Make the following three-tab Foldable to help you understand ways you can conserve resources.
How can yard waste be reused?
When leaves are raked or grass is cut, the waste is often bagged and thrown away. Instead, those wastes can be composted. Composting means piling yard wastes where they can decompose gradually. Decomposed material can provide nutrients for a garden or flowerbed. If everyone in the United States composted, it would reduce the trash put into landfills by 20 percent.

What materials can be recycled?
Recycling is processing waste materials to make a new object. Examples of recyclable wastes are glass, paper, plastic, steel, and tires. Recycling helps conserve Earth’s resources, energy, and landfill space.

Paper makes up about 40 percent of the mass of trash. As the graph above shows, Americans throw away huge amounts of paper each year. Recycling this paper would use 58 percent less water and generate 74 percent less air pollution than producing new paper from trees. The graph does not even include newspapers. More than 500,000 trees are cut every week just to print newspapers.

Many businesses have found that recycling can be good for business. For example, some companies can make back some of the money they spend on materials by recycling the waste. Some businesses use scrap materials such as steel to make new products.

These practices save money and reduce the amount of waste sent to landfills. The amount of garbage put in landfills has decreased since 1980. In addition to saving landfill space, reducing, reusing, and recycling also reduces energy use and reduces the amount of raw materials taken from Earth.
What kinds of programs are in use?
Many states or cities have recycling laws. In some places, people who recycle pay lower trash collection fees. In other places, a refundable deposit is made on all drink containers. You may pay a little extra for the drink when you buy it, but you can get that money back when you return the container for recycling.

Are there costs to recycling?
There are disadvantages to recycling. More people and trucks are needed to haul materials separately from trash. The materials then must be separated at special facilities, as shown in the picture below. A demand for products made from recycled materials must exist. However, the demand for recycled materials is not high because they often cost more.

What is the outlook for the human population?
It is not likely that the human population will decline or stop growing in the near future. To make up for this, resources must be used wisely. Conserving resources by reducing, reusing, and recycling is an important way that you can make a difference.

Think it Over
3. Draw Conclusions
Why do you think recycled materials often are more expensive?

4. Explain what the workers are doing in the picture.
After You Read

Mini Glossary

**composting:** piling yard wastes in an area so they can decompose gradually

**conservation:** careful use of Earth materials to reduce damage to the environment

**recycling:** processing waste materials to make a new object

1. Review the terms and their definitions in the Mini Glossary above. Then use one of the terms in a sentence explaining its role in caring for the environment.

   __________________________________________________________________________

   __________________________________________________________________________

   __________________________________________________________________________

2. Complete the chart below by listing some benefits and disadvantages of recycling.

<table>
<thead>
<tr>
<th>BENEFITS OF RECYCLING</th>
<th>DISADVANTAGES OF RECYCLING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduces trash in landfills</td>
<td>Must be carried separately from trash</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. As you read the section, you highlighted the vocabulary words and their definitions. Do you think this helped you remember the definitions of the terms? Why or why not?

   __________________________________________________________________________

   __________________________________________________________________________

   __________________________________________________________________________
Our Impact on Water and Air

section 1 Water Pollution

Before You Read

On the lines below, list some of the ways you use water.

Read to Learn

Importance of Clean Water

All organisms need water. Plants need water to make food using sunlight. Some animals, such as fish and whales, live in water. Humans and other land animals cannot live without drinking water.

What happens if water isn’t clean? Polluted water contains chemicals and organisms that can cause disease and death in many living things. Water also can be polluted with sediments, such as silt and clay.

Sources of Water Pollution

Imagine you are hiking near a stream or lake. If you become thirsty, would it be safe to drink the water? Many streams and lakes in the United States are polluted in some way. Even streams that look clear and sparkling may not be safe for drinking.

Point source pollution is pollution that enters water from a specific location, such as drainpipes. Pollution from point sources can be controlled or treated before the water flows into a body of water.

Often, no one knows exactly where water pollution comes from. Nonpoint source pollution enters a body of water from a large area, such as lawns, construction sites, and roads. Nonpoint sources also include pollutants in rain or snow. Nonpoint source pollution is the largest source of water-quality problems in the United States.
How does sediment pollute water?

The largest source of water pollution in the United States is sediment. Sediment is pieces of rock and loose soil that are moved by erosion. Although rivers always have carried sediment to oceans, human activities have increased the amount of sediment flowing into rivers, lakes, and oceans. Each year, about 25 billion metric tons of sediment are carried from farm fields to bodies of water. At least 50 billion more tons run off of construction sites, cleared forests, and land used to graze livestock.

Sediment makes water cloudy, blocking the sunlight that underwater plants need to make food. Sediment covers the eggs of organisms that live in the water, preventing them from getting the oxygen they need to develop.

How do farm and lawn chemicals pollute water?

Pesticides are substances that kill pests. Farmers and homeowners use pesticides to kill insects and plants that harm their crops and lawns. Some of these chemicals run off the land and into water, where they may be harmful to people and other organisms.

Fertilizers are chemicals that help plants grow. However, rain washes away as much as 25 percent of the fertilizers applied to farms and yards. This fertilizer ends up in ponds, streams, and rivers. Fertilizers contain nitrogen and phosphorus. The algae living in the water use these chemicals to grow and multiply. A lake or pond, such as the one in the figure below, can become choked with algae. When the algae die and decay, oxygen in the lake is used up, and fish and other organisms in the water may die.

Picture This

1. Summarize Use the information in the figure to help explain how fertilizers can cause water pollution.
**What is sewage?**
When you flush a toilet or take a shower, the water goes down a drain. **Sewage** is the wastewater that contains human waste, household detergents, and soaps. Human waste contains harmful organisms that can make people sick. In most cities, sewage treatment facilities purify sewage before it enters a body of water.

**Can metals cause water pollution?**
Many metals, such as mercury, lead, and nickel, can be poisonous. Lead and mercury in drinking water can harm the nervous system. Yet these metals are part of many useful items, such as paints, stereos, and batteries. Today, environmental laws control the amounts of metals released with wastewater from factories. Because metals remain in the environment for a long time, metals released many years ago still are polluting bodies of water today.

Mining also releases metals into water. For example, in the state of Tennessee, more than 43 percent of all streams and lakes contain metal from mining activities.

**How do oil and gasoline pollute water?**
When it rains, oil and gasoline run off roads and parking lots into streams and rivers. These compounds contain pollutants that might cause cancer. Gas stations store gasoline in tanks below the ground. If the tanks rust, they can leak gasoline into nearby soil and groundwater. As little as one gallon of gasoline can make an entire city’s water supply unsafe for drinking.

Federal laws passed in 1988 require all new gasoline storage tanks to have a double layer of steel or fiberglass. In addition, all new and old tanks must have equipment to detect spills and must be made of material that will not develop holes. These laws help protect soil and groundwater.

**How does heat pollute water?**
When a factory makes a product, heat often is released. Sometimes, water from a nearby river or lake is used to cool factory machines. Then, the heated water is released back into the river or lake. Pollution occurs because hot water contains less oxygen than cool water. Also, organisms that live in water are sensitive to temperature changes. A sudden release of hot water can quickly kill many fish. Water should be cooled in a cooling tower or pond before being released into a river.

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2. **Describe** two ways that metals enter bodies of water.

3. **Identify** How can factories cool hot water before releasing it into rivers?
Reducing Water Pollution

One way to reduce water pollution is to treat water before it enters a stream or lake. In 1972, the U.S. Congress passed the Water Pollution Control Act. This law provided funds to build sewage treatment facilities and required industries to treat polluted water before releasing it.


How can countries work together?

Sometimes countries work together to reduce water pollution. Coral reefs are an important part of the ecosystem. They are the home of many different organisms. Unfortunately, they are being damaged by water pollution. In 1998, the United States and many other countries formed a group to help protect coral reefs around the world.

How can you help?

The quality of many streams, lakes and rivers has improved. However, there is still much work to be done. You can help by disposing of wastes safely and by conserving water.

How can wastes be disposed of safely?

When you dispose of household chemicals such as paint or motor oil, don’t pour them onto the ground or down the drain. These wastes can move into groundwater or rivers. Instead, read the label on the container for instructions on how to safely dispose of these wastes.

How can water be conserved?

You use water every time you flush a toilet, take a bath, or wash dishes. Each person in the United States uses an average of 375 L of water per day. Unless it comes from a home well, this water must be purified before it reaches your home. After you use the water, it must be treated again. Some simple ways to conserve water are to turn off water while brushing your teeth, replace an old toilet with a new one, and to fix leaky faucets.
After You Read

Mini Glossary

- **fertilizer**: chemical that helps plants grow
- **nonpoint source pollution**: pollution that enters water from a large area and cannot be traced to a single location
- **pesticide**: substance used to keep insects and weeds from destroying crops and lawns
- **point source pollution**: pollution that enters water from a specific location and can be controlled or treated before it enters a body of water
- **sewage**: wastewater that goes into drains and contains human waste, household detergents, and soaps

1. Review the terms and their definitions in the Mini Glossary. Choose one term and use it to write a sentence telling how water pollution harms people or the environment.

2. Complete the concept map to show the sources of water pollution.

3. As you read this section, you highlighted the main ideas in each paragraph. How did highlighting the main ideas help you understand the information in this section?

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Our Impact on Water and Air

section 3 Air Pollution

What You’ll Learn
- sources of air pollution
- types of air pollutants and their effects
- ways to reduce air pollution

Before You Read
Air is just as important to most life on Earth as water is. What are some ways air pollution can harm your health?

Read to Learn

Causes of Air Pollution
Cities can be exciting places. They are centers of business, culture, and entertainment. However, cities also have many cars, buses, and trucks that burn fuel for energy. The brown haze you sometimes see over a city forms from the exhaust of these vehicles. Air pollution also comes from burning fuel in factories, generating electricity, and burning trash. Dust from plowed fields, construction sites, and mines also contributes to air pollution.

Natural sources may cause air pollution, too. For example, radon is a gas given off by certain kinds of rock. This gas can seep into basements of homes built on these rocks. Breathing radon can increase the risk of lung cancer. Particles and gases from fires and erupting volcanoes also are natural sources of pollution.

What is smog?
One type of air pollution found in and around cities is called smog. Cars, trucks, and motorcycles are the main sources of smog in the United States. Other major sources of smog include factories and power plants. A combination of pollutants and natural conditions leads to the formation of smog.
How does smog form?

Photochemical smog is a hazy blanket of smog that forms with the help of sunlight. When gasoline is burned, nitrogen and carbon compounds are released and pollute the air. The figure below shows how these compounds produce smog and ozone. Ozone high in the atmosphere protects you from the Sun’s radiation. However, ozone near Earth’s surface is a major component of smog. It can damage your lungs and harm plants.

How does nature contribute to smog?

Landforms may help smog form. Mountains can prevent smog from being carried away by winds. The atmosphere also can influence smog formation. Normally, warm air near the ground rises into higher layers of the atmosphere. Sometimes warm air traps cool air near the ground. This causes pollutants to accumulate near Earth’s surface.

Acid Rain

Acids form when sulfur oxides from coal-burning power plants and nitrogen oxides from cars combine with moisture in the air. Acid rain occurs when acidic moisture falls to Earth as rain or snow.

The pH scale measures how much acid a substance contains. A pH of 7 is neutral. Acids are substances with a pH below 7. Bases are substances with a pH above 7.

Natural lakes and streams have a pH between 6 and 8. Acid rain has a pH below 5.6. Acid rain may decrease the pH of streams and lakes, harming some organisms.

Picture This

1. Identify What is the source of the oxygen atoms that combine with oxygen molecules in air to form ozone?

2. Define What is the pH of acid rain?
3. Identify What is one disease caused by pollution?

### CFCs

About 20 km above Earth’s surface is a layer of atmosphere called the ozone layer. Recall that ozone is a molecule made of three oxygen atoms. Ozone in smog near the ground is harmful. However, ozone in the ozone layer helps life on Earth by absorbing some of the Sun’s harmful ultraviolet (UV) rays.

Chlorofluorocarbons (CFCs) from air conditioners and refrigerators might be destroying the ozone layer. Each CFC molecule can destroy thousands of ozone molecules. Even though use of CFCs has decreased, CFCs can remain in the upper atmosphere for many decades.

### Air Pollution and Your Health

Have you ever had to stay indoors because of an air or smog pollution alert? When smog levels are high, it is not safe to run, bike, or exercise outdoors. Some schools schedule football games for Saturday afternoons when the smog levels are lower.

**How does dirty air affect health?**

About 250,000 people in the United States suffer from breathing disorders caused by air pollution. It also causes about 70,000 deaths each year. Ozone damages lung tissue and may lead to diseases such as pneumonia and asthma. Less severe symptoms caused by ozone pollution include burning eyes, dry throat, and headache.

How do you know if ozone levels in your community are safe? You may have seen an Air Quality Index reported in your newspaper or on television. When the index is at an unhealthy level, people with breathing problems are cautioned to avoid outdoor activities. The table below shows the index along with ways to protect your health when ozone is high.

#### Air Quality Index

<table>
<thead>
<tr>
<th>Air Quality</th>
<th>Air Quality Index</th>
<th>Protect Your Health</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>0–50</td>
<td>No health impacts occur.</td>
</tr>
<tr>
<td>Moderate</td>
<td>51–100</td>
<td>People with breathing problems should limit outdoor exercise.</td>
</tr>
<tr>
<td>Unhealthy for certain people</td>
<td>101–150</td>
<td>Everyone, especially children and elderly, should not exercise outside for long periods of time.</td>
</tr>
<tr>
<td>Unhealthy</td>
<td>151–200</td>
<td>People with breathing problems should avoid outdoor activities.</td>
</tr>
</tbody>
</table>

4. Determine If the Air Quality Index were reported to be at 75, what would the air quality be?
How does carbon monoxide affect people?
Carbon monoxide contributes to air pollution. Carbon monoxide is a colorless, odorless gas found in car exhaust. This gas can make people ill, even in small amounts, because it replaces oxygen in the blood. This can cause chest pains and breathing difficulty.

How does acid rain affect your lungs?
When you breathe the humid air from acid rain, acid is inhaled deep into your lungs. This may cause irritation and reduce your ability to fight respiratory infections. When you breathe damaged by acid rain cannot move oxygen into blood easily. This puts stress on your heart.

How do particles in the air harm the lungs?
Particulate (par TIH kyuh luht) matter also harms the lungs. Particulate matter consists of fine particles such as dust, pollen, mold, ash, and soot that are in the air. It comes from forest fires, exhaust from trucks and buses, smoke from factories, or even dust picked up by the wind.

Particulate matter ranges in size from large, visible bits of dust and soil to microscopic particles that form when substances are burned. Small particles are most dangerous because they can travel deeper into the lungs. When particulate matter is breathed in, it can irritate and damage the lungs, causing breathing problems.

Reducing Air Pollution
Air pollutants cross the borders between states and countries, going wherever the wind carries them. This makes them difficult to control. Even if one state or country reduces its air pollution level, pollutants from another state or country can blow across the border. For example, burning coal in midwestern states causes acid rain in the northeastern United States and Canada.

When states and nations cooperate, pollution problems can be reduced. People from around the world have met on several occasions to try and eliminate some kinds of air pollution. At one meeting in Montreal, Canada, an agreement called the Montreal Protocol was written to stop making and using CFCs by 2000. In 1989, the 29 countries that used 82 percent of CFCs signed the agreement. By 1999, 184 countries had signed it.
How has the United States reduced air pollution?

The United States Congress has passed several laws to protect the air. One was the Clean Air Act of 1990. It helps to reduce air pollution from cars, power plants, and other industries. The Clean Air Act is summarized in the table below.

<table>
<thead>
<tr>
<th>Clean Air Regulations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Urban air pollution</strong></td>
</tr>
<tr>
<td><strong>Acid rain</strong></td>
</tr>
<tr>
<td><strong>Airborne toxins</strong></td>
</tr>
<tr>
<td><strong>Ozone-depleting chemicals</strong></td>
</tr>
</tbody>
</table>

The Clean Air Act has helped decrease the amount of some pollutants released into the air each year, as shown in the figure below. However, millions of people in the United States still breathe unhealthy air.

How can emissions be reduced?

More than 80 percent of sulfur dioxide emissions come from power plants that burn coal with a high sulfur content. When coal is burned, sulfur dioxides combine with moisture to form sulfuric acid, causing acid rain.
**Scrubbers** Sulfur dioxide can be removed from power plant emissions by passing the smoke through a scrubber. A scrubber causes the gases to react with a limestone and water mixture. Another way to decrease the amount of sulfur dioxide is by burning coal that contains less sulfur.

**Electrostatic Separators** Electric power plants that burn fossil fuels release particulates into the atmosphere. The particulate matter can be removed from smoke with a pollution-control device called an electrostatic separator. This device acts like a magnet for smoke particles. Plates in the separator give the smoke particles a positive charge. The positively-charged smoke particles then stick to negatively-charged plates in the separator.

**How can pollution from cars, trucks, and buses be reduced?**

Recent improvements in car design, as well as the use of emission-control devices such as catalytic converters, have reduced car emissions significantly. The gasoline that we use today gives off less pollution than the gas used in the past. Future advances in technology might help to reduce emissions further. This is important because Americans are driving more today than they did in the past. More time spent driving leads to more traffic jams. Cars and trucks produce a lot of pollution when they are stopped in traffic.

**Can you help reduce air pollution?**

The Clean Air Act can work only if we all cooperate. Cleaning the air takes money, time, and effort. How might you help reduce air pollution? You might change your lifestyle by walking, riding a bike, or using public transportation to get to a friend’s house instead of asking for a car ride. You also can set the thermostat in your home lower in the winter and higher in the summer.
1. Review the terms and their definitions in the Mini Glossary. Write one sentence about air pollution using two vocabulary words.

________________________________________________________________________

________________________________________________________________________

2. Complete the concept map to show the types of air pollution.

Air Pollution

- Smog
  - forms from
  - damages

- Acid Rain
  - forms when
  - damages

- CFCs
  - released from
  - damages

Visit fl7.msscience.com to access your textbook, interactive games, and projects to help you learn more about air pollution.