Reading Essentials
An Interactive Student Workbook
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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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The Nature of Science

section ● What is science?

● Before You Read
How do you find answers to questions about what is happening around you?

What You’ll Learn
■ how science is part of everyday life
■ skills and tools used in science

● Read to Learn
Science in Society
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? Perhaps you have problems to solve or questions to answer. Science is a way or a process used to investigate what is happening around you. It can give you possible answers to your questions.

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.

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.

Foldables
A Describe Make a two-tab book, as shown below. Use the Foldable to describe tools scientists use and skills they develop.
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. Think about the decisions that the people in the photos below have to make. How are these similar to the types of decisions that you have to make?

What clues do scientists use?

When you have a project to do for history class, you have a problem to solve. You look for clues to find the answers to the questions in your history project. You use several skills and tools to find the clues.

Using Prior Knowledge

Scientists 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.
What is technology?
Modern scientists use the computer 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.

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.

Why are observation and measurement skills important?
Observing and measuring are important skills, particularly for scientists. Observation sometimes does not give a complete picture of what is happening. In addition to observation, it is important to take accurate measurements to be sure that your data are useful.

Communication in Science
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.

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 to the right, 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 way or a process used to investigate what is happening around you  

**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 of Skills Scientists Need]

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

   ____________________________________________

   ____________________________________________

   ____________________________________________

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Visit [blue.msscience.com](http://blue.msscience.com) to access your textbook, interactive games, and projects to help you learn more about what science is.
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.
Experimental research design is used to answer scientific questions by testing a hypothesis through the use of a series of carefully controlled steps. Scientific methods are ways, or steps to follow, to try to solve problems. Different problems will require different scientific methods to solve them. The figure below shows one way to use scientific methods.

Descriptive Research

Scientists solve some problems by using descriptive research. Descriptive research is based mostly on observations. Scientists use this method when it would be impossible to run 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 using careful numerical measurements for all data. Bias also can happen in surveys or groups that are chosen for investigation. To get an accurate result, you need to use a random sample.
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 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.

![Image of a person creating a display]

**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.

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**Think it Over**

3. **Draw Conclusions**

Why is up-to-date material important to scientists?

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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.

### 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 is 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 your data is organized, you are ready to draw a conclusion. 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 Design

Another way to solve scientific problems is through experimentation. Experimental research design answers scientific questions by observing a controlled situation. The design includes several steps.

How do you form a hypothesis?

A hypothesis (hi PAH thuh sus) is a prediction, or statement, that can be tested. To form a hypothesis, you use your prior knowledge, new information, and any previous observations.

What are variables?

In a planned experiment, one factor, or variable, is changed at a time. This means that the variable is controlled. The variable that is changed is called the independent variable. Suppose an experiment is testing the effect of two different antibiotics on the growth of bacteria. The type of antibiotic is the independent variable. A dependent variable is the factor being measured. 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 have 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.
After You Read

Mini Glossary

constant: variable that stays the same in an experiment
control: a sample that is treated like the other experimental groups except that the independent variable is not applied to it
dependent variable: the factor being measured in an experiment
descriptive research: type of research design that answers scientific questions through observation

experimental research design: type of research design used to answer scientific questions by testing a hypothesis through the use of a series of carefully controlled steps
hypothesis: a prediction, or statement, that can be tested
independent variable: the variable that is changed in an experiment
model: a representation of things that happen too slowly, too quickly, or are too big or too small to observe directly
scientific methods: steps to follow to try to solve problems

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.
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 technologies such as DVDs.

How are technological advances helpful?
Technology helps to make your life more convenient. Foods can be prepared quickly in microwave ovens. A satellite tracking system in a car can give you directions to places in an unfamiliar city.

Science—The Product of Many
As new scientific knowledge becomes available, old ways of thinking are challenged. At one time, living organisms were classified into plants and animals. This system was used until new tools, such as the microscope, allowed scientists to study organisms in detail. The classification system that scientists use today will be used only until a new discovery lets them look at information in a different way.

Who practices science?
Scientific discoveries have been made by both men and women and by people of all races, cultures, and time periods. In fact, even students have made scientific discoveries.
How is scientific information used?

People use new information that science provides to make decisions. A new drug can help cure a disease. A new way might be developed to make electricity. However, science cannot decide whether the new information is good or bad. People have to decide whether the new information is used to help or harm the world and its people. With the use of the Internet, new information and technology can be shared quickly by people in all countries. However, any information received from the Internet must be checked for accuracy.

Looking to the Future

Today, scientists use cellular phones and computers to communicate with one another. This information technology has led to information being distributed worldwide.
After You Read

Mini Glossary

information technology: technology such as computers used for communication

1. Review the term and its definition in the Mini Glossary. Write a sentence explaining how you use information technology.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

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

Describe what happens to your hair and skin if you are exposed to the Sun for a long period of time.

Read to Learn

What are traits?

All the features that an organism inherits are its traits. Two of your traits are your eye color and ear shape.

How do humans use observable traits?

People observed the inheritance of traits long before scientists understood how inheritance works. Many breeds of animals and crops were developed using these observations. For example, over thousands of years, Native Americans developed maize (MAYZ) from a wild grass. By carefully selecting and breeding maize plants with desired traits, modern corn was developed.

What are genotypes?

You have thousands of traits. Each trait results from the coded information in the hereditary material called DNA. DNA is found in every cell and contains the information needed to produce a living organism. In cells that have a nucleus, DNA is found in chromosomes (KROH muh sohmz) within the nucleus. A gene is a part of the DNA code on a chromosome. The genes an organism has are called its genotype (JEE nuh tipe), or genetic makeup. The figure on the next page shows the DNA structure.
What are phenotypes?
When you look at an organism, you see the organism’s phenotype (FEE nuh tipe). A **phenotype** is the combination of genetic makeup and the environment’s effect on that makeup. Hair color in humans is the result of both genetic makeup and the effects of the environment. For example, you may notice that your hair color gets lighter when you are in the Sun for many hours.

**Effects of the Environment**
How much the environment affects phenotypes varies from organism to organism. The environment doesn’t have much effect on some phenotypes, such as the color of your eyes. Other phenotypes are mostly due to the environment. For example, the soil conditions affect the color of a big-leaf hydrangea plant’s flowers. The flowers vary from blue to pink.

**What are external and internal influences?**
Influences of the environment on phenotypes can be external or internal. One external influence would be the amount of light an organism receives. For example, tree leaves that grow in full sunlight are thicker than those that grow in shadier areas. Another external influence might be the temperature in which an organism lives.

Other environmental influences are internal. For example, human brain cells will not grow normally unless they are acted upon by a thyroid hormone during their development. The hormone is a part of the body’s internal environment.
How can the environment affect growth?

Trees grow differently in a forest than they would in an area where they are all alone. A tree planted away from other trees and plants will grow faster than a tree planted near existing trees. The single tree does not have to compete with other trees for light, water, soil minerals, and other environmental factors.

How does the environment affect appearance?

As you can see in the figure below, the leaves of a water buttercup differ depending on where it grows. Leaves that grow in water are threadlike. Leaves that grow above the water are broad.

The arctic fox is another species whose phenotype changes according to environmental conditions. Its fur changes color with the seasons. During the winter the arctic fox does not produce pigment that colors fur, so the fox’s fur is white. As a result, the fox blends with its background helping it avoid predators. In warmer months, the arctic fox produces fur pigment, so the fur is brown. This color helps the fox blend into the tundra.

How can the environment affect the sex of an organism?

Most living things are born male or female and remain that way for life. However, some species of fish are born with the ability to change sex. This allows the species to maintain a desired number of males and females in a population.
After You Read

Mini Glossary

gene: a part of the DNA code on a chromosome

genotype (JEE nuh tipe): genes that an organism has; genetic makeup

phenotype (FEE nuh tipe): the combination of genetic makeup and the environment’s effect on that makeup

trait: feature that an organism inherits

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the relationship of DNA and a gene.

2. Complete the diagram below to identify the influences of the environment on phenotypes.

3. How does taking turns reviewing paragraphs with a partner help you understand what you have read?

Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about traits and the environment.
Traits and How They Change

section Genetics

Before You Read

Think of a parent and a child that you know. On the lines below, list two ways the child looks like the parent.

What You’ll Learn

- the difference between genetics and heredity
- the results of Mendel’s pea plant experiments
- the results shown by a Punnett square

Read to Learn

Science of Genetics

Heredity is the passing of traits from parents to offspring. One early idea about heredity proposed that the male contributed all of the traits and that the female only supplied food for the new organism. Others proposed that parents’ traits blended to form the traits of the offspring.

What is genetics?

Over time, the study of heredity developed into a science called genetics (juh NE thks). The study of genetics explains how species can change through generations.

Beginning with Mendel

Only within the past 200 years have scientists begun to understand how organisms inherit traits. Gregor Mendel was the first researcher to use numbers to describe the results of genetics experiments. Mendel developed principles of genetics in the 1860s by experimenting with thousands of pea plants.

What determines traits?

Mendel explained that each trait of an individual is determined by at least two factors. Today, Mendel’s factors are called genes. The different forms of a gene are each called an allele (uh LEEL).
What are dominant and recessive alleles?

Mendel developed the principle of dominance which explains why only one form of a trait is shown even when both alleles are present. **Dominant** (DAH muh nunt) alleles will show their effect on the phenotype whenever they are present in the genotype. **Recessive** (rih SE sihv) alleles will show their effect on the phenotype only when two of them are present in the genotype.

Understanding how dominant and recessive alleles show their effects has helped scientists figure out how some genetic diseases are passed down through families.

Why do children have different traits than their parents?

Mendel also concluded that each parent passes only one of the alleles for a trait to its offspring. This is known as the principle of segregation. It explains why variation exists among the offspring of parents. For example, suppose a parent has three pairs of chromosomes with a different trait on each pair. The traits can be called A, B, and C. Each trait has two different alleles—A and a, B and b, and C and c. The dominant trait is represented by the capital letter. The figure below shows the eight possible combinations for these three traits. Humans have 46 chromosomes, so more than 8 million combinations are possible every time an egg or sperm forms in the parent.

![Parent reproductive cell diagram](image)
What did Mendel learn?
Mendel examined the inheritance of traits in pea plants. He found that when two plants with different alleles for a trait are crossed, three fourths of the offspring will show the dominant trait. One fourth will show the recessive trait. Mendel also discovered that the alleles for one trait have no effect on how alleles for another trait are inherited. This led to his law of independent assortment. Mendel studied two traits at the same time. His law of independent assortment—alleles for one trait are inherited independent of the alleles for another trait—helped him understand how traits from both parents can appear in future generations.

Predicting Genetic Outcomes
Reginald C. Punnett developed a chart called a Punnett square to make genetic predictions. A Punnett square is a model that is used to predict the possible offspring of crosses between different organisms of known genotypes. The figure below is a Punnett square used to predict whether an offspring will be male or female.

What are the results?
When you use a Punnett square to predict the sex of one offspring, the results are one-half male and one-half female. Suppose a woman has already given birth to three sons and is expecting a fourth child. What are the chances that it will be a girl? There is still only a 50 percent chance that the baby will be a girl. Each result is independent of the others that came before it or that come after it.
After You Read

Mini Glossary

- **allele (uh LEEL):** each gene of a gene pair
- **dominant (DAH muh nunt):** trait that will show its effect on the phenotype whenever it is present
- **genetics (juh NE tihks):** the study of how traits are passed from parents to offspring
- **Punnett square:** a chart that is used to predict the possible offspring of crosses between different organisms of known genotype
- **recessive (ree SEH shv):** trait that will show its effect on the phenotype only when two of them for a trait are present in a genotype

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that compares dominant and recessive traits.

2. Complete the table below to explain the principles and laws that Gregor Mendel developed as a result of his experiments with pea plants.

<table>
<thead>
<tr>
<th>Principle or Law</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about genetics.
Traits and How They Change

section 3 Environmental Impact over Time

● Before You Read

On the lines below, list some kinds of plants or animals that could not live in very cold environments, such as on top of a mountain.

---

● Read to Learn

Survival and the Environment

The environment influences which organisms can live in an area. You are not likely to see cacti in an area where it rains a lot. You would not see a large evergreen tree growing in a desert.

What nonliving factors influence the survival of a species?

Temperature and rainfall influence the survival of a species. Pollution limits where a species can survive. Fire, height of mountains, volcanic eruptions, and flooding of rivers can influence the animals and plants in an area.

The chaparral shrub land of California and forests of Yellowstone National Park require occasional fires to survive. Some plant species need fire for their seeds to germinate. Aspen trees can sprout from underground roots when fire has burned away other plants in the area.

As you travel up a mountain, the environment gradually changes. Temperature decreases and wind usually increases. The types of plants and animals vary at different elevations on a mountain.

What You’ll Learn

- how environmental factors impact evolution
- how natural selection occurs in a species
- the differences between selective breeding and natural selection

Create a Quiz

Write a quiz question for each heading in this section. Be sure to answer the questions.

Foldables

Identify

Make a two-tab book, as shown below. Identify the living and nonliving factors that influence the survival of species.
1. Explain According to Darwin and Wallace, why is there a large variety of species on Earth?

What living factors influence the survival of a species?
Predators limit the number of animals that live in an area. Other factors include competition for food or territory. When humans change the land, for example, by logging or building, the other species in that area must adjust to the changes, leave the area, or die.

Species and the Environment
Charles Darwin and Alfred Wallace were biologists in the 1800s who studied why there is a large variety of living things on Earth. They hypothesized that different, long-term, environmental influences on populations produced the variety of species.

What is the theory of evolution through natural selection?
Darwin and Wallace concluded that changes happen from generation to generation that result in adaptations to the environment. This process is called evolution. Evolution is the change in the genetics of a species over time.

Darwin and Wallace questioned how evolution happens. They proposed that organisms that are better adapted to an environment survive and reproduce at a greater rate than organisms that are not. They called this natural selection, because the adapted organisms are selected naturally to survive and increase in number. Natural selection can produce new organisms or new species.

How does mutation affect species?
Recall that different forms of alleles produce differences in traits. Mutation (myew TAY shun) is the process in which changes to DNA result in new alleles. Some mutations prevent an organism from surviving and reproducing. Others help an organism survive and reproduce. Helpful mutations may be inherited by offspring and can lead to the evolution of a new species.

Does selective breeding occur in nature?
Charles Darwin knew that humans could selectively breed animals that possess desirable traits to produce new breeds of animals. He inferred that the same thing might happen naturally in different environments.
How can many species develop from one ancestral species?

When nature favors more than one variation of a trait, two or more new species can develop from one ancestral species. Adaptive radiation is the production of several species from one ancestral species. Darwin visited the Galápagos Islands. He observed many species of finches on the islands. Because they were isolated geographically from the same species on the mainland, they adapted to the various conditions on the islands. Over time, each ancestral species produced several different species. Each adapted to the different environments on each island.

How does extinction occur?

Extinction occurs when the last individual of a species dies. Millions of species have become extinct. Fossils provide evidence of these species. As you can see in the chart below, the rate at which species become extinct today is much faster than at any time in the recent past.

Why does extinction occur?

Extinction can occur for many reasons. It can happen when habitats are destroyed. Extinction also can occur when a new species is introduced to an area. The introduced species might produce many offspring and crowd out existing species. Introduced species may prey on existing species that do not have defenses against them.
1. Review the terms and their definitions in the Mini Glossary. Write one or two sentences that explain the difference between evolution and extinction.

2. Complete the concept web below to show the kinds of nonliving and living environmental influences that affect the survival of species.

Nonliving

Living

Environmental Influences on Species Survival
Interactions of Human Systems

section ● The Human Organism

Before You Read
List things that you need to keep your body healthy.

What You’ll Learn
- the basic structure and function of a typical human cell
- the five levels of organization in the body

Read to Learn

Organization in the Human Body
Your body is made up of a series of building blocks that are different in size and structure. Good health depends upon all of the body parts working properly.

Chemical Basis of Life
A person is made up of matter. Matter is any substance that has mass and takes up space. It is made up of atoms, which are the smallest parts of matter.

What are elements and compounds?
Matter that has the same makeup and features throughout is called a substance. A substance is either an element or a compound.

An element is made up of only one kind of atom. Scientists have discovered 90 natural elements on Earth. Carbon (C) is an element. Oxygen (O) is an element.

Substances that are made of more than one element are called compounds. A compound is two or more elements that are chemically combined. Carbon dioxide (CO₂) is a compound. It is made up of 1 atom of the element carbon and 2 atoms of the element oxygen.

Identify Main Ideas
Highlight the main idea of each paragraph. Review what you have highlighted after you finish reading this section.

Applying Math
1. Explain Write a simple addition problem that shows how the compound CO₂ is formed.
2. Explain the role of minerals in the body.

3. Identify the four minerals needed to form bones. Then read aloud the dietary sources of each mineral.

What is an inorganic substance?

Chemicals in living things are either inorganic or organic substances. Inorganic substances usually come from nonliving sources such as air, soil, or water.

Minerals are inorganic substances that are involved in many of the body’s chemical reactions, as listed in the table below. Your body needs small amounts of these minerals to stay healthy and fight disease.

<table>
<thead>
<tr>
<th>Mineral</th>
<th>How the Body Uses the Mineral</th>
<th>Dietary Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>Formation of bones and teeth, blood clotting, muscle and nerve function</td>
<td>Dairy products, leafy green vegetables, nuts, whole grains</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Fluid balance, pH balance</td>
<td>Table salt</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Formation of red blood cells</td>
<td>Meat, dairy products</td>
</tr>
<tr>
<td>Copper</td>
<td>Development of red blood cells and respiratory enzymes</td>
<td>Kidney, liver, beans, whole-meal flour, lentils, raisins</td>
</tr>
<tr>
<td>Fluorine</td>
<td>Formation of bones and teeth</td>
<td>Fluoridated water</td>
</tr>
<tr>
<td>Iodine</td>
<td>Part of thyroid hormone</td>
<td>Seafood, table salt with iodine</td>
</tr>
<tr>
<td>Iron</td>
<td>Part of hemoglobin and some enzymes</td>
<td>Liver, egg yolk, peas, nuts, whole grains, red meat, raisins, leafy green vegetables</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Muscle and nerve functions, bone formation, breakdown of proteins and carbohydrates, enzyme function</td>
<td>Potatoes, fruits, whole-grain cereal, vegetables, dairy products</td>
</tr>
<tr>
<td>Manganese</td>
<td>Growth of cartilage and bone; breakdown of carbohydrates, proteins, and fats</td>
<td>Wheat germ, nuts, bran, leafy green vegetables</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Bone formation, nerve function, regulation of blood pH, muscle contraction</td>
<td>Milk, whole-grain cereal, meats, vegetables, nuts</td>
</tr>
<tr>
<td>Potassium</td>
<td>Muscle and nerve function</td>
<td>Grains, fruits, vegetables, ketchup</td>
</tr>
<tr>
<td>Sodium</td>
<td>Muscle and nerve function, water balance, regulation of body fluid pH</td>
<td>Table salt, bacon, butter, vegetables</td>
</tr>
<tr>
<td>Sulphur</td>
<td>Builds hair, nails, and skin, part of insulin</td>
<td>Nuts, dried fruits, oatmeal, eggs, beans</td>
</tr>
<tr>
<td>Zinc</td>
<td>Digestion, healing, taste, smell</td>
<td>Liver, seafood</td>
</tr>
</tbody>
</table>

Why does your body need salt?

Inorganic chemicals play many important roles in your body. Salt is an example of an inorganic compound. It is an important chemical in your blood. Your blood is mostly water (H₂O), but it also contains sodium ions (Na⁺) and chlorine ions (Cl⁻) in the form of dissolved sodium chloride (NaCl), also known as table salt.
Why is water important to your body?

Water makes up more than 70 percent of your body’s tissues. Water is important in digesting foods, muscle function, delivering oxygen to cells, and removing wastes from the body. Over a long period of time, a lack of water can lead to problems in digestion, circulation, and kidney function. Not getting enough water every day can cause dry skin, headaches, and fatigue.

What are organic substances?

Your body is made up of the same kinds of chemicals that are found in the things that you eat every day. Living things are made of organic compounds, which are compounds containing carbon, with a few exceptions. Two exceptions to this definition are carbon dioxide and carbon monoxide, which are inorganic substances. The four groups of organic compounds are carbohydrates, lipids, nucleic acids, and proteins. These organic compounds are found in the foods you eat.

Where do you get most of your energy?

Carbohydrates are the main source of energy for living things because they make up the largest part of an organism’s diet. Carbohydrates are made up of carbon (C), hydrogen (H), and oxygen (O). Foods such as potatoes, pasta, breads, and rice contain carbohydrates.

What are lipids?

Lipids are fats and oils. They contain more energy per molecule than carbohydrates do. Your body stores fat as energy reserves. When your body’s supply of carbohydrates is low, your body uses the stored fat for energy.

Why are nucleic acids important?

Nucleic acids are large, complex organic compounds. They store information in the form of a code. DNA is one type of nucleic acid. DNA carries information that directs cell activities and instructions for making all proteins. Another nucleic acid, RNA, makes proteins from amino acids.

What are the functions of proteins?

Many parts of the body—hair, skin, nails, muscles, and blood vessels—are made, in part, of protein. Other proteins, such as enzymes, help your body carry out important processes, such as growth, repair, digestion, respiration, and sending nerve impulses.
Cells—Living Factories

Organic and inorganic chemicals combine in an organized way to form cells. A cell is the smallest working unit in an organism. Every living thing is made up of one or more cells. The figure below shows the basic parts of a human cell. Each part of the cell has a special job.

What is the function of a cell?

Most cells are so small you need a microscope to see them. Cells contain different parts that perform activities necessary for life, such as digestion, growth, and reproduction. Cells can be compared to a factory. Many factories have separate locations inside the building to complete tasks for making things. Raw materials are brought into the factory and made into products. The products are packaged and delivered to customers. In a similar way, cells take in raw materials, such as food, oxygen, water, and minerals. Cells use these materials in chemical reactions to make proteins and other products needed for life. During some of these chemical reactions, energy is released.

Why do cells have to work together?

A cell can be compared to a member of a band. Each member plays the music for his or her instrument. However, the members must work together for the band to sound good. A cell must perform its function. However, the cells must work together so the whole organism can function. Many-celled organisms are highly organized.
How do cells work together?

Cells represent the first level of organization in the body. Cells are organized into tissues. **Tissues** are groups of similar cells that do the same kind of work. In the human body, blood tissue moves oxygen and nutrients to and from cells. Nerve tissue carries nerve impulses around the body. It helps different parts of the body communicate.

**What are organs?**

Tissues are organized into organs. An **organ** is a structure made up of different types of tissues that work together. For example, the heart is an organ made up of cardiac muscle tissue, nerve tissue, and blood tissue.

**What are organ systems?**

A group of organs that work together to do a certain job is called an **organ system**. Your circulatory system is made up of your heart and blood vessels. An organ system is the fourth level of organization. The organ systems depend on each other and work together to form the whole organism. The table below shows the organ systems of the human body.

<table>
<thead>
<tr>
<th>Organ System</th>
<th>Main Organs</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integumentary</td>
<td>Skin</td>
<td>Protects the body and prevents water loss</td>
</tr>
<tr>
<td>Muscular</td>
<td>Muscles</td>
<td>Movement of the body, attached to bones</td>
</tr>
<tr>
<td>Skeletal</td>
<td>Bones</td>
<td>Support and protection of soft body parts</td>
</tr>
<tr>
<td>Nervous</td>
<td>Brain, spinal cord, nerves</td>
<td>Controls mental and bodily functions</td>
</tr>
<tr>
<td>Endocrine</td>
<td>Pancreas, pituitary gland</td>
<td>Controls homeostasis by releasing hormones</td>
</tr>
<tr>
<td>Circulatory</td>
<td>Heart, blood vessels</td>
<td>Transport of materials to and from body cells</td>
</tr>
<tr>
<td>Lymphatic</td>
<td>Spleen, thymus, tonsils</td>
<td>Remove dead cells and foreign bodies from body fluids</td>
</tr>
<tr>
<td>Respiratory</td>
<td>Lungs, trachea</td>
<td>Exchange of gases between blood and the environment</td>
</tr>
<tr>
<td>Digestive</td>
<td>Stomach, small intestine</td>
<td>Break down food for absorption into the blood</td>
</tr>
<tr>
<td>Urinary</td>
<td>Kidneys, bladder</td>
<td>Control of water balance and chemical makeup of blood</td>
</tr>
<tr>
<td>Reproductive</td>
<td>Testes, ovaries</td>
<td>Production of sex cells</td>
</tr>
</tbody>
</table>

**Foldables**

**B Identify** Make a five-tab Foldable, as shown below. Identify the levels of organization of cells.

---

**Think it Over**

7. **Infer** Highlight the circulatory and respiratory systems and read their purposes. Why do you think these two systems work together?

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After You Read

Mini Glossary

cell: the smallest working unit in an organism

mineral: an inorganic substance that is involved in many of the body's chemical reactions

organ: a structure made up of different types of tissues that work together

organ system: a group of organs that work together to do a certain job

organic compounds: compounds containing carbon, except carbon dioxide and carbon monoxide
tissue: a group of similar cells that do the same kind of work

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

2. Complete the graphic organizer below to show the levels of organization in a human body.

1. Cells

2.

3.

4.

5.

3. How did highlighting the main ideas help you understand what you learned in this section?

End of Section

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Interactions of Human Systems

section 3 How Your Body Works

Before You Read

On the lines below, describe how your body responds to exercise.

What You’ll Learn

- how body systems work together
- how negative feedback mechanisms help the body maintain homeostasis
- differences between negative and positive feedback mechanisms

Read to Learn

Body System Connections

Organ systems in your body are interdependent. The organ systems depend on each other and work together to carry out important life processes.

Feeding Cells

The foods you eat are filled with the chemicals that your body needs to grow strong and healthy. Organ systems help distribute these chemicals throughout your body for energy, growth, repair, and other important functions.

What is the digestive system?

Digestion is the breakdown of the foods that you eat into smaller and simpler molecules to be used by the cells in your body. In the figure on the next page, you can see that the digestive system is basically a long tube that runs through your body. Food is taken into the body through the mouth. Your teeth chew the food and break it down into smaller pieces. As the food passes through the digestion tube, it is broken down even more. During digestion, glucose, salt, vitamins, and water can be absorbed immediately into the bloodstream. All other foods must be broken down first.

Make Flash Cards

Write each vocabulary word or term on one side of the flash card and the definition on the other side. Keep quizzing yourself until you know the meanings of all the terms.

Foldables

Foldable using notebook paper, as shown below. As you read the section, write notes that explain how your body systems work together.
2. Describe How does saliva help with digestion?

Your brain tells certain cells in your mouth to make saliva when you see, smell, or taste food. Saliva makes food soft and wet and contains an enzyme that helps with digestion. An enzyme (EN zime) is a protein that helps the body carry out chemical reactions. When food reaches other parts of the digestive tract, the brain tells the body to make other enzymes that help break down the food even more.

What happens in the small intestine?

The small intestine is an important connection between the digestive system and the circulatory system. Your small intestine is lined with tiny fingerlike projections called villi. Villi contain many blood vessels. By the time food reaches the small intestine, it is broken down into molecules that are small enough to pass through the walls of the villi.
3. Explain What structures in the small intestine absorb food into the bloodstream?

How do nutrients get to body cells?

After the molecules pass through the walls of the villi, they enter the bloodstream. This process is called **absorption**. The bloodstream carries nutrients to cells throughout the body.

**Energy for the Body**

**Cellular respiration** is a series of chemical processes in which oxygen combines with food molecules and energy is released. This occurs in the mitochondria of every cell. A cell uses this released energy to perform all of its jobs.

For cellular respiration to occur, there must be a constant supply of nutrients and oxygen. When not enough oxygen is available, the cycle cannot be completed. If not enough oxygen is available, lactic acid forms. As lactic acid increases, muscles get tired and breathing gets faster.

**How do the respiratory and circulatory systems work together?**

Oxygen absorption occurs in the lungs, where the respiratory and circulatory systems work together. Look at the figure below. At the lower end of the trachea are two short branches called bronchi, which carry air into the lungs. Within the lungs, the bronchi branch out into smaller passageways. At the end of these passageways are groups of tiny, thin-walled sacs called **alveoli** (al VEE uh li). Lungs are made up of millions of alveoli. Each group of alveoli is surrounded by a network of blood vessels called capillaries. The exchange of oxygen and carbon dioxide occurs between the alveoli and the capillaries.

**Picture This**

4. Identify Highlight the structures in the figure that are used to exchange oxygen and carbon dioxide.
How does your body get rid of wastes?

The removal of waste products, or excretion, is a necessary process in all organisms. The circulatory, respiratory, digestive, and urinary systems make up the excretory system. The excretory system works to remove wastes from your body.

What does the urinary system do?

The main organs of the urinary system are the two kidneys. All of your blood passes through the kidneys many times each day. The kidneys remove cell wastes and help control the amount of water in the blood. Each kidney is made up of millions of tiny units called nephrons, which filter the blood. Water, sugar, and salt are returned to the blood. Anything left behind is waste. This liquid waste is called urine. Urine eventually is removed from the body.

Interdependence of Body Systems

Your body makes changes in body functions in response to changes in its environment. The process by which the body maintains a stable internal environment is called homeostasis.

How does your body respond to exercise?

Your heart rate and breathing increase as you exercise. During exercise, your muscle cells use more and more oxygen and produce lots of carbon dioxide waste. As a result, your brain tells your heart and lungs to work harder. This delivers oxygen to your muscle cells and gets rid of carbon dioxide much faster.

When your body becomes overheated, your brain tells the body to make changes that will keep it from becoming too hot. Sweating is one way the body responds to an increase in temperature. As sweat evaporates, it cools the skin. Another way the body responds when overheated is to widen the blood vessels in the skin to release body heat.

What is negative feedback?

In a negative feedback mechanism, the body changes an internal condition back to its normal state. The responses your body makes to exercise and to being overheated are examples of negative feedback. Blood pressure also is controlled by a negative feedback system. If blood pressure rises, special cells send a message to the brain. The brain responds by sending a message to the heart to slow down. Slowing the heart causes blood pressure to decrease.
How does the body keep its chemical balance?

The body uses negative feedback to keep chemicals, such as blood sugar levels, in balance. When you eat, the amount of glucose in your blood rises above normal. Glucose is a type of sugar. When glucose levels are too high, a hormone called insulin is produced by the pancreas. Insulin stimulates the cells to absorb glucose and helps the liver turn glucose into glycogen. Glycogen is a sugar that can be stored in the liver and muscle cells. As glucose levels decrease, less insulin is made by the pancreas.

When does the body use positive feedback?

A healthy body rarely uses positive feedback. Positive feedback does not bring the body back to a normal state. Instead, it causes an even greater change. For example, during childbirth the uterus contracts as shown in the figure. The contractions push the baby against the opening of the birth canal. When this happens, the brain signals the uterus to increase the contractions. The positive feedback mechanism goes on until the baby passes through the birth canal.

How does a blood clot form?

The body also uses positive feedback in blood clotting. When a blood vessel is cut or torn, the vessel constricts and chemicals are released. The walls of the blood vessel become sticky and adhere to each other. Platelets attach to the walls of the blood vessel. This causes more chemicals to be released, which causes more platelets to stick to each other. A blood clot forms and the cut or tear is plugged, which stops the process. The clot becomes hard, white blood cells destroy bacteria, and skin cells begin to repair the cut or tear.

Think it Over

6. Analyze What triggers the release of insulin by your pancreas?

7. Identify What type of feedback mechanism is shown in the figure?
After You Read

Mini Glossary

- absorption: the process of digested food passing through the walls of the villi into the bloodstream
- alveoli (al VEE uh li): clusters of tiny, thin-walled sacs at the end of bronchi
- cellular respiration: a series of chemical processes in which oxygen mixes with food molecules and energy is released
- digestion: the breakdown of foods into smaller and simpler molecules that can be used by cells in the body
- enzyme (EN zime): a protein that helps the body carry out chemical reactions
- excretion: the removal of waste products
- homeostasis: the process by which the body maintains a stable internal environment
- negative feedback: the body changes an internal condition back to its normal state
- villi: tiny fingerlike projections in the small intestine

1. Review the terms and their definitions in the Mini Glossary. Select a term and write a sentence that explains to which organ system the term belongs.

2. Describe negative and positive feedback mechanisms in the Venn diagram below. Then write what both have in common in the overlapping area.

End of Section

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Interactions of Life

section Living Earth

Before You Read
On the lines below, list the living things that are part of your neighborhood.

What You’ll Learn
- places where life is found on Earth
- what ecology is
- how the environment influences life

Read to Learn

The Biosphere
Earth has many living organisms. The part of Earth that supports life is the biosphere (BI uh sfhr). The biosphere includes the top part of Earth’s crust, the waters that cover Earth’s surface, and the atmosphere that surrounds Earth.

The biosphere is made up of different environments. Different kinds of organisms live in each environment. For example, a desert environment gets little rain. Organisms that live in a desert environment include cactus plants, coyotes, and lizards. Tropical rain forest environments get a lot of rain and warm weather. Parrots, monkeys, and tens of thousands of other organisms live in tropical rain forests. Arctic regions near the north pole are covered with ice and snow. Polar bears and walruses are two organisms that live in an arctic environment.

Why is life on Earth possible?
In our solar system, Earth is the third planet from the Sun. The amount of energy that reaches Earth from the Sun helps make the temperature just right for life. Other planets are either too close or too far from the Sun to have the right conditions for life.

Study Coach Notes
Organize notes into two columns. On the left, list a main idea about the material in each subheading. On the right, list the details that support the main idea.

Two-Column Notes

1. Describe how the energy from the Sun helps make life on Earth possible.
Ecosystems

An *ecosystem* is all the organisms living in an area and the nonliving parts of that environment. In a prairie ecosystem, the living organisms include bison, grass, and birds. Water, sunlight, and soil are nonliving parts of the ecosystem. *Ecology* is the study of interactions that occur among organisms and their environments. Scientists who study these interactions are ecologists.

Populations

A *population* is all organisms of the same species that live in an area at the same time. For example, all the bison in a prairie ecosystem make up one population.

Ecologists often study how populations in an ecosystem interact. For example, they might study a prairie ecosystem. How does grazing by bison affect prairie grasses and the insects that live in the grass? By studying the interactions of organisms in a place, ecologists are studying a community. A *community* is all the populations of all species living in an ecosystem, as shown in the figure below.

**Habitats**

The place in which an organism lives is called its *habitat*. In a forest ecosystem, trees are the habitat of the woodpecker. The forest floor is the habitat of the salamander. An organism’s habitat provides the food, shelter, temperature, and the amount of moisture the organism needs to survive.
1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains how a community is different from an ecosystem.

2. Complete the illustration below to help you understand how scientists organize the living organisms on Earth.

---

**Mini Glossary**

- **biosphere**: the part of Earth that supports life
- **community**: the populations of all species living in an ecosystem
- **ecology**: the study of interactions that occur among organisms and their environments
- **ecosystem**: all the organisms living in an area and the nonliving parts of that environment
- **habitat**: the place in which an organism lives
- **population**: all organisms of the same species that live in an area at the same time

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Create a Quiz
As you study the information in this section, create questions about the information you read. The questions can be used to review the section's content.

Before You Read
Is the human population in your area getting larger or smaller? What is causing the increase or decrease?

Read to Learn

Competition
Sometimes organisms living in the wild do not have enough food or living space. The Gila woodpecker makes its nest by drilling a hole in a saguaro (suh GWAR oh) cactus. Sometimes Gila woodpeckers have to compete with each other for these living spaces. Competition occurs when two or more organisms are looking for the same resource at the same time.

How can competition limit population growth?
Competition can limit the size of a population. For example, if enough living spaces are not available, some organisms will not be able to raise their young. If there is not enough food, organisms might not live long enough to reproduce. Competition for living space, food, and other resources can limit population growth.

In nature, the most intense competition usually occurs among individuals of the same species. This is because they need the same kinds of food and shelter. Competition also takes place among different species. For example, after a Gila woodpecker has moved from its nest, owls, snakes, and lizards might compete for the empty hole.
Population Size

Ecologists often need to measure the size of a population to find out whether or not the population is healthy and growing. Measuring the size of the population can help ecologists know if a population is in danger of disappearing. One measurement ecologists use is population density. Population density is the number of individuals of one species in a specific area.

How are populations measured?

Imagine having to count all the crickets in an area. They look alike, move a lot, and hide. You might count a cricket more than once. Or you might miss other crickets completely. One method ecologists use to count populations is called trap-mark-release. When ecologists want to count wild rabbits, for example, they set traps that catch the rabbits without hurting them. Each captured rabbit is then marked and let go. Later, another set of rabbits is caught. Some of these rabbits will have marks, but others will not. The ecologists compare the number of marked and unmarked rabbits in the second sample. By doing this, they can estimate the size of the rabbit population.

How are sample counts used?

To estimate the size of large populations, ecologists use sample counts. For example, pretend you wanted to estimate the number of rabbits in an area of 100 acres. You might count the rabbits in one acre and then multiply by 100.

How does a limiting factor affect population?

In an ecosystem, food, water, space, and other resources are limited. A limiting factor is anything that restricts the number of individuals in a population.

A limiting factor can affect more than one population. For example, when the plants in a meadow do not get enough rain, fewer plants survive. Because there are fewer plants, fewer seeds are produced. The seeds are a source of food for the seed-eating mice that live in the meadow. The smaller food supply could become a limiting factor for mice. In turn, a smaller mouse population could be a limiting factor for the hawks and owls that eat the mice. Limiting factors include living and nonliving parts in a community of an ecosystem.
3. Explain How is a population affected when it goes beyond the carrying capacity of the ecosystem?

How does carrying capacity affect population?
The largest number of individuals of one species that an ecosystem can support over time is the carrying capacity. For example, if the number of robins living in a park increases, nesting space might become difficult to find. Available nesting space limits the robin population. If the population gets larger than its carrying capacity, some individuals of a species will not have enough resources. They could die or have to move somewhere else.

What is biotic potential?
If a population had an unlimited supply of food, water, and living space, and was not limited by disease, predators, or competition with other species, the population would continue to grow. The highest rate of reproduction under ideal conditions is a population's biotic potential. The more offspring organisms produce, the higher the species' biotic potential. Tangerines have a higher biotic potential than avocados because tangerines have many seeds in each fruit, while an avocado has only one seed in each fruit.

Changes in Populations
A population’s birthrate and death rate also influence the size of the population and its rate of growth. A population gets larger when the number of individuals born is greater than the number of individuals that die. A population gets smaller when the number of deaths is greater than the number of births. As the table below shows, countries with a faster population growth have birthrates much higher than death rates. Countries with a slower population growth have only slightly higher birthrates than death rates.

<table>
<thead>
<tr>
<th>Countries with Rapid Growth</th>
<th>Population Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birthrate*</td>
<td>Death Rate*</td>
</tr>
<tr>
<td>Jordan</td>
<td>38.8</td>
</tr>
<tr>
<td>Uganda</td>
<td>50.8</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>34.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Countries with Slow Growth</th>
<th>Population Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birthrate*</td>
<td>Death Rate*</td>
</tr>
<tr>
<td>Germany</td>
<td>9.4</td>
</tr>
<tr>
<td>Sweden</td>
<td>10.8</td>
</tr>
<tr>
<td>United States</td>
<td>14.8</td>
</tr>
</tbody>
</table>

*Number per 1,000 people
5. Identify three things that move plant seeds from place to place.

What is exponential growth?

When a species moves to a new area that has plenty of food, living space, and other resources, the population can grow quickly. This pattern of growth is called exponential growth. Exponential growth means that the larger a population gets, the faster it grows. Over time, the population will reach the carrying capacity of the ecosystem for that species.

The figure below shows the exponential growth of the human population. By the year 2050, the population could reach 9 billion people.

Picture This

6. Estimate Use the graph to estimate the increase in the human population from 1950 to 2000.
1. Review the terms and their definitions in the Mini Glossary. Choose one of the terms and explain how it can affect the population size of a species.

2. Complete the diagram below to help you describe the things that affect changes in population size.

3. How do the quiz questions and answers help you review what you have learned?

Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about populations.
Interactions of Life

section 4 Interactions Within Communities

Before You Read

How do you get the energy you need to do the things you want to do?

What You’ll Learn

- how organisms get energy for life
- how organisms interact
- that every organism occupies a niche

Read to Learn

Obtaining Energy

Living organisms need a constant supply of energy. The Sun provides the energy for most of life on Earth. Some organisms use this energy to make energy-rich molecules through photosynthesis. The energy-rich molecules are food for the organism. They are made up of different combinations of carbon, hydrogen, and oxygen atoms. Chemical bonds hold the atoms of these molecules together. Energy is stored in the chemical bonds. During digestion, the molecules break apart and release energy. The organism uses the energy to grow, develop, and stay alive.

What are producers?

Organisms that use an outside energy source like the Sun to make energy-rich molecules are called producers. Most producers have chlorophyll (KLOH ruh fuhl). Chlorophyll is needed for photosynthesis. Green plants are producers.

Not all producers have chlorophyll or use energy from the Sun. Some use chemosynthesis (kee moh SIHN thuh sus) to make energy-rich molecules. These organisms live near volcanic vents on the ocean floor. Inorganic molecules in the water provide the energy for chemosynthesis.
What are consumers?
Organisms that get energy by eating other organisms are called consumers. There are four kinds of consumers. Herbivores, such as rabbits, eat plants. Carnivores, such as frogs, eat other animals. Omnivores, such as pigs, eat both plants and animals. Decomposers, such as earthworms, consume wastes and dead organisms. Decomposers help recycle once-living matter.

What are food chains?
Ecology includes the study of how organisms depend on each other for food. A food chain is a simple model of the feeding relationships and energy flow in an ecosystem. For example, shrubs are food for deer. Deer are food for mountain lions, as shown in the figure below.

Symbiotic Relationships
Organisms may share food and other resources. Any close relationship between species is called symbiosis.

What is mutualism?
A symbiotic relationship in which both species benefit is called mutualism (MYEW chuh wuh lih zum). Ants and acacia trees illustrate mutualism. The ants protect the tree by attacking any animal that tries to feed on it. The tree provides food and a home for ants.

What is commensalism?
A symbiotic relationship in which one organism benefits and the other one is not affected is called commensalism (kuh MEN suh lih zum). For example, a sea anemone has tentacles that have a mild poison. The clown fish is not harmed by the poison. It swims among the tentacles and is protected from predators. The clown fish benefits, but the sea anemone is not helped or hurt.
What is parasitism?
A symbiotic relationship in which one organism benefits and one is harmed is called parasitism (PER uh suh tih zum). An example of this relationship is a pet dog and roundworms. A roundworm sometimes attaches itself to the inside of the dog’s intestine. It feeds on the nutrients in the dog’s blood. The dog may have abdominal pain and diarrhea. Sometimes the dog may die. In this relationship, the roundworm benefits, but the dog is harmed.

Niches
Hundreds of species might live in one habitat. For example, a rotting log is home to many species. Spiders, ants, termites, and worms are some species that live on or under the rotting log. Although many species use the log as their habitat, the species do not compete for resources. This is because each species needs different things to survive. So, each species has its own niche (NICH). An organism’s niche is its role in its environment—how it obtains food and shelter, finds a mate, cares for its young, and avoids danger.

Special adaptations that improve survival are often part of an organism’s niche. For example, a poison in milkweed plants stops many insects from eating them. Monarch butterfly caterpillars have an adaptation that lets them eat milkweed. When they eat milkweed, the caterpillars become slightly poisonous. Birds avoid eating these caterpillars because they know that the caterpillars and adult butterflies have an awful taste and can make them sick.

How do predator and prey fit in a niche?
An organism’s niche includes how it avoids being eaten and how it gets its food. Predators are consumers that capture and eat other consumers. The prey is the organism that is captured by the predator. Having predators in an ecosystem usually increases the number of species that can live in the ecosystem. Predators limit the size of the prey population. So, food and other resources are less likely to become difficult to find. Competition between species is reduced.

How do species in a niche cooperate?
Individual organisms often cooperate, or work together, in ways that improve survival. For example, a white-tailed deer that detects the presence of a wolf will warn other deer in the herd. These cooperative actions are part of the species’ niche.
After You Read

Mini Glossary

commensalism (kuh MEN suh lih zum): a symbiotic relationship in which one organism benefits and the other is not affected

consumer: an organism that gets energy by eating other organisms

mutualism (MYEW chuh wuh lih zum): a symbiotic relationship in which both species benefit

coreniche (NICH): an organism’s role in its environment
parasitism (PER uh suh tih zum): a symbiotic relationship in which one organism benefits but the other is harmed
producer: an organism that uses an outside energy source like the Sun to make energy-rich molecules
symbiosis: any close relationship between species

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

_________________________________________________________________________________________

_________________________________________________________________________________________

_________________________________________________________________________________________


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

Write your question here.

_________________________________________________________________________________________

_________________________________________________________________________________________

_________________________________________________________________________________________

_________________________________________________________________________________________

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The Nonliving Environment

section  Abiotic Factors

Before You Read

How would you describe the climate where you live? How does it affect the plant and animal life around you?

What You’ll Learn

■ the common abiotic factors in most ecosystems
■ the components of air that are needed for life
■ how climate influences life in an ecosystem

Read to Learn

Environmental Factors

Living things depend on one another for food and shelter. The features of the environment that are alive, or were once alive, are called biotic (bi AH tihk) factors.

Biotic factors are not the only things needed for life. Plants and animals cannot survive without the nonliving environment. The nonliving, physical features of the environment are called abiotic (ay bi AH tihk) factors. Abiotic factors include air, water, sunlight, soil, temperature, and climate. These factors often determine the kinds of organisms that live there.

Air

The air that surrounds Earth is called the atmosphere. Air is made up of 78 percent nitrogen, 21 percent oxygen, 0.94 percent argon, 0.03 percent carbon dioxide, and trace amounts of other gases. Some of these gases are important in supporting life.

Carbon dioxide (CO₂) is necessary for photosynthesis. Photosynthesis uses CO₂, water, and energy from sunlight to make sugar molecules. Organisms such as plants use photosynthesis to produce their own food.

Mark the Text

Summarize Write a phrase beside each main heading that summarizes the main point of the section.

1. List What three things are needed for photosynthesis?
Respiration Oxygen is released into the atmosphere during photosynthesis. Cells use oxygen to release the chemical energy stored in sugar molecules. This process, called respiration, provides cells with the energy needed for all life processes.

Water

Water is necessary to life on Earth. It is a major part of the fluid inside the cells of all organisms. Most organisms are 50 percent to 95 percent water. Processes such as respiration, digestion, and photosynthesis occur only if water is present. Environments that have plenty of water usually have a greater variety of and a larger number of organisms than environments that have little water.

Soil

Soil is a mixture of mineral and rock particles, the remains of dead organisms, water, and air. Soil is the top layer of Earth’s crust where plants grow. It is formed partly of rock that has been broken down into tiny particles.

Soil is considered an abiotic factor because most of it is made up of nonliving rock and mineral particles. But soil also contains living organisms and the remains of dead organisms. The decaying matter in soil is called humus. Soils contain different combinations of sand, clay, and humus. The kind of soil in a region affects the kinds of plant life that grow there.

Sunlight

Sunlight is the energy source for almost all life on Earth. Plants and other organisms that use photosynthesis are called producers. They use light energy from the Sun to produce their own food. Organisms that cannot make their own food are called consumers. Energy is passed to consumers when they eat producers or other consumers.

Temperature

Sunlight provides the light energy for photosynthesis and the heat energy for warmth. Most organisms can live only if their body temperatures are between the freezing point of water, 0°C, and 50°C. The temperature of a region depends partly on the amount of sunlight it gets. The amount of sunlight depends on the area’s latitude and elevation.
How does latitude affect temperature?

The temperature of a region is affected by its latitude. Places farther from the equator generally have colder temperatures than places at latitudes nearer to the equator. Look at the figure below. Near the equator, sunlight directly hits Earth. Sunlight hits Earth at an angle near the poles. This spreads the energy over a larger area.

Picture This

4. Identify Use one color to highlight the sunlight directly hitting Earth at the equator. Use another color to highlight the sunlight hitting Earth at the poles.

How does elevation affect temperature?

A region's elevation, or distance above sea level, affects its temperature. Earth's atmosphere traps the Sun's heat. At higher elevations, the atmosphere is thinner than at lower elevations. Air becomes warmer when sunlight heats the air molecules. Because there are fewer air molecules at higher elevations, the air temperature at higher elevations tends to be cooler. ✓

Trees at higher elevations are usually shorter. The timberline is the elevation above which trees do not grow. Only low-growing plants exist above the timberline. The tops of some mountains are so cold that no plants grow there.

Climate

In Fairbanks, Alaska, winter temperatures may be as low as −52°C. More than one meter of snow might fall in one month. In Key West, Florida, winter temperatures rarely go below 5°C. Snow never falls. These two cities have different climates. The climate of an area is its average weather conditions over time. Climate includes temperature, rainfall or other precipitation, and wind.

5. Explain Why is the air temperature at higher elevations usually cooler than the air temperature at lower elevations?
How does climate affect life in an area?
Temperature and precipitation are the two most important parts of climate for most living things. They affect the kinds of organisms that live in an area. For example, an area that has an average temperature of 25°C and gets less than 25 cm of rain per year probably has cactus plants growing there. An area with the same average temperature and more than 300 cm of rain every year is probably a tropical rain forest.

How are winds created?
In addition to affecting the temperature of an area, the heat energy from the Sun causes wind. Air is made up of gas molecules. As the temperature increases, the molecules spread farther apart. So, warm air is lighter than cold air. Colder air sinks below warmer air and pushes it upward. This movement creates air currents that are called wind.

What is the rain shadow effect?
Mountains can affect rainfall patterns. As the figure below shows, moist air is carried toward land by the wind. The wind is forced upward by the slope of the mountain. As the air moves to the top, it cools. When air cools, the moisture in it falls as rain or snow. By the time the air crosses over the top of the mountain, it has lost most of its moisture. The drier air warms as it flows down the mountain. The other side of the mountain is in a rain shadow and receives much less precipitation. As a result, one side of the mountain could be covered with forests, while the other side is a desert.

Picture This
7. Explain On the figure below, label the first and fourth arrows to complete the explanation of the rain shadow effect.
After You Read

Mini Glossary

abiotic (ay bi AH thik): nonliving, physical features of the environment, including air, water, sunlight, soil, temperature, and climate

atmosphere: the air that surrounds Earth

biotic (bi AH thik): 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 blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about abiotic factors.
The Nonliving Environment

section 2 Cycles in Nature

What You’ll Learn

- why Earth’s water cycle is important
- about the carbon cycle
- how nitrogen affects life on Earth

Before You Read

What happens when you boil water in a covered pot? What do you see on the lid of the pot when you remove it?

Read to Learn

The Cycles of Matter

Imagine an aquarium with water, fish, snails, plants, algae, and bacteria. The tank is sealed so that only light can enter. How can the organisms survive without adding food, water, and air? The plants and algae produce their own food through photosynthesis. They also supply oxygen to the tank. The fish and snails eat the plants and algae and take in the oxygen. The wastes from the fish and snails fertilize the plants and algae. Bacteria decompose those organisms that die. The organisms in this closed environment can survive because the materials are recycled.

The environment in the aquarium is similar to Earth’s biosphere. Earth only has a certain amount of water, carbon, nitrogen, oxygen, and other materials needed for life. These materials are constantly being recycled.

Picture This

1. Explain to a partner how the fish in the tank survive without anyone adding food, water, and air.
The Water Cycle

When you leave a glass of water on a sunny windowsill, the water evaporates. **Evaporation** takes place when liquid water changes into a gas, called water vapor, and enters the atmosphere. Water evaporates from the surfaces of lakes, streams, and oceans. It enters the atmosphere from plants in a process known as transpiration (trans puh RAY shun). Animals release water vapor as they exhale. Water is returned to the environment from animal wastes.

**What is condensation?**

After water vapor enters the atmosphere, eventually it will come into contact with colder air. The temperature of the water vapor drops. Over time, the water vapor becomes cool enough to change back into liquid water. The process of changing from a gas to a liquid is called **condensation**.

The water vapor condenses on particles of dust in the air and forms tiny droplets. The droplets join together to form clouds. When the droplets become large and heavy enough, they fall to the ground as rain or other precipitation.

As the figure below shows, the **water cycle** is a model that describes how water moves from the surface of Earth to the atmosphere and back to the surface again.

---

**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 steps 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.

The cycle begins when producers take CO₂ from the air during photosynthesis. They use CO₂, water, and sunlight to make energy-rich sugar molecules. Energy is released from these molecules during respiration—the chemical process that provides energy for cells. Respiration uses oxygen and releases CO₂. Photosynthesis uses CO₂ and releases oxygen. The two processes help recycle carbon on Earth.

Human activities also release CO₂ into the atmosphere. For example, when fossil fuels are burned, CO₂ is released into the atmosphere as a waste product. People also use wood for building and for fuel. Trees that are cut down for these purposes cannot remove CO₂ from the atmosphere during photosynthesis. The amount of CO₂ in the atmosphere is increasing. The extra CO₂ could trap more heat from the Sun and cause average temperatures on Earth to rise.
After You Read

Mini Glossary

carbon cycle: a model that describes how carbon molecules move between the living and nonliving world
condensation: process that occurs when a gas changes to a liquid
evaporation: process that occurs when liquid water changes into water vapor and enters the atmosphere
nitrogen cycle: the transfer of nitrogen from the atmosphere to the soil, to living organisms, and back to the atmosphere

nitrogen fixation: process in which some types of soil bacteria form the nitrogen compounds that plants need
water cycle: a model that describes how water moves from the surface of Earth to the atmosphere and back to the surface again

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

2. In the chart, list the steps in the nitrogen cycle.

<table>
<thead>
<tr>
<th>Steps in the Nitrogen Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
</tr>
<tr>
<td>2.</td>
</tr>
<tr>
<td>3.</td>
</tr>
<tr>
<td>4.</td>
</tr>
</tbody>
</table>

End of Section

Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about the cycles in nature.
The Nonliving Environment

section © Energy Flow

Before You Read

Why do you need energy? What is your source of energy?

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

Read to Learn

Converting Energy

All living things are made up of matter, and all living things need energy. Matter can be recycled over and over. Energy is not recycled, but it is converted from one form to another. This conversion is important to all life on Earth.

How is energy converted during photosynthesis?

During photosynthesis, producers convert light energy into the chemical energy in sugar molecules. Some of these sugar molecules are broken down as energy. Some are used to build complex carbohydrate molecules that become part of the producer’s body. Fats and proteins also contain stored energy.

What are hydrothermal vents?

Some producers do not rely on light for energy. These producers live deep underwater in total darkness. They live near powerful hydrothermal vents. Hydrothermal vents are deep cracks in the ocean floor. The water from these vents is very hot from contact with molten rock deep in the Earth’s crust.
What is chemosynthesis?

Because sunlight does not reach deep ocean regions, the organisms that live there cannot get energy from sunlight. Scientists have learned that the hot water has nutrients that bacteria use to make their own food. The production of energy-rich nutrient molecules from chemicals is called chemosynthesis (kee moh SIN thuh sus). Consumers that live in hydrothermal vent communities rely on chemosynthetic bacteria for nutrients and energy.

Energy Transfer

Energy can be converted from one form to another. It also can be transferred from one organism to another. Consumers cannot make their own food. Instead, they obtain energy by eating producers or other consumers. The energy that is stored in the molecules of one organism is transferred to another organism. That organism can release the energy stored in the food. It can use the energy for growth, or it can transform the energy into heat. At the same time, the matter that makes up those molecules is transferred from one organism to another. Throughout nature, energy and matter are transferred from organism to organism.

How does energy flow in food chains?

The food chain in the figure below shows how matter and energy pass from one organism to another. Producers, such as plants, are the first step in a food chain. All producers make their own food using either photosynthesis or chemosynthesis. Animals, such as herbivores, that eat producers are the second step. Animals that eat other consumers are the third and higher steps of food chains.

Picture This

2. Identify Write Producer or Consumer below each organism on the food chain.

Berries → Mouse → Black Bear
What are food webs?

There are many feeding relationships in a forest community. For example, bears eat berries, insects, and fish. Berries are eaten by many different organisms. A **food web** is a model that shows all the possible feeding relationships among the organisms in a community. A food web is made up of many different food chains.

**Energy Pyramids**

Most food chains have three to five links. The number of links is limited because the amount of available energy is reduced as you move from one level to the next.

**How does available energy decline?**

When a mouse eats seeds, energy stored in the seeds transfers to the mouse. But most of the energy the plant took in from the Sun was used to help the plant grow. The mouse uses energy from the seed for its own processes, such as digestion and growth. Some of the energy is given off as heat. A hawk that eats the mouse gets even less energy. The amount of available energy is reduced from one level of a food chain to another.

An **energy pyramid** shows the amount of energy available at each feeding level in an ecosystem. The bottom of the pyramid below includes all producers. It is the first and largest level because it contains the most energy and the largest number of organisms. As the energy is reduced from one level to another, each level becomes smaller. In fact, only about 10 percent of the energy available at each feeding level is transferred to the next higher level.

---

**Foldables**

**C Identify** Make a pyramid Foldable, as shown below, to identify the flow of energy from producers, to herbivores, to carnivores.

---

**Think it Over**

3. **Synthesize** Why are there more producers than consumers?
After You Read

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

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?

Science online Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about energy flow.
Ecological Succession

What would happen if the lawn at your home were never cut? The grass would get longer, and it would look like a meadow. Later, larger plants would grow from seeds brought to the area by animals or the wind. Then trees might sprout. In 20 years or less you wouldn't be able to tell that the land was once a mowed lawn.

An ecologist can tell you what type of ecosystem your lawn would become. Ecosystems are all the organisms that live in an area and the nonliving parts of that environment. Succession is the normal, gradual changes that occur in the types of species that live in an area. Succession occurs differently in different places around the world.

What is primary succession?

The process of succession that begins in a place where no plants grew before is called primary succession. It begins with the arrival of living things such as lichens (LI kunz). The first living things to inhabit an area are called pioneer species. They can survive the harsh conditions of the area, such as drought and extreme heat and cold.
How does soil form?

Pioneer species often start the soil-building process in an area that is made up of rock. Soil begins to form as lichens and the forces of weather and erosion help to break down rocks into smaller pieces. When lichens die, they decay, adding organic matter to the rocks. Moss and ferns can grow in this new soil as shown in the photo. When these plants die, they add more organic material to the soil. Soon there is enough soil for grasses, wildflowers, and other plants to grow. When these plants die, they make the soil richer and deep enough for shrubs and trees to grow. During these changes, insects, small birds, and mammals have begun to move into the area.

Where does secondary succession occur?

Succession that begins in a place that already has soil and was once home to living organisms is called secondary succession. Since the area already has soil, secondary succession is much faster than primary succession. The soil in an area that had a forest fire or a building torn down will not remain lifeless for long. The soil already contains seeds. Wind and birds will carry more seeds to the area. Wildlife will move in.

What are climax communities?

A **climax community** is a community of plants that is mostly stable and has reached the end stage of succession. New trees grow when larger, older trees die. The individual trees change, but the species does not. For example, a climax community that is a forest of beeches and maples will stay a forest of beeches and maples even though some older trees will die and new trees grow. It can take hundreds or thousands of years for a climax community to develop.
After You Read

Mini Glossary

climax community: a community of plants that is mostly stable and has reached the end stage of succession

pioneer species: the first living things to inhabit an area

succession: the normal, gradual changes that occur in the types of species that live in an area

1. Review the terms and their definitions in the Mini Glossary. Write two or three sentences that explain the difference between pioneer species and climax communities.

2. Fill in the blanks in the graphic organizer below to show how soil is formed.

How Soil Is Formed

1. ___________________ are the first living things to grow.

2. ___________________ begins to form as pioneer species, erosion, and weathering break down rocks.

3. ___________________ and ___________________ grow in new soil. As they die, they add organic material to the soil.

4. ___________________, ___________________, and other plants can now grow. As they die, they make the soil richer and deeper.

5. ___________________ and ___________________ can now grow in the soil.

3. How does the quiz you created help you prepare for a test?

4. Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about how ecosystems change.
What You’ll Learn
- how climate affects land environments
- the seven biomes of Earth
- how organisms adapt to different biomes

Before You Read
On the lines below, describe the geographic area where you live. Include information about the climate, the landforms, and the kinds of plants and animals that live there.

Read to Learn

Factors That Affect Biomes
Does a desert in Arizona have anything in common with a desert in Africa? Both have heat, little rain, poor soil, water-conserving plants with thorns, and lizards. Large geographic areas that have similar climates and ecosystems are called **biomes** (BI ohmz).

What climate factors affect biomes?
Deserts are biomes that have little rainfall. Plants and animals living in a desert are adapted to the small amount of rainfall. Climate is the average weather pattern in an area over many years. The two most important factors of climate that affect life are temperature and precipitation.

Major Biomes
The seven types of land biomes are shown on the map on the next page. The major land biomes are tundra, taiga, temperate deciduous forest, temperate rain forest, tropical rain forest, desert, and grassland. Areas with similar climates have similar plants and animals.
What kind of climate does tundra have?

The **tundra** is a cold, dry, treeless area. The tundra is found in latitudes just south of the North Pole or on high mountains.

Locate the tundra areas on the map below. Notice how far these areas are from the equator. The average amount of precipitation in the tundra is less than 25 cm per year. The average daily temperature is \(-12^\circ C\). The tundra is covered with ice most of the year. Summers are short and cold. The top part of the soil thaws in summer. Below this thawed surface is a layer of soil called permafrost that is always frozen.

What plants and animals live on the tundra?

Tundra plants include mosses, grasses, small shrubs, and lichens. Since the growing season is so short, it can take many years for the plant life to recover when damaged. During the summer, insects and migratory birds such as ducks and geese live on the tundra. Other animals that live on the tundra include hawks, owls, mice, reindeer, and musk oxen.

---

**Think it Over**

1. **Infer** Would you expect to find few or many species of plants and animals in the tundra? Explain.

---

**Picture This**

2. **Locate** Circle the names of continents on which deserts are found.
What is the world’s largest biome?

The taiga (TI guh) is the world’s largest biome. The taiga is located between latitudes 50°N and 60°N and stretches across North America, northern Europe, and Asia. The taiga is a cold, forest region. Its climate is warmer and wetter than the tundra’s. Precipitation is mostly snow and averages 35 cm to 100 cm a year. Cone-bearing evergreen trees grow in the taiga.

What are temperate deciduous forests like?

The temperate deciduous forests are climax communities of deciduous trees, which lose their leaves every autumn. The yearly precipitation is between 75 cm and 150 cm. Precipitation is received evenly throughout the year. Temperatures range from below freezing during the winter to 30°C or more during the summer. White-tailed deer are one of the many species found in temperate deciduous forests.

Where are temperate rain forests located?

Temperate rain forests are found in places such as New Zealand, southern Chile, and the Pacific Northwest of the United States. This biome receives precipitation ranging from 200 cm to 400 cm throughout the year. The average temperature ranges from 9°C to 12°C. Temperate rain forests do not have the temperature extremes found in the taiga.

Activities in Temperate Rain Forests

Tall trees with needlelike leaves, like fir, cedar, and spruce, grow in temperate rain forests. Lichens and mosses also grow there. Animals that live in temperate rain forests include black bear, bobcats, and many species of amphibians.

The logging industry in the Northwest provides jobs for many people. However, logging removes large parts of the temperate rain forest and destroys the habitat of many organisms. Logging companies in the Pacific Northwest of the United States are required to replant trees to replace the ones they cut down. Some rain forest areas are protected as national parks and forests.

What is the climate in tropical rain forests?

Warm temperatures, wet weather, and dense plant growth are found in tropical rain forests. These forests have warm temperatures that average about 25°C because they are located near the equator. Tropical rain forests receive at least 200 cm and as much as 600 cm of rain per year. This is the most precipitation of any biome.
Zones in Tropical Rain Forests

More species of animals are found in tropical rain forests than in any other biome. The variety of species is so large that many have not been discovered. Scientists divide the rain forests into zones based on the types of plants and animals that live there. As shown in the figure below, the zones include forest floor, understory, canopy, and emergents.

**Picture This**

5. Identify Highlight the zones in which birds live. Circle the zones in which insects live.

**Emergents** These giant trees are much higher than the average canopy tree. Birds, such as the macaw, and insects are found here.

**Canopy** The canopy includes the upper parts of the trees. It's full of life—insects, birds, reptiles, and mammals.

**Understory** This dark, cool environment is under the canopy leaves but above the ground. Many insects, reptiles, and amphibians live in the understory.

**Forest Floor** The forest floor is home to many insects and the largest mammals in the rain forest generally live here.
6. Explain why much of the ground in a desert is bare.

7. Determine What keeps forests from developing on grasslands?

Think it Over

6. Explain why much of the ground in a desert is bare.

What is the driest biome?

The **desert** is the driest biome. Deserts receive less than 25 cm of rain each year. The temperatures are extreme heat and cold. Few plants live in desert areas and much of the ground is bare. Most deserts are covered with a thin, sandy, or rocky soil that contains little organic matter. The driest deserts have windblown sand dunes.

Desert Plants and Animals Most desert plants, like cactus, survive the extreme dryness because they are able to store water. Desert plants and animals also are adapted to hot and cold temperatures. Some animals, like the kangaroo rat, never need to drink water. They get the moisture they need from the food they eat. Most animals are active only during the night, late afternoon, or early morning when the temperatures are less extreme. Most animals in the desert are small.

What are grasslands like?

Temperate and tropical regions that receive between 25 cm and 75 cm of precipitation each year and are made up of climax communities of grasses are called **grasslands**. Most grasslands have a dry season, with little or no rain. This lack of rain prevents the development of forests.

Grassland Plants and Animals The animals in grasslands are mostly mammals that eat the stems, leaves, and seeds of grass plants. Kangaroos are found in the grasslands of Australia. Zebras live in the grasslands of Africa. Many crops, such as wheat, rye, and corn are grown in grasslands. Sheep and cattle are raised on grasslands.
After You Read

Mini Glossary

biomes (BI ohmz): large geographic areas that have similar climates and ecosystems
desert: dry biome with extreme hot and cold temperatures
grasslands: biome of temperate and tropical regions that receive little precipitation and are made up of climax communities of grasses
taiga (TI guh): biome with long, cold winters, moderate precipitation, and forests of evergreen trees
temperate deciduous forests: biome with four seasons and climax forests of deciduous trees, which lose their leaves every autumn
temperate rain forests: biome with warm temperatures, much precipitation, and forests of tall trees that have needlelike leaves
tropical rain forests: biome of warm temperatures, wet weather, and dense plant growth	tundra: a cold, dry, treeless biome that gets little precipitation and is covered with ice most of the year

1. Review the terms and their definitions in the Mini Glossary. Write two sentences that explain the difference between temperate deciduous forests and temperate rain forests.

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

2. How did underlining the important ideas in this section help you understand biomes?

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

_____________________________________________________________________
_____________________________________________________________________
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_____________________________________________________________________
3. Complete the chart below to help you compare and contrast the seven biomes of the world.

<table>
<thead>
<tr>
<th>Biomes</th>
<th>Climate</th>
<th>Plants and Animals</th>
<th>Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tundra</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taiga</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperate deciduous forests</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperate rain forests</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tropical rain forests</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deserts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grasslands</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

On each line below, name a different body of water. Next to each body of water, classify it as freshwater or salt water.

Factors That Affect Aquatic Ecosystems

Aquatic ecosystems are places where organisms grow or live in water. There are four factors that affect aquatic ecosystems—water temperature, the amount of sunlight present, dissolved oxygen, and salt in the water.

Freshwater Ecosystems

Earth’s freshwater ecosystems include flowing water such as rivers and streams. Freshwater ecosystems also include standing water such as lakes, ponds, and wetlands. Freshwater ecosystems contain very low amounts of salt.

How are river and stream environments alike?

Rivers and streams that flow fast have clearer water and higher levels of oxygen than slow-flowing rivers and streams. This is because the faster the water moves, the more air mixes in. In flowing-water ecosystems, nutrients that support life are washed in from the land. Plants and animals that live in rivers and streams are adapted to the flowing water.
How are lake and pond environments alike?

The water in lakes and ponds hardly moves. These environments have more plants than flowing-water environments. Lakes and ponds contain organisms that are not well adapted to flowing-water environments.

Lakes are larger and deeper than ponds. They have more open water because plant growth is limited to shallow areas along the shoreline. Colder temperatures and lower light levels limit the types of organisms that can live in deep lake waters. Microscopic algae, plants, and other organisms known as plankton live near the surface and the shoreline of freshwater lakes and in ponds where the water is warm and sunlit. Many ponds are filled almost completely with plant material, which make them high in nutrients.

What are wetlands?

Regions that are wet for all or most of the year are called wetlands. These regions, also known as swamps, bogs, and fens, are located between land areas and water. Wetlands are filled with plants and animals that are adapted to water-logged soil. Fish, shellfish, and cranberries are some products that come from wetlands. Wetland animals include beavers, muskrats, alligators, and some species of turtles. Many birds use wetland areas to have their young.

How do humans affect freshwater ecosystems?

Sometimes freshwater ecosystems are used as places to dump waste and other pollutants. Fertilizer from farms and lawns runs off into freshwater. Wetlands were once drained and destroyed because people thought they were useless and full of diseases. The drained land was used for shopping centers and houses.

People are being educated about the damage caused by polluting freshwater ecosystems. Sewage is treated before it is released into the water to prevent problems. People who pollute waterways may be fined. Many developers now are working to restore wetlands.

Saltwater Ecosystems

About 95 percent of Earth’s water contains high amounts of salts. Saltwater ecosystems include oceans, seas, a few inland lakes such as the Great Salt Lake in Utah, coastal inlets, and estuaries.
What are ocean life zones?
Scientists divide the ocean into life zones. There are two zones based on the depth to which sunlight penetrates the water—the lighted zone and the dark zone. The lighted zone of the ocean is about the upper 200 m. Plankton make up the base of the food chain in this zone. Below about 200 m is the dark zone. Animals living in this zone feed on each other or on material that floats down from the lighted zone. A few organisms produce their own food.

How do coral reefs form?
Coral reefs are one of the most varied ecosystems in the world. Coral reefs form in oceans over long periods of time from the calcium carbonate shells of ocean animals called corals. When corals die, their shells remain. Over time the shell deposits form coral reefs. Coral reefs contain colorful fish and many other organisms.

Waste materials easily damage coral reefs. World organizations are helping protect coral reefs from harm.

What are the characteristics of seashores?
The shallow waters along the world’s coastlines have many kinds of saltwater ecosystems. These waters are affected by the tides and by the action of the waves. The height of the tides changes based on the phases of the Moon, the season, and the slope of the shoreline. The part of the shoreline that is covered with water at high tide and exposed to air during low tide is called the intertidal zone. Organisms that live in the intertidal zone must withstand the force of the waves. They must also be adapted to changes in temperature, moisture, and the amount of salt in the water.

What is an estuary?
Almost every river eventually flows into an ocean. The area where they meet contains a mixture of freshwater and salt water and is called an estuary (ES chuh wer ee). Estuaries are located near coastlines and border the land. Other names for estuaries include bays, lagoons, and sounds. An estuary is a very fertile environment. Freshwater streams bring in great amounts of nutrients washed from inland soils. An estuary is an important aquatic ecosystem because many kinds of organisms live there, including algae, grasses, shrimp, crabs, clams, and fish. Estuaries are places where the young of many species of ocean fish grow and develop.
After You Read

Mini Glossary

coral reefs: ecosystems in oceans that formed over long time periods from the calcium carbonate shells of corals

estuary (ES chuh wer ee): the area where a river meets an ocean and contains a mixture of freshwater and salt water

intertidal zone: the part of the shoreline that is covered with water at high tide and exposed to air during low tide

wetlands: regions that are wet for all or most of the year

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the difference between a wetland and an estuary.

2. Complete the graphic organizer below to identify the kinds of aquatic ecosystems.

Aquatic Ecosystems

Freshwater

Rivers

Coral reefs

Seashores/intertidal zones

End of Section

Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about aquatic ecosystems.
Plate Tectonics

section ○ Continental Drift

● Before You Read
After you peel an orange, can you fit the pieces of peel back together again like a puzzle? Why or why not?

What You’ll Learn
■ what continental drift is
■ what evidence supports continental drift

● Read to Learn

Evidence for Continental Drift
Take a look at a map of Earth’s surface. Look carefully at the shape of each continent. The continents look like they might fit together like pieces of a puzzle, don’t they? People throughout history have noticed this and wondered what it meant. For example, over 400 years ago Abraham Ortelius, a Dutch mapmaker, noticed that the coastlines of South America and Africa fit together.

Have you ever been to Pangaea?
In 1912, a German scientist named Alfred Wegener (VEG nur) proposed that the continents did at one time fit together. He suggested that all the continents were once connected. Wegener said they were once one big landmass. He called this landmass Pangaea (pan JEE uh), which means “all land.”

According to Wegener, about 200 million years ago, Pangaea broke into pieces. The pieces drifted away from each other. We call these pieces continents. Wegner’s hypothesis is called continental (kahn tuh NEN tul) drift. Continental drift is the hypothesis that Pangaea broke apart into continents that moved slowly to where they are today. So even though you haven’t visited Pangaea, the area where you live probably was part of Pangaea millions of years ago.

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

A Organize Make a four-door Foldable as shown below to help organize facts you learn about Alfred Wegener and continental drift.

A Foldables
2. Explain  Why didn’t Wegener convince people his ideas were right?

---

Did everyone accept Wegner’s idea?

Wegener’s hypothesis on continental drift was a controversial idea. It caused a lot of argument. Wegener didn’t convince people that his ideas were right during his lifetime. He didn’t have enough evidence. For example, he couldn’t explain what made the continents drift. He thought Earth spinning on its axis might cause the continents to plow through the ocean floor. But geologists and physicists of that time rejected this explanation. Wegener’s basic idea wasn’t accepted until long after his death in 1930. More evidence came later to support his ideas.

How do animal fossils support continental drift?

Animal fossils offer one clue that the continents might have been joined together millions of years ago. Fossils are the remains, imprints, or traces of prehistoric organisms. Fossils can tell when and where organisms once lived and how they lived. For example, fossils of *Mesosaurus* have been found in South America and in Africa. *Mesosaurus* is a reptile that lived on land and in fresh water. How could this reptile move between two continents separated by a salty ocean? It is not likely that it swam across the Atlantic Ocean. Wegener’s hypothesis of continental drift proposes that *Mesosaurus* lived on both continents when they were joined together. The map on the next page shows where fossil remains of different animals have been found on different continents.
How do plant fossils support continental drift?

Another fossil that supports continental drift is Glossopteris (glahs AHP tur us). Fossils of this plant are found on five continents—Africa, Australia, Asia, South America, and Antarctica. Finding Glossopteris in so many areas supported the idea that all of these regions once were connected and had similar climates.

What do climates tell us about continental drift?

Scientists have found fossils of warm-weather plants on the island of Spitsbergen in the Arctic Ocean. This is one of the coldest places on Earth. How did this happen? Wegener’s hypothesis of continental drift proposes that Spitsbergen Island drifted to the Arctic from a tropical region of Earth.

How do rocks support continental drift?

Glaciers are large, slow moving bodies of ice on land. Glaciers leave tracks as they move, scouring and polishing rock surfaces under them. They also leave deposits of glacial rock and sediment. Glaciers are found in cold areas. Yet there are traces of glaciers and deposits in many tropical and temperate regions of Earth. How is this possible?

Wegener’s hypothesis of continental drift says that millions of years ago, some tropical and temperate lands had cold climates and were located near Earth’s south pole. These continents were joined together and partly covered with ice. When the continents drifted apart into warmer climates, the glaciers melted away from these areas. The glacial deposits left behind add more evidence to support continental drift.


5. Explain How do rocks provide evidence for continental drift?

If the continents were connected at one time, then the rocks located where the land broke apart should be similar. Similar rock structures are found on different continents. For example, rock structures found in the Appalachian Mountains of the eastern United States are similar to rock structures found in Greenland and western Europe. Some rock structures from eastern South America are similar to rock structures in western Africa. Rock clues like these support the idea that the continents were connected in the past.

How could continents drift?

Wegener used clues found in rock, fossil, and climate to support his hypothesis of continental drift. The computer model below shows how the continents might have drifted over millions of years. But Wegener was not able to explain why the continents broke apart. Most importantly, he could not explain what caused the continents to drift. Wegener hypothesized that the continents plowed through the ocean floor. He thought that the spinning of Earth on its axis might have been the cause. He couldn’t prove his ideas with facts. Physicists of his day thought he was wrong. The idea was rejected because it was too unusual.

Today, there is more evidence for continental drift. After Wegener’s death, new technology provided new evidence. New ideas about continental drift were developed. One of these ideas is called seafloor spreading. You’ll read about this in the next section.
After You Read

Mini Glossary

continental (kahn tuh NEN tul) drift: Wegener's hypothesis that all continents were once connected in a single large landmass that broke apart and drifted slowly to their current positions.

Pangaea: a single landmass composed of all the continents joined together.

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains how Pangaea relates to the hypothesis of continental drift.

2. According to the continental drift hypothesis, in what order did these three events take place? Write the events in the correct order.

   Climates on continents changed.
   Pangaea broke apart.
   Continents began to drift.

   First
   
   Second
   
   Third

3. In this section you read about later evidence that supports continental drift. Choose one piece of evidence. Write one or two sentences explaining how this evidence supports Wegener's hypothesis.

Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about continental drift.
Plate Tectonics

section 2 Seafloor Spreading

What You’ll Learn
- seafloor spreading
- what evidence supports seafloor spreading

Before You Read

Have you ever seen the rings inside a tree that has been cut down? Do you think the rings closest to the center are the youngest or the oldest? Why?

Mapping the Ocean Floor

If you were to lower a rope from a boat until it reached the seafloor, you would know how deep the ocean was in that spot. This is the first way people mapped the ocean floor.

How did technology improve seafloor mapping?

The rope method was used until German scientists discovered how to use sound waves to locate submarines. Later, sound waves on ships were used to map the seafloor. Sound waves travel through the water. When they hit the seafloor, they bounce back. The longer it takes for the sound waves to bounce back to the ship, the deeper the water is. The new sound wave technology made it easier to make better maps of the seafloor.

What did sound waves help discover?

By using sound waves, scientists found that the seafloor had an underwater system of ridges. These ridges are like mountain ranges and valleys on land. In some of these ridges are long rift valleys. These rift valleys are like rips in the ocean floor. Volcanic eruptions and earthquakes occur in the rift valleys from time to time. Underwater volcanic eruptions create underwater mountains. When these mountains push out of the water, they create islands.
What are mid-ocean ridges?

The mid-ocean ridges are a chain of ridges and valleys stretching along Earth's ocean floor. Many of these ridges are connected. They circle Earth much like the stitching on a baseball.

Is the seafloor spreading?

In the 1960s, Harry Hess, an American scientist, proposed that the ocean floor moves. He called his theory seafloor spreading. The theory of seafloor spreading proposes that magma, or melted rock, under Earth’s crust is forced up toward the surface at the mid-ocean ridges, forming new seafloor. When the less dense magma hits Earth’s crust, it flows sideways. The magma carries the seafloor away from the central ridge in both directions. New seafloor is continuously being created. Older sea floor is pushed away from the central ridge as shown in the figure above.

Evidence for Spreading

In 1968, scientists began studying rocks on the seafloor. They took rock samples from the mid-ocean ridges. They also took rock samples farther away from the ridge. They found that rocks near the mid-ocean ridge were the youngest rocks. Rocks farther away from the ridge were older.

According to Hess’s theory of seafloor spreading, the seafloor near the ridge has formed more recently from magma. The older seafloor is pushed away from the ridge. Like tree rings, the further away the rocks, the older they are. The age of the rocks and their distance from the mid-ocean ridge supports the theory of seafloor spreading.

New life-forms have been discovered near the mid-ocean ridges. These giant clams, mussels, and tube worms, get heat and chemicals from magma pouring out of rifts in mid-ocean ridges.

Picture This

1. Interpret Circle the mid-ocean ridge in the figure. Trace over the arrows that show the direction in which the old seafloor is moving.

2. Distinguish Are the oldest seafloor rocks located close to or far from the mid-ocean ridges?
Does Earth's magnetic field change?

Earth's magnetic field has a north pole and a south pole. Invisible lines of magnetic force leave Earth near the south pole and enter Earth near the north pole. At this time, Earth's magnetic field travels from south to north. This is not always true. At times, the lines of magnetic force have traveled in the opposite direction, north to south. These direction changes are called magnetic reversals. During a magnetic reversal, the lines of magnetic force run the opposite way. All of these magnetic reversals are recorded in rocks forming along mid-ocean ridges.

How does the seafloor record history?

Minerals containing iron, such as magnetite, are found in rocks on the seafloor. Iron in the rock records the magnetic reversal. A device called a magnetometer (mag nuh TAH muh tur) tells scientists what direction a magnetic field has.

How do scientists know when a magnetic reversal happened and when it changed back? A strong magnetic reading is recorded when the polarity of a rock is the same as the polarity of Earth's magnetic field. Look at the figure below. Normal polarities in rocks show up as large peaks. After the magnetic reversal, the magnetometer records a weak reading. Over time, the reversals are shown in strips parallel to mid-ocean ridges.

Changes in Earth's magnetic field can be seen on both sides of mid-ocean ridges. This discovery adds to the evidence that the seafloor is spreading. The magnetic reversals showed that new rock was being formed at mid-ocean ridges. This helped explain how Earth's crust could move. It gives evidence that the continental drift hypothesis did not provide.
After You Read

Mini Glossary

seafloor spreading: Hess’s theory that magma under Earth’s crust is forced up toward the surface at the mid-ocean ridges, forming new seafloor

1. Review the term and its definition in the Mini Glossary. Write a sentence explaining where the magma at the mid-ocean ridge comes from.

2. Find the effect of this cause. Write a sentence describing the effect in the box.
   
   CAUSE:
   According to the theory of seafloor spreading, magma pushes up through cracks in the seafloor.
   
   EFFECT:

3. You put sticky notes on pages that you found interesting or that you had a question about. Did you discuss the facts or questions? How did this strategy help you understand more about seafloor spreading?

Science online Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about seafloor spreading.
Plate Tectonics

section © Theory of Plate Tectonics

What You’ll Learn
- about plate boundaries
- about features caused by plate tectonics
- how heat inside Earth causes plate tectonics

Before You Read

Have you ever been swimming and noticed some areas in the water are colder and other areas are warmer? Why do you think this happens?

Read to Learn

Plate Tectonics

In the 1960s, scientists developed a new theory that combined continental drift and seafloor spreading. According to the theory of plate tectonics (tek TAH niks), Earth's crust and part of the upper mantle are broken into plates, or sections, that move around on a plasticlike layer of the mantle.

What are plates?

Plates are large sections of Earth's crust and upper mantle. These plates float and move around on a plasticlike layer of the upper mantle. You can think of the plates as rafts that float on this layer.

What are the lithosphere and the asthenosphere?

Together, the crust and the rigid upper mantle form the lithosphere (LIH thuh sfihr). The lithosphere is about 100 km thick. The layer below is called the asthenosphere (as THE nuh sfihr). The asthenosphere is plasticlike. The rigid plates of the lithosphere float and move around on the plasticlike asthenosphere.
Plate Boundaries

When plates move, several things can happen. They can move closer together and converge, or collide. They also can pull apart or slide by one another. When plates move, the result of these movements shows up at plate boundaries. Movements at one boundary means that changes must happen at other boundaries. The figure above shows the major plates, the way these plates are moving, and plate boundaries.

What is a divergent boundary?

The area where two plates meet is called a boundary. When two plates are moving apart, the area between them is called a divergent boundary. In the figure above, find the North American Plate. Now find the African and Eurasian plates. The arrows show the North American Plate moving away from the Eurasian and African Plates. The divergent boundary between these plates is called the Mid-Atlantic Ridge. It is a mid-ocean ridge. As the plates pull apart, magma pushes up and becomes new seafloor. At some divergent plate boundaries, rift valleys form as the plates pull apart and crust sinks.

Reading Check

2. Define What type of boundary occurs when two plates move away from each other?
What is a convergent boundary?

When two plates converge, or come together, they form a convergent boundary. What happens to the plates when they come together? One plate can sink and disappear under the other plate. For example, oceanic plates are denser than continental plates. When an oceanic plate converges with a less dense continental plate, the denser oceanic plate sinks under the continental plate.

What is subduction?

The area where an oceanic plate subducts into the mantle is called a subduction zone. As the plate subducts into the mantle, it begins to melt. The melting rock becomes magma. The newly formed magma is forced upward along these plate boundaries. Volcanoes form above these subduction zones. Subduction zones occur at convergent boundaries.

The Andes mountain range in South America is located at a convergent boundary. The Nazca and the South American Plates converged to form them. There are many volcanoes in the Andes mountain range. When the Nazca Plate subducted, newly formed magma was forced upward, creating these volcanoes.

The figure above shows a subduction zone and what can occur at a convergent boundary between oceanic and continental plates. The denser oceanic plate is sinking under the less dense continental plate. High temperatures cause the rock to melt around the subducting slab as it moves under the other plate.
What happens when oceanic plates converge?

When two oceanic plates converge, the colder, older, denser plate bends and sinks down into the mantle. A subduction zone forms where these plates collide. Volcanoes can form and, over time, some volcanoes form islands. The Mariana Islands in the western Pacific Ocean are a chain of volcanic islands that formed where two oceanic plates collided.

What occurs if continental plates collide?

When two continental plates collide or converge, neither of the plates sinks under the other. Subduction usually doesn’t occur. The continental plates are less dense than the asthenosphere below them. As a result, when these two plates collide, they fold and crumple to form mountain ranges. Earthquakes are common at these convergent boundaries. Volcanoes do not form because there is no, or little, subduction.

The Indo-Australian Plate is colliding with the Eurasian Plate. These converging plates are forming the Himalaya in Asia.

What is a transform boundary?

The third type of plate boundary is called a transform boundary. Transform boundaries occur when two plates slide past one another. In one type of transform boundary, two plates slide past each other in opposite directions. In another type, two plates are moving in the same direction, but at different rates. When one plate moves past another, earthquakes occur.

As shown below, the San Andreas (an DRAY us) Fault in California is part of a transform plate boundary. The Pacific Plate is sliding past the North American Plate. Both plates are moving in the same direction, but at different rates. As a result, this area has many earthquakes.
Causes of Plate Tectonics

Scientists don’t know exactly why Earth’s plates move. They hypothesize that plates move by the same basic process that occurs when soup is heated in a pan.

What is convection current?

Convection (kun VEK shun) currents can be found in a pan of soup that is cooking. As it heats, some of the soup becomes hotter and less dense. Some of the soup is cooler and more dense. This difference in temperature causes movement in the soup.

The cooler soup sinks and forces the hotter soup to rise to the top of the pot. As the hot soup reaches the surface, it cools and sinks back down into the pan. This happens in a cycle, over and over. This cycle of heating, rising, cooling and sinking is called a convection current.

Are there convection currents inside Earth?

What causes Earth’s plates to move? A type of convection current is occurring inside Earth. Materials deep inside Earth have different amounts of heat and density. The colder, denser materials force the hotter, less dense materials towards Earth’s surface. The arrows in the figure below show the rise and fall of materials in Earth’s mantle.

One hypothesis suggests the transfer of heat inside Earth provides the energy to move plates and causes many of Earth’s surface features. All of the hypotheses use convection currents in some way to explain the movements of plates.
Features Caused by Plate Tectonics

Earth is an active planet with a hot interior. The heat inside Earth causes convection that powers the movement of Earth’s plates. When the plates move and interact, they produce forces that cause Earth’s surface to change. These changes may happen over millions of years.

How do normal faults and rift valleys form?

If forces are pulling Earth’s crust in opposite directions, the crust will stretch. These pull-apart forces are called tension forces. As the crust stretches, large blocks of crust will break and slip down the broken surface of the crust.

When rocks break and move along surfaces, a fault forms. Faults move rock layers out of place. In the process, mountains can form. Usually faults that form this way are called normal faults. In normal faults, the rock layers above the fault move down when compared with the rock layers below the fault. Look at the figure below. The arrows show how tension forces stretch Earth’s crust causing the movement of rock along normal faults. A range of mountains, called fault-block mountains, can form in the process.

Tension forces also cause rift valleys and mid-ocean ridges. Rift valleys and mid-ocean ridges are large cracks that form where Earth’s crust separates. One example of a rift valley is the Great Rift Valley in Africa. Valleys also occur in the middle of mid-ocean ridges. The Mid-Atlantic Ridge and the East Pacific Rise are two examples of mid-ocean ridges.
How do mountains, reverse faults, and volcanoes form?

Compression forces squeeze objects together. Where Earth’s plates come together, compression forces produce several effects. As continental plates collide, compression forces cause rock layers to fold and fault. Mountains can form. The Himalaya (hih muh LAY uh) are mountains being formed where two plates are colliding and forcing huge sections of rock to fold and break. The figure above shows compression forces forming a mountain range.

Usually compression forces cause a reverse fault. In a reverse fault, rock layers above the fault surface move up when compared with the rock layers below the fault. This is the opposite of a normal fault.

As you read earlier, when two oceanic plates converge, the denser plate will sink under the less dense plate. If an oceanic plate converges with a continental plate, the denser oceanic plate slides under the continental plate. Mountains and volcanoes can form as a result of the folding and faulting that occurs at the plate boundaries.

What are strike-slip faults?

Strike-slip faults occur where two plates stick, or strike, and then slip by one another. Strike-slip faults occur at transform boundaries. A transform boundary is where two plates slide past one another. The plates can slide by in opposite directions or they may slide by in the same direction, but at different rates. When the plates move suddenly, they cause vibrations inside Earth that we feel as earthquakes. The San Andreas Fault is a strike-slip fault.
Testing for Plate Tectonics

Only recently have scientists been able to measure exact movements of Earth’s crust. All the early methods to check for plate movements were indirect.

What are indirect methods of testing?

You have been reading about indirect methods of testing plate movements in this chapter. One method is studying the magnetic properties of rocks on the ocean floor. Scientists also could study volcanoes and earthquakes. These methods supported the theory that plates have moved and are still moving. However, these methods did not prove that plates are moving.

How is plate movement measured?

There is a new method of measuring small amounts of plate movement that uses lasers and satellites. The figure below shows the Satellite Laser Ranging System. From the ground, scientists aim laser pulses at a satellite in orbit. The pulse reflects off of the satellite and returns to Earth. With this new technology, scientists can measure exact amounts of movement of Earth’s plates. This new method shows that the plates move at rates between 1 cm to 12 cm per year. For example, Hawaii is moving toward Japan at a rate of 8.3 cm per year.

Reading Check

11. Infer Is an earthquake an example of direct or indirect evidence of plate movement?

Picture This

12. Interpret What happens to the laser light when it reaches the satellite in the ranging system?
After You Read

Mini Glossary

asthenosphere (as THE nuh sfhr): plasticlike layer of Earth on which the lithosphere plates move

convection current: cycle of heating, rising, cooling, and sinking

lithosphere (LIH thuh sfhr): rigid layer of Earth made of the crust and upper mantle that move on the asthenosphere

plate: large section of Earth’s crust layer and upper mantle layer that moves around on the asthenosphere

plate tectonics (tek TAH nihks): theory that Earth’s crust and upper mantle are broken into plates that move around on a plasticlike layer of mantle.

1. Review the terms and their definitions in the Mini Glossary. Write a sentence explaining how the asthenosphere and the lithosphere interact according to the theory of plate tectonics.

2. Complete the concept map with the name of the plate boundary.

   Major Plates of the Lithosphere

   move

   apart at

   together at

   past each other at

3. You learned about three types of faults in this section—normal, reverse, and strike-slip. Choose one fault. Write two sentences describing the force that causes the fault and what occurs as a result of the movement.

End of Section

Visit blue.mssscience.com to access your textbook, interactive games, and projects to help you learn more about the theory of plate tectonics.
Earthquakes and Volcanoes

section ● Earthquakes

● Before You Read

Have you ever experienced an earthquake or perhaps seen an earthquake in a movie or on TV? On the lines below, describe an earthquake.


What You’ll Learn

● how energy from an earthquake reaches points on Earth’s surface
● about primary, secondary, and surface waves produced by earthquakes
● how to recognize earthquake hazards and prepare for them

● Read to Learn

What causes earthquakes?

Have you ever bent a stick? If so, you probably noticed that it changes shape while you are bending it and springs back when you stop. But if you don’t stop bending the stick, it changes permanently. If its elastic limit is passed, the stick may break. As it breaks, you can feel vibrations in the stick.

What is elastic rebound?

Rocks are like other solid materials. If enough force pulls or pushes on them, they will change shape. They may even break. After breaking, the ends of the broken pieces may snap back. This snapping back is called elastic rebound.

Inside Earth, pushing and pulling forces cause rocks to change shape slowly over time. As they are strained, potential energy builds up in them. This energy is released suddenly when the rocks finally break or move. The breaking and the movement that follows causes vibrations that move through rock. If they are strong enough, the vibrations are felt as earthquakes. An earthquake is a movement of the ground that occurs when rocks inside Earth pass their elastic limit, break suddenly, and experience elastic rebound.

Underline As you read this section, underline the key terms and main ideas in each paragraph to help you understand new information.

Foldables

A Organize Information

Construct a three-tab Foldable as shown. Under the tabs, write information about faults.
1. Determine Trace over the arrows in each figure. What do the arrows show?

**Picture This**

**What is a fault?**

When part of a rock breaks, rocks on either side move as a result of elastic rebound. The surface where rocks break and move is called a fault. Rocks can break in different ways, depending on the forces that cause the break. The figures above show three different faults, a normal fault, a reverse fault, and a strike-slip fault.

**What are the types of faults?**

Sometimes rocks are pulled apart because of tension forces. This is what occurs in a normal fault, as shown in the normal fault figure. Normal faults form where tension forces pull rocks apart, and the rock above the fault moves down.

Sometimes rocks are pushed together, or compressed. Reverse faults are caused by compression. This is shown in the reverse fault figure. When the two rocks push together, rock above the fault is pushed up.

Sometimes sections of rock move past one another in opposite directions along Earth’s surface as shown in the strike-slip fault figure. This is called shearing. Strike-slip faults are caused by shear forces.
Making Waves

Do you recall the last time you shouted for a friend to save you a seat on the bus? When you called out, energy traveled through the air in the form of sound waves. These sound waves were released by your vocal cords and were affected by your tongue and mouth. The sound waves traveled from your mouth outward through the air to your friend. Your friend identified the familiar sound of your voice as belonging to you. Sound is a form of energy that travels through the air in waves.

Earthquakes also release energy in waves. Earthquake waves move through material inside Earth and along Earth’s surface. Waves from an earthquake are called **seismic waves**.

**How does energy from an earthquake reach Earth’s surface?**

Movement along a fault releases energy causing vibrations. When this energy is released, it moves away from the fault in the form of seismic waves. The point deep inside Earth where energy is released causing an earthquake is a **focus**. Some of the energy from the earthquake travels straight up to Earth’s surface where it can be felt. The **epicenter** is the point on Earth’s surface directly above the earthquake focus. This release of energy can be seen in the figure below.

**Reading Check**

2. Identify What are waves from an earthquake called?

**Picture This**

3. Label Add the labels *epicenter* and *seismic wave* to the figure.
4. Determine What two types of seismic waves travel through Earth’s interior?

How do seismic waves travel?
When seismic waves leave the focus of an earthquake, some travel through Earth’s interior, and others travel along the surface.

**Primary Waves** The seismic waves that travel fastest through rock material are primary waves, or P-waves. Primary waves cause the material to move from side to side, in the same direction that the wave is moving.

**Secondary waves** Other seismic waves that travel through Earth’s interior are called secondary waves. Secondary waves, or S-waves, do not move as fast as P-waves. As they move through rock material, they cause the material to vibrate at right angles to the direction of the wave.

**Surface waves** Seismic waves that travel along Earth’s surface are called surface waves. They are the largest and slowest type of seismic wave. They cause more damage than other types of seismic waves. Surface waves move in different ways. When some surface waves travel over Earth’s surface, they may move the rock and soil in a backward rolling motion. They move across land like waves of water. Some surface waves shake or sway the rock and soil from side to side.

Learning from Earthquakes
On your way to lunch, suppose you walk twice as fast as your friend does. What would happen to the distance between the two of you? The distance between you would become greater the farther you walk, and you would arrive first. When scientists study seismic waves, they apply the same principle. Scientists look at the different speeds of seismic waves and at the different arrival times to figure out the exact location of an earthquake’s epicenter.

How are earthquakes measured?
Scientists who study earthquakes are called seismologists. They use instruments called seismographs to record seismic waves. One type of seismograph has a drum that holds a roll of paper on a frame. A pendulum with an attached pen hangs over the frame. When seismic waves reach the station, the drum vibrates. The pen on the pendulum traces a record of the vibration. The height of the lines traced on the paper measures the magnitude of the earthquake. **Magnitude** is the measure of energy released by an earthquake.
6. Interpret Look at the seismograph reading. How far away was the earthquake epicenter from this location? How many minutes apart did the waves arrive?

7. Interpret On the map, which seismograph station is closest to the epicenter of the earthquake?

How is an epicenter located?
The epicenter of an earthquake is the point on the surface of Earth directly above the focus. Far away from the epicenter, the P-waves and S-waves arrive at different times. But close to the epicenter, the waves arrive at almost the same time. This difference in arrival time is shown in the graph above.

Once scientists know the P-wave and S-wave arrival times for at least three seismograph stations, they can figure out the location of an earthquake’s epicenter. They draw circles on a map. Each circle shows the distance from a seismograph station to the earthquake. The point where three or more circles intersect is the location of the epicenter. Look at the map below. The three seismographic stations are in Tokyo, Berkeley, and Anchorage. The epicenter is the point where the three circles intersect.
How strong are earthquakes?

Some earthquakes are not felt on the surface of Earth. People do not even know these small earthquakes are happening. Larger earthquakes, on the other hand, can cause major damage.

What is the Richter scale?

Richter (RIHK tur) magnitude is based on the measurements of heights of seismic waves as they are recorded on seismographs. Scientists use this information to determine the Richter magnitude of an earthquake. Richter magnitude describes how much energy an earthquake releases. Very weak earthquakes have low magnitudes like 1.0 on the Richter scale. Strong earthquakes have high magnitudes in the range of 6 to 7. For every increase of 1.0 on the Richter scale, an earthquake actually releases 32 times more energy. This means that an earthquake with a magnitude of 7.5 releases 32 times more energy than an earthquake with a magnitude of 6.5.

How is earthquake intensity measured?

Another way to measure earthquakes is by the modified Mercalli intensity scale. This scale measures the intensity of an earthquake. Intensity is a measure of the amount of damage to structures and to rocks and soil in a specific area. The amount of damage depends on how strong the earthquake is, kinds of structures in an area, distance from the earthquake’s epicenter, and the nature of the surface material.

The Mercalli scale uses Roman numerals I through XII. An earthquake with an intensity of I would be felt by few people. An intensity-VI earthquake would be felt by everyone. An intensity-XII earthquake would cause major damage to Earth’s surface and to human-built structures.

What are tsunamis?

When an earthquake occurs on the ocean floor, powerful waves are produced. These waves travel outward from the earthquake in all directions. A powerful seismic sea wave is called a tsunami. Tsunamis traveling in open ocean water are low and fast moving. But tsunamis change as they approach land. The speed of the tsunami slows and the height of the wave increases. Huge tsunami waves can be up to 30 m high. These huge waves can cause large amounts of damage along coastal areas.
Earthquake Safety
You have read about the destruction earthquakes can cause. If the area you are in has had earthquakes before, chances are it will again. You can prepare for that.

What measures can you take to be safer?
There are things you can do to make your home safe. Put heavy things on lower shelves so they won’t fall on you. Make sure your gas hot-water heater and appliances are well secured. There are now sensors that can be placed on gas lines. The sensors shut off the gas when the vibrations of an earthquake are felt. This helps prevent fires.

During an earthquake, stay away from windows and anything that could fall on you. Sometimes the safest thing is to get outside. But then you must watch for fallen power lines and fire hazards.

How do people build seismic-safe structures?
Seismic-safe structures are buildings that can stand up against the vibrations caused by most earthquakes. It is not possible to prevent earthquakes, but structures can be built that withstand them. California has many regulations for making sure that buildings are seismic-safe. Many high-rise office buildings now stand on huge steel-and-rubber supports. This can help buildings to ride out the vibrations of an earthquake. Underground water and gas pipes are replaced with pipes that will bend during an earthquake. This can help prevent broken gas lines and therefore prevent damage from fires. Highways and bridges are built with spiral rods in the concrete columns. These spiral rods reinforce the structure, and keep it from collapsing.

Can earthquakes be predicted?
Right now, it is impossible to predict the exact time and place an earthquake will occur. However, scientists do know which locations are more likely to have earthquakes. In these places, they monitor the movement along faults to see when an earthquake might occur. They also watch the groundwater levels and electrical properties in rocks. It is possible to predict that an earthquake of a certain magnitude will probably occur in a certain location within the next 30 to 100 years. But it is difficult to predict an earthquake more exactly than that.
After You Read

Mini Glossary

**earthquake:** movement of the ground that occurs when rocks inside Earth pass their elastic limit, break suddenly, and experience rebound

**epicenter:** point on Earth’s surface directly above the earthquake’s focus

**fault:** fracture that occurs where rocks break which results in movement of opposing sides

**focus:** point deep inside Earth where energy is released, causing an earthquake

**magnitude:** measure of energy released by an earthquake

**seismic-safe:** describes the ability of structures to stand up against vibrations caused by an earthquake

**seismic waves:** earthquake waves including primary waves, secondary waves, and surface waves

**seismograph:** instrument used to record seismic waves

**tsunami:** powerful seismic sea wave that begins over an ocean-floor earthquake

1. Review the terms and their definitions in the Mini Glossary. Write two sentences explaining how earthquakes are measured. Use at least three glossary words.

2. Fill in the boxes with the correct terms.

<table>
<thead>
<tr>
<th>Waves</th>
<th>P-waves</th>
<th>S-waves</th>
<th>Slowest waves</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Travel fastest through rock</td>
<td>Travel slower through rock</td>
<td>Travel on Earth’s surface</td>
</tr>
</tbody>
</table>

3. You underlined key terms and main ideas in each paragraph in this section. Did this strategy help you learn more about earthquakes? Would you use it again?

End of Section

Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about earthquakes.
Earthquakes and Volcanoes

section ☞ Volcanoes

Before You Read

What do you think of when you hear the word *volcano*? On the lines below, write words that describe volcanoes.

What You’ll Learn

- how volcanoes form
- how volcanoes affect humans
- about three types of volcanoes
- ways that volcanoes add material to Earth’s surface

Read to Learn

How do volcanoes form?

Inside Earth is a layer of hot, liquid rock material called magma. Most of the time magma remains deep inside Earth. Sometimes, however, it is forced to the surface. Rising magma can lead to an eruption—an event where magma, solids, and gas spew onto Earth’s surface. A *volcano* is a cone-shaped hill or mountain formed when hot magma, solids, and gas erupt onto Earth’s surface.

When magma flows to Earth’s surface, it is called *lava*. Volcanoes have circular holes called craters. Lava can flow gently or explode violently out of the crater. Some violent eruptions throw lava and rock thousands of meters into the air.

What occurs when plates collide?

Earth’s upper mantle and crust are made up of large plates that move around on a layer of magma. When these plates collide, volcanoes can form. When two plates collide, the denser plate sinks below the less dense plate. As the denser plate sinks, it melts and forms chambers of magma. This magma is the source of volcanic eruptions that formed the Caribbean Islands.

Flash Cards  As you read the sections, write important words on flash cards. On the back of each flash card, write an explanation in your own words. Use the flash cards to review this section.
Forms of Volcanoes

The figure above shows a view inside a volcano forming where a denser plate sinks under a less dense plate. The magma is rising toward Earth’s surface. Volcanoes can cause great destruction. But they also can add new material to Earth’s surface. The way volcanoes add this new material to Earth’s surface varies greatly. Different types of eruptions produce different types of volcanoes.

What determines how a volcano erupts?

All volcanoes are a result of magma rising to Earth’s surface. But some volcanic eruptions are violent, while others are quiet. Different factors affect volcanic eruptions. The composition of the magma and the amount of pressure in the magma determine how a volcano erupts.

How does magma composition affect eruptions?

Lava contains many different compounds, including silica. Silica is made of silicon and oxygen. Lava that contains more silica tends to be thicker and does not flow easily. Lava containing more iron and magnesium and less silica tends to flow more easily.

How does magma pressure affect eruptions?

The amount of pressure built up in the magma also affects the type of eruption. When you shake a bottle of carbonated soft drink before opening it, the pressure from the gas builds up and is released suddenly when the container is opened. In the same way, steam builds pressure in magma. Lava containing more silica is thicker, so it tends to trap more water vapor and other gases. This creates tremendous pressure.
How does water vapor affect eruptions?

Water can be carried from the surface of Earth to the mantle when one plate sinks beneath another. The magma produced when plates melt tends to contain more silica than the magma produced deep inside Earth. This silica traps more water, which turns to steam. Steam produces tremendous pressure in thick, silica-rich magma. When enough pressure builds up, an eruption occurs.

How are shield volcanoes formed?

Basaltic lava contains more iron and magnesium than silica, so it flows in broad, flat layers. The buildup of basaltic layers forms a large, broad volcano with gently sloping sides called a shield volcano. A shield volcano is shown on the left in the figure below. They are the largest type of volcano. Shield volcanoes occur where plates are separating, or in other places where magma can be forced up from deep inside Earth.

How do cinder cone volcanoes form?

Gases build up in magma as it rises to Earth’s surface. When the gas builds up enough pressure, the volcano erupts. The eruption throws ash, cinders, and lava into the air. The lava cools quickly and particles of solid lava, ash, and cinders fall to the surface. These particles of solid lava, ash, and cinders, called tephra, form a small cone of volcanic material. A cinder cone volcano is a relatively small volcano formed by moderate to explosive eruptions of tephra. This type of volcano is shown on the right in the figure above. Cinder cone volcanoes erupt violently because the eruption is powered by the high gas content. However, the eruptions usually do not last very long. After the gas is released, the force behind the eruption is gone.
What is a composite volcano?

Composite volcanoes are steep-sided volcanoes formed by alternating layers of tephra and lava. This volcano is shown in the figure below. Sometimes composite volcanoes erupt violently as in a cinder cone volcano and spew out tephra. At other times, lava flows out gently as in a shield volcano.

Composite volcanoes form where one plate sinks under another plate. They are intermediate in size and shape compared to shield volcanoes and cinder cone volcanoes.

Think it Over

4. Infer Why do composite volcanoes have steep sides?

What is a fissure eruption?

Magma that is highly fluid can ooze through cracks or fissures in Earth’s surface. This type of magma is usually linked to fissure eruptions. The lava flows freely across the land to form flood basalts. When flood basalts are exposed to erosion over time, they can become large, flat landforms called lava plateaus. The Columbia River Plateau in the northwestern United States was formed millions of years ago. Several fissures erupted and lava flows built up layer by layer. The map below shows the location of the Columbia River Basalts.
1. Review the terms and their definitions in the Mini Glossary. Write two to three sentences using at least two terms to describe different volcanic eruptions.

2. Compare shield volcanoes to cinder cone volcanoes, using this Venn diagram. In the middle, write things that the two types of volcanoes have in common. On each side, write things that are different.

3. In this section you made flash cards. How did the flash cards help you to learn about volcanoes?

Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about volcanoes.
Think-Pair-Share

Work with a partner. As you read this section, discuss what you already know about the topic and what you learn from the text.

Organize Information

Construct a three-tab Foldable. Under the tabs, write information about divergent boundaries, convergent boundaries, and hot spots.

What You’ll Learn

- different ways Earth’s plates move
- how plate motion causes earthquakes and volcanoes
- where the energy for plate motion comes from

Before You Read

You have read about volcanoes and earthquakes. On the lines below, list some ways they are alike.

Read to Learn

Earth’s Moving Plates

Imagine you and your classmates are moving long tables to get ready for a program in the cafeteria. As you move the tables, two or three of them crash into each other. What would happen if you kept pushing on them? For a while, one or two of the tables might keep another table from moving. But if enough force were used, the tables would slide past each other. One table might even slide up on top of the other.

What is plate tectonics?

The movement of the tables and the possible crashing among them is like the movement of the lithosphere. The lithosphere is Earth’s crust and part of the upper mantle. Earth’s lithosphere is broken into separate sections, or plates. As these plates move around slowly, they collide, move apart, or slide past each other. These movements, or plate tectonics, can cause vibrations known as earthquakes. These movements also can create conditions that cause volcanoes to form.
Where Volcanoes Form

Most volcanoes form near plate boundaries. Look at the map above. It shows the location of volcanoes and plate boundaries. There is a link between volcanic activity and plate tectonics. Perhaps the energy involved in plate tectonics causes magma to form deep under Earth's surface. Plate movement often explains why volcanoes form in certain areas.

What happens when plates move apart?

Divergent plate boundaries are boundaries where tectonic plates move apart. On the map above, notice the arrows pointing in opposite directions at divergent plate boundaries. As the plates separate, rifts form. A rift is a long crack that forms between tectonic plates at plate boundaries. Rifts act like passageways for magma to flow through. Most of the lava that flows onto Earth's surface comes through rift zones. Fissure eruptions often occur along rift zones. These eruptions form lava that cools and hardens as basalt. Basalt is the most common type of rock in Earth's crust.

1. Interpret With your pencil trace areas where there are many volcanoes. What do you notice about the location of volcanoes?
What are convergent plate boundaries?

Plates move together at convergent plate boundaries. When plates move toward each other and collide, the more dense plate sinks under the less dense plate. This movement can cause a volcano to form.

When one plate sinks under another plate, basalt and sediment move down into the mantle. Water from the sediment and altered basalt lowers the melting point of the rock in the area. Heat in the mantle causes part of the sinking plate to melt. The mantle over it also starts melting. This melted material is then forced upward. Volcanoes form in this way all around the Pacific Ocean where the Pacific Plate collides with other plates.

What is a hot spot?

Some volcanoes do not form along plate boundaries. For example, the Hawaiian Islands are in the middle of the Pacific Plate. Scientists suggest this is because the islands are over a hot spot. A hot spot is a large body of magma that has been forced upward through Earth’s mantle and crust. When magma breaks through Earth’s crust, a volcano forms. As the figure below shows, new islands are formed as the Pacific Plate moves over the hot spot.

Volcanoes usually form at rift zones, subduction zones (where one plate sinks under another), or over hot spots. In these areas, magma deep inside Earth is forced upward toward the surface. When magma breaks through, it flows out as lava. The lava either piles up into layers or forms a volcanic cone.

Picture This

3. Determine Circle the newest island. Put a box around the island that probably formed first.
Moving Plates Cause Earthquakes

Place two notebooks on your desk with the page edges facing each other. Then push them together slowly. The individual sheets of paper will start to bend upward from the stress. If you keep pushing the notebooks, one will slip past the other suddenly. This sudden movement is like an earthquake.

Imagine what would happen if tectonic plates were moving like notebooks. What do you think would happen if the plates collided and then stopped moving? Pressure would build up. Both plates would start to bend upward like the sheets of paper did. In time, the plates may pass their elastic limit. The breaking and elastic rebounding would release energy in the form of vibrations felt as earthquakes.

Where do earthquakes occur?

Most earthquakes occur along plate boundaries. Many earthquakes occur in the same places where volcanoes form. This is because the movement of the plates that causes volcanoes also can cause earthquakes. The Pacific Ring of Fire is a belt of earthquakes and volcanoes all around the Pacific Ocean.

How are seismic waves helpful?

By studying seismic waves, scientists have learned about plate tectonics and Earth's major layers. Seismic waves pass through different materials in different ways. This helped scientists discover the asthenosphere, the partially molten layer that Earth's plates float on.

What is driving Earth's plates?

Energy causes Earth's plates to move. There are several theories about where this energy comes from. One idea is that the energy comes from Earth's core. Heat from the core makes the rock in the mantle hotter. The hotter magma rises towards the surface. As it cools, the magma gets denser and then sinks back down towards the core. This cycle of heating, rising, cooling, and sinking is a convection current. Convection currents may be the reason Earth's tectonic plates move.
After You Read

Mini Glossary

hot spot: large body of magma that has been forced upward from deep within Earth, which may cause volcanoes to form in the middle of a plate

rift: long crack, fissure, or trough that forms between tectonic plates moving apart at plate boundaries

1. Review the terms and their definitions in the Mini Glossary. Use the terms to explain two reasons why volcanoes can occur.

2. Choose a sentence and write it in the correct box to show how a volcanic island forms.

   Over time, lava flows build up into a volcanic mountain.
   Magma breaks through Earth’s surface.
   Lava cools on the bottom of the ocean.

   | 1 | Hot spot forms in Earth’s mantle. |
   | 2 | Volcanic island is formed. |

3. How did the strategy of sharing with your partner help you learn information from this section?

   Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about earthquakes, volcanoes, and plate tectonics.
Before You Read

Every person’s history may be revealed by photos, letters, and other things they own. Earth has a history, too. What things might be used to reveal Earth’s history?

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.

Formation of Fossils

Fossils are the remains, imprints, or traces of animals or plants 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. Fossils can tell a lot about the past.

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 animals and plants do become fossils. Sometimes conditions are just right for fossils to form.
1. Explain What is one reason that hard parts of organisms have a better chance of becoming fossils than soft parts do?

2. Identify What is the source of the minerals that form permineralized remains?

How do fossils form?
Dead organisms that are protected from scavengers and other harmful forces may leave fossils. 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, it would be protected from scavengers. 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 by scavengers 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 fossil bones. What preserves fossil bones?

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 are filled with minerals from groundwater. Sometimes minerals replace all of the original hard parts of an organism.

Scientists learn about past forms of life from remains that are permineralized. Other types of fossils can be found as well.

What are carbon films?
The tissues of living organisms contain carbon. Some fossils are made only of 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. Then, just a thin layer, or film, of carbon is left. It looks like a shadow 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 plants may build up in swamps. Over millions of years, heat and pressure change the plant material into coal which contains large amounts of carbon. Coal is another kind of fossil, but it doesn’t reveal much about the past. As the coal forms, 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, such as mud. Then more sediment buries the object. In time, pressure and cementation turn the sediment into rock. Cementation is when minerals from water are deposited in the spaces between sediment particles. Then water and air flow through open spaces in the rock and dissolve the organism’s hard parts. This leaves a hole, or cavity, in the rock called a mold. A mold is a body fossil that forms when an organism decays, or dissolves, and leaves a cavity in 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 body fossil that forms when minerals fill a mold and harden into rock. The figure below shows a cast resulting 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?
5. Identify List three different trace fossils.

6. Define What are index fossils?
Fossils in a Sequence of Sedimentary Rock

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 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.

7. Interpret  According to the chart, during what span of time did all three fossils appear together on Earth?

8. Infer  If fossil sea shells are found on the tops of mountains today, what does that tell you about the location of the mountains long ago?
After You Read

Mini Glossary

**carbon film:** thin film of carbon left from an organism and preserved as a fossil

**cast:** body 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:** body 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

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 together.

2. Complete the concept map below.

---

Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about fossils.
Clues to Earth’s Past

section 2 Relative Ages of Rocks

Before You Read
Think of two friends. You want to know who is older. What information do you need to figure out who’s older?

What You’ll Learn
■ how to tell the relative ages of rock layers
■ how to interpret gaps in the rock record

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?

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 and younger toward the top.

Why are rocks in layers?
Sediments build up, forming layers of sedimentary rocks. 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. **Relative age** is the age of something compared with the ages of other things.

Relative age is the age of something compared with the ages of other things. Scientists 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 the lower layer, it shows that the layers have been turned upside down. This could have been caused by folding during mountain building.
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?

Now and then, a layer of rock is missing from a stack of 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.
Clues to Earth’s Past

Picture This

5. Identify Highlight the surface where rocks were exposed and eroded before new sediments were deposited over them.

Picture This

6. Determine In the figure color the rock being uplifted red. Color the sedimentary rock being deposited blue.

Think it Over

7. Explain What are two ways to correlate rock layers?

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 exposed rock layer 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. Layers can also be matched using fossil evidence. If the same types of fossils are found in the same rock layer in both places, it shows that the rock layer in each place is the same age and also that it is from 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 become younger and 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. Complete the table about unconformities.

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angular unconformity</td>
<td></td>
<td>Erosion of whole layers or no new deposition</td>
</tr>
<tr>
<td>Sedimentary rock layers over igneous or metamorphic rock</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

3. 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?

---

Visit [blue.msscience.com](http://blue.msscience.com) to access your textbook, interactive games, and projects to help you learn more about the relative ages of rocks.
Clues to Earth’s Past

section 3 Absolute Ages of Rocks

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 verify 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 them 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 easily.

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. Knowing the absolute age of rocks leads to a better understanding of events in Earth’s history.
Radioactive Decay

Each atom has a dense center called the nucleus, which is surrounded by particles with a negative charge called electrons. Inside the nucleus are 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 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.

Picture This

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

2. Determine 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 don’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.
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?

Aside from carbon-14 dating, 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 the 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.
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>Half-Life of Carbon-14</th>
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</thead>
<tbody>
<tr>
<td>Percent Carbon-14</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>12.5</td>
</tr>
<tr>
<td>6.25</td>
</tr>
<tr>
<td>3.125</td>
</tr>
</tbody>
</table>

3. In this section you highlighted vocabulary terms. Was this strategy helpful? Explain why or why not.

Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about the absolute ages of rocks.
Geologic Time

section 0 Life and Geologic Time

Before You Read

Think about a giraffe you have seen. On the lines below, describe the giraffe and tell why you think it has a long neck.

What You’ll Learn

• how geologic time is divided
• how plate tectonics and other changes on Earth affect species

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. Index fossils 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 millions of years ago.

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, scientists who study the prehistoric world, divide Earth’s history into time units based on life-forms that existed only during certain periods. This division of Earth’s history is known as the geologic time scale. Sometimes few fossils remain from a period. Then paleontologists use other methods to define a division of geologic time.
What are major subdivisions of geologic time?

The fossil record is used to divide Earth’s history into geologic time periods. The figure below shows the four major subdivisions of geologic time—eons, eras, periods, and epochs. **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 fossils present. For example, at the end of the Mesozoic Era, many kinds of invertebrates, birds, mammals, and reptiles became extinct.

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.

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### Table: Geologic Time

<table>
<thead>
<tr>
<th>Precambrian Time</th>
<th>Phanerozoic Eon</th>
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<tbody>
<tr>
<td></td>
<td>Paleozoic Era</td>
</tr>
<tr>
<td></td>
<td>Hadean Eon</td>
</tr>
<tr>
<td></td>
<td>Archean Eon</td>
</tr>
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<td></td>
<td>3.800</td>
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</tbody>
</table>

- **Origin of Earth**: 4.54 billion years ago
- **First life**: 3.5 billion years ago
- **First trilobites**: 544 million years ago
- **Mass extinction**: 65 million years ago
- **First flowering plants**: 118 million years ago

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Organic Evolution

The fossil record shows that species (SPEE sheez), or types of life-forms, have changed over geologic time. Organic evolution is the change in species over geologic time. Most scientists believe that changes in the environment affect an organism’s survival. Organisms that do not adapt to the changes are less likely to survive or reproduce. Over time, the disappearance of individuals that are not adapted to the new conditions can cause changes to species of organisms.

What is a species?

There are many ways to define the term species. Life scientists often define a species as a group of organisms that normally reproduce only with other members of their group. For example, horses generally reproduce only with other horses. Sometimes, members of different species can mate and produce offspring. Horses sometimes mate with donkeys and produce mules. However, the offspring of two different species are often sterile.

What is natural selection?

Charles Darwin was a naturalist—someone who studies the natural world. Between 1831 and 1836, Darwin sailed around the world, carefully observing plants and animals. He collected samples of life-forms and studied them to learn how they were related.

After returning home to England, Darwin explained his theory of natural selection. Darwin defined natural selection as the process by which organisms with characteristics suited to a certain environment have a better chance of surviving and reproducing than organisms that do not have these characteristics. Darwin understood that all organisms compete for resources, such as food and living space. He also knew that individuals within a species could be different, or show variation. An individual’s differences might help or hurt its chances of surviving in a changing environment.

Some organisms that were well suited to their environment lived longer and had a better chance of producing offspring. Organisms that were poorly adapted to their environment produced few or no offspring. Because many characteristics are inherited, the characteristics of organisms that are better adapted to the environment get passed on to offspring more often. According to Darwin, this can cause a species to change over time.
What is natural selection within a species?

Suppose that an animal species exists in which a few of the individuals have long necks, but most have short necks. The main food for the animal is the leaves on trees in the area. Then suppose the climate changes and the area becomes dry. The lower branches of the trees might not have any leaves. Now which of the animals will be better suited to survive? In this case, the animals with the longer necks will be better able to eat the leaves. Clearly, the long-necked animals have a better chance of surviving and reproducing. Their offspring will have a greater chance of inheriting the important characteristic. Gradually, as the number of long-necked animals becomes greater, the number of short-necked animals decreases. Over time, the species might change so that nearly all of its members have long necks—just like the giraffe.

It is important to notice that individual, short-necked animals did not change into long-necked animals. A new characteristic becomes common in a species only under two conditions. First, some members must already have that characteristic. Second, the trait must increase the animal’s chance of survival. If no animal in the species had a long neck in the first place, a long-necked species could not have evolved by means of natural selection.

What is artificial selection?

Humans have long used artificial selection to breed domestic animals. Animal breeders carefully choose individuals animals with desired characteristics to mate. Their offspring also have the desired characteristics. In this way, animal breeders have created many different breeds of cats, dogs, cattle, and chickens.

How do new species evolve?

Natural selection explains how characteristics change and how new species arise. Remember the animals with short necks? If they had moved, or migrated, to a different area, they may have survived. Then they may have reproduced in the new area, developing different characteristics from the long-necked animals. If the short-necked animals were different enough from the long-necked animals that they could no longer breed, then a new species would have evolved.
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 above shows the three parts of the trilobite shell. The three parts, called lobes, run the length of its body. Trilobites also have a head (cephalon), a middle that is segmented or divided into sections (thorax), and 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 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.

---

**Picture This**

7. **Identify** Look carefully at the picture of a trilobite. With a red pencil, outline the trilobite’s lobes. With a blue pencil, circle its head, middle, and tail.

---

8. **Identify** What were the two things that happened to trilobite species during the Paleozoic Era?

---

**Reading Check**

✓
What do trilobite eyes reveal?

Trilobites may have been the first organisms on Earth with complex eyes as shown in the figure above. Trilobite eyes are the result of natural selection.

The position of an organism's eyes tells 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 tells us 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 some trilobites changed. Gradually, the eyes of many trilobite species became smaller and smaller. Eventually, their eyes disappeared completely. These blind trilobites, shown above, might have burrowed into sediments on the ocean floor. Or they 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, as shown in the figure below. Some early trilobite species had many segments in the middle part of the body. Later trilobites had fewer segments.
What evidence do fossils provide?

The exoskeletons of trilobites changed as their environment changed. Each change in the trilobite body shows how different species of trilobite adapted to new conditions. Some species of trilobite could not adapt. These species disappeared, or became extinct.

Plate Tectonics and Earth History

Earth’s crust is made up of several plates. These plates are in slow but constant motion. This motion, called plate tectonics, caused continents to split apart or to collide. At the time the trilobites dominated Earth’s seas, Earth’s plates were moving together. When all the continents collided, they formed a single, enormous continent known as Pangaea (pan JEE uh), shown in the figure below. Pangaea was one giant landmass, or supercontinent. When Pangaea was forming, sea levels were dropping. Because trilobites lived in the ocean, they could not survive in the changed environment. At the end of the Paleozoic Era, trilobites became extinct.

Some scientists do not accept that the formation of Pangaea caused the extinctions at the end of the Paleozoic Era. Changes in the climate or other conditions may have led to the Paleozoic extinctions. As in all scientific debates, evidence must be considered carefully, and conclusions must be drawn based on the evidence.

Reading Check

11. Explain What did each change in the trilobite body show?

12. Outline In the figure, outline the borders of the continents that crashed together to form the supercontinent, Pangaea.

Picture This

Pangaea was one giant landmass, or supercontinent. When Pangaea was forming, sea levels were dropping. Because trilobites lived in the ocean, they could not survive in the changed environment. At the end of the Paleozoic Era, trilobites became extinct.
After You Read

Mini Glossary

eon: largest geologic time division that is based on the abundance of certain fossils
epoch: geologic time division characterized by differences in life-forms, which may vary from continent to continent
era: geologic time division marked by major worldwide changes in the types of fossils present
geologic time scale: divisions of time in Earth’s history
natural selection: process by which organisms with characteristics suited to a certain environment have a better chance of surviving and reproducing than organisms that do not have these characteristics

organic evolution: change in species over geologic time
Pangaea: one giant landmass, or supercontinent, that formed at the end of the Paleozoic Era
period: subdivision of geologic time during which certain types of life-forms existed all over the world
species: group of organisms that normally reproduce only with other members of their group
trilobite (TRI loh bite): small, hard-shelled animal that lived in ancient seas

1. Review the terms and their definitions in the Mini Glossary. Then write two sentences about geologic time and natural selection. Use at least four vocabulary words in your sentences.

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

Think of a picture of a volcano you have seen. Describe what Earth would be like if the land were almost completely covered with volcanoes.

Precambrian Time

It may seem strange, but during the first billion years of Earth’s history, the land was covered with volcanoes.

Over the next 3 billion years, simple life-forms began to live in the oceans. Precambrian (pree KAM bree un) time is the longest part of Earth’s history. Precambrian time lasted from about 4.5 billion years ago to about 544 million years ago.

What is known about early life forms?

Little is known about the organisms that lived during Precambrian time. Most Precambrian rocks are buried deep within Earth where they have been changed by heat and pressure. Few fossils can survive these conditions. Most Precambrian organisms had soft bodies. These organisms did not have hard body parts that leave fossil imprints in rock.

One clue to early history of life is found in ancient stromatolites (stroh MA tuh lites). Stromatolites are layered mats formed by colonies, or groups, of cyanobacteria. Cyanobacteria are blue-green algae thought to be one of the earliest life-forms on Earth.
How did early life affect the atmosphere?

Cyanobacteria first appeared on Earth about 3.5 billion years ago. Cyanobacteria contained chlorophyll and used photosynthesis. This is important because during photosynthesis, they produced oxygen, which helped change Earth’s atmosphere. Following the appearance of cyanobacteria, oxygen became a major gas in the atmosphere.

Also of importance was that the ozone layer in the atmosphere began to develop, shielding Earth from ultraviolet rays. It is hypothesized that these changes allowed species of single-celled organisms to evolve into more complex organisms.

Near the end of Precambrian time, invertebrates (ihn VUR tuh brayts) appeared. Invertebrates are animals without backbones. Early invertebrates had soft bodies, so few were preserved as fossils. Because of this, many Precambrian fossils are trace fossils. Examples of trace fossils are tracks, trails, or burrows. Trace fossils provide information about how organisms lived and behaved.

What were other unusual life-forms?

In the late Precambrian, a group of animals lived that were similar to some animals today. These soft-bodied animals looked like modern jellyfish and worms. The first fossils of these earliest invertebrates were found in the Ediacara Hills of Australia. This group of organisms became known as the Ediacaran (ee dee uh KAR un) animals. They have been found on every continent, except Antarctica.

Ediacaran animals lived on the bottom of Precambrian seas. Some scientists think these animals may have had tough outer coverings on their bodies. Trilobites may have outcompeted the Ediacaran animals and caused their extinction. However, no one knows for sure why the Ediacaran animals disappeared.

The Paleozoic Era

Beginning in the Paleozoic (pay lee uh ZOH ihk) Era, animals with shells and other hard body parts began to appear. Because hard body parts are well preserved in fossils, it is easier to find traces of life in this era. The Paleozoic Era, or era of ancient life, began about 544 million years ago and ended about 248 million years ago.
What organisms lived during this era?

During most of the Paleozoic Era, warm, shallow seas covered much of the planet. Many life-forms lived in the oceans. Trilobites were common, especially early in the Paleozoic. Other organisms developed shells. As a result, the fossil record of this time contains many shells. However, invertebrates weren’t the only animals in Paleozoic seas. Animals with backbones, called vertebrates, evolved during this time. The earliest vertebrates were fishlike creatures without jaws. During the Devonian Period, fish with strong jaws evolved. These huge fish, armed with heavy protective coverings on their bodies, could eat large sharks. By the Devonian Period, forests began to grow on land. Some vertebrates adapted to the land environment.

How did early life forms move onto land?

Most fish, both ancient and modern, breathe through gills. But in the Devonian Period, many fish also had lungs. Because of their lungs, they could live in water that had low levels of oxygen and swim to the surface to breathe air.

One kind of ancient fish with lungs also developed fins that were like legs, as shown in the figure below. These leglike fins were used to swim and to crawl around on the ocean floor. Paleontologists hypothesize that today’s amphibians might have evolved from these fish. Modern amphibians, such as frogs, live both in water and on land. All amphibians have one thing in common—they all lay their eggs in water or in a moist place.

3. Describe What did the earliest vertebrates look like?

4. Circle Draw a circle around the leglike fins on the fish shown in the figure.
What adaptations allowed reptiles to remain on land?

By the Pennsylvanian Period, some amphibians evolved eggs that were covered by a protective coating. The coating helped prevent the eggs from drying out. As a result, these animals, called reptiles, did not need to lay their eggs in water. Reptiles also have skin covered with hard scales. The scales prevent water loss from their bodies. These adaptations allow reptiles to live farther from water and in dry climates where many amphibians cannot live.

How were mountains formed?

During the Paleozoic Era, there were great changes on Earth's surface. Several mountain ranges formed during this time. One example is the Appalachian Mountains in the Eastern United States. Mountain building occurred in several stages.

First, North America moved closer to Europe and Africa. This closed the ocean that had separated them. Several volcanic island chains that had been in the ocean collided with the North American Plate. The collision of the plate and the island chains created high mountains.

The next mountain-building event occurred when the African Plate crashed into the North American Plate. This collision formed mountains on both North America and Africa. Rock layers were folded and faulted. Some rocks that were near the eastern coast of the North American Plate were pushed west along faults as far as 65 km. Sediments were uplifted to form an immense mountain belt. Then, about 200 million years ago, the North American and African plates began to separate. The ocean between them began to open up again.

What caused the end of the Paleozoic Era?

At the end of the Paleozoic Era, more than 90 percent of all ocean species and 70 percent of all land species died. Perhaps as the supercontinent Pangaea formed, changes in the ocean and land caused species to die. Another hypothesis is that erupting volcanoes changed Earth so much that organisms could not survive. Perhaps an asteroid hit the planet and destroyed its environments.
After You Read

Mini Glossary

**cyanobacteria**: blue-green algae thought to be one of the earliest life-forms on Earth

**Paleozoic Era**: era that began about 544 million years ago and ended about 248 million years ago; has abundant fossils

**Precambrian time**: longest part of Earth’s history, lasting from about 4.5 billion years ago to about 544 million years ago

1. Review the terms and their definitions in the Mini Glossary. Then write two sentences, one about each time period covered in this section. Use the three vocabulary words in your sentences.

__________________________________________________________________________

__________________________________________________________________________

2. Fill in the blanks in the boxes below.

Blue-green algae, called ____________________________ arose during the ________

Animals without backbones, called ____________________________ arose during the ________

when animals with backbones, called ____________________________, evolved, also evolved.

3. Did highlighting help you understand the information in this section?

__________________________________________________________________________

ScienceOnline Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about the early history of Earth.
What You’ll Learn
■ about Mesozoic and Cenozoic life-forms
■ how plate tectonics affected organisms during the Mesozoic Era
■ when humans first appeared

Before You Read
Think about a picture of a dinosaur you have seen. On the lines below, describe how dinosaurs are different from modern animals.

Read to Learn

The Mesozoic Era
People have been interested in dinosaurs since their bones were first discovered more than 150 years ago. Dinosaurs lived during the Mesozoic (meh zuh ZOH ihk) Era. The Mesozoic Era, or era of middle life, occurred between 248 and 65 million years ago and was a time marked by rapid movement of Earth’s plates.

What changes occurred to Pangaea?
At the beginning of the Mesozoic Era, all the continents were joined and formed one landmass called Pangaea. During a part of the Mesozoic Era called the Triassic Period, Pangaea began to break up. The continents began to drift apart as Earth’s plates moved away from each other. Pangaea split in two. Over time, the continents we know today formed.

Some species, such as reptiles, survived the tremendous changes and mass extinction that occurred at the end of the Paleozoic Era. In the early Mesozoic Era, the climate became drier. The reptile’s scaly skin kept in moisture, so reptiles could live in this drier climate. Reptile eggs are protected by a shell, so their young survived as well. Reptiles became the most abundant animals of the Mesozoic Era.
What were the dinosaurs like?

Dinosaurs came in all shapes and sizes. Some were less than 1 m tall. Others, like *Apatosaurus* and *Tyrannosaurus*, were enormous. The first small dinosaurs appeared in the Triassic Period. Larger dinosaur species evolved during the Jurassic and Cretaceous Periods. Throughout the Mesozoic Era, some dinosaurs became extinct as others evolved.

Were dinosaurs active?

Generally, the faster an animal runs, the farther apart its footprints are. Paleontologists have studied fossil footprints from dinosaurs. They have found that some dinosaur footprints were far apart, indicating that these species were fast runners. Scientists figured out that some dinosaurs could run up to 65 km/h—as fast as a modern racehorse.

Studies also indicate that some dinosaurs might have been warm-blooded animals, not cold-blooded like reptiles. What evidence shows this? The bones of warm-blooded animals don’t have growth rings, like the bones of cold-blooded animals. Dinosaur bones don’t have growth rings either. They are similar to mammal bones as shown in the figures below.

These findings indicate that some dinosaurs were likely active warm-blooded, fast-running animals, similar to modern mammals and birds. In fact, dinosaurs may have been very different from present-day reptiles.

Were dinosaurs good mothers?

The fossil record shows that some dinosaur species fed and took care of their young. These dinosaurs also traveled in herds, so the young were protected. *Maiasaura* acted in this way. *Maiasaura* mothers gathered together to build nests in colonies. The mothers laid their eggs and, after the young hatched, fed and cared for their offspring. Scientists have found fossils of hatchlings and adult dinosaurs in the same nest. *Maiasaura* mothers may have fed and tended their young until they were old enough to leave the nest.
What were the first bird-like creatures?
Some paleontologists believe that modern birds evolved from small, meat-eating dinosaurs. The earliest bird-like dinosaur known, *Archaeopteryx*, had both wings and feathers. Since *Archaeopteryx* had some features different from modern birds, it is not a direct ancestor of today’s birds.

What were the first mammals like?
The first mammals appeared in the Triassic Period. These tiny, mouselike animals were warm-blooded and covered with fur, as shown in the figure below. The females produced milk to feed their young. Because of their furry coat and milk production, mammals were able to survive many changing environments.

What are gymnosperms?
Gymnosperms (JIHM nuh spurmz) first appeared during the Paleozoic Era. By the Mesozoic Era, gymnosperms dominated the land. Gymnosperms are plants that produce seeds in cones, like pine cones. They do not produce flowers. There are many species of gymnosperms on Earth today, including pine trees and ginkgo trees.

What are angiosperms?
Angiosperms (AN jee uh spurmz) are flowering plants that evolved during the Cretaceous Period. Angiosperms produce seeds with hard outer coverings. Because their seeds are covered and protected, angiosperms can survive in many environments. Angiosperms are the most diverse and abundant plants on Earth today. Today’s magnolia trees and oak trees first evolved during the Mesozoic Era.
What ended the Mesozioic Era?

The Mesozoic Era ended about 65 million years ago, when most land and ocean species became extinct. The dinosaurs disappeared. Many paleontologists hypothesize that this mass extinction was caused by an asteroid that collided with Earth. The impact put a huge cloud of dust and smoke in the air, blocking sunlight. Without sunlight, plants died. As a result, the animals that fed on plants died. Some organisms managed to survive. They are the ancestors of the many species on Earth today.

The Cenozoic Era

The Cenozoic (se nuh ZOH ihk) Era began about 65 million years ago and continues today. During this time, mountain ranges in North and South America formed. In the late Cenozoic, the climate cooled and ice ages occurred. The early Cenozoic Era is called the Tertiary Period. The present time is part of the Quaternary Period, which began about 1.8 million years ago.

Which mountain ranges formed during this era?

Many mountain ranges formed during the Cenozoic Era as Earth’s plates moved and collided. These include the Alps in Europe and the Andes in South America. Many people think the growth of these mountains helped create cooler worldwide climates.

How have mammals evolved?

During the Cenozoic Era, grasslands expanded. As a result, grazing mammals like horses, deer, and elephants survived and grew larger. Horses evolved from small animals with many toes into the large, hoofed animals of today. Some mammals evolved to live in the sea, such as dolphins and whales.

As the continents continued to move apart, some species became isolated. For this reason, animals like kangaroos and koalas evolved in Australia and are not found anywhere else on Earth.

Modern humans, Homo sapiens, probably first appeared about 140,000 years ago. The appearance of early humans may have caused the extinction of many other mammals. Humans competed for food that other animals ate and also hunted animals.
After You Read

Mini Glossary

**Cenozoic Era:** geologic time that began about 65 million years ago and is continuing today

**Mesozoic Era:** geologic time between about 248 and 65 million years ago, that was marked by rapid movement of Earth’s plates and was when dinosaurs lived

1. Review the terms and their definitions in the Mini Glossary. Then write one sentence describing one of the eras.

2. Fill in the blanks in the boxes below by listing the plants, animals, and Earth changes for each era.

3. You summarized the main idea in each paragraph as you read this section. How did summarizing help you understand and remember the information in the text?
The Sun-Earth-Moon System

section ● Earth

Before You Read

What do you already know about Earth's shape, its size, and how it moves? Write what you know on the lines below.

What You'll Learn

■ Earth's shape, size, and movements
■ the difference between rotation and revolution
■ what causes the seasons

Read to Learn

Properties of Earth

In the morning, the Sun rises in the east. It moves across the sky during the day. Finally, the Sun sets in the west. Is the Sun moving—or are you?

People once thought that Earth was a flat object at the center of the universe. They believed that the Sun went around Earth in a big circle each day. Now, most people know that Earth is not flat, and the Sun only looks like it is moving around Earth. Scientists have discovered that Earth spins and that Earth moves around the Sun. It is the spinning motion of Earth that makes it look like the Sun is moving across the sky.

What is Earth's shape?

Basketballs, tennis balls, and Earth have something in common. They are all round, three-dimensional objects called spheres (SFIHRZ). The distance from the center of a sphere to any point on the surface is the same.

Aristotle, a Greek astronomer and philosopher who lived around 350 B.C., observed that Earth made a curved shadow on the Moon during an eclipse. His observations led him to think that Earth was a sphere.
How do we know Earth is a sphere?

Today, we have observations from astronauts and pictures from artificial satellites and space probes to show us Earth’s shape. Now we also know Earth is not a perfect sphere. It bulges at the equator and is somewhat flat at the poles. The table below shows the differences in Earth’s diameter at the equator and from pole to pole.

<table>
<thead>
<tr>
<th>Physical Properties of Earth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (pole to pole)</td>
</tr>
<tr>
<td>Diameter (equator)</td>
</tr>
<tr>
<td>Circumference (poles)</td>
</tr>
<tr>
<td>Circumference (equator)</td>
</tr>
<tr>
<td>Mass</td>
</tr>
<tr>
<td>Average density</td>
</tr>
<tr>
<td>Average distance to the Sun</td>
</tr>
<tr>
<td>Period of rotation (1 day)</td>
</tr>
<tr>
<td>Period of revolution (1 year)</td>
</tr>
</tbody>
</table>

Does Earth spin?

Earth spins like a top. The imaginary center line around which Earth spins is called Earth’s **axis**. The poles are at the north and the south ends of Earth’s axis. The spinning of Earth on its axis is called **rotation**.

Earth’s rotation causes day and night. As Earth rotates, your area of Earth faces toward the Sun in the morning and away from the Sun at night. Earth rotates once each day. A rotation takes about 24 hours.

Magnetic Field

Scientists hypothesize that the movement of material inside Earth’s core, along with Earth’s rotation, generates a magnetic field. Like a bar magnet, Earth has opposite north and south magnetic poles. Earth’s magnetic field protects you from harmful radiation. It does this by trapping many charged particles that reach Earth from the Sun.
What is Earth’s magnetic axis?

When a compass needle points north, you are seeing proof of Earth’s magnetic field. The line that joins Earth’s north and south magnetic poles is called its magnetic axis. As shown in the figure above, the magnetic axis does not line up with Earth’s rotational axis. In fact, the location of the magnetic axis changes slowly over time. A compass whose needle points north will lead you to Earth’s magnetic north pole, not the rotational north pole.

What causes changing seasons?

Flowers bloom as the days get warmer. The Sun appears higher in the sky, and daylight lasts longer. Spring seems like a fresh, new beginning. What causes these changes?

Does Earth’s orbit cause seasons?

Recall that Earth’s rotation causes day and night. Another movement of Earth is called revolution. Revolution is Earth’s orbit, or the path of Earth, as it goes around the Sun. It takes a year for Earth to orbit the Sun.

The shape of Earth’s path around the Sun is an ellipse—a long, curved shape, similar to a stretched-out circle. The Sun is not located in the center of the ellipse but is a little toward one end. Earth is closest to the Sun around January 3, and farthest from the Sun around July 4.

Although Earth’s orbit takes it nearer and farther from the Sun, the change in distance is small and does not cause seasons. If Earth’s distance from the Sun caused the seasons, January—when the Earth is nearest to the Sun—would have the warmest days. This is not the case, however, in the northern hemisphere.
Does Earth’s tilted axis cause seasons?

Earth’s axis is tilted 23.5 degrees from a line drawn perpendicular to the plane of its orbit. It is this tilt that causes seasons. The tilt explains why Earth receives such a different amount of solar energy from place to place during the year.

In the northern hemisphere, summer begins in June and ends in September. This is when the northern hemisphere is tilted toward the Sun. During summer, there are more hours of sunlight—or solar energy. Longer periods of sunlight are one reason that summer is warmer than winter, but this is not the only reason.

How does Earth’s tilt affect solar radiation?

Earth’s tilt causes the Sun’s radiation to strike the hemispheres at different angles. Sunlight strikes the hemisphere tilted toward the Sun at an angle closer to 90 degrees than the hemisphere tilted away. Thus the hemisphere tilted toward the Sun receives more solar radiation than the hemisphere tilted away from the Sun.

Summer occurs in the hemisphere tilted toward the Sun, when its radiation strikes Earth at a high angle and for longer periods of time. The hemisphere receiving less radiation experiences winter.

Solstices

The solstice is the day when the Sun reaches its greatest distance north or south of the equator. In the northern hemisphere, the summer solstice occurs on June 21 or 22, and the winter solstice occurs on December 21 or 22. The position of Earth in relation to the Sun at different times of the year is shown in the figure on the next page. In the southern hemisphere, the winter solstice is in June and the summer solstice is in December.

Summer solstice is the longest period of daylight of the year. From the summer solstice to the winter solstice, the number of daylight hours keeps decreasing. The winter solstice is the shortest period of daylight of the year. Then the number of daylight hours begins increasing again.
Equinoxes

An **equinox** (EE kwuh nahks) occurs when the Sun is directly above Earth’s equator. The tilt of Earth’s axis means that the Sun’s position relative to the equator is constantly changing. Most of the time, the Sun is either north or south of the equator. But two times a year the Sun is directly over the equator. This results in the spring and fall equinoxes. At an equinox, the Sun strikes the equator at the highest possible angle, 90 degrees. This can be seen in the figure above.

During an equinox, neither the northern hemisphere nor the southern hemisphere is tilted toward the Sun. The number of daylight hours and nighttime hours is nearly equal all over the world.

In the northern hemisphere, the spring equinox occurs on March 20 or 21, and the fall equinox occurs on September 22 or 23. In the southern hemisphere, the spring equinox occurs in September, while the fall equinox occurs in March.
After You Read

Mini Glossary

axis: imaginary center line around which Earth spins
ellipse (ee LIHPS): elongated, closed curve that described Earth’s yearlong orbit around the sun
equinox (EE kwuh nahks): twice-yearly time—each spring and fall—when the Sun is directly over the equator and the number of daylight and nighttime hours are equal worldwide

revolution: Earth’s yearlong elliptical orbit around the Sun
rotation: spinning of Earth on its axis
solstice: twice-yearly point at which the Sun reaches its greatest distance north or south of the equator
sphere (SFIHR): a round, three-dimensional object whose surface is the same distance from its center at all points

1. Review the terms and their definitions in the Mini Glossary. Write a sentence or two about the effects of Earth’s rotation and its tilted axis.

2. Complete the table by labeling the statements true or false.

<table>
<thead>
<tr>
<th>Earth’s Properties and Seasons</th>
<th>True or False?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth’s shape is a slightly flattened sphere.</td>
<td></td>
</tr>
<tr>
<td>Earth’s seasons are caused by its tilt.</td>
<td></td>
</tr>
<tr>
<td>The shape of Earth’s orbit is a circle.</td>
<td></td>
</tr>
<tr>
<td>The shape of Earth’s orbit is an ellipse.</td>
<td></td>
</tr>
<tr>
<td>After the summer solstice, daylight hours increase.</td>
<td></td>
</tr>
<tr>
<td>During a solstice, the Sun is at its farthest point north or south of the equator.</td>
<td></td>
</tr>
</tbody>
</table>
The Sun-Earth-Moon System

section 2 The Moon—Earth’s Satellite

Before You Read
What do you already know about the moon? List physical characteristics or phases of the moon on the lines below. Check your information as you read the section.

Read to Learn

Motions of the Moon

The Moon’s movements are similar to Earth’s movements. Just as Earth rotates on its axis, the Moon rotates on its axis. Earth revolves around the Sun, while the Moon revolves around Earth. The Moon’s revolution around Earth is responsible for the changes in the Moon’s appearance.

If the Moon rotates on its axis, why can’t you see it spin around in space? The Moon’s rotation takes 27.3 days—the same amount of time it takes to revolve once around Earth. Because these two motions take the same amount of time, the same side of the Moon always faces Earth. So, even though the Moon rotates on its axis, the same side is always visible from Earth.

What lights the Moon?

The surface of the Moon reflects the light of the Sun. Just as half of Earth experiences day as the other half experiences night, half of the Moon is lighted while the other half is dark. As the Moon revolves around Earth, different portions of its lighted side can be seen. This is why the Moon appears to change form or shape.

What You’ll Learn

■ the phases of the Moon
■ why solar and lunar eclipses occur
■ the Moon’s physical characteristics
Phases of the Moon

Moon phases are the different ways the Moon appears from Earth. The phase of the Moon depends on the relative positions of the Moon, Earth, and the Sun, as shown in the figure below.

A new moon occurs when the Moon is between Earth and the Sun. During a new moon, the lighted half of the Moon is facing the Sun and the dark side of the Moon faces Earth. Even though the Moon is in the sky, it cannot be seen. A new moon rises and sets in the sky at the same time as the Sun.

Waxing Phases After the new moon, the phases begin waxing. Waxing means that more of the lighted half of the Moon can be seen each night. About 24 h after a new moon, a thin slice of the Moon can be seen. This phase is called the waxing crescent. About a week after a new moon, you can see half of the lighted side of the Moon, or about one quarter of the Moon’s surface. This is the first quarter phase.

The phases continue to wax. When more than one quarter of the Moon’s surface is visible, it is called waxing gibbous. Gibbous is the Latin word for “humpbacked.” A full moon occurs when all of the Moon’s surface that faces Earth reflects light.
**Waning Phases** After the full moon, the phases are said to be waning. **Waning** means that you can see less and less of the lighted half of the Moon each night. About 24 h after a full moon, you begin to see the waning gibbous moon. About a week after a full moon, you can again see half of the lighted side of the Moon, or one quarter of the Moon’s surface. This is the third-quarter phase. As the waning phases continue, you see less and less of the Moon. The last of the waning phases is the waning crescent, when just a small slice of the Moon is visible. This takes place just before another new moon.

It takes about 29.5 days for the Moon to complete its cycle of phases. Recall that it takes about 27.3 days for the Moon to revolve around Earth. The difference in the numbers is due to Earth’s revolution. It takes about two extra days for the Sun, Earth, and the Moon to return to their same relative positions.

**Eclipses**

Imagine living 10,000 years ago. You are gathering nuts and berries when, without warning, the Sun disappears. The darkness lasts only a short time, and the Sun soon returns to full brightness. You know something strange has happened, but you don’t know why or how. It will be almost 8,000 years before anyone can explain what you just experienced.

The event just described was a total solar eclipse (ih KLIPS). Today, most people know what causes eclipses. What causes the day to become night and then change back into day?

**What causes an eclipse?**

The revolution of the Moon around Earth causes eclipses. Eclipses take place when Earth blocks light from reaching the Moon, or when the Moon blocks light from reaching a part of Earth. Sometimes, during a new moon, the Moon’s shadow falls on Earth. This causes a solar eclipse. During a full moon, Earth may cast a shadow on the Moon. This causes a lunar eclipse.

An eclipse can take place only when the Sun, the Moon, and Earth are lined up perfectly. Because the Moon’s orbit is not in the same plane as Earth’s orbit around the Sun, lunar eclipses take place only a few times each year.
What is an eclipse of the Sun?

A solar eclipse occurs when the Moon moves directly between the Sun and Earth and casts its shadow over part of Earth. A solar eclipse is shown in the figure below. Depending on where you are on Earth, you may be in a total eclipse or a partial eclipse. Only a small area of Earth is part of the total solar eclipse during the eclipse event.

The darkest portion of the Moon’s shadow on Earth is called the umbra (UM bruh). A person standing within the umbra experiences a total solar eclipse. During a total solar eclipse, the only part of the Sun that is visible is a white glow around the edge of the eclipsing Moon.

Surrounding the umbra is a lighter shadow on Earth’s surface. This lighter shadow is called the penumbra (puh NUM bruh). Those who are standing in the penumbra experience a partial solar eclipse. **WARNING:** Regardless of which eclipse you view, never look directly at the Sun. The light can permanently damage your eyes.

---

**Picture This**

5. **Label** On the diagram, label the umbra and the penumbra.
What is an eclipse of the Moon?

When Earth moves directly between the Sun and the Moon and its shadow falls on the Moon, a lunar eclipse occurs. A lunar eclipse begins when the Moon moves into Earth’s penumbra. As the Moon continues to move, it enters Earth’s umbra, and you can see a curved shadow on the Moon’s surface. As the Moon moves completely into Earth’s umbra, it goes dark. This is a total lunar eclipse. A total lunar eclipse is shown in the figure above. Sometimes sunlight bent through Earth’s atmosphere will cause the eclipsed Moon to have a reddish appearance.

A partial lunar eclipse occurs when only a portion of the Moon moves into Earth’s shadow. Then, the rest of the Moon is in Earth’s penumbra and still gets some direct sunlight. When the Moon is totally within Earth’s penumbra, it is called a penumbral lunar eclipse. It is difficult to tell when a penumbral lunar eclipse happens because some sunlight continues to fall on the side of the Moon facing Earth.

Picture This

6. Label On the diagram, label the umbra and penumbra.
During which lunar phase do eclipses occur?
Lunar eclipses do not happen every month. Lunar eclipses happen only during the full moon phase. 
A total lunar eclipse can be seen by anyone on the nighttime side of Earth as long as the Moon is not hidden by clouds. Only a few people get to witness a total solar eclipse, however. Only those in the small area where the Moon’s umbra strikes Earth can witness it.

The Moon’s Surface
When you look at the Moon, you can see many depressions called craters. Meteorites, asteroids, and comets striking the Moon’s surface created most of these craters. When the objects struck the Moon, cracks may have formed in the Moon’s crust, allowing lava to reach the surface and fill up the large craters. Dark, flat regions formed as the lava spread. These regions are called maria (MAHR ee uh).
The igneous rocks of the maria are 3 billion to 4 billion years old. So far, they are the youngest rocks to be found on the Moon. This shows that craters formed after the Moon’s surface had cooled. The maria formed early while molten rock still remained in the Moon’s interior. The Moon must once have been as geologically active as Earth is today. As the Moon cooled, the interior separated into distinct layers.

The Moon’s Origin
Before the Apollo space missions in the 1960s and 1970s, there were three leading theories about the origin of the Moon. One theory was that the Moon was captured by Earth’s gravity. Another stated that the Moon and Earth condensed from the same cloud of dust and gas. An alternative theory proposed that Earth ejected molten material that became the Moon.

What is the impact theory?
The data gathered by the Apollo missions led many scientists to support a new theory. This theory, called the impact theory, states that the Moon formed billions of years ago from condensing gas and debris thrown off when Earth collided with a Mars-sized object. The blast that resulted ejected material from both objects into space. A ring of gas and debris formed around Earth. Finally, particles in that ring joined together to form the Moon.
Inside the Moon

Just as scientists study earthquakes to gather information about Earth’s interior, scientists study moonquakes to understand the structure of the Moon. The information scientists gather from moonquakes has helped them make several possible models of the Moon’s interior. One model is shown in the figure below. In it, the Moon’s crust is about 60 km thick on the side facing Earth. On the side facing away from Earth, the Moon’s crust is thought to be about 150 km thick. Under the crust, another solid layer, the mantle, may be 1,000 km deep. A zone of the mantle where the rock is partly melted may extend even farther down. Below this mantle, there may be a solid, iron-rich core.

What has been learned about the Moon in history?

Much has been learned about the Moon and Earth by studying the Moon’s phases and eclipses. Earth and the Moon are in motion around the Sun. From studying the curved shadow that Earth casts on the Moon, early scientists learned that Earth is a sphere. When Galileo first used his telescope to look at the Moon, he saw that it was not smooth but had craters and maria. Today, scientists study rocks collected from the Moon. By doing so, they hope to learn more about Earth.

Applying Math

10. Calculate About what is the difference in thickness between the Moon’s crust on the side facing Earth and the crust facing away from Earth?

Picture This

11. Interpret Scientific Illustrations List the layers of the Moon in order from the interior to the surface.
After You Read

Mini Glossary

full moon: phase that occurs when all of the Moon's surface facing Earth reflects light

lunar eclipse: occurs when Earth passes directly between the Sun and the Moon and Earth's shadow falls on the Moon

maria (MAHR ee uh): dark-colored, relatively flat regions of the Moon formed when ancient lava reached the surface and filled craters on the Moon's surface

moon phase: change in appearance of the Moon as viewed from the Earth, due to the relative positions of the Moon, Earth, and the Sun

new moon: moon phase that occurs when the Moon is between Earth and the Sun, at which point the Moon cannot be seen because its lighted half is facing the Sun and its dark side faces Earth

solar eclipse: occurs when the Moon passes directly between the Sun and Earth and casts a shadow over part of Earth

waning: describes phases that occur after a full moon, as the visible lighted side of the Moon grows smaller

waxing: describes phases following a new moon, as more of the Moon's lighted side becomes visible

1. Review the terms and their definitions in the Mini Glossary. Write two sentences explaining different phases of the Moon.

2. Fill in the concept map with what you know about eclipses.

Solar eclipses occur at the ____________________________ phase.

A(n) ____________________________ is the darkest portion of the Moon's or Earth's shadow.

Eclipses

People are less likely to see a ____________________________ eclipse than a ____________________________ eclipse.

Lunar eclipses occur at the ____________________________ phase.

End of Section

166 The Sun-Earth-Moon System
The Sun-Earth-Moon System

section 3 Exploring Earth’s Moon

Before You Read

People have always been curious about the Moon. What would you like to know about the Moon? In the space below, write some questions you have about the Moon.

What You’ll Learn

- recent discoveries about the Moon
- facts that might affect future space travel to the Moon

Read to Learn

Missions to the Moon

For centuries, scientists have tried to discover what the Moon is made of and how it formed. In 1959, the former Soviet Union launched the first \textit{Luna} spacecraft. This spacecraft made it possible to study the Moon up close.

Two years later, the United States began a similar space program. The United States launched the first \textit{Ranger} spacecraft and a series of \textit{Lunar Orbiters}. The spacecraft in these early missions took detailed photographs of the Moon.

The \textit{Surveyor} spacecraft were the next step. The \textit{Surveyor} spacecraft were designed to take more detailed photographs and to actually land on the Moon. Five of these spacecraft landed on the Moon’s surface and analyzed lunar soil. The goal of the \textit{Surveyor} program was to gather information about the Moon that would allow astronauts to land there one day.

In 1969, the astronauts of \textit{Apollo 11} landed on the Moon. Between 1969 and 1972, when the \textit{Apollo} missions ended, 12 U.S. astronauts had walked on the Moon.
1. Use Tables  Which Apollo mission deployed the first lunar roving vehicle?

Is the Moon being studied today?
The time line above shows important events in the exploration of the Moon. But, there is still much to learn about the Moon. The United States has started to study the Moon again. In 1994, the spacecraft `Clementine` was placed into lunar orbit. `Clementine`'s purpose was to conduct a survey of the Moon’s surface. An important part of the study was to collect data on the mineral content of Moon rocks. While in orbit around the Moon, `Clementine` also mapped features on the Moon’s surface, including huge impact basins.

What is an impact basin?
An impact basin, or impact crater, is a depression left behind when a meteorite or other object strikes the Moon. The South Pole-Aitken Basin is the oldest impact basin that has been identified so far.

Impact basins like the South Pole-Aitken Basin are very interesting to scientists. Because this deep crater is located at one of the poles, the Sun’s rays never reach the bottom of the crater. Therefore, the bottom of the crater is always in shadow. The temperatures there are extremely cold. Scientists hypothesize that if a comet collided with the Moon, ice could have been deposited there. Some of that ice might still be found in the shadows at the bottom of the crater. In fact, `Clementine` sent information that showed the presence of water, just as scientists had hypothesized.
**Mapping the Moon**

Photographs taken by *Clementine* were used to create detailed maps of the Moon’s surface. Data from *Clementine* showed that the Moon’s crust did not have the same thickness all over the Moon. The crust on the side of the Moon that faces Earth is much thinner than the crust on the far side. Additional information showed that the Moon’s crust is thinnest under impact basins.

**What is the Lunar Prospector?**

In 1998, NASA sent the small *Lunar Prospector* spacecraft into orbit around the Moon. For one year the spacecraft circled the Moon from one pole to the other. It flew around the Moon once every two hours.

The *Lunar Prospector* collected data that confirmed that the Moon has a small, iron-rich core at its center. This finding supports the impact theory of how the Moon was formed. The small core is a result of a small amount of iron that could have blasted away from Earth.

**Where is there ice on the Moon?**

In addition to photographing the surface, *Lunar Prospector* carried instruments that gathered information for mapping the Moon. The maps were of the Moon’s gravity, its magnetic field, and how much and where certain elements were found in the Moon’s crust. Scientists finally had data from the entire surface of the Moon, rather than just the areas around the Moon’s equator.

The *Lunar Prospector* confirmed that ice was present in deep craters at both poles of the Moon. Using data from *Lunar Prospector*, scientists made maps that show the location of ice at each pole. At first scientists thought that ice crystals were mixed with lunar soil. More recent information suggests that the ice deposit may be in the form of more compact deposits.
After You Read

Mini Glossary

impact basin: a depression left on the surface of the Moon caused by an object striking its surface

1. Review the term and its definition in the Mini Glossary. Write a sentence explaining what causes impact basins to form.

2. Complete the chart to review missions that gathered information about the Moon.

<table>
<thead>
<tr>
<th>Spacecraft</th>
<th>Mission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ranger and Lunar Orbiters</td>
<td>To photograph the Moon</td>
</tr>
<tr>
<td>Surveyor</td>
<td></td>
</tr>
<tr>
<td>Clementine</td>
<td></td>
</tr>
<tr>
<td>Lunar Prospector</td>
<td></td>
</tr>
</tbody>
</table>

3. How did highlighting help you read this section? Reread the sentences you highlighted in the text. Now that you have read the entire section, do you think you highlighted the right sentences? Make any corrections you think would help you.

End of Section

Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about exploring Earth’s moon.
Before You Read

Name the planets in the solar system that you already know.

Read to Learn

Ideas About the Solar System

Based on their observations, early humans believed the Sun and planets moved around Earth. Today, people understand that Earth and the other planets and objects in the solar system orbit, or move around, the Sun.

Earth-Centered Model Early Greek scientists thought the planets, the Sun, the Moon, and the stars rotated around Earth. This is called the Earth-centered model of the solar system. It included Earth, the Moon, the Sun, five planets—Mercury, Venus, Mars, Jupiter, and Saturn—and the stars.

Sun-Centered Model In 1543, Nicholas Copernicus published his model of the solar system. He stated that Earth and the other planets revolved around the Sun and that the Moon revolved around Earth. He explained that the Sun and the planets only looked like they were moving around Earth because Earth rotates. This is the Sun-centered model of the solar system.

Galileo Galilei used his telescope to observe that Venus went through a full cycle of phases like the Moon’s. Also, Venus looked smaller when its phase was near full. This could only be explained if Venus were orbiting the Sun, not Earth. Galileo concluded that the Sun is the center of the solar system.

What You’ll Learn

- past and present ideas about the solar system
- how the solar system formed
- how the Sun’s gravity holds planets in orbit

Ask Questions As you read, write down your questions. Use the questions to find out more about topics that are not clear, or topics that are particularly interesting.

Find Main Ideas Make the following two-tab Foldable to help you identify the main ideas about past and present views on the solar system.
What is the modern view of the solar system?

Today, we know that the solar system is made up of nine planets, including Earth, and many smaller objects that orbit the Sun. The Sun and the position of the nine planets relative to the Sun are shown in the figure on this page and the next page. The solar system also includes a huge amount of space that stretches out in all directions from the Sun.

The Sun contains 99.86 percent of the mass in the solar system. Therefore, the Sun has a lot of gravity. The Sun’s gravity is strong enough to hold the planets and other objects in their orbits.

How the Solar System Formed

Scientists hypothesize that the solar system formed more than 4.6 billion years ago. They have found clues that it may have formed from a cloud of gas, ice, and dust. Over time, this cloud pulled together to form a large, tightly packed, spinning disk. The center of the disk heated up to about 10 million degrees Celsius, and the reaction known as nuclear fusion began. That is how the star, the Sun, formed at the center of the solar system.

How did the planets form?

Not all of the gas, ice, and dust was pulled into the center of the spinning disk to form the Sun. Some matter collided and stuck together to form planets and asteroids. The nine planets of the solar system are divided into two groups, the inner planets and the outer planets.
What are the nine planets?

The inner planets of the solar system—Mercury, Venus, Earth, and Mars—are small, rocky planets with iron cores. The outer planets are Jupiter, Saturn, Uranus, Neptune, and Pluto. Except for Pluto, the outer planets are much larger than the inner planets. They are made up mostly of lighter substances, including hydrogen, helium, methane, and ammonia.

These light substances are not found in great quantities in the inner planets. The high temperatures closer to the Sun turned these substances to gas. They could not cool enough to form solids.

Motions of the Planets

When Nicholas Copernicus developed his Sun-centered model of the solar system, he thought the orbits of the planets were circles. In the early 1600s, Johannes Kepler discovered that the orbits of the planets are oval shaped, or elliptical. He also found that the Sun’s position in the orbits is slightly off-center.

Kepler discovered that the planets orbit the Sun at different speeds. Planets closer to the Sun travel faster than planets farther away from the Sun. The outer planets also have longer distances to travel and take much longer to orbit the Sun than the inner planets.
After You Read

Mini Glossary

solar system: system of nine planets, including Earth, and many smaller objects that orbit the Sun

1. Review the term and its definition in the Mini Glossary. On the lines below, write something you have learned about the solar system.

_________________________________________________________________

_________________________________________________________________

2. Complete the chart that shows how the solar system may have formed.

| 1. The solar system formed from a cloud of ________________, ________________, and ________________. |
| 2. The cloud condensed to form a(n) ________________________________. |
| 3. ________________ formed first. It was at the center of the new solar system. |
| 4. The other material in the solar system collided and formed ________________ planets. |
| 5. The inner planets are ________________, ________________, ________________, and ________________. The outer planets are ________________, ________________, ________________, ________________, and ________________. |

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 write help you understand the information?

_________________________________________________________________

ScienceOnline Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about the solar system.
Before You Read

What do you know about Mercury and Venus? What would you like to know about these inner planets?

Read to Learn

Inner Planets

Today, people know a great deal about the solar system. Scientists use telescopes to study the planets both from Earth and from space. They also use space probes to study the solar system. Much of the information you will read in this section was gathered by space probes.

Mercury

Mercury is the planet closest to the Sun. The spacecraft Mariner 10 sent pictures of Mercury to Earth in 1974 and 1975. Scientists learned that Mercury, like Earth’s Moon, has many craters. But unlike the Moon, Mercury has cliffs as high as 3 km on its surface. These cliffs might have formed when the crust of the planet broke as the core of the planet was cooling and shrinking.

Scientists learned that Mercury has a weak magnetic field. This shows that Mercury has an iron core, the same as Earth. Some scientists think that Mercury’s crust solidified while the iron core was still hot and liquid. As the core became more solid, it became smaller. The cliffs resulted from breaks in Mercury’s crust caused by the shrinking of the core.

Study Coach

Make Flash Cards Make four flash cards to help you study this section. On one side of the card, write the name of an inner planet. On the other side, write facts about that planet.

Compare and Contrast

Foldable to understand how the inner planets are similar and different.
Does Mercury have an atmosphere?
Mercury has no true atmosphere. This is because Mercury has a low gravitational pull and high temperatures during the day. Most gases that could form an atmosphere escape into space. Earth-based observations have found traces of sodium and potassium around the planet. However, these atoms probably come from rocks in Mercury’s crust. Therefore, Mercury has no true atmosphere. This lack of atmosphere and its nearness to the Sun cause Mercury to have great extremes in temperature. Mercury’s temperature can reach as high as 425°C during the day, and it can fall to as low as −170°C at night. A picture of Mercury and some facts about the planet are shown below.

Venus

Venus is the second planet from the Sun. Venus is sometimes called Earth’s twin because its size and mass are similar to Earth’s. When Mariner 2 flew past Venus in 1962, the satellite sent back information about Venus’s atmosphere and rotation. From 1990 to 1994, the U.S. Magellan probe used radar to make detailed maps of Venus’s surface. A picture of Venus and some facts about the planet are shown below.

Think it Over
2. Identify What are some physical characteristics of Venus?

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How hot is it on Venus?

The thick clouds on Venus block most of the Sun’s light from reaching the planet’s surface. The clouds and carbon dioxide gas in the atmosphere trap heat from the Sun. Temperatures on the surface of Venus range from 450°C to 475°C.

Earth

Earth is the third planet from the Sun. It is about 150 million km from the Sun, or one astronomical unit (AU). Earth is the only planet in the solar system that has large amounts of liquid water. More than 70 percent of Earth’s surface is covered by liquid water. Earth is also the only planet that supports life. Earth’s atmosphere protects life forms from the Sun’s harmful radiation. The atmosphere also causes most meteors to burn up before they reach the surface of the planet. A picture of Earth and some facts about the planet are shown below.

Mars

Mars is the fourth planet from the Sun. It is called the red planet. Its red color is caused by iron oxide in the soil. Polar ice caps on Mars can be seen through telescopes from Earth. The ice caps are made of frozen water covered by a layer of frozen carbon dioxide. A picture of Mars and some facts about the planet are shown below.
What have scientists learned from missions to Mars?
Several spacecraft have made missions to Mars. From these missions, scientists have learned that there are long channels on the planet that might have been carved by flowing water. The largest known volcano in the solar system is on Mars. It is called Olympus Mons. It is probably not an active volcano. There are also large valleys in the Martian crust.

What did the Viking probes do?
The Viking 1 and 2 probes arrived at Mars in 1976. Each probe had two parts—an orbiter and a lander. The orbiters remained in space. They took photographs of the entire surface of Mars. The landers touched down on the surface of Mars. They carried equipment to search for signs of life on the planet. No conclusive evidence of life was found on Mars.

How were Pathfinder, Global Surveyor, and Odyssey used?
The Mars Pathfinder analyzed Martian rock and soil. These data indicated that iron might have reached the surface of Mars from underground. Global Surveyor took pictures that showed features like gullies that could have been formed by flowing water. Mars Odyssey had instruments that detected frozen water. The water forms a layer of frost under a thin layer of soil. It is possible that volcanic activity might melt frost beneath the Martian surface. The features look similar to those formed by flash floods on Earth, such as on Mount St. Helens. You can see how they compare in the figure below.
What makes up Mars’s atmosphere?
Mars’s atmosphere is much thinner than Earth’s atmosphere. It is made up mostly of carbon dioxide with some nitrogen and argon. Temperatures on the surface of Mars can be as high as 35°C and as low as −125°C. The change in temperature between day and night causes strong winds, which in turn cause global dust storms. This information is important if humans ever explore Mars.

Are there seasons on Mars?
Mars’s axis is tilted 25°, which is close to Earth’s tilt of 23.5°. So, Mars has seasons as it orbits the Sun. The polar ice caps on Mars change with the season. During winter, carbon dioxide freezes at the poles. The polar ice caps get larger. During summer, the carbon dioxide ice changes to gas. The ice caps get smaller. It is winter at one pole when it is summer at the other pole. The color of the ice caps and other areas on Mars also changes with the seasons. This is due to the movement of dust and sand during dust storms.

Does Mars have moons?
Mars has two small moons—Phobos and Deimos. Phobos orbits Mars once every 7 hours. It has a large crater and chains of smaller craters. Deimos orbits Mars once every 31 hours. It is farther away from Mars’s surface. Its surface looks smoother than that of Phobos. Its craters have partially filled with soil and rock.
After You Read

Mini Glossary

Earth: third planet from the Sun; has plenty of liquid water and an atmosphere that protects life

Mars: fourth planet from the Sun; has polar ice caps and a reddish appearance caused by iron oxide in the soil

Mercury: planet closest to the Sun; does not have a true atmosphere; has a surface with many craters and high cliffs

Venus: second planet from the Sun; similar to Earth in mass and size; has thick clouds

1. Review the terms and their definitions in the Mini Glossary. Write something interesting you learned about Mars, Venus, or Mercury.

2. Complete the table to organize the information from this section.

<table>
<thead>
<tr>
<th>THE INNER PLANETS</th>
<th>ORDER FROM SUN</th>
<th>ATMOSPHERE</th>
<th>TEMPERATURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>MERCURY</td>
<td>Closest</td>
<td></td>
<td>Highs: 425°C Lows: –170°C</td>
</tr>
<tr>
<td>VENUS</td>
<td></td>
<td>Heavy clouds Carbon dioxide gas</td>
<td>Highs: _____ Lows: _____</td>
</tr>
<tr>
<td>EARTH</td>
<td>3rd</td>
<td></td>
<td>Not given</td>
</tr>
<tr>
<td>MARS</td>
<td></td>
<td>Mostly carbon dioxide Some nitrogen and argon</td>
<td></td>
</tr>
</tbody>
</table>

3. Review the flash cards you made. How did this help you learn the content of the section? How could you use the flash cards to prepare for a test on the inner planets?
The Solar System

section ☞ The Outer Planets

Before You Read
What do you know about the outer planets Jupiter, Uranus, Saturn, Neptune, or Pluto? What would you like to learn?

What You’ll Learn
■ facts about the outer planets: Jupiter, Uranus, Saturn, Neptune, and Pluto
■ how Pluto is different from other planets

Read to Learn

Outer Planets

Voyager, Galileo, and Cassini were not the first space probes to explore the outer planets. However, much new information about the outer planets has come from these probes.

Jupiter

Jupiter is the fifth planet from the Sun. It is the largest planet in the solar system. Data from space probes show that Jupiter has faint rings around it made of dust. Io, one of Jupiter’s moons, has active volcanoes.

What is Jupiter’s atmosphere made of?

Jupiter is made up mostly of hydrogen and helium with some ammonia, methane, and water vapor. Scientists hypothesize that the atmosphere of hydrogen and helium gas changes to liquid hydrogen and helium toward the middle of the planet. Below this liquid layer may be a rocky core that is probably different from any rock on Earth.

Jupiter’s atmosphere has bands of white, red, brown, and tan clouds. Storms of swirling gas have been observed on the planet. The Great Red Spot is the most spectacular of these storms.

Make Flash Cards
Make five flash cards to help you study this section. On one side of each card, write the name of one of the outer planets. On the other side, write facts about that planet.

Compare and Contrast

Foldables™
Foldable to help you understand how the outer planets are similar and different.
How many moons orbit Jupiter?
At least 61 moons orbit Jupiter. In 1610, the astronomer Galileo Galilei was the first person to see the four largest moons. Io (I oh) is the large moon closest to Jupiter. Jupiter’s gravity and the gravity of the next large moon, Europa, pull on Io. This force heats up Io. The result is that Io has the most active volcanoes in the entire solar system.

Europa is made up mostly of rock. It has a thick crust of ice. Under the ice there might be a deep ocean. If this ocean does exist, it would be one of the few places in the solar system with large quantities of liquid water. The next moon is Ganymede. Ganymede is the largest moon in the solar system—larger than the planet Mercury. Callisto, the last of Jupiter’s large moons, is made up mostly of ice and rock. Callisto is another place in the solar system where there may be a large quantity of water. Pictures of Jupiter and Callisto, as well as some facts about Jupiter, are shown below.

Saturn
Saturn is the sixth planet from the Sun. It is the second-largest planet in the solar system. Saturn is the least dense planet in the solar system.

What is Saturn’s atmosphere like?
Saturn is similar to Jupiter. Both planets are large and made up mostly of gas. Saturn has a thick outer atmosphere made up mostly of hydrogen and helium. Deeper within the atmosphere the gases change to liquid. Below its atmosphere and liquid layers, Saturn might have a small, rocky core.
What are Saturn’s rings and moons like?

Each of Saturn’s large rings is made up of thousands of thin rings. These are made of ice and rock particles. Some particles are as tiny as a speck of dust, and some are tens of meters across. Saturn has the most complex ring system in the solar system.

At least 31 moons orbit Saturn. The planet’s gravity holds them in their orbits. Titan is the largest of Saturn’s moons. It is larger than the planet Mercury. A picture of Saturn and some facts about the planet are shown below.

Uranus

Uranus (YOOR uh nus) is the seventh planet from the Sun. It is a large planet and also is made up mostly of gas. Thin, dark rings surround the equator. Scientists know that Uranus has at least 21 moons. Its largest moon, Titania, has many craters and deep valleys.

What are the characteristics of Uranus?

The atmosphere of Uranus is made up of hydrogen, helium, and some methane. Methane gives the planet a bluish-green color. A few clouds and storms can be seen on Uranus. There may be liquid water under its atmosphere.

Uranus has an unusual rotation. It is tilted on its side. The axes of rotation of the other planets, except Pluto, are nearly perpendicular to the planes of their orbits. Uranus’s axis of rotation is nearly parallel to the plane of its orbit. Some scientists believe that a collision may have caused Uranus to tip over in this way. A picture of Uranus and some facts about the planet are shown above.
5. Recognize Cause and Effect

What gas causes Uranus and Neptune to have a bluish-green color?

a. hydrogen  
b. methane  
c. helium  
d. carbon dioxide

6. Infer

Could Pluto support life?

Neptune

Neptune is usually the eighth planet from the Sun. However, part of Pluto’s orbit crosses inside Neptune’s orbit. From 1979 until 1999, Pluto was closer to the Sun than Neptune was.

What characteristics does Neptune have?

Neptune’s atmosphere is similar to Uranus’s atmosphere. Methane gives the atmosphere of Neptune its bluish-green color, just as it does for Uranus. Neptune has dark-colored storms similar to the Great Red Spot on Jupiter. These storms and bright clouds form and disappear. This shows that Neptune’s atmosphere is active and changes rapidly.

There may be a layer of liquid water under Neptune’s atmosphere. The planet probably has a rocky core. Neptune has at least 11 moons and several rings. Neptune’s largest moon, Triton, has a thin atmosphere made up mostly of nitrogen and methane.

Pluto

Pluto is the smallest planet in the solar system. It is the ninth planet from the Sun. However, at times Pluto’s orbit crosses inside Neptune’s orbit. It takes Pluto 248 years to orbit the Sun.

Pluto is very different from the other outer planets. It has a thin atmosphere, and all the other outer planets have very thick atmospheres. Pluto has a solid, icy-rock surface. All the other outer planets are believed to have liquid layers around rocky cores.

Does Pluto have a moon?

Pluto has one moon, called Charon. Pluto and Charon are so close in size that some scientists consider them to be two planets. Many scientists think that Pluto and Charon are actually part of an area called the Kuiper Belt. The Kuiper Belt is a large disk of icy objects that lies beyond the orbit of Neptune.
After You Read

Mini Glossary

Great Red Spot: giant, high-pressure storm in Jupiter’s atmosphere
Jupiter: largest planet, and fifth planet from the Sun; has an atmosphere made up mostly of hydrogen and helium
Neptune: usually the eighth planet from the Sun; is large, gaseous, and bluish-green in color
Pluto: usually the ninth planet from the Sun; has a solid icy-rock surface and a single moon, Charon
Saturn: second-largest and sixth planet from the Sun; has a complex ring system, at least 31 moons, and a thick atmosphere made mostly of hydrogen and helium
Uranus (YOO rh uhs): seventh planet from the Sun; is large and gaseous, has a distinct bluish-green color.

1. Review the terms and their definitions in the Mini Glossary. Choose an outer planet and write a sentence that tells something you learned about it.

2. Complete the table below to organize the information from this section.

<table>
<thead>
<tr>
<th>THE OUTER PLANETS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORDER FROM THE Sun</td>
</tr>
<tr>
<td>Jupiter 5th</td>
</tr>
<tr>
<td>Saturn</td>
</tr>
<tr>
<td>Uranus 7th</td>
</tr>
<tr>
<td>Neptune</td>
</tr>
<tr>
<td>Pluto Usually, 9th</td>
</tr>
</tbody>
</table>

Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about the outer planets.
Before You Read

Look up into the sky on a clear night. There are many objects you can see in addition to the Moon. What do you think these objects are? What would you like to know about them?

Read to Learn

Comets

Planets and moons are not the only objects in the solar system. Comets, meteoroids, and asteroids are other important objects that orbit the Sun.

You may have heard of Halley’s Comet. A comet is made up of dust and pieces of rock mixed with frozen water, methane, and ammonia. Halley’s Comet was last seen from Earth in 1986. It takes Halley’s Comet 76 years to orbit the Sun. Astronomer Jan Oort suggested that billions of comets surround the solar system. This cloud of comets, called the Oort Cloud, is located beyond the orbit of Pluto.

What is the structure of a comet?

A comet is a mass of frozen ice and rock similar to a large, dirty snowball. As a comet approaches the Sun, the Sun’s heat turns the ice to gas. This releases dust and bits of rock which form a bright cloud, or coma, around the nucleus, or solid part, of the comet. The solar wind pushes on the gas and dust to form tails that point away from the Sun.
1. Define What is a meteor shower?

2. Interpret Scientific Illustrations Between the orbits of which planets is the asteroid belt located?

3. Explain What is important about studying objects in space?

Meteoroids, Meteors, and Meteorites

After many trips around the Sun, most of the ice in a comet’s nucleus has evaporated. The comet is now just rocks and dust, spread out within the original comet’s orbit. These objects are called meteoroids. A meteoroid that enters Earth’s atmosphere and burns up is called a meteor. Another term for a meteor is a shooting star.

Whenever Earth passes through the old orbit of a comet, small pieces of rock and dust enter Earth’s atmosphere. The event is called a meteor shower. A meteorite is a large meteoroid that does not burn up completely in Earth’s atmosphere and strikes Earth. Most meteorites are probably the remains from asteroid collisions or broken-up comets. Others come from the Moon and Mars.

Asteroids

An asteroid is a piece of rock made up of material like that which formed the planets. Most asteroids are located in an area between the orbits of Mars and Jupiter called the asteroid belt as shown in the figure. Other asteroids are scattered throughout the solar system.

What else do we know about asteroids?

Some asteroids are tiny. Others measure hundreds of kilometers. The first asteroid ever discovered, Ceres, is the largest. It measures 940 km in diameter.

Comets, asteroids, and most meteorites were formed early in the history of the solar system. Scientists study these space objects to learn what the solar system might have been like long ago. Understanding this could help scientists better understand how Earth formed.
After You Read

Mini Glossary

asteroid: a piece of rock made up of material similar to that which formed the planets
comet: space object made of dust and rock particles mixed with frozen water, methane, and ammonia

1. Review the terms and their definitions in the Mini Glossary. Write a sentence to tell what the Oort cloud is.

2. Complete the concept chart with the correct words from the Mini Glossary.

<table>
<thead>
<tr>
<th>Other Objects in the Solar System</th>
</tr>
</thead>
<tbody>
<tr>
<td>meteor: a meteoroid that burns up in Earth’s atmosphere</td>
</tr>
<tr>
<td>lies between the orbits of Mars and Jupiter</td>
</tr>
<tr>
<td>rock from space that strikes Earth’s surface</td>
</tr>
<tr>
<td>space object made of dust and rock particles mixed with frozen water, methane, and ammonia</td>
</tr>
</tbody>
</table>

3. Reread the sentences you highlighted in the text. Did this strategy help you describe comets, meteors, and asteroids? Work with a partner and take turns describing space objects to each other.

End of Section

Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about other objects in the solar system.
Before You Read
Describe the sky on a cloudless, moonless night. What would you see? Write the names of any stars you know about.

Read to Learn
Constellations
It’s fun to look at clouds and find animals, faces, and objects. It takes more imagination to play this game with stars. Ancient Greeks, Romans, and other people who lived long ago found patterns, or shapes, made by stars in the night sky. These star patterns are called constellations (kah-nuh stuh LAY shuns). In these star patterns, they saw characters, animals, and objects from stories they knew well.

From Earth, a constellation looks like spots of light arranged in a particular shape against the night sky. However, the stars in a constellation often have no relationship to each other in space.

What are some common constellations?
Modern astronomy divides the sky into 88 constellations. Many of these were named by early astronomers. The Big Dipper is part of the constellation Ursa Major. The two stars at the front of the Big Dipper point to the star Polaris. Polaris is often called the North Star. That is because Polaris is almost directly over Earth’s north pole. Polaris is located at the end of the Little Dipper in the constellation Ursa Minor. See the figure on the next page for the locations of Polaris, the Big Dipper, and the Little Dipper.
Why do constellations appear to move?

You may have noticed that stars appear to move during the night. Constellations in the northern sky appear to circle around Polaris. Because of this, they are called circumpolar constellations. They appear to move because Earth is moving.

The figure above shows the circumpolar constellations rotating around Polaris. Because of their unique position, you can see the circumpolar constellations all year long. Other constellations, like Orion, can only be seen in certain seasons. In the summer, Orion can’t be seen north of the equator because the northern hemisphere faces Orion during the day.

Absolute and Apparent Magnitudes

When you look at constellations, you’ll notice that some stars are brighter than others. Sometimes stars look brighter than others because they’re closer to Earth.

There are two ways to describe a star’s brightness. The absolute magnitude (MAG nuh tewd) of a star is the amount of light it gives off. The apparent magnitude is the amount of light that reaches Earth, or how bright it looks. A star that is dim can look bright in the sky if it’s close to Earth. A star that is bright can appear dim if it’s far away. For example, Rigel is a brighter star than Sirius, but Sirius appears brighter because it is 100 times closer to Earth than Rigel is.
Measurement In Space

One way scientists measure the distance between Earth and a nearby star is to measure parallax (PER uh laks). Parallax is what makes an object seem to change its position when you look at it from two different positions. Stretch your arm out in front of you and look at your thumb with one eye closed. Now open your eye and close your other eye and look at your thumb. Your thumb looks like it has moved, even though it has not. That apparent shift is parallax. Try it again, but with your thumb closer to your face. What did you see? Your thumb appears to move when it is closer to your eyes. The nearer an object is, the greater its parallax.

How is parallax measured?

Astronomers measure the parallax of a nearby star to see how far away it is from Earth. Astronomers observe the same star at two different times of the year. Astronomers look at how the star seems to change positions compared with stars that are farther away. Then they use the angle of the parallax and the size of Earth’s orbit to calculate the distance of the star from Earth.

Space is so enormous that scientists need a special way to describe distances. Distances between stars and galaxies are measured in light-years. A light-year is the distance that light travels in one year. Light travels 300,000 km/s.

Properties of Stars

The color of a star indicates its temperature. For example, hot stars are a blue-white color. Stars that have a medium temperature, like the Sun, are yellow. A cooler star looks orange or red.

Astronomers use an instrument called a spectroscope to learn what a star is made of. The spectroscope spreads light out into a band of colors which might include dark lines. These dark lines stand for elements in a star’s atmosphere. These patterns of lines help astronomers identify the elements in a star’s atmosphere.
After You Read

Mini Glossary

absolute magnitude (MAG nuh tewd): the amount of light that a star gives off
apparent magnitude: the amount of a star's light that reaches Earth

constellation (kahn stuh LAY shun): a group of stars that forms a pattern in the night sky
light-year: the distance that light travels in one year

1. Review the terms and their definitions in the Mini Glossary. Write a sentence to explain why two stars can have the same absolute magnitude but may have different apparent magnitudes.

2. Complete the diagram to explain what you learned about stars.

Stars

- are a group of stars arranged in a pattern.
- is often called the North Star.
- Stars seem to move in the night sky because Earth

- Absolute magnitude describes a star's ___________________.
- The hottest stars are blue-white. Cooler stars are ___________________.
- The distance between stars is measured in ___________________.

3. Look back at the K-W-L chart you made as you read this section. Did you add to what you already knew? Did you learn what you wanted to know? Did the K-W-L chart help you to understand what you read?
The Sun

The Sun is an ordinary star and is the center of our solar system. It is also the closest star to Earth. Almost all life on Earth depends on energy from the Sun.

Like other stars, the Sun is an enormous ball of gas that produces energy in its core, or center. This energy is produced by fusing hydrogen into helium. This energy travels outward to the Sun’s atmosphere. The energy is given off as light and heat.

The Sun’s Atmosphere

The Sun is made up of different layers. The lowest layer of the Sun’s atmosphere is the photosphere (FOH tuh sfihr). This is the layer that gives off the light we see from Earth. The photosphere is often called the surface of the Sun. Temperatures there are about 6,000 K. The layer above the photosphere is called the chromosphere (KROH muh sfihr). This layer is about 2,000 km thick. There is a change of zone between 2,000 km and 10,000 km above the photosphere. Above this zone is the outer layer of the Sun’s atmosphere. This outer layer is called the corona (kuh ROH nuh). The corona is the largest layer of the Sun’s atmosphere. It reaches millions of kilometers into space. The illustration on the next page shows the different layers of the Sun.
Surface Features

From our point of view on Earth, the Sun’s surface looks smooth. But the Sun’s surface has many features. Among them are sunspots, prominences, flares, and CMEs.

**What is a sunspot?**

Sunspots are areas of the Sun’s surface that appear dark. Sunspots look this way because they are cooler than the area around them. Scientists have been studying sunspots for hundreds of years. They have observed the way that sunspots move. The fact that sunspots move has led scientists to determine that the Sun rotates. However, the Sun does not rotate like Earth does. The Sun rotates faster at its equator than at its poles. Sunspots near the equator take about 25 days to rotate once. Near the poles, sunspots take about 35 days.

Sunspots are not permanent features on the Sun. They appear and disappear over days, weeks, or months. The number of sunspots increases and decreases in a regular cycle of time. About every 10 or 11 years, there is a period of many large sunspots. In between those times, there are fewer sunspots.

**What are prominences and solar flares?**

Sunspots are related to other features on the Sun’s surface. Sunspots and strong magnetic fields are found together on the Sun. The magnetic fields might cause prominences, which are huge arching columns of gas.

The gases near a sunspot may suddenly brighten and rapidly shoot outward. This is called a solar flare.
What is a CME?

When large amounts of electrically-charged gas shoot out from the Sun's corona, the event is called a CME. CME stands for coronal mass ejection.

CMEs present little danger to life on Earth, but they do affect our planet. CMEs can damage satellites. They can cause radio interference. Near the poles, they can produce a display of shifting colorful lights in the night sky. These displays tend to occur at Earth's poles. One such display of lights is called the Aurora borealis, or northern lights. The picture below shows the Aurora borealis.

Think it Over

3. Infer Why do you think the Aurora borealis is also known as the northern lights?

The Sun—An Average Star

The Sun is an average star. It is middle-aged and its absolute magnitude is about average. The Sun shines with a yellow light. Although the Sun is an average star, it is much closer to Earth than other stars. Light from the Sun reaches Earth in about eight minutes. Light from other stars takes many years to reach Earth.

The Sun is unusual in one way. It is not close to any other stars. Most stars are found in groups of two or more stars that orbit each other. Stars can also be held together by each other's gravity. This kind of group is a star cluster. Most star clusters are far from the solar system. They might be visible as a fuzzy bright patch in the night sky.

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After You Read

Mini Glossary

- **chromosphere (KROH muh sfihr)**: one of the middle layers of the Sun’s atmosphere
- **corona (kuh ROH nuh)**: the top, largest layer of the Sun’s atmosphere
- **photosphere (FOH tuh sfihr)**: the lowest layer of the Sun’s atmosphere; gives off light
- **sunspot**: an area on the Sun’s surface that is cooler and less bright than surrounding areas

1. Review the terms and their definitions in the Mini Glossary. Write a sentence using three terms to describe the Sun’s atmosphere.

2. Complete the chart to show how the Sun is like other stars and different from other stars.

<table>
<thead>
<tr>
<th>Similarities</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is a huge ball of _______________.</td>
<td>Its light reaches Earth in _______________.</td>
</tr>
<tr>
<td>It produces energy in its _______________.</td>
<td>Life on _______________. depends on it.</td>
</tr>
<tr>
<td>It has an _______________. that has different layers. One is the corona.</td>
<td>It is not close to other _______________.</td>
</tr>
</tbody>
</table>

3. Look at the list of words you brainstormed to describe the Sun before you read this section. What words would you add to this list? Look at the text you underlined to describe the Sun. Now look at your new list. What was the most surprising thing you learned about the Sun?

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End of Section

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

What makes one star different from another? Do you think the Sun is the same as other stars? Write your ideas on the lines below.

What You’ll Learn

- how stars are sorted into groups
- ways the Sun is the same as other types of stars
- ways the Sun is different from other types of stars
- how stars develop

Read to Learn

Classifying Stars

When you look at the night sky, all stars might look about the same. However, they’re very different. They vary in age and size. They vary in temperature and brightness as well. These features led scientists to organize stars into categories, or groups.

How is a star’s temperature related to its brightness?

In the early 1900s, two scientists named Ejnar Hertzsprung and Henry Russell noticed that hotter stars are usually brighter. In other words, stars with higher temperatures have brighter absolute magnitudes.

How do scientists show this relationship?

Hertzsprung and Russell developed a graph to show this relationship. You can see this graph on the next page. The temperatures are at the bottom. Absolute magnitude goes up the left side. A graph that shows this relationship between a star’s temperature and its brightness is called a Hertzsprung-Russell diagram, or an H-R diagram.

Make Flash Cards to help you record new vocabulary words. Write the word on one side of the flash card and a brief definition on the other side.

Create a Foldable as shown below about evolution of stars. Label the three columns Star Classification, Star Temperature and Color, and How a Star Evolves.
What is the main sequence?

The H-R diagram above shows the connection between a star’s temperature and its brightness. As you can see, most stars seem to fit into a band that runs from the upper left to the lower right. This band is called the main sequence. Hot, blue, bright stars begin at 20,000 K and continue to about 15,000 K. Cool, red, dim stars range from 5,000 K to 3,000 K. Yellow stars, like the Sun, are in between.

What are dwarfs?

About 90 percent of all stars are main sequence stars. Most of these are small, red stars found in the lower right of the H-R diagram. Some of the stars that are not in the main sequence are hot, but they are not bright. These small stars are called white dwarfs, although they are usually blue in color. White dwarfs are found on the lower left of the H-R diagram.

What are giants?

Other stars are very bright, but they are not hot. These large stars are called giants or red giants, because they are usually red in color. They’re found on the upper right of the H-R diagram. The largest giants are called supergiants. These stars can be hundreds of times bigger than the Sun and thousands of times brighter.
How do stars shine?

For centuries, people have wondered what stars were made of and what made them shine. Over time, people realized the Sun had been shining for billions of years. What material could burn for so long?

What process creates the light that reaches Earth?

In the 1930s, scientists made an important discovery about atoms. Scientists observed that the nuclei, or centers, of atoms reacted with one another. They hypothesized that the center of the Sun was hot enough to cause hydrogen atoms to fuse, or link together, and form another kind of atom—helium atoms. This reaction, called fusion, releases huge amounts of energy. Much of this energy is released as different kinds of light. A very small part of this light comes to Earth.

Evolution of Stars

The H-R diagram explained a lot about stars. However, scientists wondered why some stars didn’t fit in the main sequence. Scientists also wondered what happened when a star used up its hydrogen fuel. Now, there are theories about how stars evolve, or change over time. These theories also explain what makes stars different from one another, and what happens when a star “dies.”

When a star uses up its hydrogen, that star is no longer in the main sequence. This can take less than 1 million years for the brightest stars. It can take billions of years for the dimmest stars. The Sun has a main sequence life span of about 10 billion years. Half of its life is still in the future.

How are stars formed?

Stars begin as a large cloud of gas and dust called a nebula (NEB yuh luh). The pull of gravity between the particles of gas and dust causes the nebula to contract, or shrink. The nebula can break apart into smaller and smaller pieces. Each piece eventually might collapse to form a star.

The particles in the smaller pieces of nebula move closer together. This causes temperatures in each piece to rise. When the temperature in the core of a piece of nebula reaches 10 million K, fusion begins. Energy is released from the core and travels outward. Now the object is a star.
What is a giant?

After a star is formed, the heat created by fusion creates outward pressure. Without this pressure, the star would collapse from its own gravity. The star becomes a main sequence star. It continues to use its hydrogen fuel. The different stages in the life of a star are shown in the illustration on this page and the next page.

When hydrogen in the core of the star runs out, the core contracts and temperatures inside the star increase. The outer layers of the star expand and cool. In this late stage in its life cycle, a star is called a giant.

As the core contracts, its temperature continues to rise. By the time it reaches 100 million K, the star is huge. Its outer layers are much cooler than when it was a main sequence star. In about 5 billion years, the Sun will become a giant.

What is a white dwarf?

The star’s core contracts even more after it uses much of its helium and the outer layers escape into space. This leaves only the hot, dense core. At this stage in a star’s life cycle, it is about the size of Earth. It is called a white dwarf. In time, the white dwarf will cool and stop giving off light.

What are supergiants and supernovas?

The length time it takes for a star to go through its stages of life depends on its mass. The stages happen more quickly and more violently in stars that are more than eight times more massive than the Sun. In massive stars, the core heats up to much higher temperatures. Heavier and heavier elements form in the core. The star expands into a supergiant. Finally, iron forms in the core. Iron can’t release energy through fusion. The core collapses violently. This sends a shock wave outward through the star. The outer part of the star explodes. This produces a kind of star called a supernova. A supernova can be millions of times brighter than the original star was.
What is a neutron star?
What happens next depends on the size of the supernova’s collapsed core. If the collapsed core is between 1.4 and 3 times as massive as the Sun, the core shrinks until it is only about 20 km in diameter. In this dense core, there are only neutrons. This kind of star is called a **neutron star**. Because the star is so dense, one teaspoonful of a neutron star would weigh more than 600 million metric tons on Earth.

What is a black hole?
The core of some supernovas is more than three times more massive than the Sun. Nothing can stop the core’s collapse in these supernovas. All of the core’s mass collapses to a point. The gravity near this point is so strong that not even light can escape from it. Because light cannot escape from this region, it is called a **black hole**. If you could shine a light into a black hole, the light would disappear into it. However, a black hole is not like a vacuum cleaner. It does not pull in faraway objects. Stars and planets can orbit around a black hole, as long as they are far enough away.

Where does a nebula’s matter come from?
You learned that a star begins as a nebula. Where does the matter, or gas and dust, come from to form the nebula? Some of it was once in other stars. A star ejects large amounts of matter during the course of its life. Some of this matter becomes part of a nebula. It can develop into new stars. The matter in stars is recycled many times.

The matter that is created in the cores of stars and during supernova explosions is also recycled. Elements such as carbon and iron can become parts of new stars. Spectrographs of the Sun show that it contains some carbon, iron, and other heavy elements. However, the Sun is too young to have formed these elements itself. The Sun condensed from material that was created in stars that died long ago.

Some elements condense to form planets and other objects. In fact, your body contains many atoms that were formed in the cores of ancient stars.

---

**Think it Over**

6. **Infer** If the collapsed core of a supernova is 2.4 times as massive as the Sun, what will it become next?
After You Read

Mini Glossary

black hole: the final stage in the evolution of a very massive star, where the core collapses to a point that its gravity is so strong that not even light can escape

giant: a late stage in the life of a low-mass star, when the core contracts but its outer layers expand and cool; a large, bright, cool star

nebula (NEB yuh luh): a large cloud of gas and dust where stars are formed

neutron star: a very dense core of a collapsed star that can shrink to about 20 km in diameter and contains only neutrons

supergiant: late stage in the life cycle of a massive star in which the core heats up and the star expands; a large, very bright star

white dwarf: a late stage in the life cycle of a low-mass star; formed when its outer layers escape into space, leaving behind a hot, dense core; a small, dim, hot star

1. Review the terms and their definitions in the Mini Glossary. Write a sentence to compare a white dwarf and a giant.

2. Fill in the blanks to review what you have learned about the life of a massive star.

A massive star forms in a ______________. The star burns hydrogen fuel as a main ______________ star. The core heats up. The star expands and cools into a ______________. The star then explodes as a ______________. Depending on its mass, it will then become either a ______________ or a ______________.

3. Could you use the flash cards you created to describe how the Sun developed? What information was helpful? What other information should have been on the cards?

End of Section

Visit blue.mssscience.com to access your textbook, interactive games, and projects to help you learn more about the evolution of stars.
Before You Read
Imagine that someone on the other side of the universe wanted to send you mail. How might you give someone an address for Earth?

Read to Learn
Galaxies
How can you describe the location of Earth? We are in the solar system. The solar system is in a galaxy called the Milky Way. A galaxy is a large group of stars, gas, and dust held together by gravity.

There are many other galaxies. Every galaxy has the same elements, forces, and types of energy that are found in our solar system.

You learned that stars are grouped together in galaxies. In the same way, galaxies are grouped into clusters. The Milky Way is part of a cluster called the Local Group. The Local Group is made up of about 45 galaxies in different sizes and shapes. There are three major types of galaxies.

What are the three major types of galaxies?
Spiral galaxies have spiral arms that wind outward from the center. The arms are made up of bright stars, dust, and gas. The Milky Way galaxy is a spiral galaxy.

Elliptical (ih LIHP tih kul) galaxies are a common type of galaxy. They are shaped like large, three-dimensional ellipses.

Irregular galaxies include all the galaxies that don’t fit into the other two groups. These galaxies have many different shapes.

What You’ll Learn
- the Sun’s position in the Milky Way Galaxy
- what forces affect our solar system
- what forces affect other galaxies

Mark the Text
Highlight the main point in each paragraph. Use a different color to highlight a detail or example that helps explain the main point.

Summarize
Create a three-tab Foldable to summarize the main ideas from the section.
The Milky Way Galaxy

There might be one trillion stars in the Milky Way. It is about 100,000 light-years across. Find the Sun in the image of the Milky Way below. It is about 26,000 light-years from the galaxy’s center in one of the spiral arms. In the galaxy, all stars orbit around a central region, or core. It takes about 225 million years for the Sun to orbit the center of the Milky Way.

Scientists put the Milky Way into the spiral galaxy group. However, it’s difficult to know the exact shape because we can’t look at the galaxy from the outside. You can’t see the shape of the Milky Way because the location of our solar system is in one of its spiral arms. But you can see the Milky Way stretching across the sky. It looks like a dusty band of dim light. All the stars you can see in the night sky are part of the Milky Way. Like many other galaxies, the Milky Way has a black hole at its center.

Origin of the Universe

Scientists have offered different models, or ideas, for how the universe began. One model is the steady state theory. It suggests that the universe always has been the same as it is now. The universe expands and new matter is created. This keeps the density of the universe in a steady state.

A second model is the oscillating (AH sih lay ting) model. This model states that the universe formed and then it expanded, or grew larger. Over time, the rate of growth slowed down. Then the universe began to contract, or shrink. Then the whole process began again. In other words, it oscillates back and forth in size.

A third model is called the big bang theory. This theory states that the universe began with a big bang and has been expanding ever since.
Expansion of the Universe

Think of the sound of a whistle on a passing train. The pitch of the whistle rises as the train moves closer. Then the pitch of the whistle drops as the train moves away. This happens because the sound waves coming from the whistle are compressed, or shortened, as the train gets closer. This effect is called the Doppler (DAH plur) shift.

Does the Doppler shift affect light?

The Doppler shift happens with light too. Like sound, light moves in waves. If a star is moving toward Earth, the light waves are shortened. If a star is moving away from Earth, the light waves are stretched out. Blue-violet light waves are shorter than red light waves. Scientists can identify blue-violet light from stars moving toward Earth. When a star is moving away from Earth, the light shifts toward red. This is called a red shift.

How do we know the universe is expanding?

In 1929, Edwin Hubble noticed a red shift in the light from galaxies outside the Local Group. This meant the galaxies are moving away. If all galaxies outside the Local Group are moving away from Earth, then the entire universe must be expanding.

The Big Bang Theory

The big bang theory is the leading theory about how the universe formed. It states that the universe began about 13.7 billion years ago. There was a huge explosion. In less than a second, the universe grew from the size of a pinhead to 2,000 times the size of the Sun. Even today, galaxies are still moving away from this explosion.

Scientists don’t know if the universe will expand forever or stop expanding. If there is enough matter in the universe, gravity might stop the expansion. Then the universe would contract until everything came back to a single point. But studies show the universe is expanding faster, not slower. Scientists are still trying to figure out what will happen to the universe.
After You Read

Mini Glossary

big bang theory: the theory that the universe began about 13.7 billion years ago with a huge explosion and has been expanding ever since.

galaxy: a large group of stars, dust, and gas held together by gravity.

1. Review the terms and their definitions in the Mini Glossary. Write a sentence using the terms big bang theory and galaxy.

2. Complete the diagram to show how Earth fits into the Universe. Use the following terms: Milky Way, Solar System, and Local Group.

3. Look at your highlighted text about the Milky Way. Write a short description of the Milky Way that includes three details. Did highlighted text help you write your description? What other strategy could have helped you keep track of details about the Milky Way?

Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about galaxies and the universe.
Before You Read

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

Read to Learn

First Thoughts

Do you like mysteries? Are you curious? People are usually curious. They always want to know something that is not easy to understand. Or they want to know about something they cannot see.

For example, people first began wondering about what matter was made of more than 2,500 years ago. 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. They named this smallest piece 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. Even if they wanted to experiment to find out about atoms, they could not have. Early scientists 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 is a cathode-ray 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. In Crookes’s 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, as you can see in the figure.
What happened in Crookes’ tube?

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.

Discovering Charged Particles

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 are a 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 exist.

What did Thomson’s discovery mean?

Thomson’s discovery meant that atoms must have negatively charged particles called electrons 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.
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. In Thomson’s model, an atom is something like a ball of chocolate chip cookie dough. The sphere of dough represents the positive charge. The chocolate chips represent electrons, which have a negative charge.

Rutherford’s Experiments

In 1906, Ernest Rutherford did an experiment to find out if Thomson’s model of the atom was correct. He and his coworkers fired alpha particles at a very thin piece of gold foil. Alpha particles are positively charged bits of matter. Two positive particles repel, or push away each other. So, alpha particles would be repelled by matter that is positively charged.

Look at the figure below. Alpha particles were fired at a sheet of gold foil. The foil was only 400 nm 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.
Was Thomson’s model wrong?

Rutherford’s hypothesis made sense. Remember that, in Thomson’s model, the positive charge is neutralized by nearby electrons. Rutherford was so sure what his results would be that he had one of his students complete the experiment.

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 and his team had to explain these unexpected results. If Thomson’s model was correct, an alpha particle might be affected slightly by a positive charge in the atom and turn a bit off course. The large changes in direction that Rutherford observed would not be expected with this model.

How were protons identified?

Rutherford proposed a new model of the atom, shown in the figure. He hypothesized that almost all of the mass and positive charge of an atom are crammed into a tiny space at the center of an atom called the nucleus. In 1920, his prediction was proved true when scientists identified protons. A proton is a positively charged particle that is in the nucleus of every atom. 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. The mass of most atoms is at least twice as great as the mass of its protons. Rutherford’s model would 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. 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 a neutron has no charge. So, 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, 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 can’t show you the actual size of an atom. Drawings also 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. Now you understand why most of the alpha particles in Rutherford’s experiment went straight through the gold foil. 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.

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

alpha particles: positively charged bits of matter
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
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?

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

section 1 The Nucleus

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

What You’ll Learn
- what radioactive decay is
- 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. Isotopes (I suh tohps) are atoms of the same element that have different numbers of neutrons. Carbon-12 is an isotope that has 6 protons and 6 neutrons. Carbon-13 has 6 protons and 7 neutrons. Carbon-14 has 6 protons and 8 neutrons. Together, the protons and neutrons make up most of the mass in an atom.
What is the mass number?

The mass number of an isotope is the number of neutrons plus protons. The table 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>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon-12</td>
</tr>
<tr>
<td>Mass number</td>
</tr>
<tr>
<td>Number of protons</td>
</tr>
<tr>
<td>Number of neutrons</td>
</tr>
<tr>
<td>Number of electrons</td>
</tr>
<tr>
<td>Atomic number</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 in a nucleus are tightly packed together, 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. So 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.

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

4. Define What are alpha particles made of? ✓

5. 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.
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 pesticide in the environment.
After You Read

Mini Glossary

- **atomic number**: the number of protons in the nucleus of an atom of an element
- **beta particle**: a high-energy electron that comes from the nucleus, not the electron cloud
- **half-life**: the amount of time it takes for half of a sample of the element to decay
- **isotopes**: atoms of the same element that have different numbers of neutrons
- **mass number**: the number of neutrons plus protons
- **radioactive decay**: the release of particles and energy from the nucleus
- **transmutation**: the changing of one element into another through radioactive decay

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>Radioactive Decay</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of Particle Released</strong></td>
</tr>
<tr>
<td>Alpha particle</td>
</tr>
</tbody>
</table>

Visit [blue.msscience.com](http://blue.msscience.com) to access your textbook, interactive games, and projects to help you learn more about the nucleus of an atom.
The Periodic Table

section • Introduction to the Periodic Table

Before You Read

Write what you think an element is on the lines below.

Read to Learn

Development of the Periodic Table

People who lived long ago knew about a few of the substances that are now called elements. They used gold and silver to make coins and jewelry. They used copper, tin, and iron to make tools. By 1830, scientists had found and named 55 different elements. The list of elements is still growing.

What was Mendeleev’s table of elements?

Dmitri Mendeleev (men duh LAY uhf) was a Russian chemist. In 1869, he published his first periodic table. Mendeleev arranged the elements according to increasing atomic mass. Elements with similar properties made groups. Not all of the elements were known. So, Mendeleev left three spaces for missing elements. He predicted what the missing elements were like. Within 15 years, all three elements were found. They were gallium, scandium, and germanium.

How did Moseley add to the periodic table?

In the early 1900s, the English physicist Henry Moseley rearranged Mendeleev’s table. He arranged the elements according to atomic number instead of atomic mass. Moseley put the elements in order of increasing number of protons in the nucleus. With Moseley’s table, it was easy to see how many elements still had not been discovered.
Today’s Periodic Table

Today, the elements are still organized by increasing atomic number. Look at the periodic table at the back of your textbook. The periods, or rows, are labeled 1–7. A **period** is a row of elements whose properties change gradually. The periodic table has 18 columns. Each column has a group, or family, of elements. A **group** has elements that have similar physical or chemical properties.

**How is the periodic table divided?**

The periodic table can be divided into parts. Look at the figure below. The **representative elements** are the elements in Groups 1 and 2 and the elements in Groups 13–18. They include metals, metalloids, and nonmetals. The **transition elements** are the elements in Groups 3–12. They are all metals. Some transition elements are placed below the main table. These inner transition elements are called the lanthanide and actinide series. One series follows the element lanthanum, element 57. The other series follows actinium, element 89.

**What are metals?**

The periodic table is divided into metals, nonmetals, and metalloids. Examples of a metal, a nonmetal, and a metalloid are shown in the figure near the top of the next page. All of the metals except for mercury are solids. Most metals have high melting points. A **metal** is an element that has luster, is a good conductor of heat and electricity, is malleable (MAL yuh bul), and is ductile (DUK tul).
**Metal Properties** Luster is the ability to reflect light. A good conductor of heat and electricity lets heat and electricity pass through it easily. Something that is malleable can be shaped easily into objects or pounded into thin sheets. Something that is ductile can be stretched into wire.

**What are nonmetals and metalloids?**

Nonmetals are usually gases or brittle solids at room temperature. They do not conduct heat and electricity well. Brittle solids break apart easily. Carbon, sulfur, nitrogen, oxygen, and phosphorus are nonmetals that are necessary for life.

The elements between metals and nonmetals on the periodic table are metalloids (ME tuh loydz). A metalloid is an element that shares some properties with metals and some with nonmetals. They are also called semimetals.

**What does an element key show?**

Each element on the periodic table has an element key. The key shows the name of the element, its atomic number, its symbol, and its average atomic mass. The figure shows the element key for hydrogen.

Element keys also have symbols that show an element’s state of matter at room temperature. Gases are marked with a balloon. Solids are marked with a cube. Liquids are marked with a drop. The elements that are not found naturally on Earth, or synthetic elements, are marked with a bull’s-eye.
What are element symbols?
The symbols for the elements are either one or two letters, often based on the element’s name. For example, V is the symbol for vanadium and Sc is the symbol for scandium. Sometimes the symbols do not match the names. Ag is the symbol for silver and Na is the symbol for sodium. In those cases, the symbols might come from Greek or Latin names for the elements. Some elements are named for scientists such as Lise Meitner (meitnerium, Mt). Some are named for geographic locations such as France (francium, Fr).

New Elements
Newly discovered elements are given a temporary name and three-letter symbol. The symbol is related to the element’s atomic number. The International Union of Pure and Applied Chemistry (IUPAC) started using this system in 1978. When the discovery of an element is confirmed, the discoverers can choose a name. The table shows where some element names and symbols come from.

<table>
<thead>
<tr>
<th>Name</th>
<th>Symbol</th>
<th>Where the Name Comes From</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mendelevium</td>
<td>Md</td>
<td>For Dimitri Mendeleev</td>
</tr>
<tr>
<td>Lead</td>
<td>Pb</td>
<td>The Latin name for lead is <em>plumbum</em>.</td>
</tr>
<tr>
<td>Thorium</td>
<td>Th</td>
<td>The Norse god of thunder is Thor.</td>
</tr>
<tr>
<td>Polonium</td>
<td>Po</td>
<td>For Poland, where Marie Curie, a famous scientist, was born</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>H</td>
<td>From Greek words meaning “water former.”</td>
</tr>
<tr>
<td>Mercury</td>
<td>Hg</td>
<td><em>Hydrargyrum</em> means “liquid silver” in Greek.</td>
</tr>
<tr>
<td>Gold</td>
<td>Au</td>
<td><em>Aurum</em> means “shining dawn” in Latin.</td>
</tr>
<tr>
<td>Unununium</td>
<td>Uuu</td>
<td>Named using the IUPAC naming system.</td>
</tr>
</tbody>
</table>

Picture This
5. Explain Why is the symbol for gold Au instead of G?

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After You Read

Mini Glossary

group: a collection of elements that have similar physical or chemical properties

metal: an element that has luster, is a good conductor of heat and electricity, is malleable, and is ductile

metalloid: an element that shares some properties with metals and some with nonmetals

nonmetals: elements that are gases or brittle solids at room temperature and do not conduct heat and electricity well

period: a row of elements whose properties change gradually

representative elements: the elements in Groups 1 and 2 and the elements in Groups 13–18

transition elements: the elements in Groups 3–12

1. Read the key terms and definitions in the Mini Glossary above. Write a sentence that tells how to locate a period and a group on the periodic table of elements.

2. In the Venn diagram, write properties of metals and nonmetals. In the middle, write the name of the group that has properties of both.

3. How would you explain to an elementary school student what the periodic table is?
What You’ll Learn

- the properties of representative elements
- uses for the representative elements
- to group elements based on similar properties

Before You Read

Look at the periodic table in the back of your textbook. Choose a representative element that you have heard of. Give an example of how that element is used.

Read to Learn

Groups 1 and 2

Groups 1 and 2 are not found by themselves in nature. They are always combined with other elements. Groups 1 and 2 are called active metals because they easily make new substances with other elements. They are all metals except hydrogen. Hydrogen is the first element in Group 1. Even though it is placed in Group 1, hydrogen shares properties with the elements in Group 1 and Group 17.

What are alkali metals?

The Group 1 elements are shown in the figure. They have a family name—alkali metals. All the alkali metals are silvery solids with low densities and low melting points. As you move from top to bottom on the periodic table, alkali metals increase in reactivity. Reactivity is how easily an element combines with other elements.

Alkali metals are found in many things. Lithium batteries are used in cameras. Sodium chloride is common table salt. Sodium and potassium are elements you need in your diet. They are found in potatoes and bananas.
What are alkaline earth metals?

Next to the alkali metals are the Group 2 metals. They are called the alkaline earth metals. The Group 2 metals are shown in the figure to the right.

Each alkaline earth metal is denser and harder and has a higher melting point than the alkali metal in the same period. Look at the periodic table in the back of your textbook. Calcium is denser and harder and has a higher melting point than potassium. Strontium is denser and harder and has a higher melting point than rubidium.

Alkaline earth metals are reactive. But they are not as reactive as the alkali metals. Group 2 elements are found in many things. Beryllium is found in the gems emerald and aquamarine. Magnesium is found in chlorophyll, a chemical in green plants.

Groups 13 through 18

The elements in Groups 13–18 are not all solid metals like the elements in Groups 1 and 2. In fact, a single group can contain metals, nonmetals, and metalloids. A single group also can contain elements that are solid, liquids, and gases. 

What elements are in the boron family?

The figure to the right shows the Group 13 elements. The elements in Group 13 are all metals except boron. Boron is a black metalloid that is brittle, or breaks easily.

The Group 13 family of elements is used to make many different things. Pots and pans made with boron can be moved straight from the refrigerator to the oven without cracking. Aluminum is used to make soft drink cans, cookware, and baseball bats. It also is used to make siding for homes. Gallium is a solid metal. Its melting point is so low that it will melt in your hand. Gallium is used to make computer chips.
What elements are in the carbon group?

The Group 14 elements, shown in the figure to the right, are called the carbon group. Carbon is a nonmetal. Silicon and germanium are metalloids. Tin and lead are metals.

**Carbon**  Carbon exists as an element in different forms. Two forms that you have probably heard of are diamond and graphite. Carbon also is found in all living things.

**Silicon and Germanium**  After carbon in the periodic table is the metalloid silicon. Silicon is an element in sand. Sand has ground-up particles of minerals like quartz. Quartz is made of silicon and oxygen. Glass is an important product made from sand.

  Germanium, another metalloid, is found below silicon in the periodic table. They both are used in electronics as semiconductors. A **semiconductor** is a material that does not conduct electricity as well as a metal. But it does conduct electricity better than a nonmetal. Silicon and small amounts of other elements are used for computer chips.

**Tin and Lead**  Tin and lead are the two heaviest elements in Group 14. Lead is used in aprons you wear when the dentist takes X rays of your teeth. It protects the rest of your body from the radiation from X rays. Lead also is used in car batteries and X-ray equipment. Tin is used in toothpaste and the coating on steel cans used for food.

What is the nitrogen group?

The Group 15 elements are shown in the figure to the right. At the top of Group 15 are the two nonmetals—nitrogen and phosphorus. Living things need nitrogen and phosphorus.

**Nitrogen**  Almost 80 percent of the air you breathe is nitrogen. But, you cannot get the nitrogen you need by breathing nitrogen gas. Bacteria in the soil must first change nitrogen gas into things that can be absorbed by the roots of plants. When you eat the plants, you get the nitrogen you need.
Nitrogen, along with hydrogen, is used to make ammonia. When ammonia is dissolved in water, it can be used as a cleaner. Liquid ammonia is used as a soil fertilizer. Ammonia also is used to freeze-dry food and to make nylon for parachutes.

**Phosphorus** Phosphorus also is in Group 15. It comes in two forms—white and red. White phosphorus combines easily with other elements. When it comes into contact with oxygen in air, it will burst into flames. The heads of matches are red because they are made of the less-reactive red phosphorus. The phosphorus in a match makes a fire from the heat made by friction when the match is struck. Phosphorus compounds are important for healthy teeth and bones. Plants also need phosphorus. It is used in most fertilizers.

**What elements are in the oxygen family?**

The Group 16 elements are shown in the figure. The first two elements in Group 16 are oxygen and sulfur. They are necessary for life. The heavier elements in the group are tellurium and polonium. They are both metalloids.

**Oxygen** About 20 percent of Earth’s atmosphere is oxygen. Your body needs oxygen to get energy from the foods you eat. Oxygen is in Earth’s rocks and minerals because it combines easily with other elements. Oxygen also is needed to burn things. Firefighters use foam to keep oxygen away from something that is burning.

Ozone is a less common form of oxygen. It is made in the upper atmosphere by electricity during thunderstorms. Ozone is important. It protects living things from some harmful radiation from the Sun.

**Sulfur** Sulfur is a solid, yellow nonmetal. Large amounts of sulfur are used to make sulfuric acid. This is one of the most commonly used chemicals in the world. Sulfuric acid is a combination of sulfur, hydrogen, and oxygen. It is used to make paints, fertilizers, detergents, synthetic fibers, and rubber.

**Selenium** Selenium conducts electricity when it is in the light. Selenium is used in solar cells, light meters, and photographic materials. It is also used in copy machines. Small amounts of selenium also are needed for good health.

**Think it Over**

6. **Evaluate** Why aren’t matches made with white phosphorus?

---

7. **Identify** Which element has the symbol Te?
What elements are in the halogen group?

The elements in Group 17 are called **halogens**. The word *halogen* means “salt-former.” All of the halogens make salts with sodium and with other alkali metals. Table salt is made from sodium and chlorine. All the elements in Group 17, shown in the figure to the right, are nonmetals except for astatine. Astatine is a radioactive metalloid.

Fluorine is the most reactive of the halogens. Chlorine is less reactive than fluorine. Chlorine is added to water to kill bacteria. Bromine is less reactive than chlorine. Iodine is the least reactive of the four nonmetals. Iodine is used by many systems of your body.

What elements are noble gases?

The Group 18 elements, shown in the figure to the right, are called noble gases. **Noble gases** are elements that do not often combine with other elements. They are found as uncombined elements in nature. Their reactivity is very low.

Helium is less dense than air, so it is used in all kinds of balloons. Helium balloons lift instruments into the upper atmosphere to measure atmospheric conditions.

How are noble gases used?

All of the noble gases, not just neon, are used in “neon” lights like those used for signs. The signs are made of glass tubes filled with noble gas. Electricity makes the noble gases in the glass tubes glow. Each noble gas makes a different color. Helium glows yellow, neon glows red-orange, and argon glows bluish-violet.

Argon is the most common noble gas on Earth. Argon, krypton, and xenon are used in lightbulbs. Krypton lights are used on airport runways. Xenon is used in strobe lights.

Radon is a radioactive gas. It is made naturally from uranium that decays in rocks and soil. Radon can be harmful. When people breathe radon gas over a period of time, it can cause lung cancer.
After You Read

Mini Glossary

alkali metals: silvery solids with low densities and low melting points
alkaline earth metals: metals that are denser and harder and have a higher melting point than the alkali metals in the same period
halogens: elements in Group 17 that make salts

1. Review the terms and their definitions in the Mini Glossary. Describe how an alkali metal is different from an alkaline earth metal in the same period of the periodic table.


2. In the outline of the periodic table below, write the group number for each group of representative elements at the top of each column. Then, write the family name for each column.


3. How did highlighting elements and their uses help you to learn about them?

ScienceOnline Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about representative elements.
Before You Read

Name three things you use every day that are made from metals.

The Metals in the Middle

Groups 3–12 are called the transition elements. All of them are metals. The properties of the transition elements change less as you move across a period than they do for the representative elements.

Most transition elements are found combined with other elements in ores. An ore is a mineral that is found naturally on Earth. A few transition elements like gold and silver are found as pure elements.

What is the iron triad?

Iron, cobalt, and nickel are in period 4 and are known as the iron triad. They are shown in the figure. They have very similar properties. These elements and others have magnetic properties. Large magnets are made from a mixture of nickel, cobalt, and aluminum.

The iron triad also has many other uses. Nickel is used in batteries along with cadmium. Iron is a necessary part of hemoglobin, the substance that moves oxygen in your blood. Iron is mixed with other metals and with carbon to create steels with different properties. Bridges and skyscrapers are built with steel because it is strong.
How are transition elements used?

Look at the figure below. The transition elements are in the middle of the periodic table. They are Groups 3–12. Most transition metals have higher melting points than the representative elements. The filaments of lightbulbs are made with tungsten, element 74. Tungsten has the highest melting point of any metal (3,410°C). Tungsten will not melt when a current passes through it.

Mercury  Mercury has the lowest melting point of any metal (−39°C). It is used in thermometers and barometers. It is the only metal that is liquid at room temperature. Like many of the heavy metals, mercury is poisonous to living things. It must be handled carefully.

Chromium  The name chromium comes from the Greek word chroma. It means color. Chromium is a colorful element. Many other transition elements also combine to make colorful substances.

Platinum Group  Ruthenium, rhodium, palladium, osmium, iridium, and platinum are sometimes called the platinum group. They have similar properties. They do not combine easily with other elements. So, they can be used as catalysts.

What is a catalyst?

A catalyst is a substance that can make something happen faster. However, the catalyst is not changed. Other transition elements like nickel, zinc, and cobalt can be used as catalysts. Transition elements are used as catalysts to make electronics, plastics, and medicines.
3. Calculate How many lanthanide and actinide elements are there altogether?

Applying Math

Inner Transition Elements

There are two series of inner transition elements. The lanthanides is the name of the first series of inner transition elements. The lanthanides go from cerium to lutetium. The lanthanides also are called the rare earths because at one time people thought they were not common. They are usually found combined with oxygen in Earth's crust. The actinides is the name of the second series of inner transition elements. The actinides go from thorium to lawrencium. The figure above shows the lanthanides and the actinides.

What are the lanthanides?

The lanthanides are soft metals. They can be cut with a knife. The lanthanides often are found in the same ore. They are so much alike that they are hard to separate when they are in the same ore. Lanthanides are not as rare as people once thought. Earth's crust has more cerium than lead. Cerium makes up 50 percent of a mixture called misch (MIHSH) metal. Flints in lighters are made from misch metal. Lighters are used to start fires. Lanthanum, iron, and neodymium also are in flint.

Lanthanides also are used in color TV screens. A blend of some lanthanide elements will give off a bright red light. Other compounds are used to make the other colors for a natural-looking picture on the screen.

What are the actinides?

All the actinides are radioactive. The nuclei of atoms of radioactive elements are unstable. They break down to make other elements. Thorium, protactinium, and uranium are the only actinides that now are found naturally on Earth. Uranium is found in Earth's crust.

All other actinides are synthetic elements. Synthetic elements are made in laboratories and in nuclear reactors. Synthetic elements have many uses. Plutonium is used as a fuel in nuclear power plants. Americium is used in home smoke detectors. Californium-252 is used to kill cancer cells.
How can scientists make synthetic elements?

Scientists can make synthetic elements by using a device called a particle accelerator. In the particle accelerator, the nuclei of atoms are made to crash into each other at high speeds. Some of the nuclei might stick together to make new, heavier elements. Some of the synthetic elements are very unstable. Synthetic elements may only last a fraction of a second before they break down into other elements.

What elements do dentists use?

For over 150 years, dentists have used a substance called amalgam to fill cavities in decayed teeth. Amalgam is a mixture of silver, copper, tin, and mercury. Some people are worried that amalgam is harmful because it contains mercury. Today, dentists can use things other than amalgam to fill cavities. New materials are used to fix decayed, broken, or missing teeth. These new materials are strong. Body fluids will not break them down. They can also be changed to match the natural color of the tooth. Some of the new materials have fluoride in them. Fluoride protects teeth from more decay.

Bonding Agents To use these new materials, dentists use new bonding agents. Bonding agents are like glue. They glue the materials to the natural tooth. The bonding agents must be strong and not be broken down by body fluids.

Braces Orthodontists, dentists who straighten teeth, use new nickel and titanium alloys for the wires on braces. These wires have shape memory. This means they will always try to keep their shape. The wires are heated to lock in their shapes. The wires are forced out of shape when they are put on crooked teeth. They will try to return to their original shape, straightening the teeth as they do.
After You Read

Mini Glossary

**actinides**: the name of the second series of inner transition elements

**catalyst**: a substance that can make something happen faster, but not change itself

**lanthanides**: the name of the first series of inner transition elements

**synthetic elements**: elements made in laboratories and in nuclear reactors

---

1. Review the terms and their definitions in the Mini Glossary. Write a sentence describing why you would add a catalyst to something.

---

2. Complete the table. In the second column, write whether each element is a regular transition element, a lanthanide, or an actinide. Write a use for the element in the third column.

<table>
<thead>
<tr>
<th>Element</th>
<th>Element Group</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plutonium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cerium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tungsten</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iron</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

3. You were asked to make flash cards of the transition elements. What is another method you could use to learn the transition elements?

---

Science online: Visit [blue.mssscience.com](http://blue.mssscience.com) to access your textbook, interactive games, and projects to help you learn more about transition elements.
Atomic Structure and Chemical Bonds

section Why do atoms combine?

Before You Read

Think of a rock. How would you describe it? Now think of a balloon. How is a balloon different from a rock?

Read to Learn

Atomic Structure

You might be surprised to learn that all matter contains mostly empty space. Even solids like rocks and metals have empty space. How can this be? Although there might be little or no space between atoms, there is a lot of empty space within each atom.

At the center of an atom is the nucleus. It contains protons and neutrons. The rest of the atom is empty except for electrons. Electrons are extremely small compared to the nucleus. The electron cloud is the space around the nucleus where the electrons travel. However, the exact location of any one electron cannot be determined and their paths are not well-defined, as shown in the figure.

Imagine that the nucleus of an atom is the size of a penny. Electrons would be smaller than grains of dust. The electron cloud would go out as far as 20 football fields.

What You’ll Learn

- how electrons are arranged in an atom
- the amount of energy electrons have
- how the periodic table is organized

Mark the Text

Highlight As you read highlight important sentences and terms. When you are finished reading, review what you have highlighted.

Organize Information

A Organize Information

Make the following layered book Foldable using four sheets of notebook paper to help you organize information about atoms.
Where in the electron cloud are electrons?
You might think that electrons are like the planets that circle the Sun, but they are not. Planets travel in predictable orbits. You can tell exactly where a planet will be at any time. This is not true for electrons. Although electrons do travel in predictable areas, it is impossible to tell exactly where any one electron will be at any time. So, scientists use a mathematical model to predict where an electron might be.

What makes the atoms of elements different?
The atoms of every element are different. Each element has a certain number of protons, neutrons, and electrons in its atoms. The number of protons is always the same as the number of electrons in neutral atoms. The figure shows a two-dimensional model of the electron structure of a lithium atom. A neutral lithium atom has three protons and four neutrons in its nucleus. Three electrons move around its nucleus.

Electron Arrangement
You know that different elements have different numbers of electrons. The way electrons are arranged in the electron cloud is also different for different elements. The physical and chemical properties of an element can be different, depending on the number of electrons and how they are arranged.

What are energy levels?
Electrons move in the electron cloud in an atom. Some electrons are closer to the nucleus than others. So, electrons can be in different areas. Energy levels are the different areas for electrons in an atom. The figure at the top of the next page shows a model of what energy levels might look like in an atom. The dark bands in the diagram represent the energy levels. Each level has a different amount of energy.
How many electrons are in an energy level?

Each energy level can hold only a certain number of electrons. Energy levels farther away from the nucleus can hold more electrons. Energy levels close to the nucleus hold fewer electrons. Energy level one, the closest to the nucleus, can hold one or two electrons. Energy level two can hold up to eight electrons. Energy level three can hold up to 18 electrons. Energy level four can hold up to 32 electrons.

How can energy levels be represented?

Look at the stairway in the figure below. This stairway shows the maximum number of electrons each energy level can hold. The electrons in each energy level have different amounts of energy.
Which levels have the most energy?

Energy level one electrons are closest to the nucleus. They have the least energy. Electrons in energy level two have more energy. They are on the second stair step. The electrons farthest from the nucleus have the highest amount of energy. They are easiest to remove. To find the number of electrons an energy level can hold, use the formula \(2n^2\), where \(n\) is the number of the energy level.

If the electrons in the highest energy level have the highest energy, why are they easiest to remove? Remember that electrons are negatively charged. The nucleus is positively charged because it contains protons. The farther the electrons are from the nucleus, the less they are attracted to it. So, it takes less energy to remove an electron in a higher energy level. It takes more energy to remove an electron in a lower energy level.

Periodic Table and Energy Levels

The periodic table has a lot of data about the elements. You can use it to understand energy levels, too. Remember that the atomic number of an element is the number of protons in an atom of the element. The number of protons is equal to the number of electrons in a neutral atom. So, you can look at the atomic number of an element and find how many protons and electrons it has. For example, oxygen is atomic number 8. This means that oxygen has eight protons in its nucleus and eight electrons.

Electron Configurations

In the periodic table, the elements are arranged in a certain order. Part of the periodic table is shown on the next page. Look at the horizontal rows, or periods. The number of electrons in a neutral atom of each element increases by one from left to right in each period.

First Period In the first period, hydrogen has one electron and helium has two. The first energy level can hold two electrons, so helium’s outer energy level is complete. Atoms with a complete outer energy level are stable and do not combine easily with other elements. So, helium is stable.
**Second Period** In the second period, or row, lithium has three electrons. Two electrons fill energy level one. This leaves only one electron for energy level two. Energy level two can hold up to eight electrons. Look at each element to the right of lithium. The electrons begin to fill energy level two. On the right side of the periodic table, neon has a total of 10 electrons. Two are in energy level one. Eight are in energy level two. Because the outer energy level of neon is complete, neon is a stable element.

**Third Period** In the third period, the electrons begin filling energy level three. On the right side, argon has eight electrons in energy level three. Is it full? No, energy level three can hold 18 electrons. An atom with exactly eight electrons in its outer energy level is stable. Argon is a stable element. Each period in the periodic table ends with a stable element.

**Element Families**

Each column in the periodic table is an element group, or family. The first element family begins with lithium. Hydrogen is separate from the first family. The elements in each family have the same number of electrons in their outer energy level. So the members of each element family have similar chemical properties.

Dmitri Mendeleev, a Russian chemist, noticed this repeating pattern of properties. In 1869, he created his first periodic table of elements using this pattern. Mendeleev’s table is much like the one used today.

---

**Picture This**

7. **Identify** Circle all of the elements that have three electrons in their outer energy level.

---

**Reading Check**

8. **Determine** What is true about elements in a family?

---
What are noble gases?
Look at the periodic table on the previous page. Find neon. Notice that neon and the elements below it have eight electrons in their outer energy levels. These are very stable elements. They do not combine easily with other elements.

Helium does not have eight electrons, but its outer energy level is complete because energy level 1 can hold only two electrons. So, helium is also stable. The Group 18 elements are called noble gases. The noble gases are the most stable elements.

How are noble gases used?
Noble gases are useful because they are so stable. Lightbulbs have noble gases to keep the filaments from reacting with air. Noble gases also are used to make colored lights in signs. If an electric current passes through the noble gases, they glow with different colors. Neon makes orange-red, argon makes lavender, and helium makes a yellow-white light.

What are halogens?
The elements in Group 17 are called halogens. Look at the elements in Group 17 in the periodic table on the previous page. Notice that their outer energy levels have seven electrons. If they gain one electron, they become stable. The halogens are very reactive.

Fluorine is the most reactive halogen because its outer energy level is closest to the nucleus. The other halogens get less reactive as their outer energy levels get farther away from the nucleus. So, chlorine in period 3 is less reactive than fluorine in period 2.

What are alkali metals?
Look at the elements lithium and sodium in the periodic table on the previous page. Except for hydrogen, the elements in this group are called alkali metals. Alkali metals have one electron in their outer energy levels. When these elements react, this one electron in the outer energy level is removed.

Remember that it is easier to remove electrons that are farther away from the nucleus because less energy is needed. Elements at the bottom of the group give up the one electron in their outer energy levels more easily than those at the top. The elements toward the bottom of this group are more reactive. For example, sodium in period 3 is more reactive than lithium in period 2. This is the opposite of the halogens.
Electron Dot Diagrams

You have read that the properties of an element depend on the number of electrons in its outer energy level. That’s why chemists often make models of atoms showing only the electrons in the outer energy level. These models are called electron dot diagrams. An electron dot diagram is the chemical symbol for an element surrounded by as many dots as there are electrons in its outer energy level.

Why not draw dots for all of the electrons in an atom? You could do that. But for some elements, you would have to draw a lot of dots. For example, iodine has 53 electrons. So, you would have to draw 53 dots. What really matters is the number of electrons in the outer energy level. These are the electrons that determine how an element can react. Iodine has seven electrons in the outer energy level. Drawing seven dots is easier than drawing 53 dots.

How do you write electron dot diagrams?

How many dots do you draw? Where do you put them? First, you need to know how many electrons are in the outer energy level. You can use the periodic table to find out. To make the diagram, write the symbol for the element. For boron, you write the letter B. Boron has three electrons in its outer energy level. So, you need to draw three dots. Start by making one dot above the letter B. Next, go clockwise and draw a dot to the right of the B. Then, draw a dot below the B. If there are more electrons, keep drawing dots clockwise around the symbol. If there are more than four electrons, draw dots in pairs. The diagram below shows electron dot diagrams for boron, carbon, nitrogen, and oxygen.

How do you use electron dot diagrams?

You can use electron dot diagrams to show how atoms bond with each other. A chemical bond is the force that holds two atoms together. Chemical bonds hold atoms together like glue holds things together. Atoms bond with other atoms in ways that make each atom more stable. That means the outer energy levels of bonded atoms becomes like those of the noble gases.
After You Read

Mini Glossary

- **chemical bond**: the force that holds two atoms together
- **electron cloud**: the space around the nucleus where the electrons travel
- **electron dot diagram**: the chemical symbol for an element surrounded by as many dots as there are electrons in its outer energy level
- **energy levels**: the different areas for electrons in an atom

1. Review the terms and their definitions in the Mini Glossary. Where in an atom are the energy levels located? Answer in a complete sentence.

   ____________________________________________________________

   ____________________________________________________________

2. Below is the electron dot diagram for nitrogen and the symbol P for the element phosphorus. Both nitrogen and phosphorus are in Group 15 on the periodic table. Complete the electron dot diagram for phosphorus.

   ![N and P electron dot diagrams]

3. Look at the dot diagrams above. What do nitrogen and phosphorus have in common?

   ____________________________________________________________

   ____________________________________________________________

4. At the beginning of the section, you were asked to highlight important sentences and terms as you read. How did highlighting help you learn about electrons in an atom?

   ____________________________________________________________

   ____________________________________________________________

Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about how atoms combine.
Atomic Structure and Chemical Bonds

section 3 How Elements Bond

Before You Read

What does it mean when two things are bonded? What are some things you might use to bond two items?

What You’ll Learn

- about ionic and covalent bonds
- about compounds and molecules
- polar and nonpolar covalent bonds
- chemical shorthand

Read to Learn

Ionic Bonds—Loss and Gain

Elements that join by chemical bonds do not fall apart easily. Atoms form bonds by using the electrons in their outer energy levels. Elements can bond in four different ways—they can lose electrons, gain electrons, pool electrons, or share electrons with another element.

Lose Electrons Sodium chloride forms when sodium and chlorine atoms bond as shown below. Sodium is a soft, silvery metal. It is a member of the alkali metal family. It reacts violently when added to water or chlorine. Sodium is so reactive because it has only one electron in its outer energy level. Removing this one electron empties the outer energy level. What is left is the completed energy level below it. Sodium is now stable, like neon. Remember, neon is a stable noble gas.

Create a Quiz

As you read the section, write quiz questions about the main ideas and vocabulary terms. When you finish reading, answer your quiz questions.

Find Main Ideas

Make the following Foldable out of notebook paper. Make quarter-sheets and a half-sheet to list the main ideas on covalent bonds, chemical shorthand, and how atoms become stable.

Foldables

How can an atom become stable?

Sodium

Chlorine
**Gain Electrons** Chlorine bonds in the opposite way. It gains an electron. Chlorine has seven electrons in its outer energy level. It gains an electron to have a complete outer energy level. When this happens, chlorine becomes stable. It then has the same number of electrons as the noble gas argon.

**What are ions?**

When a sodium atom loses an electron, it becomes more stable. But, the atom has one fewer electron than protons. This changes the balance of electric charge. The atom becomes a positively charged ion. When a chlorine atom gains an electron, it has one more electron than protons. This makes the chlorine atom a negatively charged ion. An ion (I ahn) is an atom that is no longer neutral because it has gained or lost an electron. The figure below shows how sodium ions (Na⁺) and chloride ions (Cl⁻) are formed. 

---

**Reading Check**

1. **Describe** Which of the following does not describe an ion: positive, negative, or neutral?

---

**Picture This**

2. **Draw and Label** A sodium atom loses an electron and becomes positively charged. Circle the electron in the sodium atom (Na) that is taken away. A chlorine atom gains an electron and becomes negatively charged. Circle the electron in the chloride ion (Cl⁻) that is gained.
How do ions form bonds?

Positive sodium ions and negative chloride ions are strongly attracted to each other. An ionic bond is the attraction that holds negative ions and positive ions close together.

The figure below shows how sodium and chloride ions form an ionic bond. The compound sodium chloride, or table salt, is formed. A compound is a pure substance that has two or more elements that are chemically bonded.

\[
\text{Na}^+ + \text{Cl}^- \rightarrow [\text{Na}]^+ [\text{Cl}]^-
\]

Can elements gain or lose more than one electron?

The element magnesium (Mg) in Group 2 has two electrons in its outer energy level. Magnesium can lose these two electrons to have a completed outer energy level. The symbol for a magnesium ion is Mg\(^{2+}\). The \(2^+\) shows that the ion has lost two electrons.

**One Ionic Bond** When magnesium loses its two electrons, the electrons could be gained by an oxygen atom. Oxygen needs to gain two electrons to become stable. So, a magnesium ion, Mg\(^{2+}\), and an oxide ion, O\(^{2-}\), can form an ionic bond to make magnesium oxide (MgO). The \(2^+\) charge of the magnesium ion and the \(2^-\) charge of the oxide ion balance each other.

**Two Ionic Bonds** A single magnesium ion (Mg\(^{2+}\)) also can bond with two chlorine ions (Cl\(^{-}\)). The \(2^+\) charge of the magnesium ion is balanced by the two negative charges of the two chlorine ions. Each chlorine ion gains one electron. This ionic bond between magnesium and chlorine forms the compound magnesium chloride (MgCl\(_2\)).

**Metallic Bonding—Pooling**

In the examples above, a metal formed ionic bonds with nonmetals. Metals can form bonds with other metal atoms, but in a different way.
How do metals bond?

In metal atoms, the electrons are not held tightly to the outer energy levels of the atoms. Instead, they move freely among all the metal ions. These moving electrons form a pool of shared electrons. The figure below is an example of a pool of electrons in the metal silver. **Metallic bonds** form when metal atoms share their pooled electrons.

![Metallic bond diagram](image)

What are some properties of metals?

Metallic bonds cause metals to have special properties. The pooled electrons let the atoms slide past each other to stretch and not break. So, metals can be hammered into sheets without breaking. They can also be drawn into wires without breaking. Metallic bonds also let metals conduct electricity well. An electric current in solids is a flow of electrons. The outer electrons in metal atoms move easily from one atom to the next to conduct electric current.

Covalent Bonds—Sharing

Some atoms don’t gain or lose electrons very easily. For example, carbon has six total electrons. Four of these electrons are in the outer energy level. To be more stable, carbon would either have to gain four electrons or lose four. Losing or gaining four electrons would take a lot of energy. But, carbon can form a bond by sharing electrons.

What is a covalent bond?

Atoms of many elements become more stable by sharing electrons. A **covalent** (koh VAY luhnt) **bond** is a chemical bond that forms between nonmetal atoms when they share electrons. Shared electrons are attracted to the nuclei of both atoms. They move back and forth between the outer energy levels of each atom in the covalent bond. So, each atom is stable some of the time. Compounds held together with covalent bonds are called molecular compounds.
Neutral Particles  The atoms in a covalent bond form a neutral particle. The particle is neutral because it has the same number of positive and negative charges. A molecule (MAH lih kyewl) is the neutral particle formed when atoms share electrons. A molecule is the basic unit of a molecular compound. The figure below shows how molecules form by sharing electrons. Notice in the figure that none of the atoms are ions. That’s because no electrons are gained or lost when a molecule forms. Solids that are crystals, such as sodium chloride, are not called molecules, because their basic units are ions, not molecules.

What are double and triple bonds? Sometimes an atom shares more than one electron with another atom. Look at the molecule of carbon dioxide shown below. Each oxygen atom shares two electrons with the carbon atom. The carbon atom shares two of its electrons with each oxygen atom. When two pairs of electrons form a covalent bond, it is called a double bond. A triple bond happens when three pairs of electrons are shared in a covalent bond. The nitrogen molecule in the figure below is an example of a triple bond.
**Polar and Nonpolar Molecules**

Atoms in a covalent bond don’t always share electrons equally. Some atoms have a greater attraction for electrons than others do. For example, hydrogen and chlorine can form a covalent bond. But, chlorine attracts electrons more strongly than hydrogen does. So, the shared electron pair spends more time around the chlorine atom than the hydrogen atom.

Since the electron pair spends more time around the chlorine atom, this end of the molecule has a slight negative charge. The hydrogen end of the molecule has a slight positive charge. This happens because the hydrogen atom is without its electron most of the time. A **polar bond** is a bond in which electrons are shared unevenly. The figure below shows an example of a polar bond.

What makes water molecules polar?

Water molecules form when hydrogen and oxygen share electrons. Water molecules are polar because the electrons are shared unevenly. The oxygen atom has a greater share of the electrons than the hydrogen atom. Look at the figure below. Water molecules can be attracted to positive and negative charges because they are polar. Many of the physical properties of water are due to the fact that the molecule is polar. Molecules that do not have uneven charges are called nonpolar molecules. An example of a nonpolar bond is the triple bond in a nitrogen molecule.

**Picture This**

9. **Use Models** How would you describe the sharing of the electrons in the hydrogen chloride molecule—even or uneven?

**Think it Over**

10. **Explain** Water molecules attract each other because they are polar. Many water molecules are attracted to many other water molecules. Explain which charges are attracted to each other.
**Chemical Shorthand**

In medieval times, alchemists (AL kuh mists) were the first to study chemistry. The alchemists learned about the properties of some elements. They used symbols to represent elements and chemical processes. Scientists today use symbols, too. The table below shows both ancient and modern symbols for some elements. The periodic table includes the symbol for each element. The symbols are usually one or two letters. Often, the symbol is the first letter of the name for the element. For example, the symbol for oxygen is O. Sometimes, the name for the element in another language is used. For example, the symbol for potassium is K. The Latin word for potassium is kalium.

<table>
<thead>
<tr>
<th>Sulfur</th>
<th>Iron</th>
<th>Zinc</th>
<th>Silver</th>
<th>Mercury</th>
<th>Lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modern</td>
<td>S</td>
<td>Fe</td>
<td>Zn</td>
<td>Ag</td>
<td>Hg</td>
</tr>
</tbody>
</table>

**What are chemical formulas?**

Symbols and numbers are used to show the elements in compounds. A chemical formula is a set of chemical symbols and numbers that shows which elements are in a compound and how many atoms of each element are in it. For example, two hydrogen atoms in a covalent bond are represented by the chemical formula H₂. The H stands for hydrogen. The subscript 2 tells you that there are two hydrogen atoms. A subscript is a number that is written a little below a line of text. Another example of a chemical formula is H₂O, or water. The formula tells you there are two hydrogen atoms and one oxygen atom in a water molecule. Notice that when symbols don’t have a subscript, like the O in H₂O, there is only one atom.

**Picture This**

11. **Determine** Which is probably most easily understood by people today, the ancient symbols or the modern symbols?

12. **Infer** What does a chemical formula tell you about a compound?
1. Review the terms and their definitions in the Mini Glossary. Choose two terms that describe different kinds of chemical bonds and write a sentence or two that tells how they are different.

2. Fill in the table below to summarize what you learned in this section about chemical bonds.

<table>
<thead>
<tr>
<th>Chemical Bonds</th>
<th>Type of Bond</th>
<th>Reaction</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ionic bond</td>
<td>A negative ion and a positive ion come together.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metallic bond</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Covalent bond</td>
<td>hydrogen, water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polar bond</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Chemical Reactions

section ● Chemical Formulas and Equations

● Before You Read

What happens to wood when it burns? Describe the changes on the lines below.

● Read to Learn

Physical or Chemical Change?

Have you ever seen smoke from a campfire? Smoke is a clue that a chemical reaction is taking place. There are always clues when a chemical reaction is happening.

Matter can change in two ways. It can have a physical change or a chemical change. Physical changes only affect physical properties. For example, the newspaper in the first figure is folded. It is a different shape, but it is still a newspaper. This is a physical change.

Chemical changes produce new substances. The newspaper in the second figure is burning. Burning is a chemical change because new substances are produced. The properties of the new substances are different from the properties of the original substances. A chemical reaction is a process that produces chemical change.

What You’ll Learn

- identify a chemical reaction
- how to read a balanced chemical equation
- how reactions release or absorb energy
- the law of conservation of mass

Mark the Text

Highlight Chemical Equations

Highlight each chemical equation in the section. Read the chemical equation two or three times to make sure you understand what is happening in the chemical reaction.

Foldables

Organize Information

Make the following Foldable to help you organize information in this section. Write information about each topic in the Foldable.
What are clues that a chemical reaction is happening?

You can use your senses to help you know if a chemical reaction is happening. When you watch a firefly glow, you are watching a chemical reaction. Two chemicals combine in the firefly’s body and give off light. Your senses of touch and smell help detect chemical reactions in a fire. You smell the smoke and feel the heat. Have you ever tasted sour milk? If so, you have tasted the results of a chemical reaction. You can also hear a chemical reaction happening. The hissing sound of burning firewood is from a chemical reaction.

Chemical Equations

How can you describe a chemical reaction? First, you need to know which substances are reacting. You also need to know which substances are formed in the reaction. The substances that react are called reactants (ree AK nunts). Reactants are the substances that exist before the reaction starts. Products are the substances that are formed in the reaction.

Look at the figure below. A chemical reaction happens when you mix baking soda and vinegar. It bubbles and foams. The bubbles tell you that a chemical reaction happened.

Baking soda and vinegar are the common names for the reactants in this reaction. They also have chemical names. Baking soda is sodium hydrogen carbonate (often called sodium bicarbonate). Vinegar is a solution of acetic (uh SEE tihk) acid in water. What are the products of the reaction? You can see that bubbles form. What else is happening?
What is a chemical equation?

The bubbles from the baking soda and vinegar tell you a gas was produced. But, they do not tell you what kind of gas. Are bubbles of gas the only product? More happens in a chemical reaction than you can see with your eyes. Chemists try to find out what reactants are used and what products are formed in a chemical reaction. Then, they write a chemical equation. A chemical equation tells chemists the reactants, products, physical state, and amounts of each substance in the reaction. You will see how important this is later.

How do words describe a chemical reaction?

Words can be used in an equation to name the reactants and products in a chemical reaction. The reactants in the equation are listed on the left side of an arrow. The reactants have plus signs between them. The products are on the right side of the arrow and also have plus signs between them. The arrow stands for the changes that happen during the chemical reaction. The arrow means produces.

You can begin to think of changes as chemical reactions even if you do not know the names of all the substances in the reaction. The table below shows word equations for chemical reactions you might see around your home.

<table>
<thead>
<tr>
<th>Reactants</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baking soda + Vinegar</td>
<td>Gas + White solid</td>
</tr>
<tr>
<td>Charcoal + Oxygen</td>
<td>Ash + Gas + Heat</td>
</tr>
<tr>
<td>Iron + Oxygen + Water</td>
<td>Rust</td>
</tr>
<tr>
<td>Silver + Hydrogen sulfide</td>
<td>Black tarnish + Gas</td>
</tr>
<tr>
<td>Gas (kitchen range) + Oxygen</td>
<td>Gas + Heat</td>
</tr>
<tr>
<td>Sliced apple + Oxygen</td>
<td>Apple turns brown</td>
</tr>
</tbody>
</table>

When are chemical names used?

Chemical names are usually used in word equations instead of common names like baking soda and vinegar. In the baking soda and vinegar reaction, you already know that the chemical names are sodium hydrogen carbonate and acetic acid. The chemical names of the products are sodium acetate, water, and carbon dioxide. The word equation for the reaction is:

Acetic acid + Sodium hydrogen carbonate →
Sodium acetate + Water + Carbon dioxide
**Why do chemists use chemical formulas?**

The word equation for the reaction of baking soda and vinegar is long. So, chemists replace the chemical names with chemical formulas in the equation. The chemical equation for the reaction between baking soda and vinegar is:

$$\text{CH}_3\text{COOH} + \text{NaHCO}_3 \rightarrow \text{CH}_3\text{COONa} + \text{H}_2\text{O} + \text{CO}_2$$

Acetic  Sodium  Sodium  Water  Carbon
acid  hydrogen  acetate  dioxide
(vinegar)  carbonate
(baking soda)

**What are subscripts?**

Look at the small numbers in the formula above. These numbers are called subscripts. They tell you the number of atoms of each element in that compound. For example, the subscript 2 in CO$_2$ means each molecule of carbon dioxide has two oxygen atoms. If an atom has no subscript, then there is only one atom of that element in the compound. There is only one atom of carbon in carbon dioxide.

**Conservation of Mass**

What happens to the atoms in the reactants when they are changed into products? The law of conservation of mass says that the mass of the products has to be the same as the mass of the reactants. French chemist Antoine Lavoisier proved that nothing is lost or created in chemical reactions. Chemical equations are like math equations. In math equations, the right and left sides of the equation are equal. In chemical equations, the number and kind of atoms are equal on both sides. The figure shows that every atom that is on the reactant side of the equation is also on the product side.
Balancing Chemical Equations

You need to follow the law of conservation of mass when you write a chemical equation. Look back at the figure on the previous page. Count the number of each type of atom on each side of the scale. There are equal numbers of each kind of atom on each side. This means the equation is balanced. So, the law of conservation of mass is followed.

Not all chemical equations are balanced so easily. The following unbalanced equation shows what happens when silver tarnishes by reacting with sulfur compounds in air.

\[
\text{Ag} + \text{H}_2\text{S} \rightarrow \text{Ag}_2\text{S} + \text{H}_2
\]

Silver Hydrogen Silver Hydrogen
sulfide sulfide

How do you balance an equation?

Count the number of each type of atom in the reactants and products above. The reactants and products have the same numbers of hydrogen and sulfur atoms. But, there is one silver atom on the reactant side and two silver atoms are on the product side. This cannot be true. A chemical reaction cannot create a silver atom. This equation does not represent the reaction correctly. Place a 2 in front of the reactant Ag. Now see if the equation is balanced. Count the number of atoms of each type again.

\[
2\text{Ag} + \text{H}_2\text{S} \rightarrow \text{Ag}_2\text{S} + \text{H}_2
\]

The equation is now balanced. There are equal numbers of silver atoms in the reactants and the products. To balance chemical equations, numbers are placed before the formulas. These numbers, called coefficients, show how many molecules of a compound there are. Never change the subscripts in a formula. This changes the identity of the compound.

Practice balancing equations with the following:

\[
\text{CH}_4 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}
\]

Count the number of carbon, hydrogen and oxygen atoms on each side. There are 2 more hydrogen atoms in the reactants. Multiply \(\text{H}_2\text{O}\) by 2 to give 4 hydrogen atoms.\[
\text{CH}_4 + \text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}
\]

Now there are 2 oxygen atoms in the reactants and 4 in the products. Multiply \(\text{O}_2\) by 2 to give 4 oxygen atoms. The balanced equation is:

\[
\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}
\]
Energy in Chemical Reactions

Often, energy is released or absorbed in a chemical reaction. A welding torch burns hydrogen and oxygen to produce high temperatures. The energy for the torch is released when oxygen and hydrogen combine to form water.

\[ 2H_2 + O_2 \rightarrow 2H_2O + \text{energy} \]

Where does released energy come from?

Think about the chemical bonds that break and form when atoms gain, lose, or share electrons. When a chemical reaction happens, bonds break in the reactants. New bonds form in the products. In reactions that release energy, the products are more stable. Their bonds have less energy than the bonds of the reactants. The extra energy is released. It can be released in forms like light, sound, and heat.

How is energy absorbed in a reaction?

In reactions where energy is absorbed, the reactants are more stable. Their bonds have less energy than the bonds in the products.

\[ 2H_2O + \text{energy} \rightarrow 2H_2 + O_2 \]

water    Hydrogen  Oxygen

In this reaction, electricity supplies the extra energy needed to break water into hydrogen and oxygen, as shown in the figure.

Reactions can release or absorb many forms of energy, including electricity, light, heat, and sound. Special terms are used when heat energy is gained or lost in reactions. **Endothermic** (en doh THUR mihk) **reactions** absorb heat energy. **Exothermic** (ek soh THUR mihk) **reactions** release heat energy. **Therm** means heat, as in thermometers.
What is an example of an exothermic reaction?
You probably already know of reactions that release heat. Burning is an exothermic reaction. A substance combines with oxygen to produce heat. Light, carbon dioxide, and water are also produced.

Sometimes energy is released quickly. For example, charcoal lighter fluid combines with oxygen and produces enough heat to start a charcoal fire within a few minutes. Other materials also combine with oxygen, but they release heat so slowly that you cannot see or feel it happen. This is what happens when iron combines with oxygen in the air to form rust.

What is an example of an endothermic reaction?
Sometimes heat energy must be added for a reaction to take place. The way a cold pack works is an example of an endothermic process. A cold pack is made of a thick plastic outer pouch filled with water. The pouch with water surrounds a thin plastic inner pouch filled with ammonium nitrate. When you squeeze the cold pack, the inner pouch breaks. The ammonium nitrate mixes with the water and dissolves. As the ammonium nitrate dissolves, it absorbs heat energy from its surroundings. So, the cold pack absorbs heat energy from your skin and your skin feels cold.

How is energy written in an equation?
The word energy in equations can be either a reactant or a product. When it is written as a reactant, it is something needed for the reaction to happen. For example, electricity is needed to break water into hydrogen and oxygen. It is important to know that energy must be added for this to happen.

In the equation for an exothermic reaction, energy often is written with the products. This tells you that energy is released. You include energy when you write the reaction that occurs between oxygen and methane in natural gas when you cook on a gas range. This heat energy is what cooks your food.

\[
\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} + \text{energy}
\]
Methane Oxygen Carbon Water
dioxide

You don’t have to write the word energy in an equation. But, if you do, it helps you remember that energy is an important part of the equation.
After You Read

Mini Glossary

**chemical equation:** a written form that tells the reactants, products, physical state, and amounts of each substance in the reaction

**chemical reaction:** a process that produces chemical change

**endothermic (en doh THUR mihn) reaction:** a reaction that absorbs heat energy

**product:** a substance that is formed in the reaction

**reactant (ree AK tunt):** a substance that is there before the reaction starts

**exothermic (ek soh THUR mihn) reaction:** a reaction that releases heat energy

1. Read the key terms and definitions in the Mini Glossary above. In your own words, describe how a reactant and a product are related.

2. Balance each equation in the table.

<table>
<thead>
<tr>
<th>Equation</th>
<th>Balanced Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_2 + O_2 \rightarrow H_2O$</td>
<td></td>
</tr>
<tr>
<td>$H_2 + Cl_2 \rightarrow HCl$</td>
<td></td>
</tr>
<tr>
<td>$Al + CuCl_2 \rightarrow AlCl_3 + Cu$</td>
<td></td>
</tr>
</tbody>
</table>

3. How did highlighting the chemical equations in the section help you to understand chemical equations?

End of Section

Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about chemical formulas and equations.
Chemical reactions can happen quickly or slowly. Describe a chemical reaction that happens quickly.

How Fast?

Fireworks explode one after another quickly. Old copper pennies slowly darken. How long you fry an egg makes a difference in what the yolk is like. These are common chemical reactions in your life. Time has something to do with each example. Not all chemical reactions happen at the same speed.

Some reactions, like fireworks, need help to get going. Other chemical reactions seem to start by themselves. In this section, you also will learn what makes reactions speed up or slow down once they are going.

Activation Energy—Starting a Reaction

Before a reaction can start, molecules of the reactants have to bump into each other, or collide. The reactants must smash into each other with a certain amount of energy. If they do not have enough energy, the reaction will not happen. Why is this true?

Old bonds must break in the reactants so new bonds can form. This takes energy. To start any chemical reaction, at least some energy is needed. Activation energy is the energy needed to start a reaction. Even reactions that release energy need activation energy to start.
**Think it Over**

1. **Apply**  Why do you think that the faster a product can be made, the less it usually costs?

2. **Analyze** At which temperature are the molecules moving slower?

**Picture This**

2. **Analyze** At which temperature are the molecules moving slower?

---

**Gasoline**  One example of a reaction that needs energy to start is the burning of gasoline. Because gasoline needs energy to start burning, there are signs at filling stations warning you not to smoke. Other signs tell you to turn off your car, not to use mobile phones, and not to get in your car until you are finished fueling.

**Reaction Rate**

Many physical processes can be measured by rate. A rate tells you how much something changes over a given period of time. For example, you ride your bike at a rate, or speed. Rate is the distance you ride divided by the time it takes you to ride that distance. You may ride at a rate of 20 km/h.

Chemical reactions have rates too. The **rate of reaction** tells how fast a reaction happens after it has started. You can measure the rate of reaction two ways. You can measure how fast one of the reactants is used up. You also can measure how fast one of the products is made. Both measurements tell how the amount of a substance changes per unit of time.

Reaction rate is important to companies that make products. The faster the product can be made, the less it usually costs. But sometimes fast rates of reaction are not good. A fast reaction rate can cause food to spoil quickly. A slower reaction rate will help food stay fresh longer.

**How does temperature affect rate?**

**Increasing Temperature**  Most chemical reactions speed up when temperature increases. The high temperature inside an oven speeds up the chemical reactions that turn liquid batter into a cake. Atoms and molecules move faster at higher temperatures, as shown in the figure below. Faster molecules crash into each other more often than slower molecules. They also crash with more energy. These crashes often have enough energy to break the old bonds.
Decreasing Temperature  Lowering the temperature slows down most reactions. Food spoiling is a chemical reaction. Putting food in a refrigerator or freezer lowers its temperature. This slows the rate of reaction.

**How does concentration affect rate?**

When reactant atoms and molecules are closer together, there is a greater chance they will collide and react faster. Think about a crowd of people leaving a baseball game. When you try to walk through the crowd, you will probably bump into people. If it were not so crowded, you would be less likely to bump into people.

**Concentration** is the amount of substance in a certain volume. The figure on top shows molecules at a low concentration. If you increase the concentration, you increase the number of particles of a substance per unit of volume. A higher concentration is shown in the bottom figure. Reactions happen at a faster rate in a higher concentration.

**How does surface area affect rate?**

Surface area also affects how fast a reaction happens. You can quickly start a campfire with small twigs, but starting a fire with only large logs would probably not work.

The figure on the left below shows the iron atoms in a steel beam. Most of the iron atoms are stuck inside the beam. They cannot react. Only the atoms in the outer layer of the reactant material can react. If more molecules are out in the open, the reaction speeds up. This happens with the iron atoms in steel wool, a mass of woven steel fibers, in the figure on the right below. Because more of its iron atoms are open to oxygen in the air, it will form rust faster.

**Think it Over**

3. **Explain**  Why does lowering temperature slow down a chemical reaction?

---

**Picture This**

4. **Describe**  In which circle are molecules more likely to bump into each other—the top circle or the bottom circle?

---

**Picture This**

5. **Compare**  How is the steel wool different from the steel beam?
**Slowing Down Reactions**

An **inhibitor** is a substance that slows down a chemical reaction. When an inhibitor is added to a reaction, it can take longer to form a certain amount of product. Some inhibitors completely stop reactions. Many cereals and cereal boxes contain butylated hydroxytoluene, or BHT. The BHT slows the spoiling of the cereal and the packaging material. This increases its shelf life. The shelf life is how long a product lasts without spoiling.

**Speeding Up Reactions**

You can speed up a chemical reaction by adding a catalyst (KAT uh lihst). A **catalyst** is a substance that speeds up a chemical reaction without changing permanently or being used up. Catalysts are not shown in chemical equations because they are not changed or used up in the reaction. Does a catalyst change how much product is made by a reaction? No, the same amount of product is made as would be made without the catalyst. But, with the catalyst, it will make the same amount of product faster.

**How does a catalyst work?**

Many catalysts provide a surface on which the reaction occurs. Sometimes the catalyst holds the reacting molecules in a specific position that makes it better for the reaction to occur. Other catalysts reduce the activation energy needed to start a reaction. When the activation energy is reduced, the reaction rate increases.

**How do catalytic converters work?**

Catalysts are used in the exhaust systems of cars and trucks. They help fuel combustion, or burning. The exhaust goes through the catalyst. Beads coated with metals like platinum or rhodium are often the catalysts. Catalysts speed up the reactions that change the harmful substances in exhaust to less harmful substances. For example, they change carbon monoxide, a dangerous gas, into carbon dioxide, a gas normally found in air. Catalytic converters also change hydrocarbons into carbon dioxide and water. These reactions help keep the air cleaner. Without them, more harmful substances would go into the air.
What are enzymes?
Some of the best catalysts are at work in the reactions that take place in your body. These catalysts are called enzymes. Enzymes are large protein molecules that speed up reactions needed for your cells to work correctly. They help your body change food to fuel. They also help your body build bone and muscle tissue and change extra energy to fat. They even make other enzymes.

Without enzymes, reactions would happen too slowly to be useful or they would not happen at all. Enzymes work like other catalysts. They make a chemical reaction go faster by bringing certain molecules together. The figure shows how molecules that have the right shape can fit on the surface of an enzyme. Now the molecules can react and form a new product. Enzymes are chemical specialists. They exist to carry out each type of reaction in your body.

What are other uses for enzymes?
Enzymes work in other substances, too. One group of enzymes, called proteases (PROH tee ay ses), specializes in protein reactions. They work within cells to break down proteins. Proteins are large, complicated molecules. The meat tenderizer used on meat has proteases. The proteases break down the proteins in meat, making it more tender. Contact lens cleaning solutions also contain proteases. They break down proteins from your eyes that can collect on your contact lenses and cloud your view.
After You Read

**Mini Glossary**

- **activation energy**: the energy needed to start a reaction
- **catalyst (KAT uh lihst)**: a substance that speeds up a chemical reaction without changing permanently or being used up
- **concentration**: the amount of substance in a certain volume
- **enzyme**: a large protein molecule that speeds up a reaction needed for cells to work correctly
- **inhibitor**: a substance that slows down a chemical reaction
- **rate of reaction**: tells how fast a reaction happens after it has started

1. Review the terms and their definitions in the Mini Glossary. Write one or two sentences comparing and contrasting a catalyst and an inhibitor.

2. In the cause and effect chart below, decide whether the cause makes a chemical reaction speed up or slow down. Circle the correct answer.

   ![Cause Effect on Reaction Rate Table]

   - **an increase in temperature**: speeds up / slows down
   - **a decrease in concentration**: speeds up / slows down
   - **a decrease in surface area**: speeds up / slows down
   - **adding a catalyst**: speeds up / slows down
   - **a decrease in temperature**: speeds up / slows down

3. You were asked to write questions and answers on flash cards. How did making the flash cards help you learn about rates of chemical reactions?

   ![End of Section]

Science online: Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about rates of chemical reactions.
Motion and Momentum

section ● What is motion?

Before You Read
When you move from place to place, how do you know you have moved? Write what you think on the lines below.

Read to Learn

Matter and Motion
When you are sitting quietly in a chair, are you in motion? It may surprise you to know that all matter in the universe is always in motion. Think about it. In the chair, your heart beats and you breathe. Your blood circulates through your veins. Electrons move around the nuclei of every atom in your body.

Changing Position
How do you know if something is in motion? Something is in motion if it is changing position. Changing position means moving from one place to another. Imagine runners in a 100-meter race. They sprint from the start line to the finish line. Their positions change, so they are in motion.

What is relative motion?
To find out if something changes position, you need a reference point to compare it to. An object changes position if it moves when compared to a reference point. Imagine you are competing in the 100-meter race. You begin just behind the start line. When you pass the finish line, you are 100 m from the start line. If you use the start line as your reference point, then your position has changed by 100 m when compared to the start line. You were in motion.

Reading Check
1. Explain What do you compare an object to when determining the object’s motion?

What You’ll Learn
- what distance, speed, and velocity are
- how to graph motion

Underline As you read, underline material you do not understand the first time you read it. Reread the information until you understand it. Ask your teacher if you still do not understand it after rereading it.
Picture This

2. Explain Why is the displacement in the third figure zero?

Foldables

A Organize Information

Make the following two-tab Foldable to help you organize information about how to describe and calculate speed. Write examples under the tabs.

What are distance and displacement?

Suppose you walk from your house to the park around the block. How far away is it? That depends on whether you are talking about distance or displacement. Distance is the length of the route you travel.

Suppose you travel 200 m from your house to the park. How would you describe your location now? You could say you are 200 m from your house. But where you are depends on both the distance you travel and direction. To describe exactly where you are, you need to tell the direction from your house. Displacement includes the distance between your starting and ending points and the direction in which you travel. The figure above shows the difference between distance and displacement.

Speed

When you describe motion, you usually want to say how fast something is moving. The faster something is moving, the less time it takes to travel a certain distance. The slower something is moving, the more time it takes to travel a certain distance. Speed is the distance traveled divided by the time it takes to travel that distance. Speed can be calculated with this equation:

\[ \text{speed} = \frac{\text{distance}}{\text{time}} \]

In SI units, distance is measured in m and time is measured in s. The SI measurement for speed is meters per second (m/s). This is the SI distance unit divided by the SI time unit.
What is average speed?
Suppose a sprinter ran the 100-m dash in 10 s. Did she run the whole race at a speed of 10 m/s? No, her speed could have been different at any instant during the race. You can describe her motion for the entire race by her average speed, 10 m/s. Average speed is the total distance traveled divided by the total time taken to travel the distance.

What is instantaneous speed?
Have you ever watched the speedometer when you are riding in a car? If the speedometer reads 50 km/h, the car is traveling at 50 km/h at that instant. Instantaneous speed is the speed of an object at one instant of time.

How do average and instantaneous speed differ?
If it takes two hours to travel 200 km in a car, the average speed would be 100 km/h. But the car probably was not moving at this speed the whole time. It might have gone faster on the freeway and stopped at stoplights. There your speed was 0 km/h. If the car were able to travel 100 km/h the whole time, you would have moved at a constant speed.

For another example, see the diagram of the two balls below. Both balls have the same average speed because they both travel 3 m in 4 s. The top ball is moving at a constant speed. In each second, it moves the same distance. The bottom ball is moving at different speeds. Its instantaneous speed is fast between 0 s and 1 s, slower between 2 s and 3 s, and even slower between 3 s and 4 s.

3. Identify What type of speed does the speedometer in a car show?

4. Calculate What is the average speed of both balls in the diagram? Show all your work.

Picture This
Graphing Motion

You can show the motion of an object with a distance-time graph. In a distance-time graph, time is plotted on the horizontal axis. Distance is plotted on the vertical axis.

How do distance-time graphs compare speed?

The graph below is a distance-time graph that shows the motion of two students walking. According to the graph, after 1 s student A traveled 1 m. Her average speed is 1 m/1 s, or 1 m/s. Student B traveled only 0.5 m in 1 s. His average speed is 0.5 m/1 s, or 0.5 m/s. So student A traveled faster than student B. Now compare the steepness of the lines in the graph. The line for student A is steeper than the line for student B. A steeper line shows a faster speed. If the line is horizontal, no change in position happens. A horizontal line means a speed of zero.

Applying Math

5. Calculate Look at the graph. How much farther has student A walked in 2 seconds than student B?

6. Explain When the car’s motion changed from 40 km/h north to 40 km/h east, what changed?

Velocity

Suppose you are hiking in the woods. You may want to know how fast you are hiking. But you also need to know the direction you are going or you might get lost. The velocity of an object is the speed of the object and the direction of its motion. Velocity has the same units as speed and includes the direction of motion, for example 20 km/h east.

Velocity can change when speed changes, direction changes, or both change. If a car that is moving 60 km/h slows to 40 km/h, its velocity has changed. Suppose a car is traveling 40 km/h north. It then goes around a curve until it is heading east. All the time, the car’s speed was 40 km/h. But the velocity changed. The velocity was 40 km/h north. Now it is 40 km/h east.
**After You Read**

**Mini Glossary**

- **average speed**: equals the total distance traveled divided by the total time taken to travel the distance
- **instantaneous speed**: the speed of an object at one instant of time
- **speed**: equals the distance traveled divided by the time it takes to travel that distance
- **velocity**: the speed of an object and the direction of its motion

1. Review the terms and their definitions in the Mini Glossary. Ramona divided the distance from her house to school by the time it took her to walk that distance. What quantity did Ramona find? Explain your answer in a complete sentence.

2. The distance-time graph below is for a bicyclist in a bicycle race.

   a. What was the bicyclist’s average speed after two hours?

   b. What happened to her speed during the race?

   c. How can you tell?

   d. What was her average speed for the entire race?

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Motion and Momentum

section 6 Acceleration

What You’ll Learn
- what acceleration is
- to predict how acceleration affects motion

Before You Read
Have you ever been in a foot race? What kinds of things are measured in a foot race?

Read to Learn

Acceleration and Motion

Have you ever seen a rocket launch? When the rocket first lifts off, it seems to move very slowly. But very soon the rocket is moving at a fast speed. How can you describe the change in the rocket’s motion? When an object changes its motion, it is accelerating. **Acceleration** is the change in velocity divided by the time it takes for the change to happen.

How is speeding up acceleration?
When you first get on a bike, it is not moving. When you start pedaling, the bike moves faster and faster. This is acceleration. An object that is already moving can accelerate too. Imagine you are biking along a level path. When you start to pedal harder, your speed increases. When the speed of an object increases, the object is accelerating.

How is slowing down acceleration?
Suppose you are biking at a speed of 4 m/s. If you brake, you will slow down. It might sound odd, but when you slow down you are accelerating. Any change in velocity is acceleration. Acceleration happens when an object speeds up or slows down.

When an object is speeding up, its acceleration is in the same direction as its motion. When an object is slowing down, its acceleration is in the opposite direction of its motion.
How is changing direction acceleration?

Remember that acceleration is a change in velocity. A change in velocity can be a change in speed, direction, or both. So, when an object changes direction, it accelerates. Think of yourself on a bicycle. If you lean to one side and turn the handlebars that direction, you turn. The direction of the bike’s motion changes, so the bike accelerates. The acceleration is in the direction the bike turns.

Imagine throwing a ball straight up into the air. The ball starts out moving upward. After a while the ball stops moving upward and begins to come back down. The ball has changed its direction of motion. The ball is now accelerating downward.

Calculating Acceleration

If an object is moving in a straight line, its acceleration can be calculated with this equation.

$$acceleration \ (\text{m/s}^2) = \frac{\text{final speed} \ (\text{m/s}) - \text{initial speed} \ (\text{m/s})}{\text{time} \ (\text{seconds})}$$

$$a = \frac{s_f - s_i}{t}$$

In this equation, time is the length of time it takes for the motion to change. Initial speed is the starting speed. Acceleration has units of meters per second squared (m/s²).

What are positive and negative acceleration?

Suppose you are riding your bike in a straight line. You speed up from 2 m/s to 8 m/s in 6 seconds.

$$a = \frac{s_f - s_i}{t}$$

$$= \frac{(8 \text{ m/s} - 2 \text{ m/s})}{6 \text{s}} = \frac{6 \text{ m/s}}{6 \text{s}} = +1 \text{ m/s}^2$$

So your acceleration is +1 m/s². Now suppose you slow down from 8 m/s to 2 m/s in 6 s.

$$a = \frac{s_f - s_i}{t}$$

$$= \frac{(2 \text{ m/s} - 8 \text{ m/s})}{6 \text{s}} = \frac{-6 \text{ m/s}}{6 \text{s}} = -1 \text{ m/s}^2$$

Your acceleration is −1 m/s².
What does negative acceleration mean?

When you speed up, your acceleration is positive. When you slow down, your acceleration is negative. That is because when you slow down, your final speed is less than your initial speed. This gives you a negative value in the equation and a negative acceleration.

How do you graph accelerated motion?

You can show the motion of an accelerating object on a graph. For this type of graph, speed is plotted on the vertical axis. Time is plotted on the horizontal axis. The graph below is an example.

Positive Acceleration In section A of the graph, speed increases from 0 m/s to 10 m/s during the first 2 seconds. Acceleration is $5 \text{ m/s}^2$. An object that is speeding up will have a line that slopes up on a speed-time graph.

Zero Acceleration In section B of the graph, the speed does not change. If speed does not change, the object is not accelerating. A horizontal line on a speed-time graph means zero acceleration.

Negative Acceleration In section C of the graph, the object goes from 10 m/s to 4 m/s in 2 s. Acceleration is $-3 \text{ m/s}^2$. You can see that the line on the graph slopes downward as an object slows down.
1. Review the term and its definition in the Mini Glossary. Describe the term \textit{acceleration} in your own words.

2. Fill in the chart with the different ways an object can accelerate.

3. Why do you think that slowing down is sometimes called deceleration instead of acceleration?

\hspace{200px}

\textbf{Scienceonline} Visit \texttt{blue.msscience.com} to access your textbook, interactive games, and projects to help you learn more about acceleration.
Motion and Momentum

section 3  Momentum

What You’ll Learn

■ how mass and inertia are related
■ what momentum is
■ to use the law of conservation of momentum to predict motion

Before You Read

What happens if you are riding in a car and the driver slams on the brakes? Explain on the lines below.

Read to Learn

Mass and Inertia

One important property of objects is mass. The mass of an object is the amount of matter in the object. The SI unit for mass is the kilogram. Mass is related to weight. Objects with more mass weigh more than objects with less mass. A bowling ball has more mass than a pillow. So, it weighs more. But a pillow is larger. The size of an object is not the same as its mass.

Think about what happens when you try to stop someone who is running toward you. It is easier to stop a small child than an adult. The more mass an object has, the harder it is to start moving, stop moving, slow down, speed up, or turn. Inertia is the tendency of an object to resist a change in its motion. The more inertia an object has, the harder it is to change its motion.

Momentum

You know that the faster a bicycle moves, the harder it is to stop. The momentum of an object is the measure of how hard it is to stop the object. It depends on the object’s mass and velocity. Momentum is usually symbolized by \( p \).

\[
\text{momentum (in kg} \cdot \text{m/s)} = \text{mass (in kg) } \times \text{velocity (in m/s)}
\]

\[
p = mv
\]
Mass is measured in kilograms. Velocity is measured in meters per second. So, the unit of momentum is kilograms multiplied by meters per second (kg • m/s). Momentum has a direction that is the same as the direction of the velocity.

**Conservation of Momentum**

When you play billiards, you knock the cue ball into other balls. When a cue ball hits another ball, the motion of both balls changes. The cue ball slows down and may change direction. So its momentum decreases. The other ball starts moving. So its momentum increases.

**What happens to lost momentum?**

The momentum lost by the cue ball is moved to the other ball. It is gained by the other ball. This means that the total momentum of the two balls was the same just before and just after the collision. This is true for any collision, but only as long as no outside forces like friction act on the objects. The **law of conservation of momentum** states that the total momentum of objects that collide is the same before and after the collision. This is true for the collision of the billiard balls. It is also true for collisions of atoms, cars, football players, or any other matter.

**Using Momentum Conservation**

Outside forces are almost always acting on objects that are colliding. These are forces like friction and gravity. But sometimes, these forces are very small and can be ignored. Then the law of conservation of mass can be used to predict how the motions of objects will change after a collision.

**What happens after objects collide?**

There are many ways that collisions can happen. Sometimes the objects that collide will bounce off each other. In another type of collision, objects stick to each other after they collide.

**Bounce Off** What happens when you knock down bowling pins with a bowling ball? Picture a bowling ball rolling down the alley and hitting some bowling pins. The bowling ball and pins bounce off each other. When the ball hits the pins, some of the ball’s momentum is transferred to the pins. The ball slows down and the pins speed up. The speeds change, but the total momentum does not. Momentum is conserved.
**Stick together** Suppose you’re watching a football game when one player tackles another. The two players collide, but instead of bouncing apart, they stick together. The speeds of both players change, but the total momentum does not. In this type of collision, momentum also is conserved. In both of these types of collisions, you can use the law of conservation of momentum to find the speeds of the objects after they collide.

**How do you calculate the momentum of two objects that stick together?**

Imagine you are standing still on a pair of skates. You are not moving. Then someone standing in front of you throws you a backpack. You catch the backpack and begin to move backwards. You and the backpack move in the same direction that the backpack was moving before the collision.

You can use the law of conservation of momentum to find your velocity after you catch the backpack. Suppose the backpack has a mass of 2 kg and is tossed at a velocity of 5 m/s. Your mass is 48 kg and you have no velocity because you are standing still. So, your velocity before the collision is 0 m/s.

First, find the total momentum of you and the backpack. Remember, momentum equals mass times velocity.

\[
\text{total momentum} = m_1 \cdot v_1 + m_2 \cdot v_2
\]

\[
(48 \text{ kg} \times 0 \text{ m/s}) + (2 \text{ kg} \times 5 \text{ m/s})
\]

\[
= 10 \text{ kg} \cdot \text{m/s}
\]

The law of conservation of momentum tells you that the total momentum before the collision is the same as the total momentum after the collision. After the collision, the total momentum does not change. You and the backpack have become one object and are moving at the same velocity. You can use the equation for momentum to find the final velocity.

\[
\text{total momentum} = (m_1 + m_2) \cdot v
\]

\[
10 \text{ kg} \cdot \text{m/s} = (2 \text{ kg} + 48 \text{ kg}) \cdot v
\]

\[
= 10 \text{ kg} \cdot \text{m/s}
\]

Your velocity right after you catch the backpack is 0.2 m/s.
Stopping  Friction between your skates and the ground will slow you down as you move on your skates. The momentum of you and the backpack will continue to decrease until you stop because of friction.

How can mass predict motion after collisions?

You can use the law of conservation of momentum to predict collisions between two objects. What happens when one marble hits another marble that is at rest? It depends on the masses of the marbles that collide. The figure shows a marble with a smaller mass hitting a marble with a larger mass. The larger marble is at rest. After the collision, the marble with a smaller mass bounces off in the opposite direction. The larger marble moves in the same direction that the small marble was moving.

What if the larger marble hits a smaller marble that is not moving? Both marbles will move in the same direction. But the marble with the smaller mass always moves faster than the marble with the greater mass.

How does bouncing affect momentum?

Two objects can also bounce off of each other. The two marbles in the figure have the same mass and are moving at the same speed. They bounce off each other when they collide. Before the collision, the momentum of each marble was the same but in opposite directions. So the total momentum was zero. That means that the total momentum after the collision has to be zero too. The two marbles must move in opposite directions with the same speed after the collision. Then the total momentum is zero again.

Picture This

6. Describe  From which marble to which marble was momentum moved?

Applying Math

7. Analyze  Would the total momentum still be zero if one marble had greater mass than the other marble?
After You Read

Mini Glossary

inertia: tendency of an object to resist a change in motion.

law of conservation of momentum: states that the total momentum of objects that collide is the same before and after the collision.

mass: amount of matter in an object

momentum: the measure of how hard it is to stop an object

1. Review the terms and their definitions in the Mini Glossary. Explain in complete sentences what affects the inertia of an object.

2. The sketch below shows two marbles. The arrows show the size and the direction of the momentum of the two marbles. Draw arrows in the space below that show what will happen to these two marbles because of the law of conservation of momentum when they collide.

3. How can a football game be used to explain inertia and momentum?

Science Online Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about momentum.
chapter
Force and Newton’s Laws

section • Newton’s First Law

Before You Read
What do you have to do to move an object like a shopping cart? What causes motion?

Read to Learn

Force

To make a soccer ball move, you kick it. You can pick up a book from your desk. If you hold the book in the air and then let it go, gravity pulls it to the floor. The motion of the soccer ball and the book was changed by something pushing or pulling on each of them.

A force is a push or a pull. When you throw a ball, your hand exerts, or puts, a force on the ball. Then, gravity puts another force on the ball. Gravity pulls it to the ground. When the ball hits the ground, the ground exerts a force on the ball to stop it from moving.

Forces can act on objects in different ways. For example, you can pick up a paper clip with a magnet. The magnet puts a force on the paper clip. Or, you can put a force on the paper clip with your hand to pick it up. If you let go of the paper clip, Earth’s gravity exerts a force on the paper clip and it falls to the ground.

How can forces be combined?

More than one force can act on an object at the same time. Imagine holding a paper clip near a magnet. You, the magnet, and Earth’s gravity are all putting forces on the paper clip. The net force is the combination of all forces acting on an object.

What You’ll Learn

- the difference between balanced and net forces
- Newton’s first law of motion
- how friction affects motion

Make Flash Cards
As you read, write main ideas and vocabulary terms on note cards. When you finish reading, use your flash cards to make sure you understand the main ideas and terms.
How does net force determine motion?
When more than one force is acting on an object, the net force determines the motion of the object. If a paper clip near a magnet is not moving, then the net force on the paper clip is zero.

How do forces combine to form the net force? If the forces are in the same direction, they add together. If two forces are in opposite directions, the net force is the difference between the two forces. If one of the forces is greater than the other, the motion of the object is in the direction of the greater force.

What are balanced forces?
Suppose you and a friend push on opposite ends of a wagon. You both push with the same force, and the wagon does not move. Your forces cancel each other because they are equal and in opposite directions. Balanced forces are two or more forces acting on an object that cancel each other and do not change the object’s motion. The net force is zero if the forces acting on an object are balanced. The figure below shows balanced forces.

What are unbalanced forces?
Unbalanced forces are forces that don’t cancel each other. When unbalanced forces act on an object, the net force is not zero. The net force causes the motion of the object to change. The figure below shows how unbalanced forces change the motion of an object.

Think it Over
1. Infer Imagine two people pushing on a door. One person pushes the door to close it. The other person pushes on the other side of the door to open it. If both people are pushing with the same force, what will happen to the door?

Picture This
2. Identify Look at the box with unbalanced forces. In which direction is the strongest force—to the right or to the left? In which direction is the box moving?
Newton’s First Law of Motion

When you stand on a skateboard, you don’t move. If someone gives you a push, you and the skateboard move. You and the skateboard were objects at rest until someone pushed you. An object at rest stays at rest unless an unbalanced force acts on it and causes it to move.

If someone pushes you on a skateboard, do you keep going? You probably would roll for a while, even after the person stops pushing you. An object can be moving without a net force acting on it.

One of the first to understand that objects could be moving without a force acting on them was Galileo Galilei. He was an Italian scientist who lived from 1564 to 1642. Galileo’s ideas helped Isaac Newton understand motion better. Newton was able to explain the motion of objects in three rules. These rules are called Newton’s laws of motion.

Newton’s first law of motion describes how an object moves when the net force acting on it is zero. **Newton’s first law of motion** states that if the net force acting on an object is zero, the object stays at rest or, if the object is already moving, it continues to move in a straight line with the same, or constant, speed.

Friction

Galileo knew that the motion of an object doesn’t change unless an unbalanced force acts on it. So, why does a book stop sliding across a desktop just after you push it? There is a force acting on the sliding book. **Friction** is the force that resists sliding motion between two touching surfaces.

Friction also acts on objects moving through air or water. If two objects are touching each other, friction always will try to keep them from sliding past each other. Friction always will slow an object down.

**What is static friction?**

Have you ever tried to push something heavy, like a refrigerator or a sofa? At first heavy objects don’t move. As you push harder and harder, the object will start to move.

When you first push, the friction between the object and the floor is opposite to the force you are putting on it. So, the net force is zero. The object does not move. Static friction is the type of friction that prevents an object from moving when a force is applied.
What causes static friction?
Static friction is caused by the attraction between the atoms of two surfaces that are touching each other. This makes the two surfaces stick together. The force of static friction is greater when the object is heavy or if the surfaces are rough.

What is sliding friction?
Static friction keeps an object at rest. Sliding friction slows down an object that slides. If you push a box across a floor, you have to keep pushing to overcome the force of sliding friction. Sliding friction is caused by the roughness of the surfaces that are sliding. A force must be applied to move the rough areas of one surface past the rough areas of the other. Sliding friction slows down the sliding baseball player in the figure.

What is rolling friction?
Rolling friction is what makes a wheel turn. There is rolling friction between the ground and the part of the wheel touching the ground. Rolling friction keeps the wheel from slipping on the ground. If a wheel is rolling forward, rolling friction exerts a force on the wheel that pushes the wheel forward.

It is usually easier to pull a load on a wagon that has wheels than it is to drag the load along the ground. This is because the rolling friction between the wheels and the ground is less than the sliding friction between the load and the ground.

Picture This
4. Identify Draw an arrow below the sliding baseball player to show the direction of the force due to friction.

5. Explain If a wheel is rolling forward, what type of friction pushes the wheel forward?
After You Read

Mini Glossary

balanced forces: two or more forces acting on an object that cancel each other and do not change the motion of the object
force: a push or a pull
friction: the force that resists sliding motion between two touching surfaces

net force: the combination of all forces acting on an object Newton’s first law of motion: if the net force acting on an object is zero, the object stays at rest; or, if the object is already moving, it continues to move in a straight line with constant speed unbalanced forces: forces that don’t cancel each other

1. Review the terms and their definitions in the Mini Glossary. When you push a skateboard on a flat surface, why does it stop after a while? Use at least one term in your answer.

2. Complete the table below to show how Newton’s first law of motion affects objects at rest and objects that are moving. Name the types of friction that could affect objects at rest and moving objects.

<table>
<thead>
<tr>
<th></th>
<th>How is the object affected by Newton’s first law?</th>
<th>Which type or types of friction affect it?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object at rest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Object in motion</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. At the beginning of the section, you were asked to make flash cards. Did your flash cards help you learn about Newton’s first law? Why or why not?

Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about Newton’s first law of motion.
Force and Newton’s Laws

section 2 Newton’s Second Law

What You’ll Learn
- Newton’s second law of motion
- why the direction of force is important

Before You Read
If someone told you that a car was accelerating, what would that mean to you?

Before You Read
If someone told you that a car was accelerating, what would

Mark the Text
Underline As you read, underline the main ideas under each heading. After you finish reading, review the main ideas that you have underlined.

Read to Learn

Force and Acceleration
You know that it takes force to make a heavy shopping cart go faster. You must push harder and harder to make the cart speed up. When the heavy cart is moving, what do you have to do to slow it down? You have to use force to pull on the cart to make it slow down or stop. You also have to use force to turn a cart that is already moving. When the motion of an object changes, the object is accelerating. Speeding up, slowing down, and changing directions are all examples of acceleration.

Newton’s second law of motion states that when a force acts on an object, the object accelerates in the direction of the force. You can calculate acceleration by using the equation below.

\[
\text{acceleration (in meters/second}^2) = \frac{\text{net force (in newtons)}}{\text{mass (in kilograms)}}
\]

\[
a = \frac{F_{\text{net}}}{m}
\]

In this equation, \(a\) is acceleration, \(m\) is the mass of the object, and \(F_{\text{net}}\) is the net force. You can multiply both sides of the equation by the mass, and write the equation this way:

\[
F_{\text{net}} = ma
\]
What are the units of force?

Force is measured in newtons (N). The newton is an SI measurement. So, if you are calculating force, the mass must be measured in kilograms (kg). The acceleration must be measured in meters per second squared (m/s²). One N is equal to 1 kg \cdot m/s².

Gravity

One force that you may already know about is gravity. Gravity is the force that pulls you downward when you jump into a pool or coast down a hill on a bike. Gravity also keeps Earth in orbit around the Sun and the Moon in orbit around Earth.

What is gravity?

Gravity is a force that exists between any two objects that have mass. It pulls two objects toward each other. Gravity depends on the mass of the objects and the distance between them. The force of gravity becomes weaker as objects move away from each other or as the mass of objects gets smaller. Large objects like Earth and the Sun have great gravitational forces. Objects with less mass like you or a pencil have weak gravitational forces.

There is a gravitational force between you and the Sun. There is also a gravitational force between you and Earth. Why doesn’t the Sun’s gravity pull you off of Earth? The gravitational force between you and the Sun is very weak because the Sun is so far away. Only Earth is close enough and massive enough to exert a noticeable gravitational force on you. Earth’s gravitational force on you is 1,650 times greater than the Sun’s gravitational force on you.

What is weight?

Earth’s gravity causes all objects to fall toward Earth with an acceleration of 9.8 m/s². You can use the equation of Newton’s second law to find the force of Earth’s gravity on any object near Earth’s surface:

\[ F = ma = m \times (9.8 \text{ m/s}^2) \]

Weight is the amount of gravitational force on an object. Your weight on another planet would be different from your weight on Earth. That’s because the gravitational force on other planets is different. Other planets have masses different from Earth’s. So, your weight would be different on other planets.
How do weight and mass differ?

Weight and mass are different. Weight is the amount of gravitational force on an object. Your bathroom scale measures how much Earth’s gravity pulls you down. Mass is the amount of matter in an object. Gravity doesn’t affect the amount of matter in an object. Mass is always the same, even on different planets. A person with a mass of 60 kg has a mass of 60 kg on Earth or on Mars. But, the weight of the person on Earth and Mars would be different, as shown in the table. That’s because the force of gravity on each planet is different.

<table>
<thead>
<tr>
<th>Place</th>
<th>Weight in Newtons If Your Mass Were 60 kg</th>
<th>Percent of Your Weight on Earth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mars</td>
<td>223</td>
<td>38</td>
</tr>
<tr>
<td>Earth</td>
<td>588</td>
<td>100</td>
</tr>
<tr>
<td>Jupiter</td>
<td>1,388</td>
<td>236</td>
</tr>
<tr>
<td>Pluto</td>
<td>4</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Using Newton’s Second Law

Newton’s second law tells how to calculate the acceleration of an object. You must know the object’s mass and the forces acting on the object. Remember that velocity is how fast an object is moving and in what direction. Acceleration tells how velocity changes.

How is speeding up acceleration?

When an object speeds up, it accelerates. Think about a soccer ball sitting on the ground. If you kick the ball, it starts moving. You exert a force on the ball. The ball accelerates only while your foot is in contact with the ball. While something is speeding up, something is pushing or pulling the object in the direction it is moving. The direction of the push or pull is the direction of the force. It is also the direction of the acceleration.
How is slowing down acceleration?

Slowing down also is acceleration. If you wanted to slow down an object, you would have to push or pull it against the direction it is moving.

Suppose you push a book across a tabletop. When you start pushing, the book speeds up. Sliding friction also acts on the book. After you stop pushing, sliding friction makes the book slow down and stop. In the figure, the boy is slowing down because the force exerted by his feet is in the opposite direction of his motion.

How do you calculate acceleration?

Calculate acceleration using the equation from Newton’s second law of motion. For example, suppose you pull a 10-kg sled with a net force of 5 N. You can find the acceleration as follows:

\[ a = \frac{F_{\text{net}}}{m} = \frac{5 \text{ N}}{10 \text{ kg}} = 0.5 \text{ m/s}^2 \]

The sled keeps accelerating as long as you keep pulling on it. The acceleration does not depend on how fast the sled is moving. It depends only on the net force and the mass of the sled.

Picture This

5. Label In the figure, label one arrow “Force due to friction” and the other arrow “Direction of motion.”

Applying Math

6. Calculate Suppose you kick a 2-kg ball with a force of 14 N. What is the acceleration of the ball? Show your work.

\[ a = \frac{F_{\text{net}}}{m} = \frac{14 \text{ N}}{2 \text{ kg}} = 7 \text{ m/s}^2 \]
How do objects turn?
Forces and motion don’t always happen in a straight line. If a net force acts at an angle to the direction an object is moving, the object will follow a curved path. Imagine shooting a basketball. When the ball leaves your hands, it doesn’t continue to move in a straight line. Instead, it starts to curve downward due to gravity. The curved path of the ball is a combination of its original motion and the downward motion caused by gravity.

Circular Motion
You move in a circle when you ride on a merry-go-round. This motion is called circular motion. In circular motion, your direction of motion is constantly changing. This means you are constantly accelerating. There is a force acting on you the whole time. That’s why you have to hold on tightly—to keep the force from causing you to fall off.

Imagine a ball on a string moving in a circle. The string pulls on the ball and keeps it moving in a circle. The force exerted by the string is called centripetal (cen TRIP eh tal) force. The centripetal force points to the center of the circle. Centripetal force is always perpendicular to the motion. The figure shows the direction of motion, centripetal force, and acceleration of a ball traveling in a circle on a string.

How do satellites stay in orbit?
Satellites are objects that orbit Earth. They go around Earth in nearly circular orbits. The centripetal force acting on a satellite is gravity. But why doesn’t a satellite fall to Earth like a baseball? Actually, satellites do fall toward Earth.

When you throw a baseball, its path curves until it hits Earth. If you throw the baseball faster, it goes a little farther before it hits Earth. If you could throw the ball fast enough, its curved path would follow the curve of Earth’s surface. The baseball would never hit the ground. It would keep traveling around Earth.
How fast must a satellite travel?

The speed at which a satellite must travel to stay in orbit near Earth's surface is 8 km/s, or about 29,000 km/h. To place satellites into orbit, rockets carry satellites to the proper height. Then the rockets give the satellites a push in a forward direction to get them moving fast enough to orbit around the Earth.

Air Resistance

Have you ever run against the wind? If so, you have felt the force of air resistance. When an object moves through air, there is friction between the object and the air. This friction, or air resistance, slows down the object. Air resistance is a force that gets larger as an object moves faster. Air resistance also depends on the shape of an object. Think about two pieces of paper. One piece is crumpled into a ball and the other piece is flat. The paper that is crumpled into a ball will fall faster than the flat piece of paper falls.

When an object falls it speeds up as gravity pulls it downward. At the same time, the force of air resistance pushing up on the object is increasing as the object moves faster. Finally, the upward force of air resistance becomes large enough to equal the downward force of gravity.

When the air resistance force equals the weight of an object, the net force on the object is zero. Newton's second law explains that the object’s acceleration then is zero. Its speed no longer increases. When air resistance balances the force of gravity, the object falls at a constant speed. This constant speed is called the terminal velocity.

Center of Mass

Imagine throwing a stick. The stick spins while it flies through the air. Even though the stick spins, there is one point on the stick, the center of mass, that moves in a smooth path. The center of mass is the point in an object that moves as if all the object’s mass was concentrated at that point. For a symmetrical object, such as a ball, the center of mass is the center of the object.
After You Read

Mini Glossary

**center of mass**: the point in an object that moves as if all the object’s mass was concentrated at that point

**Newton’s second law of motion**: when a force acts on an object, the object accelerates in the direction of the force

**weight**: the amount of gravitational force on an object

1. Review the terms and their definitions in the Mini Glossary. What are three ways an object can accelerate? Answer in complete sentences.

2. Look at the figures below. For each object, draw and label an arrow to show the direction of the motion. Then draw and label an arrow to show the direction of acceleration.

3. You were asked to underline the main ideas as you read this section, then review what you underlined. Why do you think you were asked to review what you underlined?

Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about Newton’s second law of motion.
Force and Newton’s Laws

section 3 Newton’s Third Law

Before You Read

Imagine stepping out of a canoe onto the shore of a lake. What happens to the canoe when you step out?

What You’ll Learn

■ about forces that objects exert on each other

Read to Learn

Action and Reaction

Newton’s first two laws of motion explain how the motion of one object changes. You have learned that if balanced forces act on an object, the object will remain at rest or stay in motion with constant velocity. If the forces are unbalanced, the object will accelerate in the direction of the net force.

Another of Newton’s laws describes something else that happens when one object exerts a force on another object. When you push on a wall, did you know that the wall also pushes on you? Newton’s third law of motion states that forces always act in equal but opposite pairs. When you push on a wall, you apply a force to the wall. But, the wall also applies a force equal in strength to you. When one object applies a force on another object, the second object exerts the same size force on the first object.

Why don’t action and reaction forces cancel?

The forces that two objects put on each other are called an action-reaction force pair. The forces in a force pair are equal in strength, but opposite in direction. The forces in a force pair don’t cancel each other out because they act on different objects. Forces can cancel each other only if they act on the same object.

Outline

As you read the section, create an outline using each heading from the text. Under each heading, write the main points or ideas that you read.

Foldables

Classify

As you read this section, use your table Foldable to write about Newton’s third law.

<table>
<thead>
<tr>
<th>Force</th>
<th>Example in Your Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Law</td>
<td></td>
</tr>
<tr>
<td>Second Law</td>
<td></td>
</tr>
<tr>
<td>Third Law</td>
<td></td>
</tr>
</tbody>
</table>
Action and Reaction Forces Imagine a bowling ball hitting a bowling pin. The action force from the bowling ball acts on the pin. The pin flies in the direction of the force. The reaction force from the pin acts on the ball. It causes the ball to slow down.

How do action-reaction force pairs work on large and small objects?

When you walk forward, your shoe pushes Earth backward. Earth pushes your shoe forward. So why do you move when Earth does not? Earth has so much mass compared to you that it does not appear to move when you push on it. If you step on a skateboard, the force from your shoe makes the skateboard roll backward. This is because you have more mass than the skateboard.

How do rockets take off?
The launching of a space shuttle is a good example of Newton’s third law. When the fuel in the shuttle’s engines is ignited, a hot gas is produced. The gas molecules collide with the inside walls of the engines. The walls exert an action force that pushes the gas out of the bottom of the engine. The gas molecules put reaction forces on the walls of the engine. These reaction forces are what push the engine and the rocket forward. The force of the rocket engines is called thrust.

Weightlessness

You may have seen pictures of astronauts floating inside a space shuttle. The astronauts are said to be weightless—as if Earth’s gravity were not pulling on them. But, Earth’s gravity is what keeps a shuttle in orbit. Newton’s laws of motion can explain why the astronauts float as if there weren’t any forces acting on them.

How is weight measured?

Think about how you measure your weight. When you stand on a bathroom scale, your weight pushes down on the scale. This causes the scale pointer to show your weight. Newton’s third law tells you that the scale pushes back up on you with a force equal to your weight. This force balances the downward pull of gravity on you, as shown in the figure on the left on the next page.
How does free fall cause weightlessness?

Imagine standing on a scale in an elevator that is falling, as shown in the figure on the right below. An object is in free fall when the only force acting on it is gravity. The elevator, you, and the scale are all in free fall. In free fall, the scale doesn’t push back up on you. That’s because the only force acting on you is gravity. According to Newton’s third law, you are also not pushing down on the scale. So, the scale pointer stays at zero. You seem to be weightless. However, you are not really weightless. Earth’s gravity is still pulling down on you. But, because nothing is pushing up on you, you have no sensation of weight.

Why are spacecraft in orbit weightless?

Remember that an object will orbit Earth when its path follows the curve of Earth’s surface. Gravity keeps pulling the object down. But, the forward motion keeps it from falling straight downward. Objects that orbit the Earth, like satellites and the space shuttle, are in free fall.

Objects inside the shuttle are also in free fall. This makes the shuttle and everything inside it seem weightless, even though gravity is acting on them.

Suppose an astronaut in the shuttle is holding a ball. When she lets go of the ball, it will not move unless she pushes it. The ball does not move because the ball, the astronaut, and the shuttle are all falling at the same speed. If the astronaut pushes the ball forward, it accelerates to a speed that is faster than the shuttle and astronaut. The ball moves forward inside the shuttle.
After You Read

Mini Glossary

Newton’s third law of motion: forces always act in equal but opposite pairs

1. Review the term and its definition in the Mini Glossary. What are the action and reaction forces that make a rocket move forward? Answer in complete sentences.

2. On the figure below, draw arrows and label the action and reaction forces that are on the objects as the bat hits the baseball.

3. How could you use a skateboard to show Newton’s third law of motion to a group of elementary school students?
Work and Simple Machines

section 20 Work and Power

Before You Read
Describe the work you have done today.

What You’ll Learn
- when work is done
- how to calculate how much work is done
- how work and power are related

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 basket of clothes. Your arms have done work because the basket moved in the same direction as the force applied by your arms. If you walk forward with the basket, your arms are still applying an upward force on the basket. But you and the basket are moving forward. The basket is not moving in the same direction as the upward force applied by your arms. 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. 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. 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.

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

\[
W = Fd
\]

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.

Picture This

1. Identify Which force in the figure does work? Circle the label and arrow.

Applying Math

2. Calculate A woman lifted a box with a force of 50 N. She lifted the box 2 m. How much work did she do? Show your work.

Think it Over

3. Infer Suppose the woman in Problem 2 above lifted the box only 1 m. What happens to the amount of work done?
**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.

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

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

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. Energy cannot be created or destroyed. If the object gains energy, you must 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.
After You Read

Mini Glossary

**power:** how quickly work is done

**work:** is done when a force makes an object move in the same direction as the force that is applied

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>The books now have potential energy.</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?

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Visit [blue.mssscience.com](http://blue.mssscience.com) to access your textbook, interactive games, and projects to help you learn more about work.
Work and Simple Machines

section 3 Using Machines

Before You Read
Describe a machine you used today and 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?
Scissors, brooms, and knives are all machines. A machine is a device that makes doing work easier.

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. The force that you apply on a machine is input force. 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. A rake applies a force to move leaves. Sometimes this force is called the resistance force. This means the machine must overcome some resistance. The force that the machine applies is output force. The work that the machine does is the output work.

The output work can never be greater than the input work when you use a machine. 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. You need less force to do the work. This kind of machine increases the input force so the output force is greater than the input force. The number of times that a machine increases the input force is the **mechanical advantage** (MA) of the machine. You can calculate mechanical advantage using this equation:

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

**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 1. This is because the output force is less than the input force.

**How 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 1. 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? Circle your answer.
   a. 2
   b. 10
   c. 20
   d. 100

**Picture This**

2. **Describe** Write the words that make the sentence true on the lines below: When a machine increases a., it is applied over a shorter b.______.
   a. _________________
   b. _________________
**Efficiency**

A machine does not increase the input work. For a real machine, the output work done by the machine is always less than the input work that is done on the machine. There is friction when parts of the machine move. Friction changes some of the input work into heat. So, the output work is less. If friction in the machine decreases, the efficiency, or amount of effort, 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?

5. **Evaluate** Which will have more friction, two pieces of sandpaper or two pieces of notebook paper?
After You Read

Mini Glossary

**efficiency**: the ratio of the output work to the input work

**input force**: the force that you apply on a machine

**mechanical advantage**: the number of times that a machine increases the input force

**output force**: the force that a machine applies

1. Review the terms and their definitions in the Mini Glossary. Describe how the input force and output force of a machine work together to make work easier.

2. In the figure below, write the way each machine can be useful. Write the terms *increases force*, *changes direction of force*, and *increases distance* in the correct locations.

   **How Machines Make Work Easier**

<table>
<thead>
<tr>
<th>Input force</th>
<th>Force applied over same distance in a different direction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Input force</th>
<th>Smaller force applied over a longer distance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Input force</th>
<th>Larger force applied over a shorter distance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. How did highlighting the answers to the headings that were questions help you make sure you understood the material in the section?
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. There are six simple machines: an inclined plane, a lever, a wheel and axle, a screw, a wedge, and a pulley. A compound machine is a machine made up of more than one simple machine. A bicycle is a compound machine.

Inclined Plane

Ramps have been used for thousands of years. Ancient Egyptians might have used them to build the 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 an inclined plane is, the less force is needed to move the object.
How are inclined planes used?

Suppose you have to lift a box weighing 1,500 N into the back of the 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 lift the box into the truck. The amount of work you need to do does not change. You still need to do 1,500 J of work. But, the distance over which you apply the force is now 5 m. You can find the force you need by dividing both sides of the work equation by distance.

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

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

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 it 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.

What is a screw?
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 stiff rod or plank that turns around a point. The point that the lever turns around is called a fulcrum. 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.

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.
**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 made up of two round objects of different sizes that are attached so they turn together. The larger object is the wheel and the smaller object is the axle. The faucet handle shown in the figure is a wheel and axle.

**How do you find the MA of a wheel and axle?**

The MA (mechanical advantage) of a wheel and axle is usually greater than 1. You find it by dividing the radius of the wheel by the radius of the axle. Suppose the radius of the wheel is 12 cm and the radius of the axle is 4 cm. The mechanical advantage is 3.

**How are wheels and axles used?**

In some wheels and axles, the input force turns the wheel. The wheel turns the axle. The turning axle makes 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 kind of wheel and axle.

In other wheels and axles, the input force turns the axle. The axle turns the wheel. The wheel makes the output force. 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 kind 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 needed. 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.
After You Read

Mini Glossary

- **compound machine:** a machine made up of more than one simple machine
- **inclined plane:** a flat, sloped surface
- **lever:** any stiff rod or plank that turns around a point
- **pulley:** a grooved wheel with a rope or cable wrapped over it
- **screw:** an inclined plane wrapped around a cylinder or post

- **simple machine:** a machine that does work with only one movement
- **wedge:** an inclined plane that moves
- **wheel and axle:** two round objects of different sizes that are attached so they turn together

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 machines 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>tooth</td>
<td>a. inclined plane</td>
</tr>
<tr>
<td>doorknob</td>
<td>b. wheel and axle</td>
</tr>
<tr>
<td>threads of a lightbulb</td>
<td>c. wedge</td>
</tr>
<tr>
<td>wheelbarrow</td>
<td>d. screw</td>
</tr>
<tr>
<td>ramp</td>
<td>e. pulley</td>
</tr>
<tr>
<td>flagpole rope</td>
<td>f. lever</td>
</tr>
</tbody>
</table>

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

Science online Visit [blue.msscience.com](http://blue.msscience.com) to access your textbook, interactive games, and projects to help you learn more about simple machines.
Thermal Energy

section  Temperature and Thermal Energy

**Before You Read**

Do you consider the temperature when you choose the clothes you wear each day? List two examples of when it's important to know the temperature of something.

**Read to Learn**

**What is temperature?**

Think of a hot summer day. You jump into a swimming pool to cool off. At first, the water feels cold on your skin. But the water might feel warm to your friend who has been swimming for awhile. How do you know if something is hot or cold? Your sense of touch tells you if something feels hot, warm, or cold.

**Why do some things feel hot and others feel cold?**

How hot or cold something feels depends on its temperature. To understand temperature, think of water in a glass. Water is made of molecules. Water molecules are always moving. When something moves, it has energy of motion, or kinetic energy.

The molecules in the glass of water move at different speeds. Some move quickly and some move slowly. The fastest molecules have the most kinetic energy. **Temperature** is a measure of the average kinetic energy of the molecules. The more kinetic energy the molecules have, the higher the temperature. Molecules have more kinetic energy when they are moving faster. So the higher the temperature, the faster the molecules are moving.
What are some effects of temperature?

Sometimes in hot weather, a sidewalk will crack. When the temperature of an object increases, its molecules move faster and farther apart. This causes the object to get larger, or to expand. Concrete in a sidewalk, like almost all substances, expands as its temperature increases. When an object cools, its molecules slow down and move closer together. The object gets smaller, or contracts.

Most materials expand when they are heated and contract when they are cooled. How much a material expands or contracts depends on the material and the change in temperature. Liquids usually expand more than solids. And, the greater the change in temperature, the more an object expands or contracts.

Measuring Temperature

Recall that an object’s temperature depends on the average kinetic energy of all its molecules. How do you measure the kinetic energy of all those tiny molecules? One way to measure temperature is to use a thermometer.

One type of thermometer is made of a glass tube with a liquid inside. When the temperature of the liquid increases, the liquid expands and moves higher inside the tube. How high the liquid moves depends on the temperature.

What temperature scales are used?

A thermometer has to have a scale on it to measure temperature change. Two temperature scales are the Fahrenheit scale and the Celsius scale. The thermometer in the figure has both scales. Water freezes at 32°F and boils at 212°F on the Fahrenheit scale. There are 180 equal degrees between the freezing and boiling point of water on the Fahrenheit scale. On the Celsius scale, water freezes at 0°C and boils at 100°C. There are 100 Celsius degrees between the boiling and freezing point of water on the Celsius scale. Celsius degrees are bigger than Fahrenheit degrees.
How is one scale changed to the other?

Use the following equations to convert, or change, °F to °C and °C to °F.

To convert temperature in °F to °C: $\text{°C} = \frac{5}{9}(\text{°F} - 32)$

To convert temperature in °C to °F: $\text{°F} = \frac{9}{5}(\text{°C}) + 32$

For example, to change 68°F to degrees Celsius, first subtract 32, multiply by 5, then divide by 9. So 68°F = 20°C.

Are there other temperature scales?

Another temperature scale is the Kelvin scale. On the Kelvin scale, 0 K is the lowest temperature possible. 0 K is also called absolute zero. It equals −273°C. To change from Celsius degrees to Kelvin degrees, add 273 to the Celsius temperature.

$K = °C + 273$

Thermal Energy

Recall that molecules in motion have kinetic energy. Molecules also have potential energy. Potential energy is energy that can be changed into kinetic energy. The sum of the kinetic energy and potential energy of all the molecules in an object is its thermal energy.

What is potential energy?

A ball being held above the ground has potential energy. When the ball is dropped, the potential energy changes to kinetic energy because the ball is now moving.

Molecules in a material attract each other. The molecules have potential energy because of this attraction. The potential energy of the molecules changes as the molecules get closer together or farther apart.

How are temperature and thermal energy different?

Suppose you have two glasses filled with the same amounts of milk. The milk in both glasses is at the same temperature. If you pour both glasses of milk into a pitcher, the temperature of the milk doesn’t change. But the thermal energy of the milk does change. The milk in the pitcher has more thermal energy than the smaller amounts of milk in either glass did. That’s because there are more molecules of milk in the pitcher than there were in either glass.


After You Read

Mini Glossary

temperature: a measure of the average kinetic energy of an object's molecules

thermal energy: the sum of the kinetic energy and potential energy of all the molecules in an object

1. Review the terms and definitions in the Mini Glossary. Write a sentence using the term thermal energy.

2. Write the letter of the term in Column 2 that matches the example in Column 1.

<table>
<thead>
<tr>
<th>Column 1</th>
<th>Column 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. water boils at 212°F</td>
<td>a. kinetic energy</td>
</tr>
<tr>
<td>2. the type of energy a ball has when you hold it above the ground</td>
<td>b. Fahrenheit scale</td>
</tr>
<tr>
<td>3. water freezes at 0°C</td>
<td>c. temperature</td>
</tr>
<tr>
<td>4. energy of motion</td>
<td>d. potential energy</td>
</tr>
<tr>
<td>5. measure of the average kinetic energy of an object's particles</td>
<td>e. Kelvin scale</td>
</tr>
<tr>
<td>6. water freezes at 273 K</td>
<td>f. Celsius scale</td>
</tr>
</tbody>
</table>

3. You were asked to think of questions your teacher might ask on a test then write each question on the front of a flash card. How could you use the flash cards to help you study for a test?
Identify Main Ideas
As you read this section, highlight the main ideas about conduction, radiation, and convection.

What You’ll Learn
- compare thermal energy and heat
- three ways heat moves
- what insulators and conductors are

Before You Read
Write down two things you do to make yourself feel warmer.

Read to Learn
Heat and Thermal Energy
It’s cold, turn up the heat. Heat the oven to 375°F. A heat wave has hit the Midwest. You’ve often heard the word heat, but what exactly is it? Heat is thermal energy that moves from one object to another when the objects are at different temperatures. Heat moves, or is transferred, when two objects are in contact with each other. More heat is transferred when the difference in temperature between the objects is large. Less heat is transferred when the temperature difference is small.

For example, no heat moves between two pots of boiling water that are touching. The water in both pots is the same temperature. Suppose a pot of boiling water touches a pot of cold water. Heat is transferred from the hot pot to the cold pot. The hot water loses heat and the cold water gains heat. Heat will transfer until both objects are the same temperature.

How does heat move?
Heat always is transferred from warmer objects to cooler objects. It never transfers from a cooler object to a warmer one. The warmer object loses thermal energy. It becomes cooler. The cooler object gains thermal energy. It becomes warmer. Heat can be transferred in three ways—by conduction, radiation, or convection.
Conduction

When you eat something hot, conduction occurs. As the hot food touches your mouth, heat moves from the food to your mouth. **Conduction** is the movement of heat between objects that are touching.

When you hold an ice cube in your hand, conduction is occurring. The ice cube starts to melt and your hand starts to feel cold. The fast-moving molecules in your warm hand bump into the slow-moving molecules in the cold ice. When the faster-moving molecules touch the slower-moving molecules, energy passes from molecule to molecule. As a result, heat moves from your warm hand to the cold ice. The slow-moving molecules in the ice start moving faster. With more energy, the ice warms and its temperature rises. The ice begins to melt. The fast-moving molecules in your hand move more slowly. They lose thermal energy and your hand becomes cooler.

**When does conduction work best?**

Conduction works best in solids and liquids. That’s because the molecules and atoms are closer together in a solid or a liquid than in a gas. The molecules and atoms have to move only a short distance before they bump into each other and transfer energy to another molecule or atom. So, heat is transferred by conduction faster in liquids and solids than in gases.

Radiation

On a beautiful, clear day, you walk outside and notice the warmth of the Sun. How does the Sun heat Earth? The Sun transfers thermal energy to Earth, but not by conduction. The Sun and Earth do not touch. Instead, the Sun transfers heat to Earth by radiation. **Radiation** is the transfer of energy by electro-magnetic waves. Electromagnetic waves can carry energy through empty space, like the space between Earth and the Sun. These waves can also carry energy through solids, liquids, and gases. ☑

The Sun is not the only object that transfers heat by radiation. Sit next to a fire in a fireplace. You feel heat transferred by radiation from the fire to your skin. All objects give off electromagnetic radiation. Warm objects give off more radiation than cool objects.
Convection

When you heat a pot of water, heat transfers by conduction from the stove to the pot. Heat can be transferred in another way, too. As gas and liquid molecules move, they carry energy with them. **Convection** is the transfer of thermal energy through the movement of molecules from one part of a material to another.

**How is heat transferred by convection?**

Heat is transferred by convection as a pot of water is heated. First, thermal energy is transferred to the water molecules near the bottom of the pot. These water molecules begin to move faster as their thermal energy increases. The faster the molecules move, the farther apart they get. Now the molecules in the warm water are farther apart than the molecules in the cooler water near the top of the pot. So, the warm water is less dense than the cool water. The warm, less dense water rises to the top of the pot. The cool, more dense water moves down to the bottom of the pot. As the cool water is heated, it rises to the top. This repeats until all the water in the pot is the same temperature.

**What is natural convection?**

Natural convection takes place when a cool, dense fluid, pushes away a warm, less dense fluid. Think of the shore of a lake. The water is cooler than the land during the day. The warm land heats the air above it by conduction. As the air gets hotter, its particles move faster and farther away from each other. The hot air is less dense and it rises. The cooler, denser air from above the lake moves toward the land. You feel this movement of cool air as wind. The figure shows that as cool air moves over the land, it pushes the warm, less dense air up. The land heats the cool air and the cycle repeats.
What is forced convection?

Forced convection takes place when an outside force pushes a fluid to make the fluid move and transfer heat. A fan is an example of an outside force. Computers use fans to keep their electronic parts from getting too hot. The fan blows cool air onto the hot parts.

Heat from the computer parts is transferred to the air around them by conduction. Warm air is pushed up and away from the hot parts and cool air moves in. The hot parts keep transferring heat to the cool air around them.

Thermal Conductors

Why are most cooking pans made of metal? Why does a metal spoon in a bowl of hot soup feel warm? Metal is a good conductor of heat. A conductor is any material that transfers heat easily. Some materials are good conductors because of the types of atoms or chemical compounds they are made up of.

Remember that an atom has a nucleus surrounded by one or more electrons. In some materials, like metals, these electrons are not held tightly in place. They can move around freely. These electrons can transfer thermal energy by bumping into other atoms. Metals such as gold and copper are the best conductors of heat.

Thermal Insulators

When you cook food in a pan, you want the pan to conduct heat from the hot burner to your food. But you do not want heat to move easily to the pan’s handle. An insulator is a material that heat does not flow through easily. Most cooking pans have handles made from insulators.

Liquids and gases are usually better insulators than solids are. Air is a good insulator. Many insulating materials have spaces filled with air. The air prevents heat from moving through the material by conduction. Metals and other good conductors of heat are poor insulators. Air and other good insulators are poor heat conductors.

Houses and other buildings contain insulating materials. These materials reduce the heat conduction between the inside and outside. Insulating windows are made of two layers of glass. There is a layer of air or other gas in between the layers of glass. The layer of air reduces heat conduction. It keeps heat from going outside in the winter and from coming inside in the summer.
Heat Absorption

On a hot day, you can walk barefoot across the lawn. But the pavement of the street is too hot to walk on. Why is the pavement hotter than the grass? The change in temperature of an object as it absorbs heat depends on the material it is made of.

What is specific heat?

The specific heat of a material is the amount of heat needed to raise 1 kilogram of that material by 1°C. More heat is needed to change the temperature of a material with a high specific heat than a material with a low specific heat.

For example, the sand on a beach has a lower specific heat than water in a lake. On a hot summer day, the sand feels warmer than the water. Both are warmed by radiation from the Sun. But, the sand heats up faster than the water because it has a lower specific heat than the water. At night, the sand feels cool and the water feels warmer. They both lose thermal energy to the cooler night air. However, the temperature of the sand decreases faster than the temperature of the water.

Thermal Pollution

Some power plants and factories use water to cool hot equipment. The cooling water becomes hot. This hot water may be released into lakes, rivers, or the ocean. The hot water increases the temperature of the nearby water. Thermal pollution is the increase in the temperature of a body of water caused by warmer water being added to it. Rainwater falling on warm roads and parking lots can also cause thermal pollution.

Why is thermal pollution harmful?

Warmer water has less dissolved oxygen than cooler water. Warm water causes fish and other animals to use more oxygen. Some animals may die because there is not enough oxygen in the water. Also, in warmer water, parasites and diseases are a bigger problem for many organisms. Factories and power plants can reduce thermal pollution by cooling hot water in cooling towers before it's released.

6. Explain Which kind of material needs more heat to raise its temperature, one with a high specific heat or one with a low specific heat?

7. Identify Name one harmful result of thermal pollution.

Think it Over

Warmer water has less dissolved oxygen than cooler water. Warm water causes fish and other animals to use more oxygen. Some animals may die because there is not enough oxygen in the water. Also, in warmer water, parasites and diseases are a bigger problem for many organisms. Factories and power plants can reduce thermal pollution by cooling hot water in cooling towers before it's released.
After You Read

Mini Glossary

**conduction:** the movement of heat between objects that are touching

**conductor:** any material that transfers heat easily

**convection:** the transfer of thermal energy through the movement of molecules from one part of a material to another

**heat:** thermal energy that moves from one object to another when the objects are at different temperatures

**radiation:** the transfer of energy by electromagnetic waves

**specific heat:** the amount of heat needed to raise 1 kilogram of a material by 1°C

**thermal pollution:** the increase in the temperature of a body of water caused by adding warmer water

1. Review the terms and definitions in the Mini Glossary. Chose one of the terms that describes how heat can be moved and use it in a sentence.

2. Fill in the blanks on the web diagram below with examples of the different methods of heat transfer.

   **Conduction**
   
   **Example:** ____________________________

   **Radiation**
   
   **Example:** ____________________________

   **Convection**
   
   **Example:** ____________________________

3. You were asked to highlight the main ideas about conduction, radiation, and convection. What would be another way to learn about these three methods of heat movement?

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Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about heat.
Before You Read
List at least two machines that have engines. Describe what each engine does.

What You’ll Learn
- what heat engines do
- forms of energy
- energy is never created or destroyed
- how internal combustion engines work
- how refrigerators move heat

Read to Learn

Heat Engines
Cars, motorcycles, and trucks use heat engines. A **heat engine** is a machine that changes thermal energy into mechanical energy. Mechanical energy is the sum of an object’s kinetic energy and potential energy. The heat engine in a car converts thermal energy into mechanical energy when it makes the car move faster. This causes the car’s kinetic energy to increase.

What are some other forms of energy?
Thermal energy and mechanical energy are not the only forms of energy. Chemical energy is stored in chemical bonds between atoms. Radiant energy is carried by electromagnetic waves. Nuclear energy is stored in the nuclei of atoms. Electrical energy is carried by electric charges as they move in an electric circuit. Devices such as heat engines convert one form of energy into other useful forms.

Can energy be created or destroyed?
When energy changes from one form to another, the total amount of energy stays the same. The law of conservation of energy states that energy only can be changed from one form to another. Energy cannot be created or destroyed.
What is the most common heat engine?

If you have ever ridden in a car, plane, bus, boat, or truck, you have used a type of heat engine. Most vehicles use a heat engine called an internal combustion engine. An internal combustion engine is an engine that burns fuel in a combustion chamber inside the engine.

How does an internal combustion engine work?

The engines in most cars have four or more combustion chambers, or cylinders. Usually the more cylinders an engine has, the more power it can produce. Inside each cylinder is a piston that moves up and down. A mixture of fuel and air is sent into the combustion chamber. A spark from a spark plug causes the fuel mixture to burn. The explosive force of the reaction pushes the piston down. As the piston moves up and down, it turns a rod called a crankshaft. The crankshaft then turns the wheels of the car. An internal combustion engine converts thermal energy to mechanical energy. The process is called a four-stroke cycle.

Are all internal combustion engines the same?

There are different types of internal combustion engines. In a diesel engine, the air in a cylinder is pushed together, or compressed, until the pressure is very high. Instead of a spark plug, the high pressure ignites the fuel, or starts the fuel burning.

Many lawn mowers use a two-stroke engine. During the first stroke, fuel and air move into the chamber and are compressed. During the second stroke, the fuel mixtures burn and push the piston down.

Refrigerators

Recall that thermal energy will flow only from something warm to something that is cooler. So how can a refrigerator be cooler inside than the air in the kitchen? Refrigerators keep food cold by moving heat. A refrigerator absorbs heat from the food and other materials inside the refrigerator. Then, it moves the heat to the outside of the refrigerator. There the heat is transferred to the air around the refrigerator.

Inside a refrigerator, a liquid material called a coolant moves through pipes. The coolant absorbs heat from inside and carries the heat outside the refrigerator through the pipes.
How does a coolant absorb heat?

The figure below shows how a refrigerator works. Liquid coolant is forced through a pipe. The liquid coolant passes through an expansion valve where it changes from a liquid into a gas. When it changes into a gas, it becomes cold. The cold gas moves through the pipes inside the refrigerator. Because the coolant gas is so cold, it absorbs heat from the inside of the refrigerator and gets warmer.

How does warm coolant get rid of heat?

Even though the coolant has absorbed heat, it is still cooler than the air outside the refrigerator. The heat in the coolant cannot be transferred to the outside air. The warm coolant gas passes through a compressor. The gas is compressed and gets warmer. Next, the gas passes through the condenser coils. Inside the coils, the coolant releases its heat to the cooler air outside the refrigerator. The coolant gas cools and changes back into a liquid. The liquid coolant is pumped through the expansion valve. The cycle is repeated.

How do air conditioners work?

You’ve probably seen air-conditioning units outside of many houses. Most air conditioners cool the same way that a refrigerator does. Just like a refrigerator, the coolant inside the pipes of an air conditioner absorbs heat. The coolant passes through a compressor and becomes warmer. The warm coolant travels through pipes outside the house where the heat from the coolant moves to the outside air.
How do heat pumps work?

Some buildings use heat pumps to heat and to cool. Just like an air conditioner or a refrigerator, a heat pump moves heat from one place to another.

The figure shows how a heat pump heats the air inside a building. First, the coolant absorbs heat from the outside air through the coils outside the building. Then, the coolant is warmed as it passes through the compressor. The warm coolant releases its heat inside the building through the inside coils. When a heat pump is used to cool a building, it removes heat from the air inside and releases the heat outside.
After You Read

Mini Glossary

**heat engine:** a machine that changes thermal energy into mechanical energy

**internal combustion engine:** an engine that burns fuel in a combustion chamber inside the engine

1. Review the terms and definitions in the Mini Glossary. Write one sentence that uses both terms.

2. Complete the flow chart below to help you organize what you learned about how an internal combustion engine works.

   A mixture of __________________________ and __________________________ comes into the chamber.

   A ___________________________ from a spark plug ___________________________ the fuel mixture.

   The force of the reaction pushes the piston ___________________________.

   The ___________________________ turns as the ___________________________ moves up and down.

   The ___________________________ turns the ___________________________ and the car moves.
3. Use the flow chart below to list the steps that explain how a refrigerator cools.

The liquid coolant becomes ______________________ as it changes to a ______________________.

The ______________________ gas moves through ______________________ inside the refrigerator.

The ______________________ gas absorbs ______________________ from the inside of the refrigerator and becomes ______________________.

The ______________________ gas passes through the ______________________ and becomes even ______________________.

The ______________________ gas passes through the condenser coils and ______________________ its ______________________ to the cooler air ______________________ the refrigerator.

4. How did underlining the answers to the questions in the section help you understand the information in the section?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about engines and refrigerators.
Electricity

section Electric Charge

Before You Read
You use electricity every day. What would be different in your life if you didn’t have electricity?

What You’ll Learn
- how objects become electrically charged
- about electric charges
- about conductors and insulators
- about electric discharge

Read to Learn

Electricity
To understand electricity, first you must think small—very small. Remember that all solids, liquids, and gases are made of tiny particles called atoms. Atoms are made of even smaller particles called protons, neutrons, and electrons. Look at the figure. Protons and neutrons are held together tightly in the nucleus at the center of an atom. Electrons swarm around the nucleus in all directions. Protons and electrons have electric charge. Neutrons have no electric charge.

What are positive and negative charges?
There are two kinds of electric charge—positive and negative. A proton has a positive charge. An electron has a negative charge. Atoms have an equal number of protons and electrons. So, atoms are electrically neutral. They have no overall electric charge.

Find the Main Idea
As you read, highlight the main idea of each paragraph.

Picture This
1. Label Use three different colored highlighters, crayons, or pencils to mark the protons, neutrons, and electrons. Use a different color for each.
Think it Over

2. Explain Does an object that is positively charged have more electrons than protons or fewer electrons than protons?

---

FOLDABLES

A Compare and Contrast

Use two quarter sheets of notebook paper to compare and contrast information about gaining and losing electrons.

Gain Electrons | Lose Electrons
---|---

---

Picture This

3. Describe Look at the figure. How would you describe the chloride and sodium ions in the water? Circle your answer.

a. tightly held together
b. all the ions are negative
c. spread out evenly
d. all the ions are positive

---

Ions

An atom can gain electrons. When it does, it becomes negatively charged. An atom also can lose electrons and become positively charged. A positively or negatively charged atom is an ion (I ahn).

How can electrons move in solids?

Electrons can move from atom to atom. They also can move from object to object. Rubbing is one way that electrons can move. Have you ever had clinging clothes when you took them out of the dryer? If so, you have seen what happens when electrons move from one object to another.

Imagine rubbing a balloon on your hair. The atoms in your hair hold their electrons more loosely than the atoms in the balloon. The electrons from the atoms in your hair move to the atoms on the surface of the balloon. So, your hair loses electrons and becomes positively charged. The balloon gains electrons and becomes negatively charged. Your hair and the balloon become attracted to one another. Your hair stands on end because of the static charge.

What is static charge?

Static charge is an imbalance of electric charge on an object. Static charge happens in solids because electrons move from one object to the other. Protons cannot easily move from the nucleus of an atom. So, protons usually do not move from one object to another.

How do ions move in solutions?

Sometimes, ions move instead of electrons. When ions move, the charge can move. Table salt, or sodium chloride, is made of sodium ions and chloride ions that are held in place and cannot move through the solid. Ions cannot move through solids, but they can move through solutions.

Look at the figure. When salt is dissolved in water, the sodium and chloride ions break apart. The ions spread out evenly in the water and form a solution. In the solution, the positive and negative ions are free to move. Solutions that have ions make parts of your body able to communicate with each other. Nerve cells use ions to send signals to other cells. These signals move throughout your body so that you can see, touch, taste, smell, move, and even think.
Electric Forces

Remember that electrons in an atom swarm around the nucleus. What keeps the electrons close to the nucleus? The positively charged protons in the nucleus exert an attractive electric force on the negatively charged electrons. **Electric force** is the force between charged objects. All charged objects exert an electric force on each other. The electric force can attract or it can repel, or push away.

Look at the figure below. Objects with unlike charges, like positive protons and negative electrons, attract each other. Objects with like charges repel each other. Two positive objects repel each other. Two negative objects repel each other.

![Unlike charges attract.](image)

The electric force between two charged objects depends on the distance between them. Electric force also depends on the amount of charge on each object. The electric force between two charges gets stronger as the charges get closer together. As positive and negative charges come closer together, the attraction gets stronger. When two like charges come closer together, they repel each other more strongly. If the amount of charge on at least one object increases, then the electric force between the two objects increases.

**What are electric fields?**

Charged objects don’t have to touch each other to exert an electric force on each other. Imagine two charged balloons. They push each other apart even though they do not touch. Why does this happen?

Every electric charge has a space, or a field, around it. An **electric field** is the space in which charges exert a force on each other. If an object with a positive charge is placed in the electric field of another positive object, the objects repel each other. If an object with a negative charge is placed in the electric field of an object with a positive charge, the objects attract each other. Also the closer the objects are, the stronger the electric fields.
Insulators and Conductors

When you rub a balloon on your hair, the electrons from your hair move to the balloon. But, only the part of the balloon that is rubbed on your hair gains the electrons. Electrons cannot move easily through rubber. So, the electrons that move from your hair to the balloon stay in one place on the balloon. The balloon is an insulator. An **insulator** is a material in which electrons cannot move easily from place to place. Plastic, wood, glass, and rubber are examples of insulators.

A **conductor** is a material in which electrons can move easily from place to place. An electric cable is made from a conductor coated with an insulator, like plastic. The electrons move easily in the conductor (the wire), but do not move easily in the insulator (the plastic). The insulator keeps the electrons in the conductor so that someone touching the cable won’t get a shock.

**What are the best conductors?**

The best conductors are metals, like copper, gold, and aluminum. In a metal atom, some electrons are not attracted as strongly to the nucleus as others. When metal atoms form a solid, the atoms cannot move far. But, the electrons inside the atoms that are not strongly attracted to each nucleus can move easily in a solid piece of metal. Insulators are different. In an insulator, the electrons of an atom are strongly attracted to the nucleus. The electrons in an insulator cannot move easily.

**Induced Charge**

Have you ever walked on carpet and then touched a doorknob? Maybe you felt an electric shock or saw a spark. Look at the figure on the next page to see what happened.

As you walk, electrons rub off the carpet onto your shoes. The electrons spread over the surface of your skin. As your hand gets near the doorknob, the electric field around the extra electrons on your hand repels the electrons in the doorknob. The doorknob is metal, so it is a good conductor. The electrons on the doorknob move easily away from your hand. The part of the doorknob closest to your hand becomes positively charged. This separation of positive and negative charges because of an electric field is called an induced charge. The word induce means “to cause”. You induced, or caused, a positive charge on the doorknob.
If the electric field between your hand and the doorknob is strong enough, charge can be pulled quickly from your hand to the doorknob. The quick movement of extra charge from one place to another place is an electric discharge. Lightning is an example of an electric discharge. Imagine a storm cloud. The movement of air causes the bottom of the cloud to become negatively charged. The negative charge induces a positive charge on the ground below the cloud. Cloud-to-ground lightning strikes when electric charge moves between the cloud and the ground.

Grounding

Lightning is an electric discharge that can cause damage and hurt people. A lightning bolt releases a large amount of electric energy. Even electric discharges that release small amounts of electric energy can cause damage to electrical objects, like computers. One way to avoid damage caused by electric discharges is to make the extra charges flow into Earth's surface. Earth is a good conductor. Since it is so large, it can absorb, or take in, a large amount of extra charge. You may have seen a lightning rod at the top of a building. The rods are metal and are connected to metal cables. These cables conduct the electric charge into Earth if the rod is struck by lightning. So, the extra charge goes to Earth and the building is protected.
After You Read

Mini Glossary

**conductor:** a material in which electrons can move easily from place to place

**electric discharge:** the quick movement of extra charge from one place to another place

**electric field:** the field, or space, in which charges exert a force on each other

**electric force:** the attraction or repulsion between charged objects

**insulator:** a material in which electrons cannot move easily from place to place.

**ion:** a positively or negatively charged atom

**static charge:** an imbalance of electric charge on an object

1. Read the key terms and definitions in the Mini Glossary above. What would cause the electric force between two objects to increase? Explain.

2. The table below lists the charges of two objects. Use the words *attract* and *repel* to describe the electric force between the objects.

<table>
<thead>
<tr>
<th>Charges of Two Objects</th>
<th>Electric Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive and positive</td>
<td></td>
</tr>
<tr>
<td>Positive and negative</td>
<td></td>
</tr>
<tr>
<td>Negative and negative</td>
<td></td>
</tr>
</tbody>
</table>

3. You were asked to highlight the main idea of each paragraph. Did this strategy help you learn about electric charge? Why or why not?

---

Scienceonline [Visit blue.msscience.com](http://blue.msscience.com) to access your textbook, interactive games, and projects to help you learn more about electric charge.
Electricity

section Electric Current

Before You Read

You can turn on the light in a room any time you wish. Where does the electricity come from?

Read to Learn

Flow of Charge

Lights, refrigerators, TV’s and other things need a steady source of electrical energy that can be controlled. Electric currents are used for steady and controlled electricity. An electric current is the flow of electric charge. In solids, the flowing charges are electrons. In liquids, the flowing charges are ions. Remember that ions can be positive or negative. Electric currents are measured in amperes (A). A model of an electric current is flowing water. Water flows downhill because a gravitational force acts on it. Electrons flow because an electric force acts on them.

What is a simple circuit?

The flow of water can create energy. Look at the figure. Water that is pumped high above the ground has potential energy because gravity acts on it. As water falls, it loses potential energy. When the water falls on a waterwheel and turns it, the waterwheel gains kinetic energy. The water flows through a continuous loop. A closed, conducting loop that electric charges flow continuously through is a circuit.
What are electric circuits?

The simplest electric circuit has a source of electric energy and an electric conductor. In the figure below, the source of electric energy is the battery. The electric conductor is the wire. The wires connect the lightbulb to the battery in a closed path. Electric current flows in the circuit as long as the wires, including the filament wire in the lightbulb, stay connected.

What is voltage?

Think of the example of the waterwheel. The pump increases the gravitational potential energy of the water by raising it from a lower level to a higher level. In an electric circuit, the battery increases the electrical potential energy of electrons. This electrical potential energy can be changed into other forms of energy.

The measure of how much electrical potential energy each electron can gain is the **voltage** of a battery. Voltage is measured in volts (V). As voltage increases, more electrical potential energy is available to be changed into other forms of energy.

How does a current flow?

The electrons in an electric circuit move slowly. When the ends of a wire are connected to a battery, the battery makes an electric field in the wire. The electric field forces electrons to move toward the positive end of the battery.
Look at the plus sign on the battery in the figure on the previous page. As electrons move, they bump into other electric charges in the wire. Then, they bounce off in different directions. Electrons start to move again toward the positive end of the battery. An electron can have more than ten trillion of these bumps each second. So, it can take several minutes for an electron to travel even one centimeter.

**How do batteries work?**

**Battery Terminals** Batteries have a negative terminal, or end, and a positive terminal. You have learned that the battery in a circuit makes an electric field that forces electrons to move toward the positive terminal of the battery. When the positive and negative terminals of a battery are connected in a circuit, the electric potential energy of electrons in the circuit increases. As electrons move toward the positive terminal, the electric potential energy turns into other forms of energy. This also happens with water. The gravitational potential energy of the water turns into kinetic energy as the water turns the waterwheel.

**Electrical Potential Energy** The battery changes chemical energy into electric potential energy. In the figure on the previous page, the battery shown is an alkaline battery. Between the positive terminal and negative terminal is a moist paste. Chemical reactions in the moist paste move electrons from the positive terminal to the negative terminal. So, the negative terminal becomes negatively charged and the positive terminal becomes positively charged. This makes the electric field in the circuit that causes the electrons to move away from the negative terminal to the positive terminal. The chemical energy is now electrical potential energy.

**How long can batteries last?**

Batteries cannot supply energy forever. Do you know what happens if the lights on a car are left on for a long time? The car battery runs down and the car won’t start. Why do batteries run down? Batteries have only a certain amount of chemicals in them that react to make chemical energy. As long as the battery is used, these chemical reactions happen. The chemicals change into other compounds. When the chemicals are used up, the chemical reactions stop. The battery is then “dead.”

4. **Explain** How does the negative terminal of a battery become negatively charged?

5. **Explain** Why does a battery “die”?
Resistance

Remember that electrons move more easily through conductors than through insulators. But, even in conductors, the flow of electrons can be slowed down. The measure of how difficult it is for electrons to flow through a material is **resistance**. The unit of resistance is the ohm (Ω). Insulators have a higher resistance than conductors.

You learned that, in a circuit, electrons bump into other electric charges. When this happens some of the electrical energy in the electrons turns into thermal energy in the form of heat or light. The amount of electrical energy that turns into heat and light depends on the resistance of the materials in the circuit.

**Why are copper wires used in buildings?**

The amount of electrical energy that turns into thermal energy increases when the resistance of the wire increases. Copper is one of the best conductors of electric energy. It also has a low resistance. So, less heat is made when an electric current flows through copper wire. Copper wire is used in houses and other buildings because copper wire usually will not become hot enough to cause fires.

**How are length and thickness of a wire related to resistance?**

A wire can have high or low electric resistance depending on what the wire is made of. The electric resistance of a wire also depends on the wire’s length and thickness. The electric resistance of a wire increases as the wire becomes longer. The electric resistance also increases as the wire becomes narrower. ☑

**How do lightbulbs work?**

Lightbulbs have a tiny wire inside called a filament. The filament wire is so narrow that it has a high resistance. Remember that a material that has high resistance can turn electric energy into thermal energy in the form of heat or light. When electric current flows in the filament, the wire becomes hot enough to make light. Why doesn’t the filament melt? The filament is made of tungsten metal. Tungsten has a much higher melting point than most other metals. So, the tungsten metal filament will not melt at the high temperature needed to make light.
1. Review the terms and their definitions in the Mini Glossary. Write one or two sentences to compare resistance in a conductor and an insulator.

2. Complete the graphic organizer to compare and contrast copper wire and tungsten wire using the information below.

3. At the beginning of the section, you were asked to create an outline of the section. How did the outline help you learn about electric current?
Electricity

section Electric Circuits

What You’ll Learn
■ how voltage, current, and resistance are related
■ about series and parallel circuits
■ how to avoid dangerous electric shock

Before You Read
You use circuits every day. Name some circuits you have used.

Read to Learn

Controlling the Current
Electric current flows through a circuit when you connect a conductor, like a wire, between the positive and negative terminals of a battery. The amount of current depends on the voltage of the battery and the resistance of the conductor.
Imagine a bucket of water with a hose attached in the bottom of it. Look at the figure. If you raise the bucket, you increase the potential energy of the water in the bucket. This causes the water to flow out of the hose faster. This happens with electric current, too. If the amount of voltage increases, the amount of current flowing through a circuit will increase.

How do voltage and resistance affect current?
As the figure shows, the higher the bucket is raised, the more energy the water has. Increasing the voltage in a battery is like increasing the height of the water. The electric current in a circuit increases if the voltage increases. If the resistance in an electric circuit is greater, less current can flow through the circuit.

Picture This
1. Infer Circle the bucket and hose that show greater resistance.
What is Ohm’s law?

In the nineteenth century, a German scientist named Georg Simon Ohm measured how changing the voltage in a circuit affects the current. He found a relationship among voltage, current, and resistance in a circuit, know as Ohm’s law. **Ohm’s law** states that when voltage in a circuit increases, the current increases. The equation below shows this relationship.

\[ \text{Voltage (in volts)} = \text{current (in amperes)} \times \text{resistance (in ohms)} \]

\[ V = IR \]

If the voltage in a circuit stays the same, but the resistance changes, the current will change, too. If the resistance increases, the current in the circuit will decrease.

**Series and Parallel Circuits**

Circuits control the movement of electric current by providing paths for electrons to follow. In order for a current to flow, the circuit must be an unbroken path. Imagine a string of lights with tiny light bulbs. In some strings of lights, if only one bulb is burned out, the whole string of lights won’t work. This is an example of a series circuit. Some strings of lights will stay lit no matter how many bulbs burn out. This is an example of a parallel circuit.

**What is a series circuit?**

A **series circuit** is a circuit that has only one path for the electric current to follow. Look at the figure. If the path is broken, current cannot flow. The bulbs in the circuit will not light. The path could be broken if a wire comes off or if a bulb burns out. The filament in the lightbulb is also part of the circuit. So, if the filament breaks, then the flow of current stops.

![Diagram of a series circuit with a battery and two light bulbs connected one after the other.](image-url)
What happens when resistance increases?

In a series circuit, electrical devices are connected along the same path. So, the current is the same through every device. But, if a new device is added to the circuit, the current will decrease throughout the circuit. Why? Each device has its own electrical resistance. In a series circuit, the total resistance increases as each new device is added. Ohm’s law tells us that if resistance increases and the voltage doesn’t change, the current will decrease.

What is branched wiring?

What would it be like if all the electrical devices in your house were on a series circuit? You would have to turn on all the appliances in your house just so you could watch TV.

Parallel Circuits

Your house, school, and other buildings are wired using parallel circuits. A parallel circuit is a circuit that has more than one path for the electric current to follow. The figure shows a parallel circuit. The circuit branches so that the electrons flow through each of the paths. If one of the paths is broken, electrons will still flow through the other paths. So, you can add or remove a device in one branch and the current will still flow.

In a parallel circuit, the resistance in each branch can be different. The resistance in a parallel circuit depends on the devices in the branch. If the resistance in one branch is low, then more current will flow through it than in other branches. So, the current in each branch of a parallel circuit can be different.
6. Explain What do fuses and circuit breakers do?

What are fuses and circuit breakers?

If wires get too hot, they can cause a fire. To make sure that wires don’t get too hot, the circuits in your house and other buildings have fuses or circuit breakers. Fuses and circuit breakers limit the amount of current in the wiring. If the current becomes greater than 15 A or 20 A, a piece of metal in the fuse melts or a switch in the circuit breaker opens, stopping the current. The device that caused the problem can be removed. Then, the fuse can be replaced or the circuit breaker can be reset.

Electric Power

When you use a toaster or a hair dryer, electrical energy changes into other kinds of energy. The rate, or speed, at which electrical energy is changed into other kinds of energy is electric power. In any electric device or electric circuit, the electric power that is used can be found by using the equation below.

\[
P = IV
\]

The electric power is equal to voltage provided to the electrical device multiplied by the current that flows into the device. The SI unit of power is the watt. The table lists the electric power used by some common devices.

<table>
<thead>
<tr>
<th>Device</th>
<th>Power (in watts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer</td>
<td>350</td>
</tr>
<tr>
<td>Color TV</td>
<td>200</td>
</tr>
<tr>
<td>Stereo</td>
<td>250</td>
</tr>
<tr>
<td>Refrigerator</td>
<td>450</td>
</tr>
<tr>
<td>Microwave</td>
<td>700–1,500</td>
</tr>
<tr>
<td>Hair dryer</td>
<td>1,000</td>
</tr>
</tbody>
</table>

7. Calculate A toaster is plugged into a wall outlet. The current in the toaster is 10 A. The voltage of the wall outlet is 110 V. How much power in watts does the toaster use? Show your work.

8. Interpret Data How many more watts does a hair dryer use than a color TV?
How do electric companies measure power?

Power is the amount of energy that is used per second. When you use a hair dryer, the amount of electrical energy you use depends on the power of the hair dryer. It also depends on how long you use it. Suppose you used the hair dryer for 10 minutes today and 5 minutes yesterday. You used twice as much energy today than you did yesterday.

How much does electrical energy cost?

Electric companies make electrical energy and sell it in units of kilowatt-hours. One kilowatt-hour (kWh) is equal to using one kilowatt of power continuously for one hour. This is about the amount of energy needed to light ten 100-W lightbulbs for one hour or just one 100-W lightbulb for 10 hours.

An electric company charges customers for the number of kilowatt-hours they use every month. An electric meter on the outside of each building measures the number of kilowatt-hours used in that building.

Electrical Safety

Electricity can be very dangerous. In 1997, electric shocks killed about 490 people in the United States. Here are some tips that will help prevent electrical accidents.

Preventing Electric Shock

Never use a device with frayed or damaged electric cords.

Unplug appliances before you work on them. For example, if a piece of toast gets stuck in a toaster, unplug the toaster before you take the toast out.

Never use an electric device near water.

Never touch power lines with anything, including a kite string or ladder.

Always pay attention to warning signs and labels.

How do electric shocks happen?

If an electric current enters your body, you feel an electric shock. Your body is like a piece of insulated wire. The fluids inside your body are good conductors of electric current. The electrical resistance of dry skin is much higher than the fluids in your body. Skin insulates the body in the same way that plastic insulates a copper wire. Remember that electrons cannot move easily in an insulator like plastic. Your skin works in the same way.
You actually become part of an electric circuit when current enters your body. The shock you feel can be mild or deadly, depending on the amount of current that flows into your body.

**How much is too much?**

The amount of current that can light a 60-W lightbulb is about 0.5 A. If this amount of current enters your body, it could be deadly. Even a current as low as 0.001 A can be painful. The table shows what you would feel when a certain amount of electric current flows through your body.

### Current’s Effects

<table>
<thead>
<tr>
<th>Amount of Current (in amperes)</th>
<th>What You Feel</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0005 A</td>
<td>Tingle</td>
</tr>
<tr>
<td>0.001 A</td>
<td>Pain</td>
</tr>
<tr>
<td>0.01 A</td>
<td>Can’t let go</td>
</tr>
<tr>
<td>0.025 A</td>
<td></td>
</tr>
<tr>
<td>0.05 A</td>
<td>Difficult to breathe</td>
</tr>
<tr>
<td>0.10 A</td>
<td></td>
</tr>
<tr>
<td>0.25 A</td>
<td></td>
</tr>
<tr>
<td>0.50 A</td>
<td>Heart failure</td>
</tr>
<tr>
<td>1.00 A</td>
<td></td>
</tr>
</tbody>
</table>

How do you keep safe from lightning?

Electricity in lightning can be very dangerous. Lightning can harm people, plants, and animals. In the United States, more people are killed every year by lightning than by hurricanes or tornadoes. Most of these lightning deaths happened outdoors. If you are outside and can see lightning or hear thunder, you need to go indoors right away. If you cannot go indoors, you need to take the following steps:

- Stay away from open fields and high places
- Stay away from tall objects like trees, flagpoles, or light towers
- Stay away from objects that conduct current such as water, metal fences, picnic shelters, and bleachers.

**11. Interpret Data**

Describe how you would feel if you were shocked by a current of 0.10 A.

---

**Picture This**

12. **Explain** Why should you stay away from metal fences when you see lightning or hear thunder?
After You Read

MINI GLOSSARY

**Electric Power:** the rate, or speed, at which electrical energy is changed into other kinds of energy

**Ohm's Law:** the relationship among voltage, current, and resistance; when the voltage in a circuit increases, the current increases

**Parallel Circuit:** a circuit that has more than one path for the electric current to follow

**Series Circuit:** a circuit that has only one path for the electric current to follow

1. Review the terms and their definitions in the Mini Glossary. Explain why it is better to have a parallel circuit in your home than a series circuit.

2. Explain the main ideas of Ohm's law in the cause-and-effect map below. Write *increases* or *decreases* in the blanks.

   ![Ohm's Law Diagram]

   **Cause**
   - Voltage increases
   - Resistance increases

   **Effect**
   - Electric current ____________
   - Electric current ____________

3. You were asked to write the main idea of each paragraph as you read this section. How did you decide which is the main idea for each paragraph?

   Visit blue.mssciences.com to access your textbook, interactive games, and projects to help you learn more about electric circuits.
Magnetism

section  ●  What is magnetism?

Before You Read

Do you have magnets on your refrigerator? Why do magnets stick to a refrigerator and other things?

What You’ll Learn

- how magnets behave
- how the behavior of magnets and magnetic fields are related
- why some materials are magnetic

Read to Learn

Early Uses

Thousands of years ago, people found that a mineral called magnetite attracted other pieces of magnetite. It also attracted bits of iron. When they rubbed small pieces of iron with magnetite, the iron began to act like magnetite. If they let the pieces turn freely, one end pointed north. These might have been the first compasses. Compasses helped sailors and explorers know which direction they were going. Before compasses, sailors and explorers had to look at the Sun and stars to know which direction they were going.

Magnets

A piece of magnetite is a magnet. Magnets attract objects made of iron or steel, like nails and paper clips. Magnets also attract or repel other magnets. To repel means “to push away.” Every magnet has two ends. The two ends are called poles. One end is called the north pole. The other end is called the south pole. The figure on the next page shows what happens when you put two magnetic poles together. Two north poles will repel each other. Two south poles also repel each other. But a north pole and a south pole are attracted to each other.

Reading Check

1. Determine  Do the north poles of two magnets attract or repel each other?
What is a magnetic field?

Remember that a force is a push or a pull that can make an object move. Gravitational and electric forces can act on an object even when objects are not touching. Magnetic force also can act on objects when they are not touching. Notice that the magnets in the figure above are not touching and a magnetic force is acting on them. A magnet can even make an object move without touching it. The magnetic force gets weaker when the magnets move farther apart.

A magnetic field is the space around a magnet where the magnetic force is. Magnetic fields are around all magnets. If you sprinkle iron fillings near a magnet, the iron filings will show the magnetic field lines of the magnet. The figure below shows these curved lines. The lines start on one pole and end on the other.

Magnetic field lines begin at a magnet’s north pole and end at the south pole. The lines are close together where the field is strong. The lines get farther apart as the field gets weaker. The magnetic field is strongest close to the magnetic poles. It gets weaker farther away from the poles. Field lines that curve toward each other show attraction. Field lines that curve away from each other show repulsion.
How are magnetic fields made?

A moving electric charge produces a magnetic field. All atoms have negatively charged particles called electrons. These electrons spin around the nucleus of an atom. Each electron produces a magnetic field because of how it moves. The electrons in atoms that make up magnets are like even smaller magnets. The magnetic fields of many of the atoms in iron and other materials point in the same direction. A group of atoms with their magnetic fields pointing in the same direction is called a magnetic domain.

How can some materials become magnetized?

A material, like iron or steel, that can become magnetized has many magnetic domains. When the material is not magnetized, these magnetic domains point in all directions as shown in the figure below. The material does not act like a magnet. This is because the magnetic fields made by the domains cancel each other out.

A magnet has a large number of magnetic domains that are lined up and pointing in the same direction. Suppose you hold a strong magnet next to a piece of iron. The magnet causes the magnetic field in many of the magnetic domains in the iron to line up with the magnet’s field, as in the figure below. The magnetic fields of the iron’s magnetic domains are added together. This magnetizes the iron.

**Picture This**

5. **Explain** How do you know that the material in this picture is not magnetized?

6. **Label** Which pole of the bar magnet on the right should be closest to the figure on the left? Label this pole of the bar magnet N for north or S for south.
Earth’s Magnetic Field

Bar magnets are not the only objects that have magnetism. Earth has a magnetic field, too. The space affected by Earth’s magnetic field is the magnetosphere (mag NEE tuh shfr). The magnetosphere repels most of the charged particles from the Sun. Earth’s magnetic field probably comes from deep within Earth’s core. Moving melted iron in the outer core might produce the magnetic field. The shape of Earth’s magnetic field is like the magnetic field of a huge bar magnet.

What are magnets found in nature?

Some animals, including honeybees, rainbow trout, and homing pigeons, use magnetism to find their way. They have tiny pieces of magnetite in their bodies. These pieces are so small that they might contain only one magnetic domain. Scientists have shown that some animals use these natural magnets to find Earth’s magnetic field. They use Earth’s magnetic field and the position of the Sun or stars to help them find their way.

How does Earth’s magnetic field change?

Earth’s magnetic poles do not stay in one place. The magnetic pole in the north today is in a different place than it was 20 years ago. Sometimes, Earth’s magnetic field also changes direction. For example, a compass needle that pointed south 700 thousand years ago would point north today. During the last 20 million years, Earth’s magnetic field has changed direction more than 70 times. The magnetism of old rocks shows these changes in the magnetic field. When some kinds of molten rock cool, magnetic domains of iron in the rock line up with Earth’s magnetic field. After the rock cools, the domains are frozen in place. So, the old rocks show the direction of Earth’s magnetic field as it was long ago.

What is a compass needle?

A compass needle is a small bar magnet. It has a north and a south magnetic pole. When a compass is in a magnetic field, the needle turns until it lines up with the magnetic field line at its location.

Earth’s magnetic field also makes a compass needle turn. The north pole of the compass needle points toward Earth’s magnetic pole that is in the north which is actually a magnetic south pole. Earth’s magnetic field is like that of a bar magnet with the south pole near Earth’s north pole.
After You Read

Mini Glossary

**magnetic domain:** a group of atoms with their magnetic fields pointing in the same direction

**magnetic field:** the space around a magnet where the magnetic force is

**magnetosphere:** the space affected by Earth’s magnetic field

1. Review the terms and their definitions in the Mini Glossary above. Circle two of the terms. On the lines below, tell how these two terms are related.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

2. Complete the flowchart below to describe how the magnetic domains of a paper clip change as it becomes magnetized.

![Flowchart](image)

3. You were asked to make an outline of the section. How can you use the outline to help you study for a quiz?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Scienceonline Visit blue.msscience.com to access your textbook, interactive games, and projects to help you learn more about magnetism.
Identify Main Ideas
Highlight the main idea of each paragraph in this section.

Before You Read
Electricity makes your radio and other things work. Where does electricity come from?

Read to Learn

Current Can Make a Magnet
Magnetic fields are produced by moving electric charges. Electrons moving around the nuclei of atoms make magnetic fields. This motion causes some materials, like iron, to be magnetic. Electric charges move in a wire when it has electric current flowing through it. A wire that has electric current flowing is surrounded by a magnetic field, too.

What is an electromagnet?
An electromagnet is a wire with current flowing through it that is wrapped around an iron core. Look at the figure. There is a magnetic field around each coil of wire. The magnetic fields add together to make a stronger magnetic field inside the coil. When the coils are wrapped around an iron core, the magnetic field of the coils makes the iron core magnetic. This makes the magnetic field inside the coils even stronger.

Picture This
1. Draw a line that shows the magnetic field inside the coils.

When a wire is wrapped in a coil, the field inside the coil is made stronger.
How do electromagnets work?
When an electric current is turned on, the magnetic field of an electromagnet is turned on. When the electric current is turned off, the magnetic field turns off, too. By changing the current, the strength and direction of the magnetic field of an electromagnet can be changed. This makes electromagnets useful.

How are electromagnets used?
The figure shows a doorbell that uses an electromagnet. When a button is pressed, a switch in a circuit that includes an electromagnet is closed. The magnet attracts an iron bar. There is a hammer attached to the iron bar. The hammer hits the bell. When it hits the bell, it has moved far enough to open the circuit again. The electromagnet loses its magnetic field. A spring pulls the iron bar and hammer back into place. This closes the circuit. This happens again and again as long as the button is pushed.

Magnets Push and Pull Currents
Think of an electric device that produces motion, like a fan. How does the electric energy going into the fan change into kinetic energy? Remember that wires with electric current flowing through them produce a magnetic field. This magnetic field acts the same way as a magnetic field made by a magnet. Two wires that are carrying current in the same direction can attract each other as if they were two magnets.
What is an electric motor?

Two magnets exert a force on each other. So do two wires that have current flowing through them. The magnetic field around a wire that has current flowing through it causes it to be pushed or pulled by a magnet.

Look at the first part of the figure below. The magnetic field will be pushed or pulled, depending on the direction the current is flowing through the wire. A magnetic field like the one shown will push a current-carrying wire upward. So, some of the electric energy carried by a current is changed into kinetic energy of the moving wire. Any machine that changes electric energy into kinetic energy is a motor.

How does a motor keep running?

The wire that has current flowing through it is made into a loop so the magnetic field can make the wire spin all the time. In the second part of the figure, the magnetic field exerts a force on the wire loop. This causes the loop to spin as long as current flows in the loop.

How do charged particles from the Sun and Earth's magnetosphere interact?

The Sun gives off charged particles. These particles flow through the solar system like a huge electric current. Earth’s magnetic field pushes and pulls on the electric current made by the Sun. This is just like how a magnetic field pushes and pulls on a wire that is carrying current. This pushing and pulling causes most of the charged particles from the Sun to be repelled. The charged particles do not hit Earth. This protects living things on Earth from damage that might be caused by the charged particles. The solar current also pushes on Earth’s magnetosphere. It stretches the magnetosphere away from the Sun.
What is the aurora?

Sometimes the Sun gives off a great number of charged particles all at once. Earth’s magnetosphere repels most of these charges. But some of the particles from the Sun produce other charged particles in Earth’s outer atmosphere. These charged particles move along Earth’s magnetic field lines. They move toward Earth’s magnetic poles. At the poles, they crash into atoms in the atmosphere. These crashes cause the atoms to give off light. The light given off from the Sun’s charged particles crashing into atoms in Earth’s atmosphere is the aurora (uh ROR uh). In northern parts of the world, the aurora is called the northern lights.

Using Magnets to Create Current

In an electric motor, a magnetic field turns electricity into motion. A machine that uses a magnetic field to turn motion into electricity is a generator. In a motor, electric energy is changed into kinetic energy. In a generator, kinetic energy is changed into electric energy.

The figures below show how current can be produced in a wire that moves in a magnetic field. As the wire moves, the electrons in the wire also move in the same direction. If a wire is pulled downward through a magnetic field, the electrons in the wire also move downward. This is shown in the figure on the left.

The magnetic field exerts a force on the moving electrons. This force pushes the electrons along the wire in the figure on the right. This produces an electric current.

Think it Over

4. Explain Would there be an aurora if Earth’s magnetosphere repelled all of the electric charges from the Sun? Why or why not?

Picture This

5. Highlight Arrows In the figure on the right, highlight the arrows that show the direction of electric current flow in the wire.
How does an electric generator work?

To produce electric current, the wire is made into a loop. Look at the figure below. A power source provides the kinetic energy to spin the wire loop. Every time the loop makes a half turn, the current in the loop changes direction. This makes the current change from positive to negative.

A current that changes direction is an **alternating current** (AC). To alternate means to switch back and forth. In the United States, electric currents change from positive to negative to positive 60 times each second.

What is a direct current?

A battery produces direct current instead of alternating current. In a **direct current** (DC), electrons flow in only one direction. In an alternating current, electrons change the direction they are moving many times each second. Some generators are built to produce direct current instead of alternating current.

Where does most of our electricity come from?

Electric generators produce almost all of the electric energy used in the world. Large generators in electric power plants can produce energy for thousands of homes. Electric power plants use different energy sources like gas, coal, and water to provide the kinetic energy needed to turn the coils of wire in a magnetic field. Coal-burning power plants are the most common. In the United States, coal-burning plants produce more than half of the electric energy made by power plants.
What voltage do power plants transmit?
Electric energy made in power plants is carried to your home in wires. Remember that voltage is how much energy the electric charges in a current are carrying. Power lines from power plants send out electric energy at a high voltage of about 700,000 V. At a high voltage, less energy is changed into heat in the wires. But, high voltage is not safe to use in homes and businesses. So, the voltage must be reduced.

Changing Voltage
A machine that changes the voltage of an alternating current without losing much energy is a transformer. Some transformers increase the voltage before sending out an electric current through the power lines. Other transformers decrease the voltage so the energy can be used in homes and businesses. Transformers also are used in power adaptors. Adaptors are used with devices that can be plugged into a wall outlet or can run on batteries. The adaptor changes the 120 V from the wall outlet to the same voltage that the batteries produce.

A transformer usually has two coils of wire wrapped around an iron core. One wire coil is connected to an alternating current source. The current produces a magnetic field in the iron core, just like in an electromagnet. The magnetic field it produces switches direction because the current is alternating. This alternating magnetic field causes an alternating current in the other wire coil.

How does a transformer change voltage?
A transformer increases or decreases the input voltage depending on the number of coils it has on each side. The number of coils on the output side divided by the number of coils on the input side equals the output voltage divided by the input voltage.

Look at the figure of a transformer. There are three coils on the input side. There are nine coils on the output side. $9 \div 3 = 3$.
The answer 3 can be used to find the output voltage of the transformer.
If the voltage going into the transformer is 60 V, the output would be found by multiplying $60 \times 3$. The output voltage would be 180 V. If the input side has more coils, the transformer decreases the voltage. If the output side has more coils, the transformer increases the voltage.
Superconductors

Electric current can flow easily through materials, like metals, that are electrical conductors. But even in conductors there is some resistance to the flow of current. Some of the electric current is changed into heat. This happens when electrons bump into atoms in the material.

A superconductor is a material that has no resistance to the flow of electrons. Superconductors are made when certain materials are cooled to low temperatures. For example, aluminum becomes a superconductor at about –272°C. No electric energy is changed into heat when electric current flows through a superconductor. So, no heat is made.

How does a superconductor affect a magnet?

Superconductors have other properties. For example, a superconductor repels a magnet. When a magnet gets close to a superconductor, the superconductor produces a magnetic field that is opposite to the field of the magnet. The field produced by a superconductor can cause a magnet to float above the superconductor.

How are superconductors used?

Superconductor materials can be used to produce very strong magnetic fields. If you make the wire of an electromagnet from superconductor material, the electromagnet will produce a very strong magnetic field. A particle accelerator is a machine that uses more than 1,000 superconducting electromagnets. A particle accelerator is used to speed up subatomic particles to nearly the speed of light.

Other uses for superconductors are being studied. If power lines were made from superconductors, they could carry electric current over long distances and not change electric energy into heat. Very fast computers could be built with microchips made from superconductor materials.

Magnetic Resonance Imaging

Magnetic fields can be used to look at the inside of the human body. Magnetic resonance imaging, or MRI, uses magnetic fields to make images of the inside of a human body. MRI images can show if tissue is damaged. It also can show if there are tumors growing in the body.

Inside an MRI machine is an electromagnet made of a superconductor. The magnetic field is more than 20,000 times stronger than Earth's magnetic field.
How does an MRI make pictures?

About 63 percent of all the atoms in your body are hydrogen atoms. The nucleus of a hydrogen atom is a proton. The proton acts like a tiny magnet. The strong magnetic field inside the MRI tube makes all the hydrogen protons line up in the direction of the magnetic field. Then radio waves are applied to the part of the body being looked at. The protons absorb some of the energy in the radio waves. When this happens, the protons change the direction in which they are lined up.

When the radio waves are turned off, the protons go back to where they were. They line up with the magnetic field again and give off the energy they took in. How much energy they give off depends on the kind of tissue in the body. A computer uses the energy to make an image, like the one below.

How are electric charges and magnets related?

Moving electric charges produce magnetic fields. Magnetic fields exert forces on moving electric charges. Together, these make electric motors and generators work.
After You Read

Mini Glossary

alternating current: a current that changes direction
aurora: the light given off from the Sun’s charged particles crashing into atoms in Earth’s atmosphere
direct current: a current in which electrons flow in only one direction
electromagnet: a wire with current flowing through it that is wrapped around an iron core
generator: a machine that uses a magnetic field to turn motion into electricity
motor: any machine that changes electric energy into kinetic energy
transformer: a machine that changes the voltage of an alternating current without losing much energy

1. Review the terms and their definitions in the Mini Glossary. Describe how a generator and a motor can be used together to make kinetic energy from a magnetic field.

2. Match each machine with the description of what the machine does. Write the letter of each machine in Column 2 on the line in front of the description in Column 1.

<table>
<thead>
<tr>
<th>Column 1</th>
<th>Column 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>_____ 1. turns motion into electricity</td>
<td>a. particle accelerator</td>
</tr>
<tr>
<td>_____ 2. uses magnetic fields to make images of the body</td>
<td>b. generator</td>
</tr>
<tr>
<td>_____ 3. moves electricity without making heat</td>
<td>c. motor</td>
</tr>
<tr>
<td>_____ 4. speeds up subatomic particles</td>
<td>d. MRI</td>
</tr>
<tr>
<td>_____ 5. changes the voltage of an alternating current</td>
<td>e. transformer</td>
</tr>
<tr>
<td>_____ 6. makes kinetic energy</td>
<td>f. superconductor</td>
</tr>
</tbody>
</table>

3. You were asked to highlight the main idea of each paragraph. How did you decide what the main ideas were?
Waves, Sound, and Light

section ● Waves

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

What You’ll Learn
■ how waves carry energy
■ the difference between 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. Sometimes the waves are so strong they knock you over. Other times, 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 carry?
A wave is a disturbance that moves through matter or through empty space. Waves do not carry matter. They carry 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 carried 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 carrying energy. But, the water molecules barely move from their places.
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 through matter. Another type of wave is an electromagnetic wave. This type of 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 makes the particles in matter 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?
When you pull a spring and let it go, 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 spring squeezes together are called compressions. The places where the spring spreads apart are called rarefactions (rare FAK shunz). The repeating compressions and rarefactions make a compressional wave. The compressions and rarefactions move along the spring. But the spring moves only back and forth.

What are electromagnetic waves?
Light, radio waves, and X rays are examples of electromagnetic waves. They are transverse waves just like waves on a rope. 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
If you move a pencil up and down slowly in a bowl of water, the pencil’s motion makes small waves that are spread apart. If you move the pencil quickly, the pencil’s motion makes larger waves that are closer together. You have changed the properties of the waves by changing the movement of the pencil. The properties of waves depend on the movement, or vibrations, that produce them.
What is the wavelength of a wave?

Wavelength is the distance between one point on a wave and the nearest point that is moving with the same speed and direction. The figure above on the left shows the wavelength 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 wavelength of a compressional wave. It is the distance from one compression to the next compression or from one rarefaction to the next rarefaction.

What is the frequency of a wave?

The frequency of a wave is the number of wavelengths that pass by a point in one second. Suppose you stand still and watch a transverse wave on a rope. You would see the crests and troughs move past you. The frequency of the wave would be the number of crests or troughs that pass you each second. The frequency of a compressional wave is the number of compressions or rarefactions that would pass by each second.

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

Another property of waves is amplitude. 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 transverse wave is half the distance between a crest and trough. You can see this in the figure at the top of the next page. As the distance between crests and troughs gets bigger, the amplitude of a transverse wave gets bigger.
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 more squeezed together. Their rarefactions are more spread 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 move 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 move a small amount of energy. You make a wave with a small amplitude.

What are seismic waves?

Waves 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 waves. These rolling waves are a combination of compressional and transverse waves. The more energy these waves have, the larger their amplitudes are. 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 faster a wave travels, the more wavelengths pass by you each second. You can calculate the speed of a wave if you know its wavelength and frequency. Use the equation below.

Wave Speed Equation
\[ v = \lambda f \]

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. Wave speed is given in m/s. Wavelength is measured in meters. The SI unit for frequency is the hertz, which is abbreviated Hz. One hertz equals one vibration per second, or one wavelength passing a point in one second. One hertz is equal to the unit 1/s.

Waves Can Change Direction
Waves do not always travel in a straight line. Waves can bounce off a surface, or reflect. They can change direction, or refract. Waves can also 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 material through which it travels. For example, a light wave travels faster through air than it does 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 also. It is greatest if the wavelength is much larger than the object.

Sound and Light Waves The wavelengths of sound waves are close in size to the objects around you. But the wavelength of light waves are much shorter. You can hear people talking in a room with a door open because the sound waves diffract around the door opening. But you cannot see them because the wavelength of the light waves is too short to diffract.
After You Read

Mini Glossary

**Compressional wave:** makes the particles in matter move back and forth in the same direction the wave is traveling.

**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.

**Transverse wave:** makes the particles in matter move back and forth at right angles to the direction that the wave is traveling.

**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 a transverse wave or write a sentence that describes a compressional wave.

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>
Before You Read

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

What You’ll Learn
- how sound waves are made
- how sound waves travel through matter
- how humans hear sound

Read to Learn

Making Sound Waves

How does hitting the head of a drum make sound waves? When you hit the head of a drum, you make it vibrate. The vibrations transfer their energy to air particles near the drum head. This makes 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 made 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 energy carried by a sound wave is moved by particles bumping into other particles. That means 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 to the right 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</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 certain area each second. The intensity of a sound decreases the farther you are from whatever is making the sound.

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 a sound is also related to the amplitude of the sound waves. Sound waves with greater amplitude have greater intensity.

How is the intensity of a sound measured?

The intensity of a sound wave is measured in units called decibels. Decibels are abbreviated as dB. The softest sound a person can hear has an intensity of 0 dB. Normal speech has an intensity of about 50 dB. The sound a jet plane makes when it takes off is about 150 dB. Any sound with an intensity of around 120 dB or higher is painful to people.

People describe the intensity of sounds by how loud they are. 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 a sound wave depends on the frequency of the vibrations that made 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. 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 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 has a part called 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 makes signals that travel to the brain. The brain understands these signals as sounds.

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

4. **Think Critically**  Think about how fast sound moves through different materials. Why do you think the cochlea is filled with fluid instead of air?
How are the parts of the ear connected?

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 find things. Echolocation is the process of finding objects by bouncing sounds off them. Bats, dolphins, and other animals give off high-frequency sound waves. They send the waves out to a certain area. The waves reflect off of objects and back to the animal. The animal can locate the object and tell what it is like 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 make pictures of the inside of the body.
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.

3. How can you use the quiz questions you created to help you study for a test about sound waves?
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. 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. You can see the light from the Moon because light waves are electromagnetic waves. Electromagnetic waves are waves that can travel through matter and through empty space.

How fast can light travel?
Have you ever seen a movie where 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 reach Earth in only eight and a half minutes. Light travels fastest through empty space and slowest through solids. This is because matter has particles in it that slow down light.

How long is a wavelength of light?
Wavelengths of light are usually measured in a unit called the nanometer (nm). One nanometer is very small. It is one billionth of a meter.
Properties of Light Waves

Light waves, and 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 parts.

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 how bright a light is. 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 waves. Together, all these waves make up what is called the electromagnetic spectrum. The electromagnetic spectrum is made of all the frequencies and wavelengths of electromagnetic waves.
How is the electromagnetic spectrum organized?

At one end of the spectrum are the waves that have the lowest frequency. They also have the lowest energy and the longest wavelength. At the other end of the spectrum are the waves that have the highest frequency. They also 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. There are special night goggles that pick up infrared waves. They can be used to see people in the dark.
Can people see electromagnetic waves?

There is part of the electromagnetic spectrum that people can see 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.

**Color** 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 different wavelength bends a different amount. You see this as a rainbow of colors coming out of 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 between 400 billionths and 10 billionths of a meter. Ultraviolet waves are shorter and carry more energy than visible light waves.

There are ultraviolet waves in sunlight. 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 sunlight can damage your skin and even 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.

**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 part of them reach Earth. Earth’s atmosphere keeps most of the ultraviolet waves from reaching Earth’s surface. That means almost all the energy from the Sun that reaches Earth is carried 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.

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Picture This

7. Think Critically Why does the light in the diagram bend when it enters the eye?

---

Think it Over

8. Infer What color light does a yellow shirt reflect?

---

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 visible light. 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.

X Rays 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.

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.
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 the object. 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 cones. 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.

9. Describe What happens to the lens of your eye when you focus on an object that is far away?

10. Identify What kind of cells help you see color?
After You Read

Mini Glossary

electromagnetic spectrum: made of all the frequencies and wavelengths of electromagnetic waves

electromagnetic waves: waves that can travel through matter and through empty space

infrared waves: electromagnetic waves that have wavelengths between 0.001 meters and 700 billionths of a meter

ultraviolet waves: electromagnetic waves that have wavelengths between 400 billionths and 10 billionths of a meter

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?

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The color of an element’s block tells you if the element is a metal, nonmetal, or metalloid.