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8th Grade NGSS

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CHAPTER 1 What is the Very Core of Science?

Chapter Outline

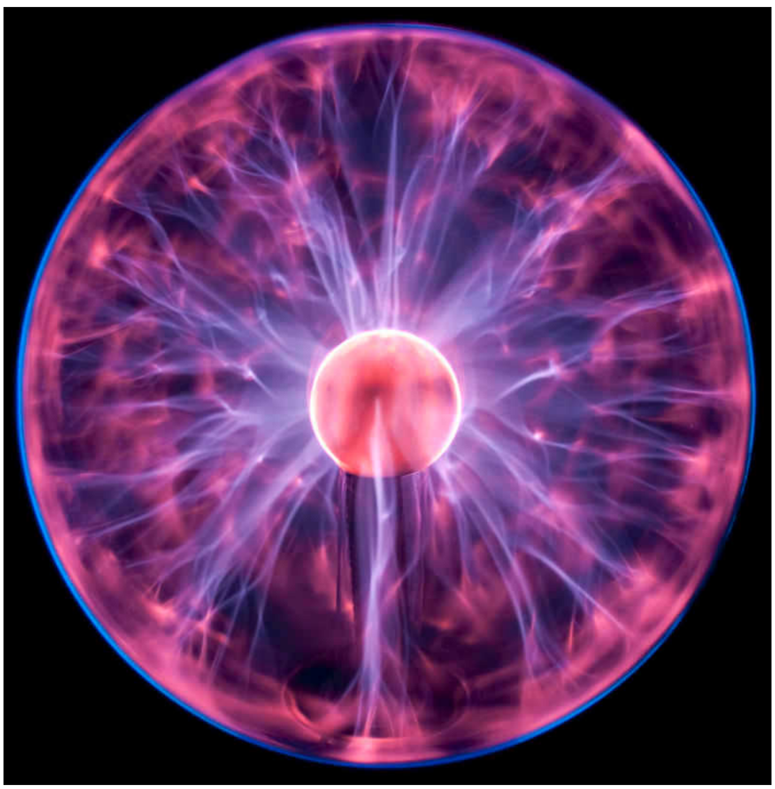

FIGURE 1.1

By the end of instruction, students should be able to answer a test which asks them to: **Define science and explain how it affects their lives.**

1.1 Nature of Science

Learning Objectives

- Define science.
- State the goal of science.
- Describe how science advances.

Does the word *science* make you think of high-tech labs and researchers in white coats like the ones in this picture? This is often an accurate image of science but not always. If you look up science in a dictionary, you would find that it comes from a Latin word that means "having knowledge." However, this isn't an adequate definition either.

What is Science?

Science is more about gaining knowledge than it is about simply having knowledge. **Science** is a way of learning about the natural world that is based on evidence and logic. In other words, science is a process, not just a body of facts. Through the process of science, our knowledge of the world advances.

The Goal of Science

Scientists may focus on very different aspects of the natural world. For example, some scientists focus on the world of tiny objects, such as atoms and molecules. Other scientists devote their attention to huge objects, such as the sun and other stars. But all scientists have at least one thing in common. They want to understand how and why things happen. Achieving this understanding is the goal of science.

Have you ever experienced the thrill of an exciting fireworks show like the one pictured in the **Figure** 1.2? Fireworks show how the goal of science leads to discovery. Fireworks were invented at least 2000 years ago in China, but explaining how and why they work didn't happen until much later. It wasn't until scientists had learned about elements and chemical reactions that they could explain what caused fireworks to create brilliant bursts of light and deep rumbling booms.

FIGURE 1.2
Fireworks were invented long before scientists could actually explain how and why they explode.

How Science Advances

Sometimes learning about science is frustrating because scientific knowledge is always changing. But that's also what makes science exciting. Occasionally, science moves forward in giant steps. More commonly, however, science advances in baby steps.

Giant steps in science may occur if a scientist introduces a major new idea. For example, in 1666, Isaac Newton introduced the idea that gravity is universal. People had long known that things fall to the ground because they are attracted by Earth. But Newton proposed that everything in the universe exerts a force of attraction on everything else. This idea is known as Newton's law of universal gravitation.

Q: How do you think Newton's law of universal gravitation might have influenced the advancement of science?

A: Newton's law allowed scientists to understand many different phenomena. It explains not only why things always fall down toward the ground or roll downhill. It also explains the motion of many other objects. For example, it explains why planets orbit the sun. The idea of universal gravity even helped scientists discover the planets Neptune and Pluto. The caption and diagram in the **Figure** 1.3 explain how.

Baby steps in science occur as small bits of evidence gradually accumulate. The accumulating evidence lets scientists refine and expand on earlier ideas. For example, the scientific idea of the atom was introduced in the early 1800s. But scientists came to understand the structure of the atom only as evidence accumulated over the next two centuries. Their understanding of atomic structure continues to expand today.

The advancement of science is sometimes a very bumpy road. New knowledge and ideas aren't always accepted at first, and scientists may be mocked for their ideas. The idea that Earth's continents drift on the planet's surface is a

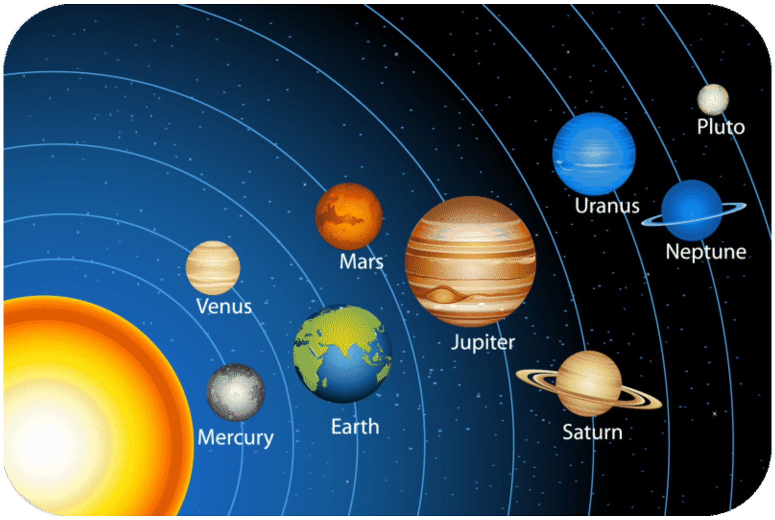

FIGURE 1.3
In the early 1800s, astronomers noticed a wobble in Uranus' orbit around the sun. They predicted that the wobble was caused by the pull of gravity of another, not-yet-discovered planet. Scientists searched the skies for the "missing" planet. When they discovered Neptune in 1846, they thought they had found their missing planet. After the astronomers took into account the effects of Neptune's gravity, they saw that Uranus still had an unexplained wobble. They predicted that there must be another planet beyond Neptune. That planet, now called Pluto, was finally discovered in 1930. Of special note, as of 2006, the International Astronomical Union (IAU) demoted Pluto from its planet status as it does not meet one of the criteria for planetary standards.

good example. This idea was first proposed by a scientist named Alfred Wegener in the early 1900s. Wegener also proposed that all of the present continents had once formed one supercontinent, which he named Pangaea. You can see a sketch of Pangaea in **Figure** 1.4. Other scientists not only rejected Wegener's ideas, but ridiculed Wegener for even suggesting them. It wasn't until the 1950s that enough evidence had accumulated for scientists to realize that Wegener had been right. Unfortunately, Wegener did not live long enough to see his ideas accepted.

Q: What types of evidence might support Wegener's ideas?

A: Several types of evidence support Wegener's ideas. For example, similar fossils and rock formations have been found on continents that are now separated by oceans. It is also now known that Earth's crust consists of rigid plates that slide over molten rock below them. This explains how continents can drift. Even the shapes of today's continents show how they once fit together, like pieces of a giant jigsaw puzzle.

Summary

- Science is a way of learning about the natural world that is based on evidence and logic.
- The goal of science is to understand how and why things happen.
- Science advances as new evidence accumulates and allows scientists to replace, refine, or expand on accepted ideas about the natural world.

Review

1. Define science.
2. What is the goal of science?
3. Use examples to show how science may advance.

FIGURE 1.4
This map shows the supercontinent Pangaea, which was first proposed by Alfred Wegener. Pangaea included all of the separate continents we know today. Scientists now know that the individual continents drifted apart to their present locations over millions of years.

Resources

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1.2 Scientific Law

Learning Objectives

- Define scientific law.
- Compare scientific laws to scientific theories.
- Discuss scientific laws of physical science.
- Describe the place of laws in science.

Did you ever drive a bumper car like the one pictured here? As you drive around the track, other drivers try to bump into your car and push it out of the way. When another car bumps into yours, both cars may bounce back from the collision. The harder the two cars collide, the farther back they bounce.

It's the Law

It may seem like common sense that bumper cars change their motion when they collide. That's because all objects behave this way - it's the law! A scientific law, called Newton's third law of motion, states that for every action there is an equal and opposite reaction. Thus, when one bumper car acts by ramming another, one or both cars react by pushing apart.

Q: What are some other examples of Newton's third law of motion? What actions are always followed by reactions?

A: Other examples of actions and reactions include hitting a ball with a bat and the ball bouncing back; and pushing a swing and the swing moving away.

Laws in Science

Newton's third law of motion is just one of many scientific laws. A **scientific law** is a statement describing what always happens under certain conditions. Other examples of laws in physical science include:

- Newton's first law of motion
- Newton's second law of motion
- Newton's law of universal gravitation
- Law of conservation of mass
- Law of conservation of energy
- Law of conservation of momentum

Laws vs. Theories

Scientific laws state *what* always happen. This can be very useful. It can let you let you predict what will happen under certain circumstances. For example, Newton's third law tells you that the harder you hit a softball with a bat, the faster and farther the ball will travel away from the bat. However, scientific laws have a basic limitation. They don't explain *why* things happen. "Why" questions are answered by scientific theories, not scientific laws.

Q: You know that the sun always sets in the west. This could be expressed as a scientific law. Think of something else that always happens in nature. How could you express it as a scientific law?

A: Something else that always happens in nature is water flowing downhill rather than uphill. This could be expressed as the law, "When water flows over a hill, it always flows from a higher to a lower elevation."

Summary

- A scientific law is a statement describing what always happens under certain conditions. Newton's three laws of motion are examples of laws in physical science.
- A scientific law states what always happens but not why it happens. Scientific theories answer "why" questions.

Review

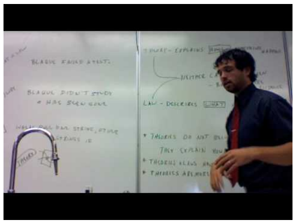
1. Define scientific law.
2. Identify three laws in physical science.
3. Which of these statements could be a scientific law?

    a. Metals such as copper conduct electric current.
    b. Metals can conduct electricity because they have free electrons.

4. How is a scientific law different from a scientific theory?
5. Contrast scientific laws with traffic laws or other laws devised by people.

Explore More

Watch this video comparing scientific laws and theories, and then answer the questions below.



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1. Do well-supported scientific theories eventually become scientific laws? Why or why not?
2. How are theories and laws related?

1.3 Scientific Process

Learning Objectives

- State the role of investigations in science.
- Outline the steps of the scientific method.

Do you think that the man in this photo is a real scientist? In science fiction, scientists may be portrayed as wild-eyed and zany, randomly mixing chemicals in a lab. But that portrayal couldn't be farther from the truth. Real scientists are disciplined professionals, and scientific investigations are very organized and methodical.

Investigations in Science

Investigations are at the heart of science. They are how scientists add to scientific knowledge and gain a better understanding of the world. Scientific investigations produce evidence that helps answer questions. Even if the evidence cannot provide answers, it may still be useful. It may lead to new questions for investigation. As more knowledge is discovered, science advances.

Steps of a Scientific Investigation

Scientists investigate the world in many ways. In different fields of science, researchers may use different methods and be guided by different theories and questions. However, most scientists follow the general steps outlined in the **Figure** 1.5. This approach is sometimes called the scientific method. Keep in mind that the scientific method is a general approach and not a strict sequence of steps. For example, scientists may follow the steps in a different order. Or they may skip or repeat some of the steps.

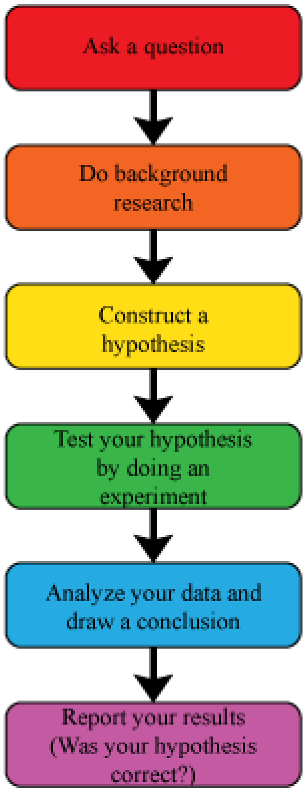


FIGURE 1.5
The general steps followed in the scientific method.

Using the Scientific Method: a Simple Example

A simple example will help you understand how the scientific method works. While Cody eats a bowl of cereal (**Figure** 1.6), he reads the ingredients list on the cereal box. He notices that the cereal contains iron. Cody is studying magnets in school and knows that magnets attract objects that contain iron. He wonders whether there is enough iron in a flake of the cereal for it to be attracted by a strong magnet. He thinks that the iron content is probably too low for this to happen, even if he uses a strong magnet.

FIGURE 1.6
Cody makes an observation that raises a question. Curiosity about observations is how most scientific investigations begin.

Q: If Cody were doing a scientific investigation, what would be his question and hypothesis?

A: Cody's question would be, "Is there enough iron in a flake of cereal for it to be attracted by a strong magnet?" His hypothesis would be, "The iron content of a flake of cereal is too low for it to be attracted by a strong magnet."

Cody decides to do an experiment to test his hypothesis. He gets a strong magnet from his mom's toolbox and places a dry flake of cereal on the table. Then he slowly moves the magnet closer to the flake. To his surprise, when the magnet gets very close to the flake, the flake moves the rest of the way to the magnet.

Q: Based on this evidence, what should Cody conclude?

A: Cody should conclude that his hypothesis is incorrect. There is enough iron in a flake of cereal for it to be attracted by a strong magnet.

Q: If Cody were a scientist doing an actual scientific investigation, what should he do next?

A: He should report his results to other scientists.

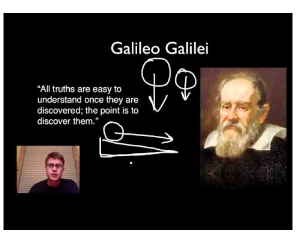
Summary

- Investigations are at the heart of science. They produce evidence that helps scientists answer questions and better understand the world.
- Most scientists follow the same general approach to investigation, which is called the scientific method. It includes the following steps: ask a question, do background research, construct a hypothesis, test the hypothesis by doing an experiment, analyze the data and draw a conclusion, and report the results.

Review

1. What is the role of investigation in science?
2. List the steps of the scientific method.
3. Assume that Cody used a weak magnet and the flake of cereal was not attracted to it. What conclusion might he have drawn then?

Resources



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1.4 Scientific Theory

Learning Objectives

- Define scientific theory.
- Compare "theory" to "scientific theory."
- Describe important theories of physical science.
- Relate the law of parsimony to scientific theories.

This photo shows a girl and her parents. They are having a discussion. As you can see, the girl is rolling her eyes. What do you think her parents may have said that caused this reaction? Could it be they have just grounded her for some reason? That's certainly one possibility, but without any other information to go on, it's "just a theory." In other words, it's just a hunch or a guess. Theories are very important in science, but in science a theory is never a hunch or a guess. It is much more than that.

Not "Just a Theory"

The term *theory* is used differently in science than it is used in everyday language. A **scientific theory** is a broad explanation that is widely accepted because it is supported by a great deal of evidence. Because it is so well supported, a scientific theory has a very good chance of being a correct explanation for events in nature. Because it is a broad explanation, it can explain many observations and pieces of evidence. In other words, it can help connect and make sense of many phenomena in the natural world.

Examples of Theories in Physical Science

A number of theories in science were first proposed many decades or even centuries ago, but they have withstood the test of time. An example of a physical science theory that has mainly withstood the test of time is Dalton's atomic theory. John Dalton was a British chemist who lived in the late 1700s and early 1800s. Around 1800, he published his atomic theory, which is one of the most important theories in science. According to Dalton's atomic theory, all substances consist of tiny particles called atoms. Furthermore, all the atoms of a given element are identical, whereas the atoms of different elements are always different. These parts of Dalton's atomic theory are still accepted today, although some other details of his theory have since been disproven.

Dalton based his theory on many pieces of evidence. For example, he studied many substances called compounds. These are substances that consist of two or more different elements. Dalton determined that a given compound always consists of the same elements in exactly the same proportions, no matter how small the sample of the compound. This idea is illustrated for the compound water in the **Figure** 1.7. Dalton concluded from this evidence that elements must be made up of tiny particles in order to always combine in the same specific proportions in any given compound.

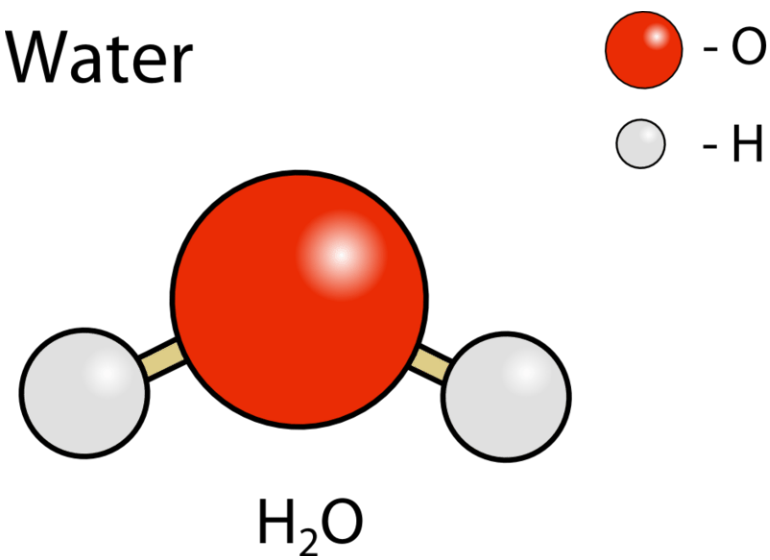

FIGURE 1.7
Water is a compound that consists of the elements hydrogen (H) and oxygen (O). Like other compounds, the smallest particles of water are called molecules. Each molecule of water (H_2O) contains two atoms of hydrogen and one atom of oxygen.

Q: Dalton thought that atoms are the smallest particles of matter. Scientists now know that atoms are composed of even smaller particles. Does this mean that the rest of Dalton's atomic theory should be thrown out?

A: The discovery of particles smaller than atoms doesn't mean that we should scrap the entire theory. Atoms are still known to be the smallest particles of elements that have the properties of the elements. Also, it is atoms—not particles of atoms—that combine in fixed proportions in compounds. Instead of throwing out Dalton's theory, scientists have refined and expanded on it.

There are many other important physical science theories. Here are three more examples:

- Einstein's theory of gravity
- Kinetic theory of matter
- Wave-particle theory of light

Keep It Simple

The formation of scientific theories is generally guided by the law of parsimony. The word *parsimony* means "thriftiness." The law of parsimony states that, when choosing between competing theories, you should select the theory that makes the fewest assumptions. In other words, the simpler theory is more likely to be correct. For example, you probably know that Earth and the other planets of our solar system orbit around the sun. But several centuries ago, it was believed that Earth is at the center of the solar system and the other planets orbit around Earth. While it is possible to explain the movement of planets according to this theory, the explanation is unnecessarily complex.

Q: Why do you think parsimony is an important characteristic of scientific theories?

A: The more assumptions that must be made to form a scientific theory, the more chances there are for the theory to be incorrect. If one assumption is wrong, so is the theory. Conversely, the theory that makes the fewest assumptions, assuming it is well supported by evidence, is most likely to be correct.

Summary

- A scientific theory is a broad explanation that is widely accepted because it is supported by a great deal of evidence.
- Examples of theories in physical science include Dalton's atomic theory, Einstein's theory of gravity, and the kinetic theory of matter.
- The formation of scientific theories is generally guided by the law of parsimony. According to this law, the simplest of competing theories is most likely to be correct.

Review

1. What is a scientific theory?
2. Compare and contrast how the term *theory* is used in science and in everyday language.
3. Identify two physical science theories.
4. Relate scientific theories to the law of parsimony.

Explore More

Watch the first presentation by Dr. Eugenie Scott and then answer the questions below.

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1. How does Dr. Scott define scientific theory?
2. From most to least important in science, how would Dr. Scott rank the following concepts? theory, fact, law, hypothesis
3. Based on the presentation, explain the importance of theories in science.

1.5 Safety in Science

Learning Objectives

- Identify the meaning of lab safety symbols.
- List rules for staying safe in the lab.
- State what to do in case of accidents in the lab or field.

Research in physical science can be exciting, but it also has potential dangers. For example, the field scientist in this photo is collecting water samples from treatment ponds. There are many microorganisms in the water that could make him sick. The water and shore can also be strewn with dangerous objects such as sharp can lids and broken glass bottles that could cause serious injury. Whether in the field or in the lab, knowing how to stay safe in science is important.

Safety Symbols

Lab procedures and equipment may be labeled with safety symbols. These symbols warn of specific hazards, such as flames or broken glass. Learn the symbols so you will recognize the dangers. Then learn how to avoid them. Many common safety symbols are shown below.

Q: Do you know how you can avoid these hazards?

A: Wearing protective gear is one way to avoid many hazards in science. For example, to avoid being burned by hot objects, use hot mitts to protect your hands. To avoid eye hazards, such as harsh liquids splashed into the eyes, wear safety goggles.

Safety Rules

Following basic safety rules is another important way to stay safe in science. Safe practices help prevent accidents. Several lab safety rules are listed below. Different rules may apply when you work in the field. But in all cases, you should always follow your teacher's instructions.

Lab Safety Rules

- Wear long sleeves and shoes that completely cover your feet.
- If your hair is long, tie it back or cover it with a hair net.
- Protect your eyes, skin, and clothing by wearing safety goggles, an apron, and gloves.
- Use hot mitts to handle hot objects.
- Never work in the lab alone.
- Never engage in horseplay in the lab.
- Never eat or drink in the lab.
- Never do experiments without your teacher's approval.
- Always add acid to water, never the other way around, and add the acid slowly to avoid splashing.
- Take care to avoid knocking over Bunsen burners, and keep them away from flammable materials such as paper.
- Use your hand to fan vapors toward your nose rather than smelling substances directly.

- Never point the open end of a test tube toward anyone—including yourself!
- Clean up any spills immediately.
- Dispose of lab wastes according to your teacher's instructions.
- Wash glassware and counters when you finish your work.
- Wash your hands with soap and water before leaving the lab.

In Case of Accident

Even when you follow the rules, accidents can happen. Immediately alert your teacher if an accident occurs. Report all accidents, whether or not you think they are serious.

Summary

- Lab safety symbols warn of specific hazards, such as flames or broken glass. Knowing the symbols allows you to recognize and avoid the dangers.
- Following basic safety rules, such as wearing safety gear, helps prevent accidents in the lab and in the field.
- All accidents should be reported immediately.

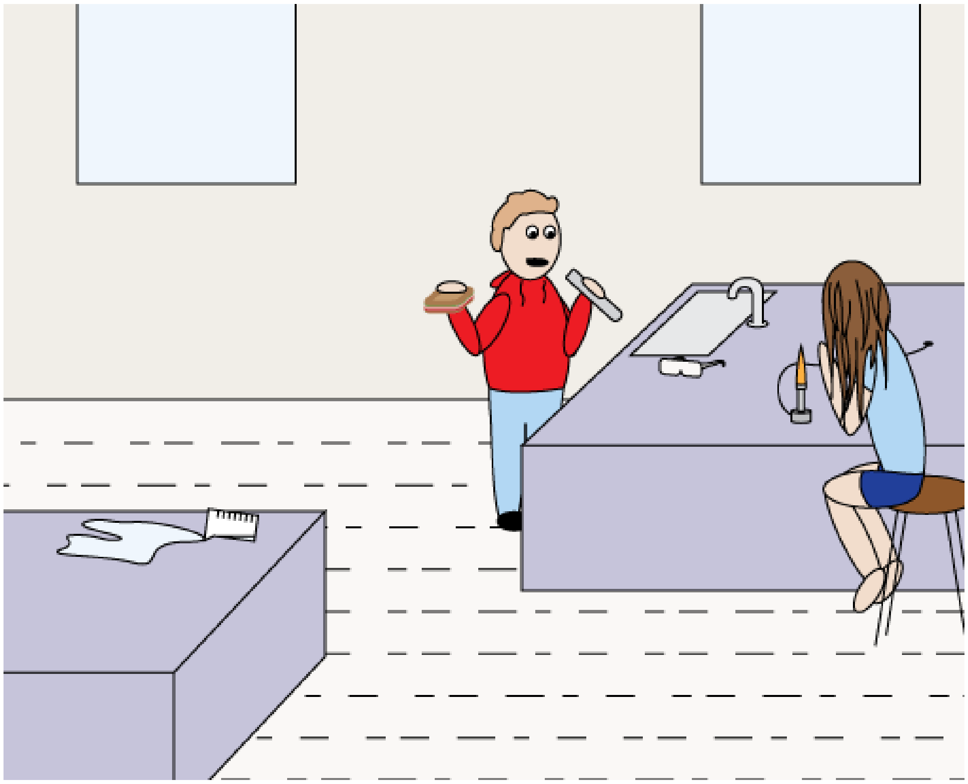
Review

1. What hazard do think this safety symbol represents?

2. Identify three safety rules that help prevent accidents in the lab.
3. Create a safety poster to convey one of the three rules you listed in your answer to 2.

Explore More

Examine this sketch of students working in a lab, and then answer the question below.



1. These students are breaking at least six lab safety rules. What are they doing that is unsafe?

Resources

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1.6 Scientific Experiments

It's exciting to roll down a skateboarding ramp, especially if you're going fast. The steeper the ramp, the faster you'll go. What else besides the steepness of a ramp influences how fast an object goes down it? You could do experiments to find out.

What is an Experiment?

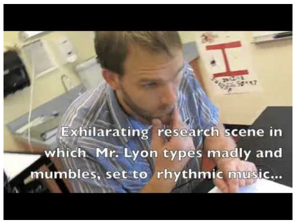
An **experiment** is a controlled scientific study of specific variables. A variable is a factor that can take on different values. For example, the speed of an object down a ramp might be one variable, and the steepness of the ramp might be another.

Experimental Variables

There must be at least two variables in any experiment: a manipulated variable and a responding variable.

- A **manipulated variable** is a variable that is changed by the researcher. A manipulated variable is also called an independent variable.
- A **responding variable** is a variable that the researcher predicts will change if the manipulated variable changes. A responding variable is also called a dependent variable.

You can learn how to identify manipulated and responding variables in an experiment by watching this video about bouncing balls:



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Q: If you were to do an experiment to find out what influences the speed of an object down a ramp, what would be the responding variable? How could you measure it?

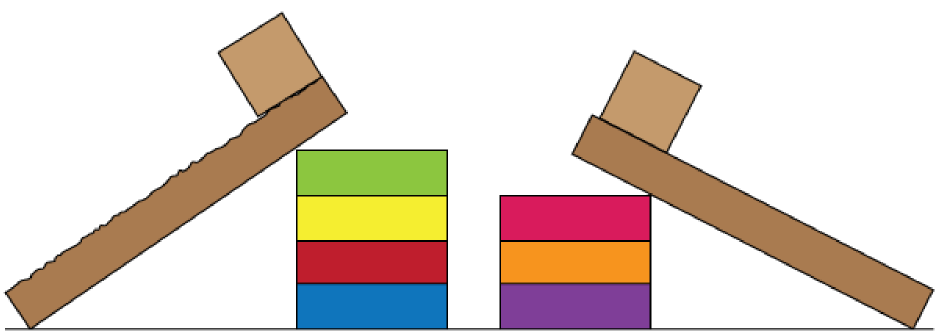
A: The responding variable would be the speed of the object. You could measure it indirectly with a stopwatch. You could clock the time it takes the object to travel from the top to the bottom of the ramp. The less time it takes, the faster the average speed down the ramp.

Q: What variables might affect the speed of an object down a ramp?

A: Variables might include factors relating to the ramp or to the object. An example of a variable relating to the ramp is its steepness. An example of a variable relating to the object is the way it moves—it might roll or slide down the ramp. Either of these variables could be manipulated by the researcher, so you could choose one of them for your manipulated variable.

Controlling Variables

Assume you are sliding wooden blocks down a ramp in your experiment. You choose steepness of the ramp for your manipulated variable. You want to measure how changes in steepness affect the time it takes a block to reach the bottom of the ramp. You decide to test two blocks on two ramps, one steeper than the other, and see which block reaches the bottom first. You use a shiny piece of varnished wood for one ramp and a rough board for the other ramp. You raise the rough board higher so it has a steeper slope (see sketch below). You let go of both blocks at the same time and observe that the block on the ramp with the gentler slope reaches the bottom sooner. You're surprised, because you expected the block on the steeper ramp to go faster and get to the bottom first.



Q: What explains your result?

A: The block on the steeper ramp would have reached the bottom sooner if all else was equal. The problem is that all else was not equal. The ramps varied not only in steepness but also in smoothness. The block on the smoother ramp went faster than the block on the rougher ramp, even though the rougher ramp was steeper.

This example illustrates another important aspect of experiments: experimental controls. A **control** is a variable that must be held constant so it won't influence the outcome of an experiment. The control can be used as a standard for comparison between experiments. In the case of your ramp experiment, smoothness of the ramps should have been controlled by making each ramp out of the same material. For other examples of controls in an experiment, watch the video below. It is Part II of the above video on bouncing balls.

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Q: What other variables do you think might influence the outcome of your ramp experiment? How could these other variables be controlled?

A: Other variables might include variables relating to the block. For example, a smoother block would be expected to go down a ramp faster than a rougher block. You could control variables relating to the block by using two identical blocks.

Summary

- An experiment is a controlled scientific study of specific variables. A variable is a factor that can take on different values.
- There must be at least two variables in any experiment: a manipulated variable and a responding variable.
- A control is a variable that must be held constant so it won't influence the outcome of an experiment.

Review

1. What is an experiment?
2. Distinguish between the manipulated variable and the responding variable in an experiment.
3. Why is it important for other variables in an experiment to be controlled?

1.7 Ethics in Science

Learning Objectives

- Define ethics.
- Identify ethical rules in science.
- Describe how scientific knowledge might influence everyday ethical decisions.

Believe it or not, the tree bark in this photo contains a revolutionary anti-cancer drug. For almost a decade after the drug was discovered, the trees, called Pacific yews, were stripped of their bark so chemists could extract the drug for cancer patients. Stripping the bark harmed the trees. This situation posed an ethical problem.

What Is Ethics?

Ethics refers to deciding what's right and what's wrong. Making ethical decisions involves weighing right and wrong in order to make the best choice. The ethical problem of the Pacific yew has both right and wrong aspects. It's right to save lives with the cancer drug that comes from the tree bark, but it's wrong to endanger the tree and risk its extinction.

Q: What do you think is the most ethical decision about the Pacific yew? Should the bark be used to make the drug and possibly save human lives? Or should this be prohibited in order to protect the tree from possible extinction?

A: This is tough ethical dilemma, and there is no right or wrong answer. Ethical dilemmas such as this often spur scientists to come up with new solutions to problems. That's what happened in the case of the Pacific yew. Scientists tackled and solved the problem of determining the chemical structure of the anti-cancer drug so it could be synthesized in labs. This is a win-win solution to the problem. The synthetic drug is now available to save lives, and the trees are no longer endangered by being stripped of their bark.

Ethical Rules in Science

Ethics is an important consideration in science. Scientific investigations must be guided by what is right and what is wrong. That's where ethical rules come in. They help ensure that science is done safely and that scientific knowledge is reliable. Here are some of the ethical rules that scientists must follow:

- Scientific research must be reported honestly. It is wrong and misleading to make up or change research results.
- Scientific researchers must try to see things as they really are. They should avoid being biased by the results they expect or hope to get.
- Researchers must be careful. They should do whatever they can to avoid errors in their data.
- Researchers must inform coworkers and members of the community about any risks of their research. They should do the research only if they have the consent of these groups.
- Researchers studying living animals must treat them humanely. They should provide for their needs and take pains to avoid harming them.
- Researchers studying human subjects must tell their subjects that they have the right to refuse to participate in the research. Human subjects also must be fully informed about their role in the research, including any potential risks. You can read about a terrible violation of this ethical rule in the **Figure** 1.8.

FIGURE 1.8

From the 1930s to 1970s, medical researchers (including the one pictured here) studied the progression of a serious disease in hundreds of poor men in Alabama. They told the men they were simply receiving free medical care. They never told the men that they had the disease, nor were the men treated for the disease when a cure was discovered in the 1940s. Instead, the study continued for another 25 years. It came to an end only when a whistleblower made it a front-page story around the nation.

Science and Everyday Ethical Decisions

Sometimes, science can help people make ethical decisions in their own lives. For example, scientific evidence shows that certain human actions—such as driving cars that burn gasoline—are contributing to changes in Earth's climate. This, in turn, is causing more severe weather and the extinction of many species. A number of ethical decisions might be influenced by this scientific knowledge.

Q: For example, should people avoid driving cars to work or school because it contributes to climate change and the serious problems associated with it? What if driving is the only way to get there? Can you think of an ethical solution?

A: This example shows that ethical decisions may not be all or nothing. For example, rather than driving alone, people might carpool with others. This would reduce their impact on climate change. They could also try to reduce their impact in other ways. For example, they might turn down their thermostat in cold weather so their furnace burns less fuel.

Summary

- Ethics refers to deciding what's right and what's wrong.
- Scientific investigations must be guided by ethical rules. The rules help ensure that science is done safely and that scientific knowledge is reliable.
- Sometimes science can help people make ethical decisions in their own lives, but other factors usually must be considered as well.

Explore More

Read this news article about a recent case of scientific fraud, and then answer the questions below.

http://www.medscape.com/viewarticle/735354

1. What ethical rules in science did the researchers violate?
2. What were the negative consequences of their unethical behavior?

Review

1. What is ethics?
2. List two ethical rules in science.
3. Think of a personal decision a young person might have to make. Identify the "rights" and "wrongs" of possible choices, and explain which choice you think is more ethical.

1.8 The Design Process in Action

In this section, we go through an example of a team using the design process. This section provides more detail about the steps of the sequential design process.

Case Study

To provide concrete examples throughout this section, we will use a design case study. In this case study, we will follow the design process used by an intrepid team of engineers who work at a small manufacturing company to develop a product that solves some of the problems with current commuting options. At the beginning of their project, the team chose a suitable engineering name for their project: the **sustainable** commuter vehicle, or SCV for short.

According to the United States Department of Transportation, in 2000, over three-fourths of the trips made to and from work were made by individuals traveling alone in a car, sport utility vehicle, or truck. In some ways, jumping in the car and going is the hallmark of modern American life. Americans prize the convenience and comfort of the modern automobile, even though it creates some serious problems.

- Vehicles create 20% of **greenhouse gas** emissions in the United States and appear to be a significant contributor to future climate change. **Carbon dioxide** is one of the principle greenhouse gasses emitted by vehicles.
- A typical American household spends more money on driving costs than it spends on food.
- In most major metropolitan areas, "rush hour" (congested traffic conditions similar to those in Figure 6) now lasts six to seven hours a day.
- Traffic congestion costs $63.1 billion per year. Each year, commuters stuck in traffic jams waste 2.3 billion gallons of fuel, not to mention their time or frustration.

Is there a way to solve some of these problems without completely giving up the comfort and convenience that we have come to expect?

Activity

To increase understanding of the issues faced by the engineering team, complete one or more of the following exercises that involve problems associated with commuting.

- Research the issues associated with commuting in your area. These issues might include traffic congestion, accidents, and pollution.
- Do you know anybody who commutes regularly to work alone in their automobile? Talk to them about the benefits and drawbacks associated with this.
- Find information on transportation planning in your area. How much money is spent developing new roadways? How much money is spent upgrading and maintaining existing roads? Is the current road network effective?
- What problems do environmental activists in your area see with the current commuting **infrastructure**?

With your understanding, write a paragraph describing the commuter problem from the perspectives of the commuter, the city planner, and the environmental activist.

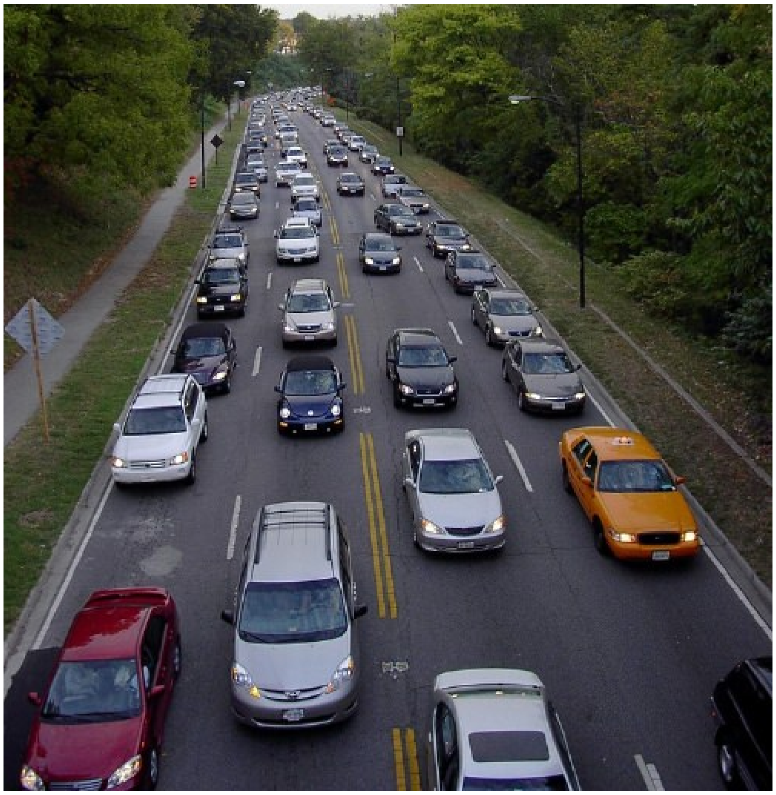

FIGURE 1.9
Rush hour traffic in Washington, D.C. Heavy traffic and long delays, as well as the associated air pollution and fuel consumption, are major problems for communities.

Activity

Spend an hour working with a team of classmates to develop a design solution to the commuter problem. Write a paragraph that describes what your team did during the hour. Then consider the following questions:

- Did your team find a solution? If not, why not?
- What processes did your team use to find solutions?
- How good is your solution? How do you know whether it is good or not?
- How well did you document your design process?

In this section, we will describe the (fictional) design process used by the SCV team to address the commuting problem.

Define the Problem

Problem definition is one of the most critical steps in the design process. Since the design team trying to solve this problem will expend a significant effort, it is very important that the problem being addressed is actually the problem that is important to potential customers. It is also important that the problem be clearly defined and understood by the design team.

Many techniques can be used to clearly define and understand the problem (see Fogler and LeBlanc, 1995). These techniques include

- gathering information from customers and other stakeholders,

- finding expert information (either in person or through books or other sources),
- doing a **root cause analysis** to identify what the real problem is.

The SCV design team began by gathering information about the issues associated with vehicular commuting and traffic congestion. They found and read several government reports. They interviewed various stakeholders in the commuting problem; these included people who commute to and from work in their car each day, officials from state and local departments of transportation, and representatives of environmental groups. They also used their own experience as commuters.

Activity

Using your understanding of the issues associated with commuting, develop a problem statement to describe the problem that the design team should solve.

On the basis of the research that they performed, the design team defined their design problem to be "Design a commuter vehicle that is environmentally friendly, acceptable to a typical commuter, and compatible with existing transportation infrastructure."

The design team also expanded this problem statement to make it more informative as follows. Environmentally friendly means that the vehicle produces as little pollution and greenhouse gases as possible and uses sources of **renewable energy**. Acceptable to the commuter means that the vehicle is convenient (does not require the commuter to wait), comfortable, and affordable. Compatible with existing infrastructure means that the vehicle does not require changing roads, bridges, etc., and does not require the development of a new fuel distribution system.

Identify Criteria and Constraints

The problem statement is used as a starting point to develop an understanding of the characteristics of a good solution. These characteristics are described in terms of constraints and criteria. A constraint is a limitation or condition that must be satisfied by a design. A criterion is a standard or attribute of a design that can be measured. The constraints and criteria are used in subsequent steps of the design process to determine which of many possible designs should be implemented.

Activity

Using your problem statement or the one developed by the design team, develop criteria and constraints that could be applied to decide whether a potential commuter vehicle design is good or not.

From the problem statement, the SCV design team identified criteria and constraints that would apply to their design. They identified the following constraint:

- Does not require new transportation infrastructure.

They identified the following criteria:

- The amount of pollution and greenhouse gases emitted per mile traveled by a commuter.
- The percent of the energy used from renewable sources.
- The convenience for the commuter.
- The comfort of the commuter.
- The cost to use the vehicle for five years (includes the purchase price, maintenance, and fuel).

Activity

Compare your criteria and constraints with the ones developed by the design team. What are the strengths of your criteria when compared to the design team's? What are the weaknesses?

Are each of your criteria measurable? Does each accurately reflect the problem statement?

Generate Concepts

With criteria and constraints identified, the design team begins to **generate concepts** for the design. This is the step in which creativity plays a very important role—good designs are often very different from existing solutions to a problem. In addition to creativity, the design team must use discipline to ensure that they explore enough options and potential solutions to guarantee a good design. Therefore, it is important to use a structured process to generate concepts for a design. Many different processes could be used. The one presented here is adapted and simplified from *Product Design and Development* by Eppinger and Ulrich. It includes the steps of problem decomposition, searching externally and internally for ideas, and systematically exploring possibilities.

Decompose the Problem into Subproblems

When a design problem is complex, it can be very beneficial to **decompose** the problem into subproblems. Subproblems are smaller problems that must be solved in order to solve the overall problem.

Activity

Think of as many subproblems as you can for the SCV.

The SCV team broke the overall problem into subproblems as shown in Figure 7. Each of the subproblems is simpler to approach than the whole problem. The energy source is how the vehicle gets energy to move; for example, the energy source for a regular car is gasoline. The vehicle **configuration** is the number of wheels on the vehicle and where they are placed relative to the driver. The drive mechanism transforms energy into the locomotion of the vehicle.

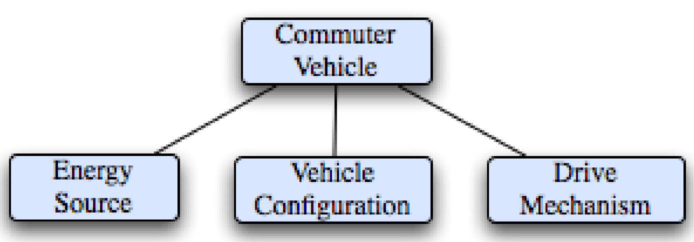

FIGURE 1.10
Decomposition of the commuter vehicle problem into three some problems: energy, configuration, and drive mechanism.

Search Externally for Ideas

Once the problem is decomposed into subproblems, the design team can begin to search for ideas to solve each subproblem. One source of ideas is to look at existing products and ideas to see whether there are already solutions to the overall problem or the identified subproblems. Sources of external information include interviews with potential customers or experts in the subproblem areas, patent and other technical databases, and existing products. Much of this information is now available on the World Wide Web.

Activity

Identify sources of information that you could use to find ideas for your subproblems. Use one these resources to develop a list of potential solutions to one of your subproblems.

The design team researched externally to find potential energy sources for their commuter vehicle. They discovered the following energy sources:

- Solar energy converted into electricity using **photovoltaic solar cells**. This is the power source used by the Mars rover Sojourner (Figure 8).
- Nuclear energy
- Wind Energy converted into electricity using a turbine and generator. This might be a smaller version of a wind turbine such as that shown in Figure 9.
- Human power.
- Gasoline, a nonrenewable fossil fuel.
- A fuel cell that converts hydrogen and oxygen into electricity. Figure 10 shows the fuel cell that provides power to the Toyota Fuel Cell Hybrid Vehicle (FCHV).
- Ethanol made from corn or other plants; ethanol can typically be used like gasoline with only slight modification to the car's fuel system.

After some reflection, the team discarded nuclear energy and a fuel cell as being **unfeasible** given the current state of technology.

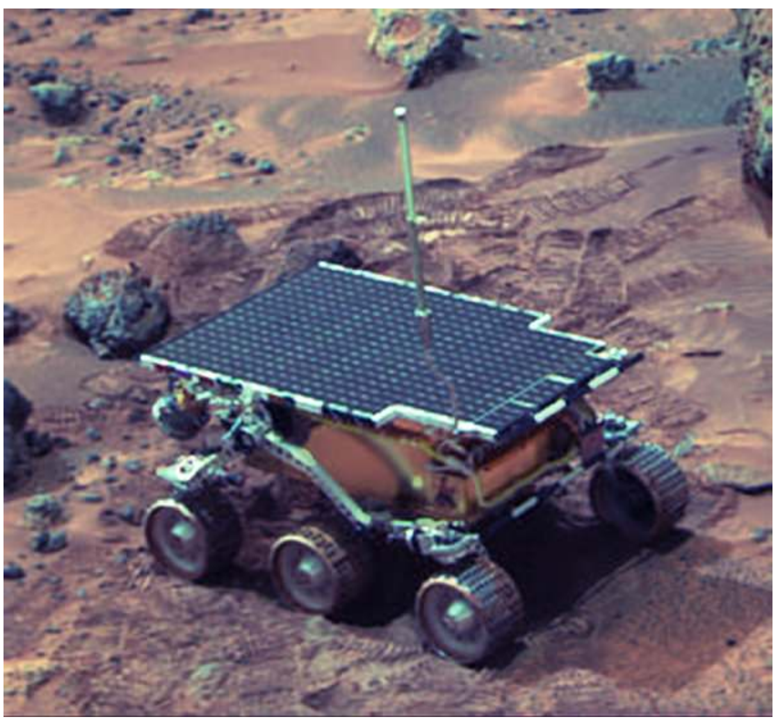

FIGURE 1.11
The rover Sojourner on the surface of Mars. The flat black panel on the rover's top is a panel of photovoltaic solar cells that provided power for 83 days.

The team also searched for possible drive mechanisms. They settled on three types:

- A clutch, gearbox, and drive shaft similar to the drive train used for most manual transmission, rear wheel drive automobiles.
- Electric motors that are located in the hubs of each wheel and drive each wheel directly. Figure 11 shows a bicycle hub that contains an electric motor; electric motors can also be put in the hubs of car wheels.

FIGURE 1.12
Large wind turbines on a wind farm in Iowa. These turbines use the wind's energy to generate electricity.

- A chain drive similar to that used in motorcycles and bicycles. Figure 12 shows a motorcycle chain drive.

Search Internally for Ideas

Searching internally for ideas is often called brainstorming; Figure 13 illustrates a group brainstorming. The goal of brainstorming is to develop as many ideas as possible without worrying whether they are feasible. Sketches are often good tools to capture ideas and to generate new ideas.

Activity

Brainstorm ideas that could solve one of your subproblems.

To solve the vehicle configuration subproblem, the design team brainstormed several possible configurations; a configuration is an arrangement of wheels around the passenger compartment. They brainstormed four different configurations, each have between one and four wheels. After brainstorming the configurations, they found photographs online to represent each configuration. These photographs are presented in Figure 14. After reflection, the team discarded the one wheel configuration as being unfeasible. They noted that both two-wheel configurations would require some method of balancing, but kept them both because there are existing vehicles that use each configuration.

Explore Systematically

Searching externally and internally will generate many possible solutions for each of the subproblems. To ensure that good solutions are not left out of the set of possible designs, it is important to use a structured process to examine possible combinations of subproblem solutions. A tool for systematic exploration is the concept combination table. In this table, solutions for each of the subproblems are combined; Figure 15 shows a concept combination table for the commuter vehicle.

To use the table, a solution for each subproblem is combined, and then a sketch or description of the resulting concept is created. For example, if the concepts are combined as shown in Figure 16, then the possible design in Figure 17

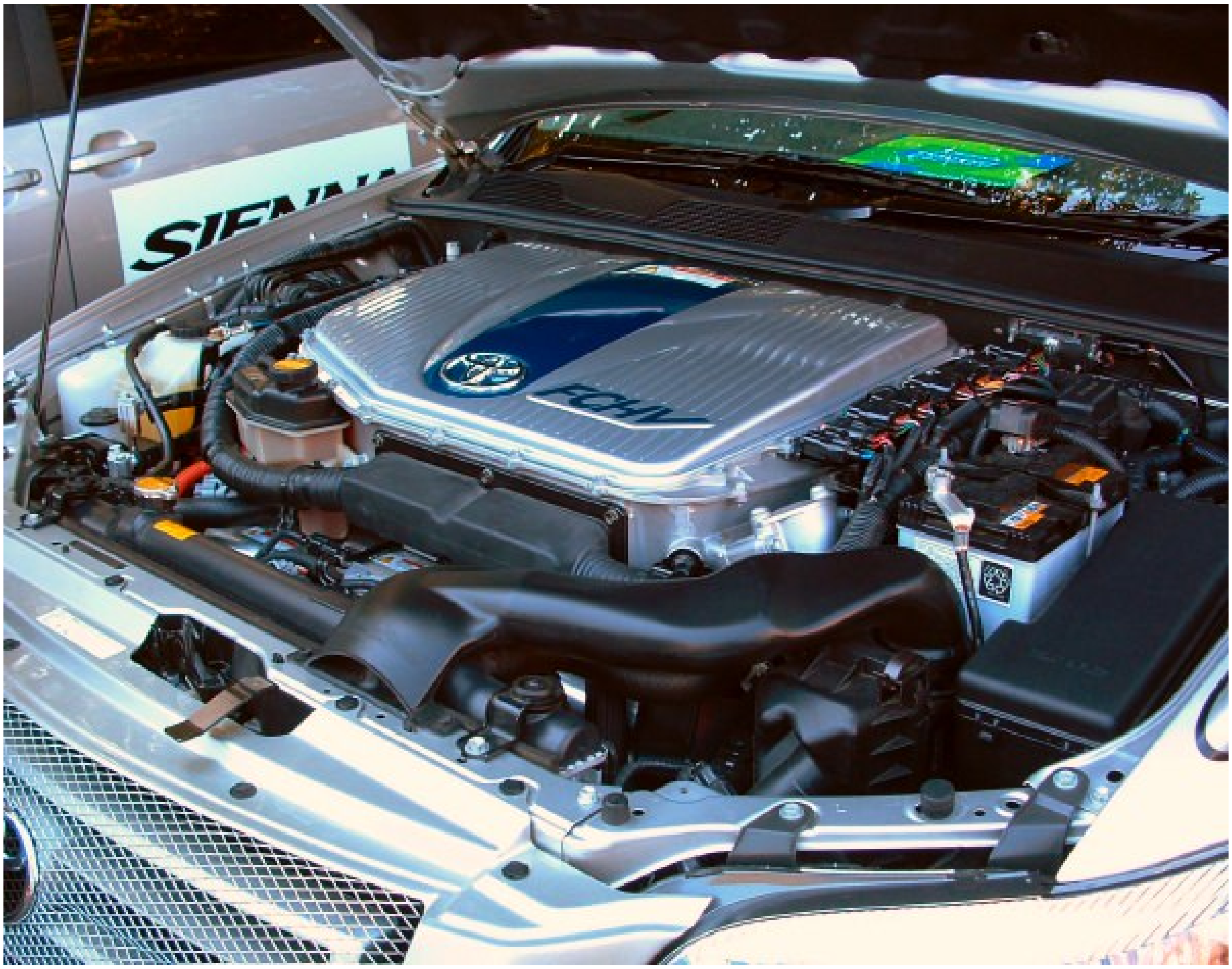

FIGURE 1.13

The Toyota Fuel Cell Hybrid Vehicle is powered by a fuel cell that generates electricity from hydrogen and oxygen. The fuel cell is still experimental technology that is currently extremely expensive, but shows promise for the future.

results. This design could be very similar to a standard bicycle with an added solar cell canopy that shades the driver. The pedals of the bicycle would be removed and replaced by an electric motor that drives the vehicle forward.

Note that the combination of design elements often does not provide a complete design concept; decisions must be made to fill in the gaps. For example, if solar cells are included as part of a design, they could be placed on the vehicle or they could be part of a fixed charging station that charges a battery on the vehicle; the design team must decide which configuration would make the most sense.

Activity

Using the solutions to subproblems that you have developed in previous activities, create a concept combination table for the problem. Use your concept combination table to generate five or six design concepts. Sketch each of your concepts.

FIGURE 1.14
This bicycle hub contains an electric motor that moves the bicycle.

FIGURE 1.15
This chain drive transmits power from the motorcycle engine to its rear wheel.

The design team used the concept combination table to develop six concepts.

Concept 1: The design in Figure 17.

Concept 2: The energy source is a combination of solar cells and wind energy; the solar cells and wind turbines are installed at centrally located municipal charging stations and used to charge batteries. The vehicle configuration is a small, three-wheeled car with an enclosed passenger cabin that seats two people. The drive mechanism is wheel hub motors installed in the three wheels, with energy supplied to the motors from the charged batteries; these motors use **regenerative braking** to recover energy as the vehicle slows down.

Concept 3: This concept combines a gas engine with a four-wheeled configuration and a clutch, gearbox and drive shaft to form a traditional automobile. To be attractive as an alternative commuter vehicle, this design would be a two-seater subcompact.

FIGURE 1.16
Students write their ideas on white boards during a brainstorming session.

Concept 4: This concept is the same as Concept 3, except that the engine is run on ethanol. Thus, Concept 4 is a small, two-seater alternative fuel vehicle.

Concept 5: The energy source is a combination of solar cells and human power. The vehicle configuration is three wheels, and the drive mechanism is a chain drive with gears. This is similar to a solar-assisted tricycle.

Concept 6: The energy source is a combination of solar cells mounted on the vehicle plus a battery; the battery can be charged at the user's home using a renewable energy source (wind or solar cells) or plugged into the user's home electricity system. The battery provides most of the energy, while the solar cells extend the life of the battery on sunny days. The configuration is two wheels side by side with room for a single passenger, and the drive mechanism is wheel hub motors. The motors are controlled to keep the vehicle balanced (similar to the Segway personal transport device in Figure 14).

Some combinations will not make sense or will result in a concept that is clearly unfeasible. For example, any concept that uses wheel hub motors must use an energy source that generates electricity.

Explore Possibilities and Select a Design

The design concepts are explored to understand their characteristics. For example, exploring Concept 1, the solar-powered bicycle in Figure 17, leads to the following conclusions:

- The design would use only renewable energy.
- The design would be relatively inexpensive to manufacture and would cost nothing to operate.
- The design may not be convenient for the commuter, since the motor will only run when sunlight falls on the solar array. This means that it is impossible to commute at night or on cloudy days.
- The design will not be particularly comfortable for the commuter, since they will be exposed to hot, cold, and rainy weather, and the seat appears to be uncomfortable.

Activity

Explore the possibilities of one of the concept combinations developed in the previous activity.

FIGURE 1.17

Possible solutions to the subproblem of configuring the wheels around the passenger.

When exploring the possibilities of a design concept, the team may discover ways in which the design can be improved. For example, Concept 1 might be improved by providing a more comfortable seat and by adding a battery that can store energy for use when it is dark or cloudy and the solar array does not generate electricity.

Once several design concepts have been developed and explored so that their advantages and disadvantages are understood, the design team must choose one concept that will be used to create the design for the product. It is usually best to choose the concept using a structured decision process. In a structured decision process, each of the concepts is evaluated to see whether it meets the constraints and is compared with the other concepts using the criteria; the best concept according to the criteria that meets the constraints is typically selected to implement the product.

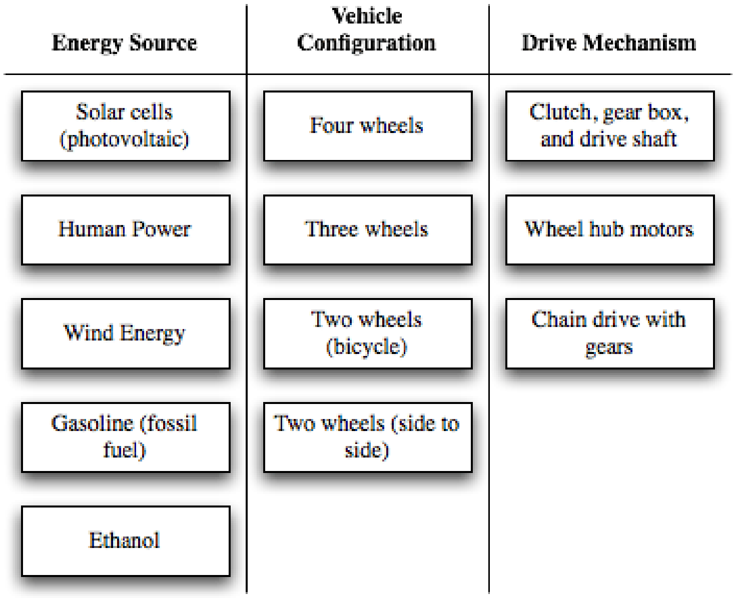

FIGURE 1.18
The concept combination table for the commuter vehicle.

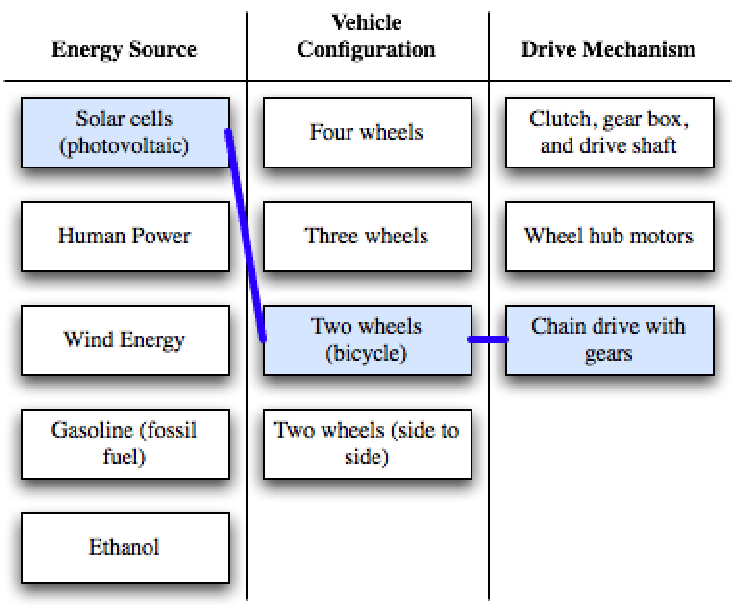

FIGURE 1.19
The concept combination table is used to generate a particular possible design.

In the case study, Concept 2 did not meet the constraint because it would require cities to build charging stations, so it was eliminated from consideration. Using the criteria as a guide, the design team determined that the two best designs were Concept 1 and Concept 5. They ranked high because of low pollution, using only renewable energy, and being low cost compared with other options. However, it is clear that these designs are the least comfortable for the consumer, and may therefore not be commercially successful. At this point, the design team could choose to use one of these designs and go forward in the design process; or, they may feel after seeing the outcome of the selection process that their criteria did not accurately capture their customers' desires. In this case, they may go back and improve their criteria, then repeat the decision process. Or, they may determine that better concepts may

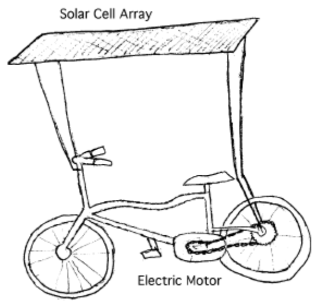

FIGURE 1.20
A sketch of the possible design obtained by from the concept combination table in Figure 16. Note that engineers often use rough, hand-drawn sketches at this point in the design process to understand design concepts and explore their strengths and weaknesses.

have been developed with different combinations of subproblem solutions or through different assumptions in the Explore Possibilities step, and thus repeat the Concept Generation and Explore Possibilities steps.

Sometimes, a design does not satisfy the constraints but could be easily modified to satisfy the constraints. For example, in Concept 2 if a battery charging station were to be built at each customer's house, the concept could be judged to meet the constraint. At other times, one design will score low because it has a particular flaw that can be corrected by combining it with characteristics of another design. Thus, the team should see if there are any designs that score low because of one aspect and can be corrected or if two designs can be combined to provide a better design.

Develop a Detailed Design

After concept selection, the team has a general design concept; they have decided how each subproblem will be addressed and have an overall understanding of the design. Before the design can be manufactured, the team needs to develop the details of the design. A detailed design includes

- The shapes and dimension of all physical components.
- An understanding of which components will be acquired from external vendors and which will be fabricated within the company and, if fabricated within the company, the materials and fabrication processes to be used.
- A detailed schematic diagram of any electrical subsystems and computer code for any embedded processors.
- Assembly processes.

The development of a detailed design from a design concept may occupy the majority of time allocated to a new product design project. This step will also have a significant impact on the success of the project; a poor detailed design can ruin a good design concept.

In the process of developing a detailed design, the team may use many or all of the subsequent design steps of prototyping, testing, and refinement. This process may require many iterations as the testing of prototypes reveals previously unknown characteristics of the design.

A major step in the process of going from a design concept to a detailed design is the development of the design architecture. The design architecture is "the assignment of the functional elements of the product to the physical building blocks of the product" (Eppinger and Ulrich, 2003).

For example, one architectural decision for the SCV design is how to incorporate the solar array into the design. Should the array be a separate physical block of the vehicle, for example creating the canopy structure in Figure 17, or should the array be created as an integral part of the frame? The first option represents a modular architecture, while the second option represents an integrated architecture.

Prototype, Test, and Refine

A prototype or model is a representation of some aspect of the design. The purpose of models and prototypes is to provide additional understanding of the design and its performance. A prototype may implement only a small portion of design or may be comprehensive and implement the whole design. For example, while developing a detailed design for Concept 1, the design team may initially wish to develop a prototype only of the electrical system (the solar cell array and the electric motor). Once the electrical system design is verified, they may implement a comprehensive prototype of the whole vehicle.

Prototypes may be physical or virtual. A physical prototype may be implemented out of materials that are very similar to those that will be used to manufacture the final design, or, to reduce cost or save time, the prototype may be implemented out of other materials. A virtual prototype may be created using a computer-aided design and drafting (**CADD**) program. Modern programs can simulate many aspects of a physical system, revealing flaws or promoting understanding of the design without the need to implement it physically.

One important function of a prototype is to test whether the design will work as expected. Understanding of the design and confidence that it will work is gained as prototypes are tested and evaluated relative to the constraints and criteria for the design. Testing procedures should be carefully planned to ensure that questions about the design are answered without requiring too much time and resources. The test results should be evaluated relative to specifications that reflect the constraints and criteria.

Testing and evaluation of the prototype may reveal weaknesses in the design or may provide information that can be used to improve the design. In this case, the design will often be refined, particularly if it does poorly with respect to some of the criteria or constraints. Sometimes, the chosen design concepts do not meet the criteria or constraints, and the design team must go back and perform more concept generation and then select another concept. This is an integral part of a spiral design process.

Communication and Implementation

As the design team has gone through the design process, they have kept records of the different processes that they used and results of these processes. Often, this information is used to create user manuals and maintenance manuals for the product. This information is important for team members who will be required to update or modify the design in the future. Lessons are learned in the design process that should be conveyed to other teams in the company or perhaps to external stakeholders in government or academia. An important part of the design process is to document these issues and communicate the results to the appropriate stakeholders.

As the design is completed, the effort to implement the design increases. If the design is of a product that is manufactured, a manufacturing system must be developed. For example, in the alternate commuter vehicle design, suppliers for components such as motors and solar cells must be located; facilities for manufacturing the frame are created; and a sales and marketing staff are identified.

Review Questions

Multiple Choice

The following questions will help you assess your understanding of the Discovering Engineering section. There may be one, two, three, or even four correct answers to each question. To demonstrate your understanding, you should find all of the correct answers.

1. Design problems are broken down into subproblems because
   a. each design team member needs a specific problem to solve
   b. the customer or stakeholders do not understand the overall problem
   c. smaller problems must be solved in order to solve the overall problem
   d. engineering companies make more money solving many smaller problems
2. When a design team searches externally for ideas they
   a. interview customers
   b. look at existing products
   c. look at technical databases
   d. talk to experts in the problem area
3. A concept combination table helps you to
   a. explore design ideas systematically
   b. see the complete design concept
   c. identify the overall design problem
   d. keep track of rejected designs
4. A concept screening matrix is used to
   a. select a design
   b. eliminate constraints
   c. develop a design
   d. eliminate criteria
5. A prototype can be
   a. a physical representation
   b. a scale model
   c. a virtual representation
   d. a final product
6. Implementation means that a
   a. physical model is built
   b. virtual model is built
   c. prototype is built
   d. product is manufactured
7. A design is refined because
   a. it has met the constraints and criteria
   b. testing has found weaknesses in the design
   c. a product must go through the spiral design process
   d. there are no further improvements to make
8. Communicating processes and results is done by
   a. posting designs on a website
   b. creating a users manual
   c. text messaging team members
   d. emailing manufacturers
9. A detailed design includes
   a. a market analysis
   b. shapes and dimensions of all physical components
   c. computer code
   d. assembly process

10. The step in the design process called Explore Possibilities is used to
    a. make additional designs
    b. improve the design
    c. understand the design characteristics
    d. test the prototype
11. Searching internally for ideas is called
    a. mind searches
    b. design sessions
    c. idea dumps
    d. brainstorming
12. When engineers generate ideas in the design process they
    a. use an unstructured approach
    b. use a step by step approach
    c. use a mathematical approach
    d. use a structured approach
13. Which techniques are used to define the design problem?
    a. Find expert information
    b. Try to identify the real problem
    c. Gather information from customers
    d. None of the above

Free Response Questions

14. How can you tell the difference between a good design and a bad design?
15. What is the difference between engineering design and other types of design (architectural, fashion, etc.)?
16. How do you know that your design team has considered enough ideas to ensure that they develop a good design?
17. What are the characteristics of a good problem definition statement?
18. What are the steps of the design process? Why are they not always completed in order?
19. How do you use team decision-making tools in the design process?
20. How do you create a detailed design from a design concept?

Review Answers

The Design Process in Action

1. c
2. a,b,c,d
3. a
4. a
5. a,b,c
6. d
7. b
8. b
9. b,c,d
10. b,c
11. d

12. d
13. a,b,c

1.9 Glossary Chapter 1

animal electricity, the electricity in living systems, once thought to be different that regular electricity.

Battle of the Currents, when there was a dispute between Thomas Edison and J.P. Morgan against Nikola Tesla and George Westinghouse about which kind of electricity should be sold to customers in order to light up their electric lights.

controversy, When people disagree about what things mean or how things are and tell each other and others that they disagree.

copernican Sun centered system, a system that teaches that the planets go around the sun, that the earth actually moves.

Endeavor, something that people are trying to do

extinction event, presumed events in the history of the earth that fit how large numbers of species in the fossil record disappear above certain layers of the Earth's crust. It is said many species (the creatures of that type) all died off at the same time due to some major catastrophic event.

extinction, when all of certain kind of organisms is dead.

global warming, a theory that says that the earth is warming up because of what people are doing, not what nature is doing.

Glossary

intelligent design, a theory that disagrees with evolution theory as being the key to explaining life on Earth. In reality, both theories focus on different aspects of life on earth, but they both require opposite world views, evolution focuses on biodiversity - the different kinds of creatures, intelligent design focuses on how life could have started in the first place.

phenomenon, a fact or observation which may or may not be understood.

phlogiston theory, a theory which said that when things burned phlogiston would leave them and they would weigh less. Modern theory understands that when things burn atoms rearrange their grouping, some of them leave as a gas, others stay behind.

scientific Method, The process in which scientists use one or more of these steps to learn about the universe: ask questions about the universe, research what others have found, make an educated guess (form a hypothesis), design an experiment which tests the hypothesis, analyze the results of the data and observations in order to draw conclusions based on the experiment(s), communicate their results to others. These do NOT have to be done in order.

ultraviolet catastrophe, A series of experiments proved that light is NOT given by hot objects according to the Rayleigh-Jeans law which describes how hot things cool off by giving off light. When new information was collected about light in the Ultraviolet color range, the law did not hold, it was a catastrophe for scientists who thought they had everything figured out.

1.10 References

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CHAPTER 2 Earth History ESS 1-4

Chapter Outline

INTRODUCTION

DISCIPLINARY CORE IDEA:

MS-ESS 1-4 By the end of instruction, students should be able to answer a test which asks them to: **Show how scientists use the evidence found in the rock strata (layers of the earth) to organize the history of the earth and determine the age of the earth.**

Science is based on the belief that the laws of nature do not change and the experiences recorded by people throughout history.

From the experiences of scientists around the world and from your own life experience scientists conclude that the laws of nature never change. They are the same today as they were billions of years ago. Water freezes at 0°C at 1 atmosphere pressure; this is always true.

Believing that natural laws never change helps scientists understand Earth's past because it allows them to interpret clues about how things happened long ago. Geologists always use present-day processes to interpret the past. If you find a fossil of a fish in a dry terrestrial environment did the fish flop around on land? Did the rock form in water and then move? Since fish do not flop around on land today, the explanation that adheres to the philosophy that natural laws do not change is that the rock moved.

History of Earth - Go to Mars Story

Here we begin our story we begin our story with where are we and how long has life been here. To answer those questions, we begin with the first part - how old is the Earth?

2.1 Earth History and Clues from Fossils

Learning Objectives

- Fossils are full of information about Earth's past and are essential for unraveling earth history.

Seashells at 20,000 feet!

On his voyage on the Beagle, Charles Darwin noticed many things besides just the Galapagos finches that made him famous. Another important discovery was shell beds high in the Andes Mountains. How did they get there? He determined that they must mean that mountains rise slowly above the ocean, an idea that was being championed at the time by Charles Lyell. If this is the case, Darwin reasoned, the mountains and Earth must be extremely old.

Clues From Fossils

Fossils are our best form of evidence about Earth history, including the history of life. Along with other geological evidence from rocks and structures, fossils even give us clues about past climates, the motions of plates, and other major geological events. Since the present is the key to the past, what we know about a type of organism that lives today can be applied to past environments.

History of Life on Earth

That life on Earth has changed over time is well illustrated by the fossil record. Fossils in relatively young rocks resemble animals and plants that are living today. In general, fossils in older rocks are less similar to modern organisms. We would know very little about the organisms that came before us if there were no fossils. Modern technology has allowed scientists to reconstruct images and learn about the biology of extinct animals like dinosaurs!

Environment of Deposition

By knowing something about the type of organism the fossil was, geologists can determine whether the region was terrestrial (on land) or marine (underwater) or even if the water was shallow or deep. The rock may give clues to whether the rate of sedimentation was slow or rapid. The amount of wear and fragmentation of a fossil allows scientists to learn about what happened to the region after the organism died; for example, whether it was exposed to wave action.

Geologic History

The presence of marine organisms in a rock indicates that the region where the rock was deposited was once marine. Sometimes fossils of marine organisms are found on tall mountains indicating that rocks that formed on the seabed were uplifted.

Climate

By knowing something about the climate a type of organism lives in now, geologists can use fossils to decipher the climate at the time the fossil was deposited. For example, coal beds form in tropical environments but ancient coal beds are found in Antarctica. Geologists know that at that time the climate on the Antarctic continent was much warmer. Recall from the chapter Plate Tectonics that Wegener used the presence of coal beds in Antarctica as one of the lines of evidence for continental drift.

Index Fossils

An **index fossil** can be used to identify a specific period of time. Organisms that make good index fossils are distinctive, widespread, and lived briefly. Their presence in a rock layer can be used to identify rocks that were deposited at that period of time over a large area.

The fossil of a juvenile mammoth found near downtown San Jose California reveals an enormous amount about these majestic creatures: what they looked like, how they lived, and what the environment of the Bay Area was like so long ago.

Science Friday: Millions of Fossils Can't Be Wrong

What's in a tar pit? In this video by Science Friday, Dr. John Harris describes how the La Brea Tar Pit has come to accumulate so many fossils.

MEDIA

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Summary

- Fossils tell a lot about the environment during the time they were deposited.

- Climate is one important thing that can be indicated by fossils since organisms have specific conditions in which they can live.
- An index fossil must be distinctive, widespread and short-lived so that it can identify a specific period of time.

Review

1. How does a single fossil or set of fossils help geologists to decipher the geological history of an area?
2. How is an index fossil used to identify a time period?
3. Why are the fossils of marine organisms sometimes found in rock units at the tops of high mountains? What evidence would you look for to determine if this reason is plausible?

Explore More

Use this resource to answer the questions that follow.

MEDIA
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1. What shows up in rocks that are 3.8 billion years old?
2. What is found in rocks that are 3.5 billion years old?
3. When do the first large lifeforms show up and what are they?
4. What happens around 500 million years ago?
5. What big thing happens 400 million years ago? What are the organisms like?
6. What happens about 300 million years ago?
7. What happened about 250 million years ago and what caused it?
8. What are the next 150 million years like?
9. What happens 66 million years ago?
10. What does that set the stage for?
11. When and where do the first human ancestors appear?
12. When did humans arrive in North America?
13. Where did a lot of that story come from?

Resources

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2.2 Principles of Relative Dating

Learning Objectives

- Steno's laws are used to determine the order in which geological events took place.

What are relative ages?

In most families a person's age fits into his or her generation: Siblings are around the same age as are first cousins. But in some families, multiple marriages, delayed childbearing, extended childbearing or other variations mixes up generations so that Aunt Julia may be five years younger than her nephew. In a family like this it's hard to tell how people are related simply by age. With rock units we use certain principles to tell their ages relative to each other.

Relative Age Dating

Early geologists had no way to determine the absolute age of a geological material. If they didn't see it form, they couldn't know if a rock was one hundred years or 100 million years old. What they could do was determine the ages of materials relative to each other. Using sensible principles they could say whether one rock was older than another and when a process occurred relative to those rocks.

Steno's Laws

Remember Nicholas Steno, who determined that fossils represented parts of once-living organisms? Steno also noticed that fossil seashells could be found in rocks and mountains far from any ocean. He wanted to explain how that could occur. Steno proposed that if a rock contained the fossils of marine animals, the rock formed from sediments that were deposited on the seafloor. These rocks were then uplifted to become mountains.

This scenario led him to develop the principles that are discussed below. They are known as Steno's laws. Steno's laws are illustrated in **Figure** 2.1.

- **Original horizontality**: Sediments are deposited in fairly flat, horizontal layers. If a sedimentary rock is found tilted, the layer was tilted after it was formed.
- **Lateral continuity**: Sediments are deposited in continuous sheets that span the body of water that they are deposited in. When a valley cuts through sedimentary layers, it is assumed that the rocks on either side of the valley were originally continuous.
- **Superposition**: Sedimentary rocks are deposited one on top of another. The youngest layers are found at the top of the sequence, and the oldest layers are found at the bottom.

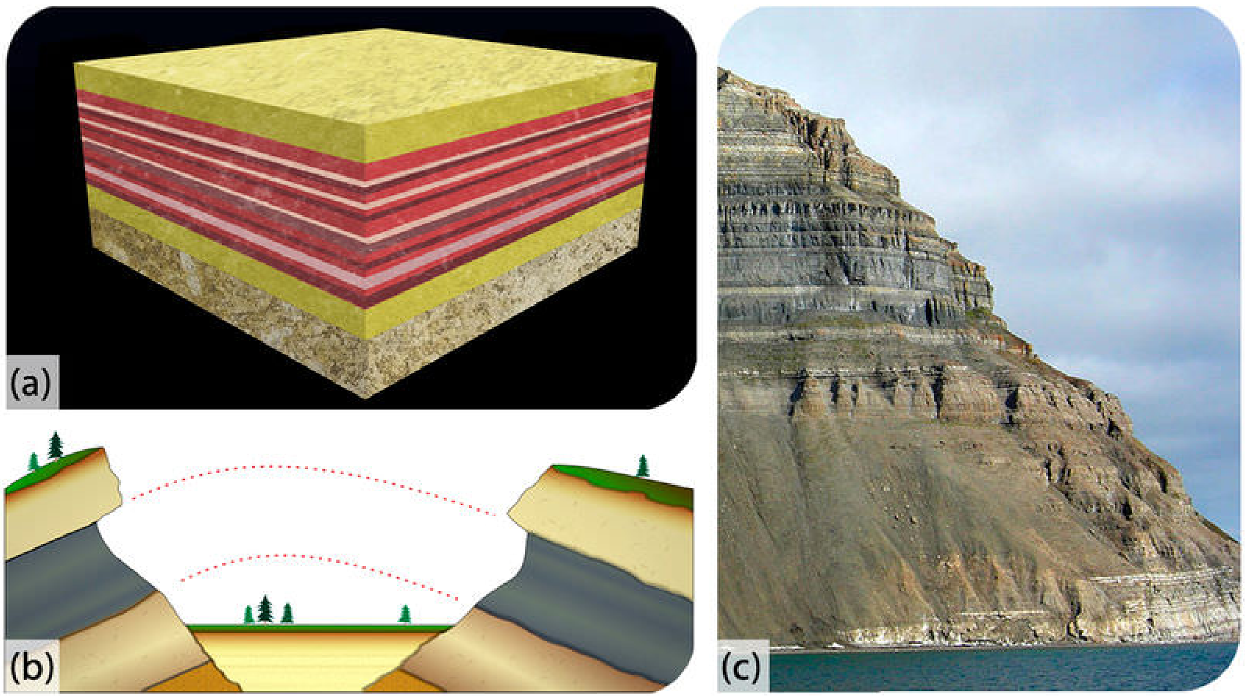


FIGURE 2.1
(a) Original horizontality. (b) Lateral continuity. (c) Superposition.

More Principles of Relative Dating

Other scientists observed rock layers and formulated other principles.

Geologist William Smith (1769-1839) identified the **principle of faunal succession**, which recognizes that:

- Some fossil types are never found with certain other fossil types (e.g. human ancestors are never found with dinosaurs) meaning that fossils in a rock layer represent what lived during the period the rock was deposited.
- Older features are replaced by more modern features in fossil organisms as species change through time; e.g. feathered dinosaurs precede birds in the fossil record.
- Fossil species with features that change distinctly and quickly can be used to determine the age of rock layers quite precisely.

Scottish geologist, James Hutton (1726-1797) recognized the **principle of cross-cutting relationships**. This helps geologists to determine the older and younger of two rock units (**Figure** 2.2).

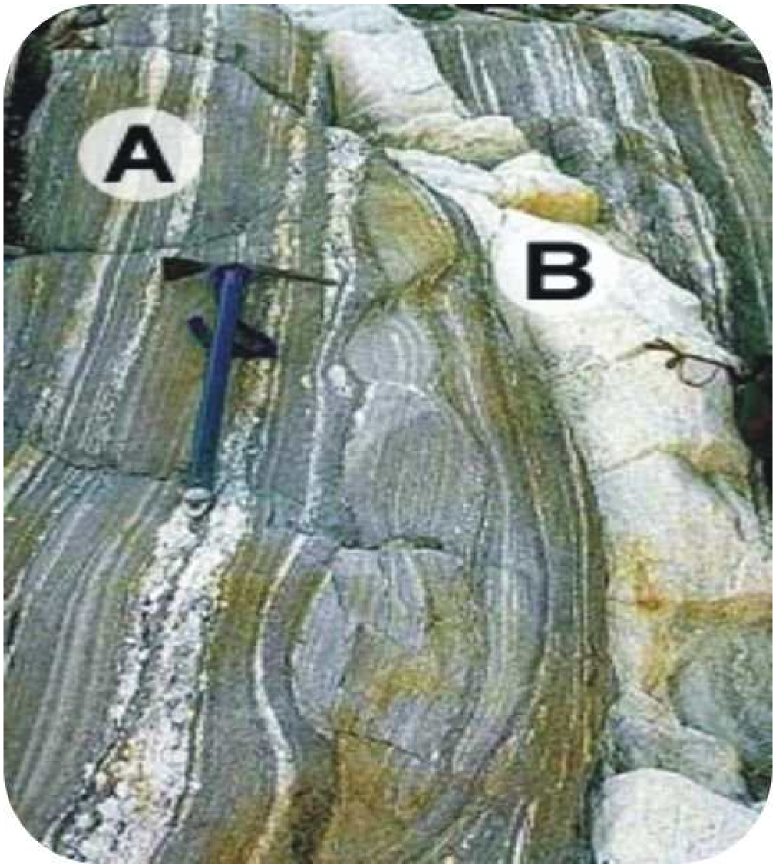


FIGURE 2.2
If an igneous dike (B) cuts a series of metamorphic rocks (A), which is older and which is younger? In this image, A must have existed first for B to cut across it.

The Grand Canyon

The Grand Canyon provides an excellent illustration of the principles above. The many horizontal layers of sedimentary rock illustrate the principle of original horizontality (**Figure** 2.3).

- The youngest rock layers are at the top and the oldest are at the bottom, which is described by the law of superposition.
- Distinctive rock layers, such as the Kaibab Limestone, are matched across the broad expanse of the canyon. These rock layers were once connected, as stated by the rule of lateral continuity.
- The Colorado River cuts through all the layers of rock to form the canyon. Based on the principle of cross-cutting relationships, the river must be younger than all of the rock layers that it cuts through.

Summary

- Sediments are deposited horizontally with the oldest at the bottom. Any difference in this pattern means that the rock units have been altered.
- The principle of faunal succession recognizes that species evolve and these changes can be seen in the rock record.

FIGURE 2.3
At the Grand Canyon, the Coconino Sandstone appears across canyons. The Coconino is the distinctive white layer; it is a vast expanse of ancient sand dunes.

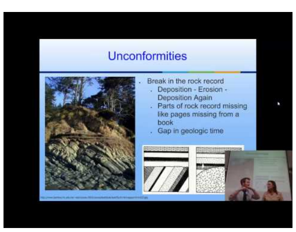
- The Grand Canyon exhibits many of the principles of relative dating and is a fantastic location for learning about the geology of the southwestern U.S.

Review

1. How do Steno's laws help geologists to decipher the geological history of a region?
2. What is the principle of faunal succession?
3. Why does just about every geology textbook use the Grand Canyon as the example in the sections on geological history?

Explore More

Use this resource (start at 1:23) to answer the questions that follow.



MEDIA
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1. What do you determine when you're doing relative dating? What are you not determining?
2. What is the Law of Superposition? What is the exception?
3. What is the Law of Original Horizontality? If rocks are not horizontal what does that mean?
4. What is the Law of Cross-Cutting Relationships?
5. What is the Law of Inclusions?
6. What is an unconformity? What can cause an unconformity?
7. What does an angular unconformity look like? What does this indicate?

8. What happened during an unconformity and how do we know that?
9. How do you know where there is a disconformity?
10. What happened to create an nonconformity? What can you look for to identify a nonconformity?

2.3 Determining Relative Ages

Learning Objectives

- Be able to determine the relative ages of a set of rocks and the processes that have altered them.

What clues indicate a person's age?

There are ways to tell the ages of people relative to each other. For children we use height, for adults we might use gray hair and wrinkles. There are also ways to tell the relative ages of rocks. We'll practice in this concept.

Determining the Relative Ages of Rocks

Steno's and Smith's principles are essential for determining the relative ages of rocks and rock layers. In the process of relative dating, scientists do not determine the exact age of a fossil or rock but look at a sequence of rocks to try to decipher the times that an event occurred relative to the other events represented in that sequence. The **relative age** of a rock then is its age in comparison with other rocks. If you know the relative ages of two rock layers, (1) Do you know which is older and which is younger? (2) Do you know how old the layers are in years?

In some cases, it is very tricky to determine the sequence of events that leads to a certain formation. Can you figure out what happened in what order in (**Figure** 2.4)? Write it down and then check the following paragraphs.

The principle of cross-cutting relationships states that a fault or intrusion is younger than the rocks that it cuts through. The fault cuts through all three sedimentary rock layers (A, B, and C) and also the intrusion (D). So the fault must be the youngest feature. The intrusion (D) cuts through the three sedimentary rock layers, so it must be younger than those layers. By the law of superposition, C is the oldest sedimentary rock, B is younger and A is still younger.

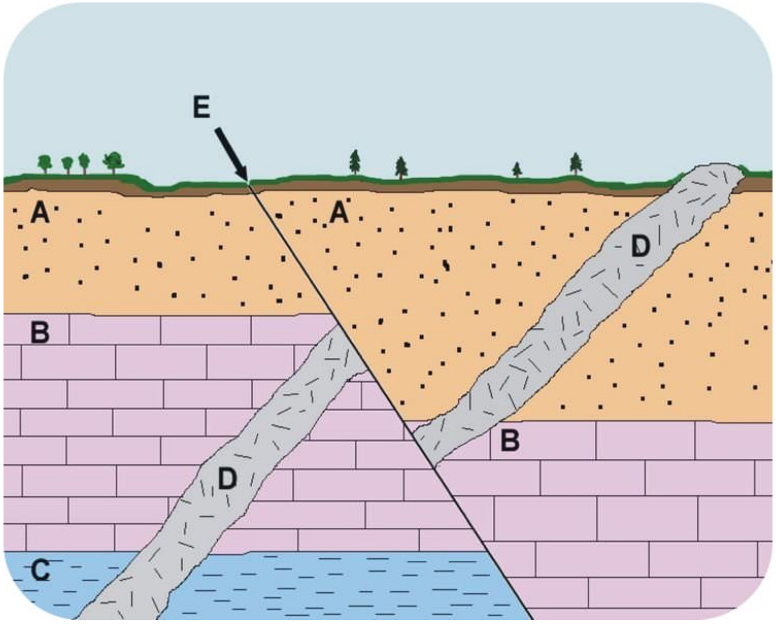
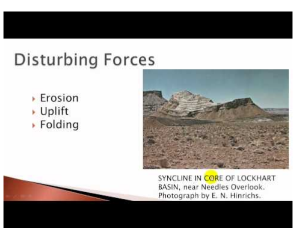


FIGURE 2.4
A geologic cross section: Sedimentary rocks (A-C), igneous intrusion (D), fault (E).

The full sequence of events is:

1. Layer C formed.
2. Layer B formed.
3. Layer A formed.
4. After layers A-B-C were present, intrusion D cut across all three.
5. Fault E formed, shifting rocks A through C and intrusion D.
6. Weathering and erosion created a layer of soil on top of layer A.



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Summary

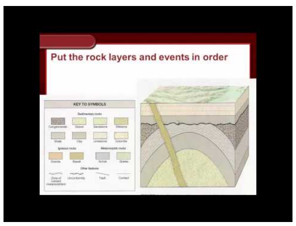
- The oldest rock units lie beneath the younger ones.
- By the principle of cross-cutting relationships (and common sense) we know that something must exist before something else can cut across it.
- The history of a section of rocks can be deciphered using the principles outlined in this Concept.

Review

1. What is relative age? How does it differ from absolute age?
2. Why do the principles of relative dating not indicate the absolute age of a rock unit?
3. Under what circumstances would a rock unit with an older fossil be above a rock until with a younger fossil?

Explore More

Use the resource below to answer the questions that follow.



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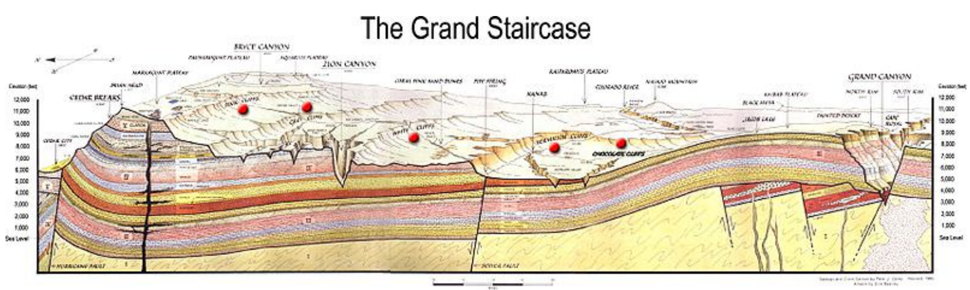
1. What does relative dating give you? What doesn't it give you?
2. What is the order of rock layers and events in the first rock section shown?
3. What is the order of rock layers and events in the second rock section shown?
4. What is the order of rock layers and events in the third rock section shown?
5. What is the order of rock layers and events in the fourth rock section shown?
6. What is the order of rock layers and events in the fifth rock section shown?
7. What is the order of rock layers and events in the sixth rock section shown?

2.4 Correlation Using Relative Ages

Learning Objectives

- Rock units can be correlated over vast distances if they are distinctive, or contain index fossils or a key bed.



What is rock matching?

If we want to understand the geological history of a location, we need to look at the rocks in that location. But if we want to understand a region, we need to correlate the rocks between different locations so that we can meld the individual histories of the different locations into one regional history.

Matching Up Rock Layers

Superposition and cross-cutting are helpful when rocks are touching one another and lateral continuity helps match up rock layers that are nearby. To match up rocks that are further apart we need the process of **correlation**. How do geologists correlate rock layers that are separated by greater distances? There are three kinds of clues:

Distinctive Rock Formations

1. Distinctive rock formations may be recognizable across large regions (**Figure** 2.5).

Index Fossils

2. Two separated rock units with the same index fossil are of very similar age. What traits do you think an index fossil should have? To become an index fossil the organism must have (1) been widespread so that it is useful for identifying rock layers over large areas and (2) existed for a relatively brief period of time so that the approximate age of the rock layer is immediately known.

Many fossils may qualify as index fossils (**Figure** below). Ammonites, trilobites, and graptolites are often used as index fossils. **Microfossils**, which are fossils of microscopic organisms, are also useful index fossils. Fossils

FIGURE 2.5
The famous White Cliffs of Dover in southwest England can be matched to similar white cliffs in Denmark and Germany.

of animals that drifted in the upper layers of the ocean are particularly useful as index fossils, since they may be distributed over very large areas.

A biostratigraphic unit, or **biozone**, is a geological rock layer that is defined by a single index fossil or a fossil assemblage. A biozone can also be used to identify rock layers across distances.

Key Beds

3. A **key bed** can be used like an index fossil since a key bed is a distinctive layer of rock that can be recognized across a large area. A volcanic ash unit could be a good key bed. One famous key bed is the clay layer at the boundary between the Cretaceous Period and the Tertiary Period, the time that the dinosaurs went extinct (**Figure** 2.6). This widespread thin clay contains a high concentration of iridium, an element that is rare on Earth but common in asteroids. In 1980, the father-son team of Luis and Walter Alvarez proposed that a huge asteroid struck Earth 66 million years ago and caused the mass extinction.

Summary

- A single rock unit contains the story of the geology of that location. To understand the geology of a region, scientists use correlation.
- To correlate rock units, something distinctive must be present in each. This can include an index fossil, a unique rock type, a key bed, or a unique sequence of rocks.
- A key bed can be global. An example is the iridium layer that was deposited at the time of the Cretaceous-Tertiary extinctions.

FIGURE 2.6
The white clay is a key bed that marks the Cretaceous-Tertiary Boundary.

Review

1. What features must the iridium layer that dates to around 66 million years ago have to be a key bed?
2. Why are microfossils especially useful as index fossils?
3. What is the process of correlation?

Explore More

Use the resource below to answer the questions that follow.

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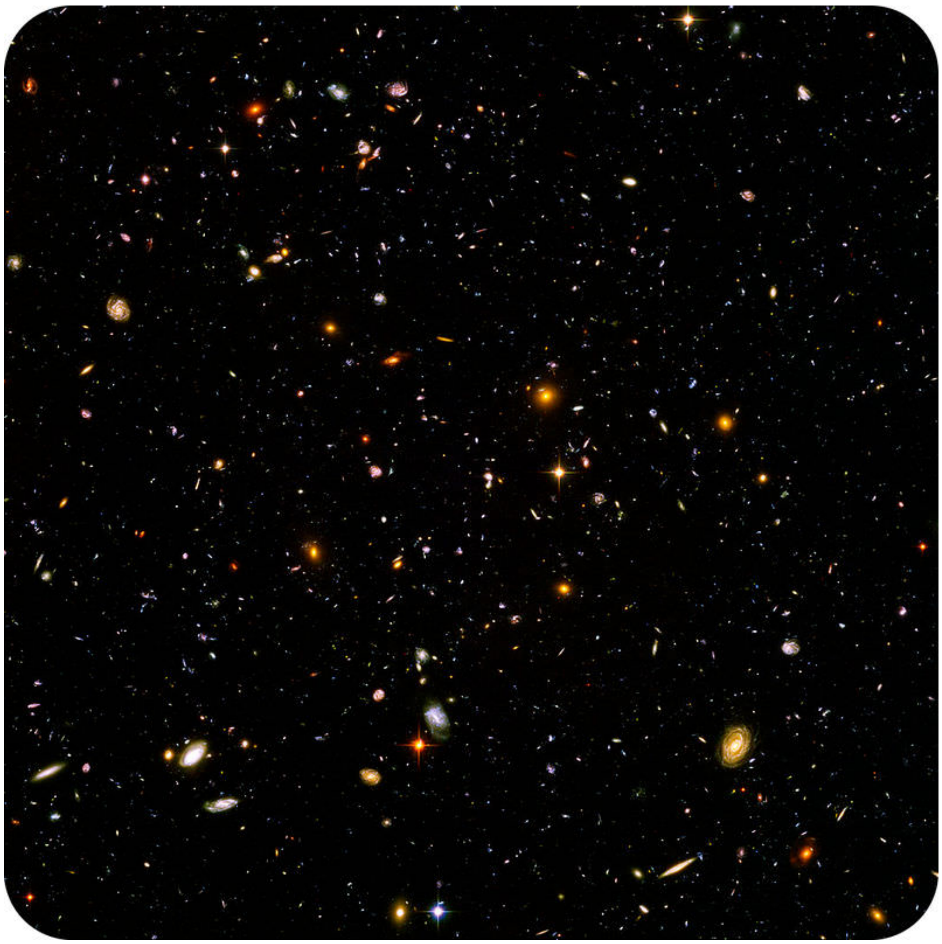
1. What does the rock that forms the hoodoos of Bryce Canyon tell geologists about the environment at the time the sediments were deposited?
2. Why are the rocks at Bryce Canyon orange?
3. What happened when the Colorado Plateau rose?
4. How were the hoodoos created for the most part?
5. What is the rock that creates the white cliffs at Zion? Why are the sands at angles?
6. When was that portion of Utah a giant sand dune? Why are there dunes stacked on top of dunes?

2.5 Geologic Time Scale

Learning Objectives

- The geologic time scale allows scientists to refer to events in Earth history in relevant units.



To infinity and beyond!

We can picture deep space, but what does deep time look like? If you divided up the 4.6 billion years of Earth history into one calendar year, as is done at the end of this concept, you might get an idea.

The Geologic Time Scale

To be able to discuss Earth history, scientists needed some way to refer to the time periods in which events happened and organisms lived. With the information they collected from fossil evidence and using Steno's principles, they created a listing of rock layers from oldest to youngest. Then they divided Earth's history into blocks of time with each block separated by important events, such as the disappearance of a species of fossil from the rock record.

Since many of the scientists who first assigned names to times in Earth's history were from Europe, they named the blocks of time from towns or other local places where the rock layers that represented that time were found.

From these blocks of time the scientists created the **geologic time scale** (**Figure** 2.7). In the geologic time scale the youngest ages are on the top and the oldest on the bottom. Why do you think that the more recent time periods are divided more finely? Do you think the divisions in the scale below are proportional to the amount of time each time period represented in Earth history?

In what eon, era, period and epoch do we now live? We live in the Holocene (sometimes called Recent) epoch, Quaternary period, Cenozoic era, and Phanerozoic eon.

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Geologic Time Condensed to One Year

It's always fun to think about geologic time in a framework that we can more readily understand. Here are when some major events in Earth history would have occurred if all of earth history was condensed down to one calendar year.

January 1 12 am: Earth forms from the planetary nebula - 4600 million years ago

February 25, 12:30 pm: The origin of life; the first cells - 3900 million years ago

March 4, 3:39 pm: Oldest dated rocks - 3800 million years ago

March 20, 1:33 pm: First stromatolite fossils - 3600 million years ago

July 17, 9:54 pm: first fossil evidence of cells with nuclei - 2100 million years ago

November 18, 5:11 pm: Cambrian Explosion - 544 million years ago

December 1, 8:49 am: first insects - 385 million years ago

December 2, 3:54 am: first land animals, amphibians - 375 million years ago

December 5, 5:50 pm: first reptiles - 330 million years ago

December 12, 12:09 pm: Permo-Triassic Extinction - 245 million years ago

December 13, 8:37 pm: first dinosaurs - 228 million years ago

December 14, 9:59 am: first mammals – 220 million years ago

December 22, 8:24 pm: first flowering plants - 115 million years ago

December 26, 7:52 pm: Cretaceous-Tertiary Extinction - 66 million years ago

December 26, 9:47 pm: first ancestors of dogs - 64 million years ago

December 27, 5:25 am: widespread grasses - 60 million years ago

December 27, 11:09 am: first ancestors of pigs and deer - 57 million years ago

December 28, 9:31 pm: first monkeys - 39 million years ago

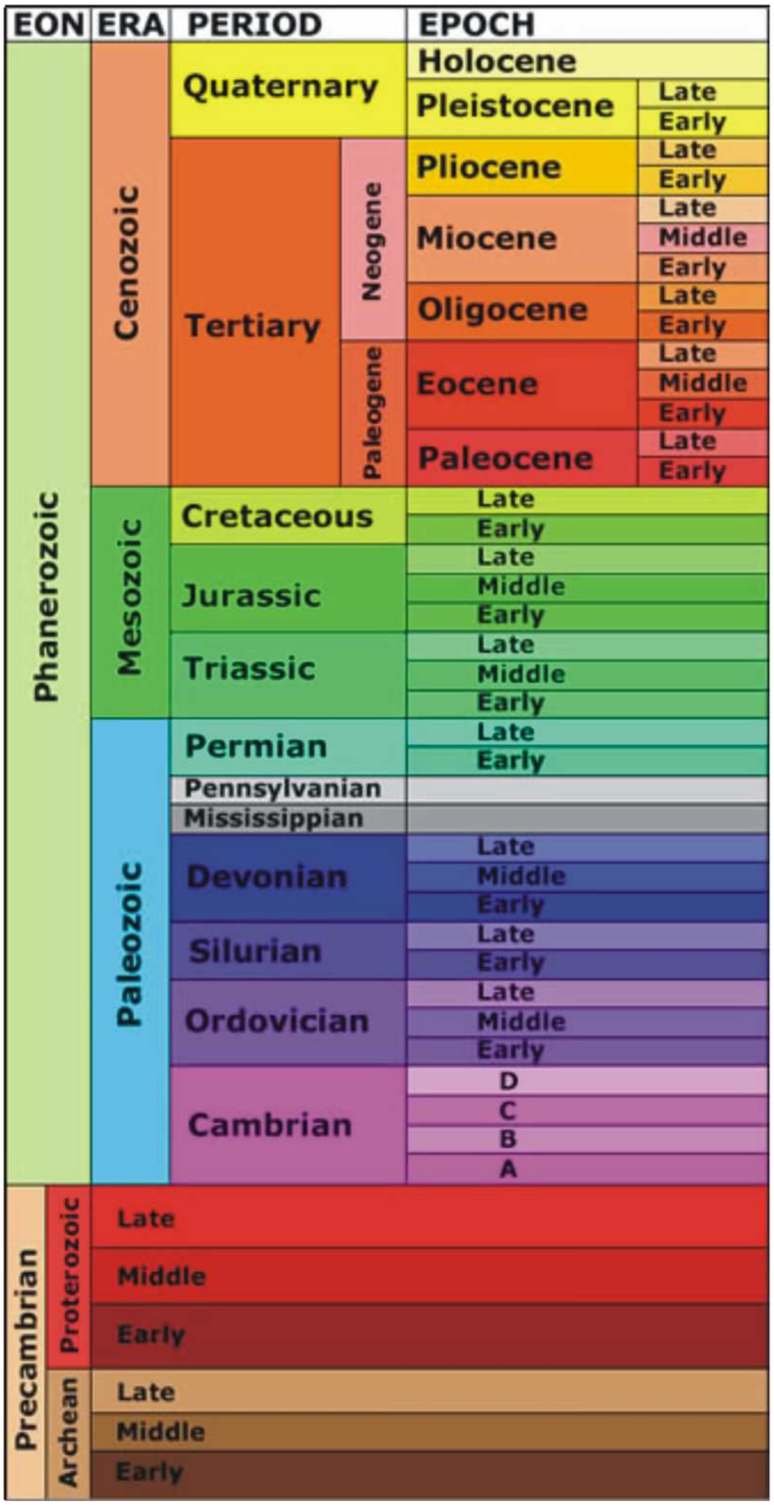


FIGURE 2.7
The geologic time scale is based on relative ages. No actual ages were placed on the original time scale.

December 31, 5:18 pm: oldest hominid - 4 million years ago

December 31, 11:02 pm: oldest direct human ancestor - 1 million years ago

December 31, 11:48 pm: first modern human - 200,000 years ago

December 31, 11:59 pm: Revolutionary War - 235 years ago

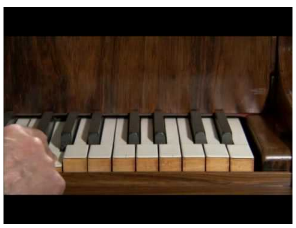
Summary

- The geologic time scale divides earth history into named units that are separated by major events in earth or life history.
- Naming time periods makes it easier to talk about them.
- Humans have been around for a miniscule portion of earth history.

Review

1. Why do earth scientists need a geologic time scale?
2. Why are some units of the geologic time scale longer and some shorter?
3. How does the section that condenses all of geologic time into one year make you feel?

Resources



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2.6 Fossils I: Fossilization

- Organisms with hard parts that are buried quickly or that end up in a tar pit are more likely to become fossils.

What kind of fossil is this?

As a paleontologist it would be great to find a new species of dinosaur or the best preserved specimen of a species like Tyrannosaurus rex. But lots of important information can be gained from less....um...glamorous finds. One example is this fossil coprolite from a meat-eating dinosaur. Fortunately, fossil poo doesn't stink!

Fossils were Parts of Living Organisms

It wasn't always known that fossils were parts of living organisms. In 1666, a young doctor named Nicholas Steno dissected the head of an enormous great white shark that had been caught by fisherman near Florence, Italy. Steno was struck by the resemblance of the shark's teeth to fossils found in inland mountains and hills (**Figure** below).

Fossil Shark Tooth (left) and Modern Shark Tooth (right).

Most people at the time did not believe that fossils were once part of living creatures. Authors in that day thought that the fossils of marine animals found in tall mountains, miles from any ocean could be explained in one of two ways:

- The shells were washed up during the Biblical flood. (This explanation could not account for the fact that fossils were not only found on mountains, but also within mountains, in rocks that had been quarried from deep below Earth's surface.)
- The fossils formed within the rocks as a result of mysterious forces.

But for Steno, the close resemblance between fossils and modern organisms was impossible to ignore. Instead of invoking supernatural forces, Steno concluded that fossils were once parts of living creatures.

How Fossils Form

A fossil is any remains or traces of an ancient organism. Fossils include **body fossils**, left behind when the soft parts have decayed away, and **trace fossils**, such as burrows, tracks, or fossilized coprolites (feces) as seen above. Collections of fossils are known as fossil assemblages.

Fossilization is Rare

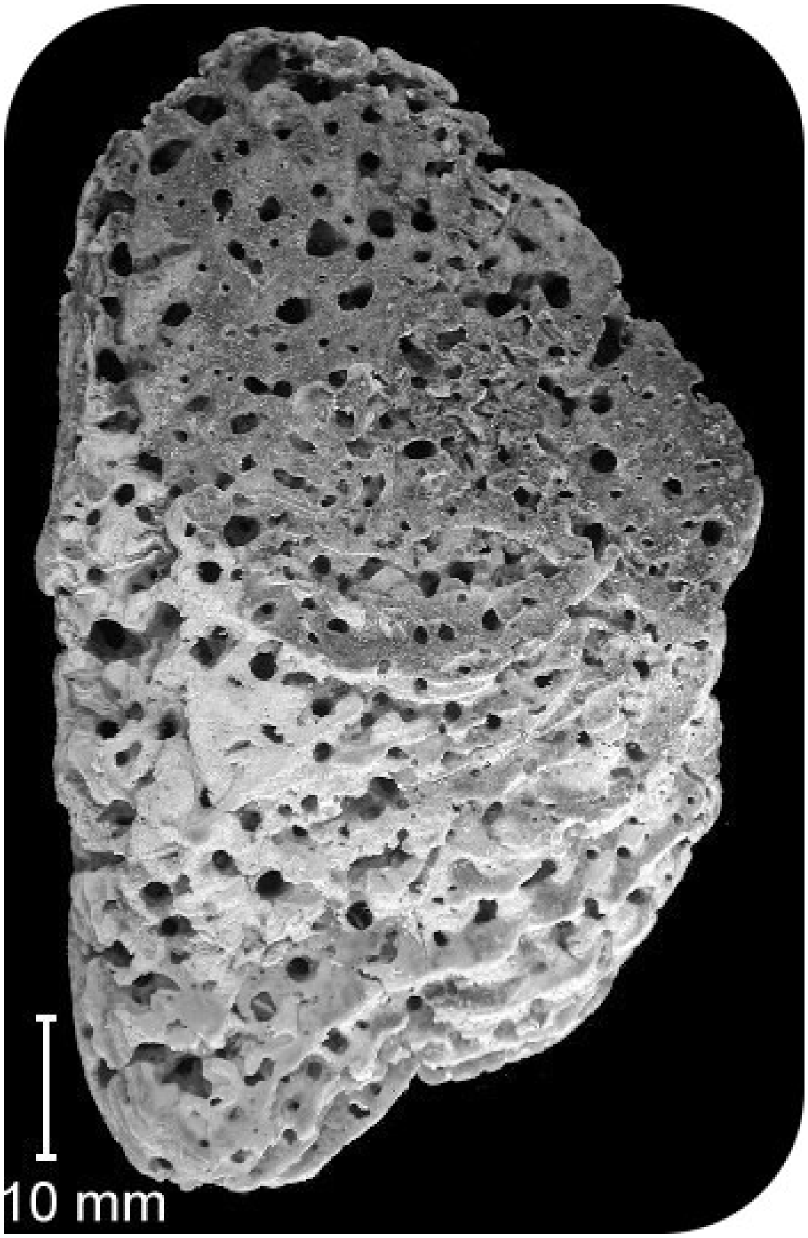
Becoming a fossil isn't easy. Only a tiny percentage of the organisms that have ever lived become fossils.

Why do you think only a tiny percentage of living organisms become fossils after death? Think about an antelope that dies on the African plain (**Figure** below).

Hyenas eating an antelope. Will the antelope in this photo become a fossil?

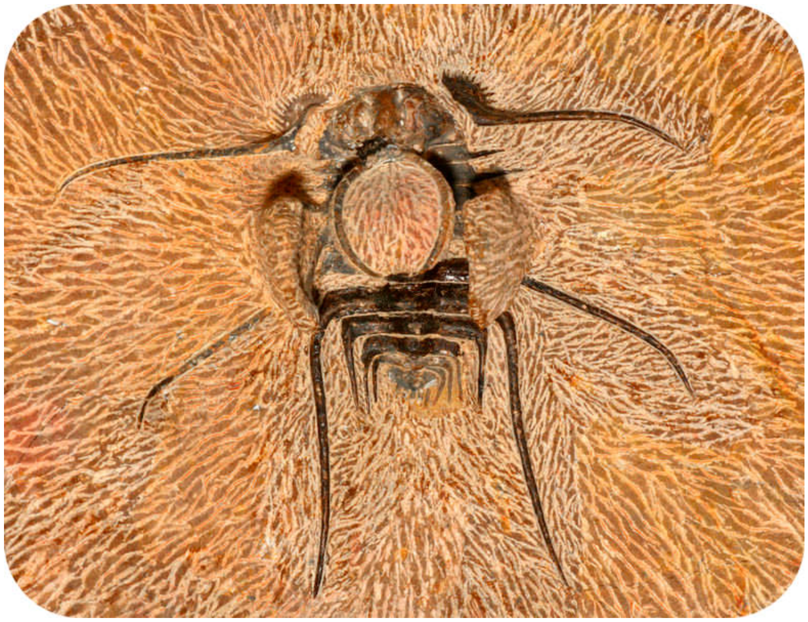
Most of its body is eaten by hyenas and other scavengers and the remaining flesh is devoured by insects and bacteria. Only bones are left behind. As the years go by, the bones are scattered and fragmented into small pieces, eventually turning into dust. The remaining nutrients return to the soil. This antelope will not be preserved as a fossil.

Is it more likely that a marine organism will become a fossil? When clams, oysters, and other shellfish die, the soft parts quickly decay, and the shells are scattered. In shallow water, wave action grinds them into sand-sized pieces. The shells are also attacked by worms, sponges, and other animals (**Figure** below).



Fossil shell that has been attacked by a boring sponge.

How about a soft bodied organism? Will a creature without hard shells or bones become a fossil? There is virtually no fossil record of soft bodied organisms such as jellyfish, worms, or slugs. Insects, which are by far the most common land animals, are only rarely found as fossils (**Figure** below).



A rare insect fossil.

Conditions that Create Fossils

Despite these problems, there is a rich fossil record. How does an organism become fossilized?

Hard Parts

Usually it's only the hard parts that are fossilized. The fossil record consists almost entirely of the shells, bones, or other hard parts of animals. Mammal teeth are much more resistant than other bones, so a large portion of the mammal fossil record consists of teeth. The shells of marine creatures are common also.

Quick Burial

Quick burial is essential because most decay and fragmentation occurs at the surface. Marine animals that die near a river delta may be rapidly buried by river sediments. A storm at sea may shift sediment on the ocean floor, covering a body and helping to preserve its skeletal remains (**Figure** below).

This fish was quickly buried in sediment to become a fossil.

Quick burial is rare on land, so fossils of land animals and plants are less common than marine fossils. Land organisms can be buried by mudslides, volcanic ash, or covered by sand in a sandstorm (**Figure** below). Skeletons can be covered by mud in lakes, swamps, or bogs.

People buried by the extremely hot eruption of ash and gases at Mt. Vesuvius in 79 AD.

Unusual Circumstances

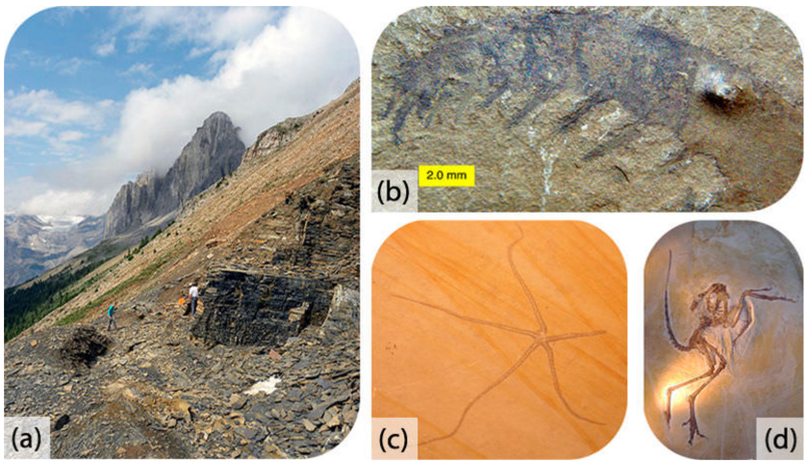
Unusual circumstances may lead to the preservation of a variety of fossils, as at the La Brea Tar Pits in Los Angeles, California. Although the animals trapped in the La Brea Tar Pits probably suffered a slow, miserable death, their bones were preserved perfectly by the sticky tar. (**Figure** below).

Artists concept of animals surrounding the La Brea Tar Pits.

In spite of the difficulties of preservation, billions of fossils have been discovered, examined, and identified by thousands of scientists. The fossil record is our best clue to the history of life on Earth, and an important indicator of past climates and geological conditions as well.

Exceptional Preservation

Some rock beds contain exceptional fossils or fossil assemblages. Two of the most famous examples of soft organism preservation are from the 505 million-year-old Burgess Shale in Canada (**Figure** below). The 145 million-year-old Solnhofen Limestone in Germany has fossils of soft body parts that are not normally preserved (**Figure** below).



(a) The Burgess shale contains soft-bodied fossils. (b) Anomalocaris, meaning "abnormal shrimp" is now extinct. The image is of a fossil. (c) A brittle star from the Solnhofen Limestone. (d) The famous Archeopteryx fossil from the Solnhofen Limestone has distinct feathers and was one of the earliest birds.

Vocabulary

- **body fossil**: The remains of an ancient organism. Examples include shells, bones, teeth, and leaves.
- **trace fossil**: Evidence of the activity of an ancient organism; e.g. tracks, tubes, and bite marks.

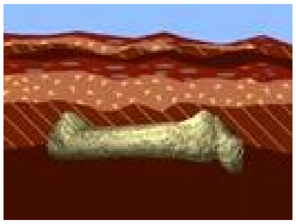
Summary

- Fossils are the remains or traces of living organisms: body fossils are the remains and trace fossils are the traces.
- Fossils are mostly made of the hard parts of organisms; there are few soft-bodied fossils.
- Some of the best preserved fossils form in extremely unusual circumstances like the La Brea tar pits.

Practice

Use this resource to answer the questions that follow.

http://www.youtube.com/watch?v=A5i5Qrp6sJU



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1. What are fossils?
2. What type of rocks are fossils found in?
3. What are sediments?
4. Explain how a fossil is created.
5. What factors have exposed sedimentary rock?

Review

1. Give three examples of body fossils and trace fossils.
2. Under what conditions do fossils form?
3. Why are more fossils of marine organisms than of land organisms?

2.7 Glossary

natural law, A known way that nature behaves. A predictable response from certain circumstances.

indirect estimate, a guess about something made by measuring something related, but not the thing itself.

quantitative(quantitatively), having to do with amounts (quantities), usually a measured value of something as opposed to a general description of what will happen.

fossil, the remains of a dead organism or the evidence of its remains.

extinct, when all individuals of a certain type of organism are dead.

index fossil, Fossils used by scientists to claim that soil layers are the same layer or the same age from different parts of the world.

Steno's Laws, three laws about soil layers: Original horizontality -Layers are originally horizontal when they form; Layer continuity - When layers form and later have the middle removed, it is still the same layer; and Superposition - layers of soil form with the newer layers on top of each older layer so that the farther down the layers, the older the layers.

Smith's Principles, Smith's claims that the principles he outlines can be counted upon to be accurate. Principle of faunal succession - some fossil type are never found with other fossil types; older features are replaced with newer features; Certain fossil species allow for accurate dating of certain layers of soil.

relative dating (age), dating of soil layers based on the understanding that older layers are underneath newer layers.

key beds, key layers of soil which can be recognized as the same layer over large areas.

geologic time scale, the idea that the earth is billions of years old as evidence by soil and fossil layers as well as radiometric dating.

tree ring dating (dendrochronology), the method of using rings in trees to find dates due to the annual change in growing patterns within the tree.

ice core, the use of ice layers formed through annual layering patterns.

varves, lake sediments at the end of a glacier which show annual layering.

radioactivity, particles given off by radioactive decay of elements.

radioactive decay, the spontaneous decay of atomic nuclei on a predictable basis.

radioactive isotope, the types of elements that radioactively decay.

parent nucleus, the starting nucleus of an element before it radioactively decays

daughter nucleus, the resulting nucleus AFTER an element radioactively decays, what is left.

nucleus, the middle of an atom, it contains protons and neutrons.

half life (lives), the amount for time for half of the nuclei in a sample to decay.

radiometric dating, the method used by scientists for finding the age of samples by measuring the ratio of parent and daughter nuclei.

radiocarbon dating, the use of carbon 14 to nitrogen decay rate to date samples with ages up to about 250,000 ya.

potassium- argon dating, the method of using potassium decay to argon for dating samples.

uranium - lead dating, the method of using uranium decay to lead for dating samples.

molten, rock or metal that has been heated enough to melt it.

differentiation, The separation of the earth into layers when it originally formed.

crust, the cool solid part of the earth, its outer layer of rock.

atmosphere, the gas layer surrounding the Earth.

ultraviolet radiation, the color of light with wavelength just slightly less than violet light which causes chemical change.

Precambrian, the epoch of the earth before living things older than 700 Mya.

convection, the process of hot parts of a fluid rising while cool parts sink due to changes in density.

plate tectonics, the description of the process of large sections of earth's crust that float and move around on the mantle and how they interact.

Rodinia, a super continent from the Precambrian epoch

Paleozoic, Paleozoic means "ancient life", the epoch when life first appeared on earth from 250 Mya to 700 Mya.

Pangaea, a super continent from the end of the Paleozoic epoch.

Mesozoic, means "middle life" the epoch where dinosaurs lived from 65 Mya to 250 Mya.

transgressions, a time where sea level rises and cover large areas of land.

regressions, when sea level drops exposing large areas o land.

Cenozoic,Means "recent life" The epoch of recent life from now back until 65 Mya.

Fossils are remnants of living creatures that can indicate something about the ecosystem and the environmental conditions that were present at the time they lived. Fossils can help geologists decipher the geological history of an area, as can clues from rocks. The principles of relative dating allow geologists to decipher the order of geological events and correlation allows them to determine the geological history of a region. Absolute age dating gives accurate dates for geological events, provided the proper materials are available and the proper techniques are followed. The most accurate and widely used absolute age dating technique is radiometric dating, which uses the ratios of radioactive isotopes to indicate age. Using these techniques, and some from astronomy, scientists have reconstructed a history of Earth and the solar system. The solar system began as a cloud of dust and gas that contracted by gravity until the center ignited to form a star and clumps of matter came together to form the planets. Shortly after Earth formed, a giant asteroid struck the planet, which melted both bodies, and flung material out into Earth's orbit. That material coalesced into the Moon. Earth had to cool before it could support an atmosphere, but when it did precipitation provided the water that filled the ocean basins. Life evolved slowly, and it was not until the evolution of photosynthesis that oxygen could collect in the atmosphere. The presence of oxygen led to the formation of the protective ozone layer and gases for animals to breathe. The early Earth was hot and so convection and plate tectonics were faster than today. From the time of the Archean, plate tectonics processes were similar to today. From then until now, supercontinents formed and broke apart, seas transgressed and regressed, and ice ages came and went.

2.8 References

1. (a) Laura Guerin; (b) User:Woudloper/Wikimedia Commons; (c) Mark A. Wilson (User:Wilson44691/Wikimedia Commons). Illustrations of original horizontality, lateral continuity, and superposition . (a) CC BY-NC 3.0; (b) Public Domain; (c) Public Domain
2. Courtesy of US Geological Survey, modified by CK-12 Foundation. Example of cross-cutting relationships . Public Domain
3. Miles Orchinik. Rock layers in the Grand Canyon show lateral continuity . CC BY-NC 3.0
4. Kurt Rosenkrantz. Example of a geologic cross section . CC BY-NC 3.0
5. Image copyright syringa, 2014. http://www.shutterstock.com . Used under license from Shutterstock.com
6. Courtesy of the US Geological Survey. The white clay is a key bed that marks the Cretaceous-Tertiary Bound ary . Public Domain
7. Courtesy of US Geological Survey. Image of the Geologic Time Scale . Public Domain

CHAPTER 3 Evolution LS 4-1, LS 4-2

Chapter Outline

INTRODUCTION

DISCIPLINARY CORE IDEA:

MS **-** LS 4-1 By the end of instruction, students should be able to answer a test which asks them to: **Look at the fossils in rock strata (layers) and find the patterns of where the fossil as are in the layers and make conclusions about existence, diversity, extinctions and changes in life forms on the earth over time by assuming that natural laws act the same both now and in the past.**

Do dinosaurs prove evolution?

For millions of years dinosaurs roamed and dominated the planet. Then 65 million years ago, they went extinct. In fact, over 90% of species that have lived are now extinct. The *change in species over time* is evolution, the focus of the lessons in the *Evolution* chapter.

History of Earth - Go to Mars Story

In this part of our story, we ask the question: "What creatures have lived on the earth and when did they live here?".

3.1 History of Life

Learning Objectives

- Define fossil.
- Describe the fossil record.
- Compare relative dating to absolute dating.
- Describe the role of molecular clocks.
- Summarize the geologic time scale.

How do we learn about the past?

We study the remains of things that existed many years ago. The Ruins of Pompeii have given archeologists, historians, and other scholars a tremendous amount of information about life two thousand years ago. This section discusses studying things that are many thousands of years older than these remains.

Earth in a Day

It's hard to grasp the vast amounts of time since Earth formed and life first appeared on its surface. It may help to think of Earth's history as a 24-hour day, as shown in **Figure** 3.1. Humans would have appeared only during the last minute of that day. If we are such newcomers on planet Earth, how do we know about the vast period of time that went before us? How have we learned about the distant past?

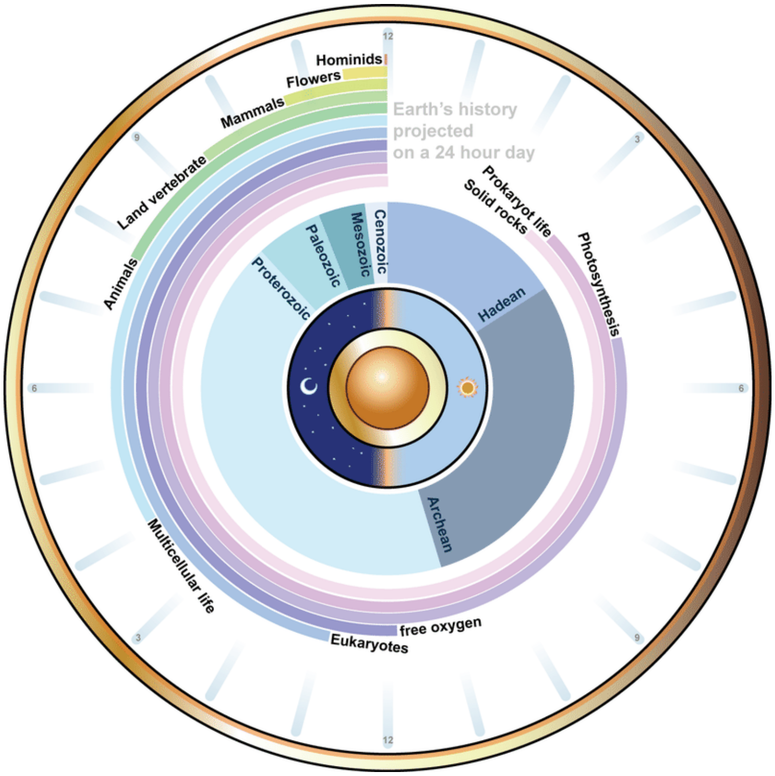


FIGURE 3.1

History of Earth in a Day. In this model of Earth's history, the planet formed at midnight. What time was it when the first prokaryotes evolved?

Learning About the Past

Much of what we know about the history of life on Earth is based on the fossil record. Detailed knowledge of modern organisms also helps us understand how life evolved.

The Fossil Record

Fossils are the preserved remains or traces of organisms that lived in the past. The soft parts of organisms almost always decompose quickly after death. On occasion, the hard parts—mainly bones, teeth, or shells—remain long enough to mineralize and form fossils. An example of a complete fossil skeleton is shown in **Figure** 3.2. The **fossil record** is the record of life that unfolded over four billion years and pieced back together through the analysis of fossils.

To be preserved as fossils, remains must be covered quickly by sediments or preserved in some other way. For example, they may be frozen in glaciers or trapped in tree resin, like the frog in **Figure** 3.3. Sometimes traces of organisms—such as footprints or burrows—are preserved (see the fossil footprints in **Figure** 3.3). The conditions required for fossils to form rarely occur. Therefore, the chance of an organism being preserved as a fossil is very low.

In order for fossils to "tell" us the story of life, they must be dated. Then they can help scientists reconstruct how life changed over time. Fossils can be dated in two different ways: relative dating and absolute dating. Both are described below.

- **Relative dating** determines which of two fossils is older or younger than the other, but not their age in years. Relative dating is based on the positions of fossils in rock layers. Lower layers were laid down earlier, so they are assumed to contain older fossils. This is illustrated in **Figure** 3.4.

FIGURE 3.2

Extinct Lion Fossil. This fossilized skeleton represents an extinct lion species. It is rare for fossils to be so complete and well preserved as this one.

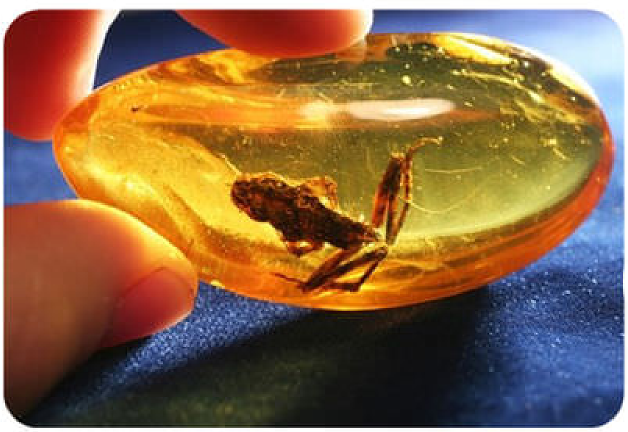


FIGURE 3.3

The photo on the left shows an ancient frog trapped in hardened tree resin, or amber. The photo on the right shows the fossil footprints of a dinosaur.

- **Absolute dating** determines about how long ago a fossil organism lived. This gives the fossil an approximate age in years. Absolute dating is often based on the amount of carbon-14 or other radioactive element that remains in a fossil.

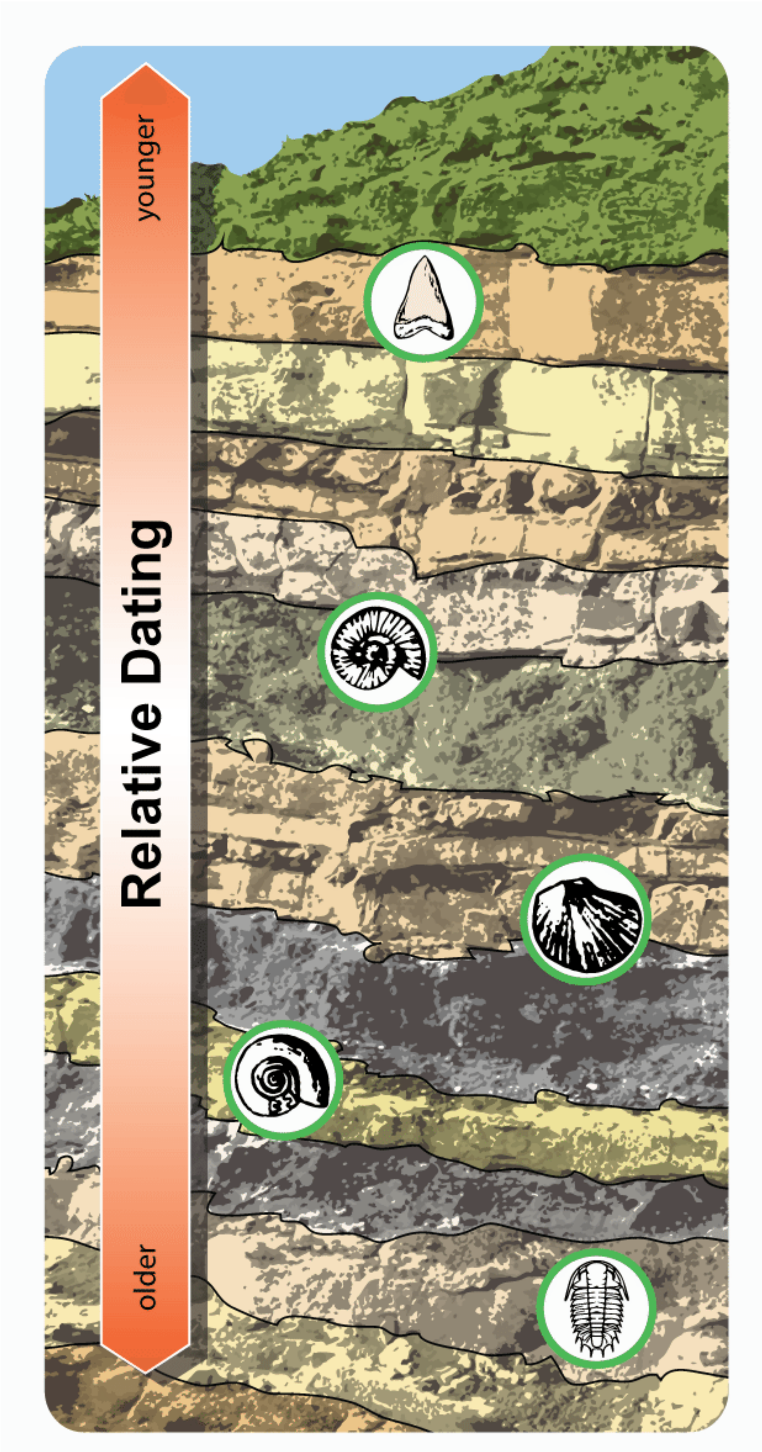
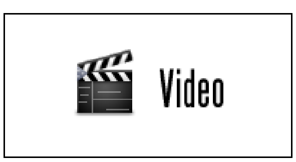


FIGURE 3.4
Relative Dating Using Rock Layers. Relative dating establishes which of two fossils is older than the other. It is based on the rock layers in which the fossils formed.



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Molecular Clocks

Evidence from the fossil record can be combined with data from molecular clocks. A **molecular clock** uses DNA sequences (or the proteins they encode) to estimate relatedness among species. Molecular clocks estimate the time in geologic history when related species diverged from a common ancestor. Molecular clocks are based on the assumption that mutations accumulate through time at a steady average rate for a given region of DNA. Species that have accumulated greater differences in their DNA sequences are assumed to have diverged from their common ancestor in the more distant past. Molecular clocks based on different regions of DNA may be used together for more accuracy.

Consider the example in **Table** 3.1. The table shows how similar the DNA of several animal species is to human DNA. Based on these data, which organism do you think shared the most recent common ancestor with humans?

TABLE 3.1: Comparing DNA: Humans and Other Animals

Organism	**Similarity with Human DNA (percent)**
Chimpanzee	98
Mouse	85
Chicken	60
Fruit Fly	44

Geologic Time Scale

Another tool for understanding the history of Earth and its life is the **geologic time scale**, shown in **Figure** 3.5. The geologic time scale divides Earth's history into divisions (such as eons, eras, and periods) that are based on major changes in geology, climate, and the evolution of life. It organizes Earth's history and the evolution of life on the basis of important events instead of time alone. It also allows more focus to be placed on recent events, about which we know the most.

Summary

- Much of what we know about the history of life on Earth is based on the fossil record.
- Molecular clocks are used to estimate how long it has been since two species diverged from a common ancestor.
- The geologic time scale is another important tool for understanding the history of life on Earth.

Review

1. What are fossils?

2. Describe how fossils form.

3. Distinguish relative dating from absolute dating.

4. This table shows DNA sequence comparisons for some hypothetical species. Based on the data, describe evolutionary relationships between Species A and the other four species. Explain your answer.

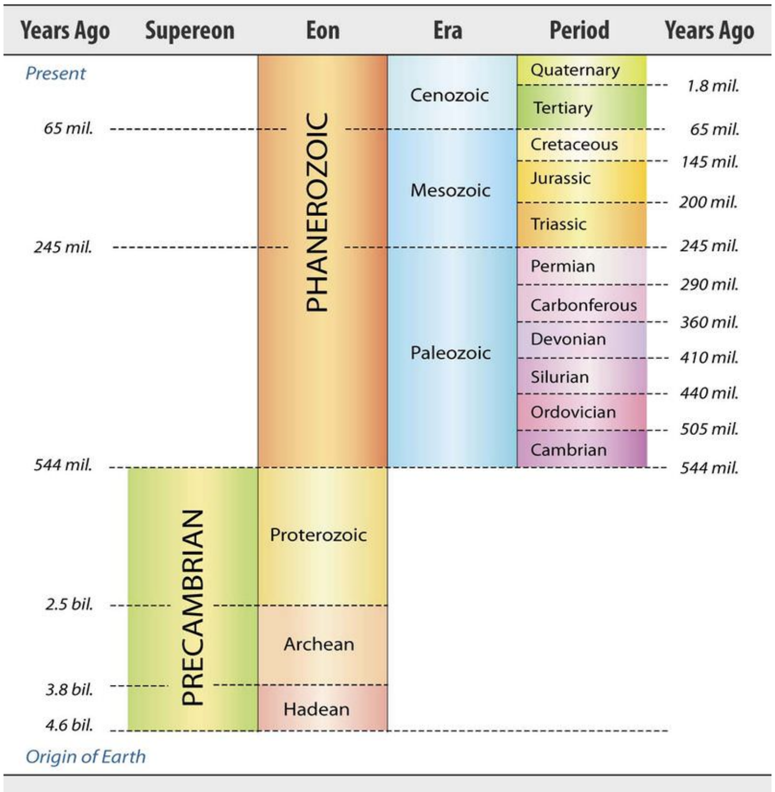


FIGURE 3.5

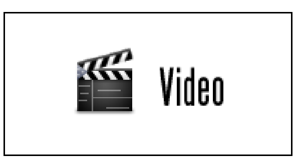
Geologic Time Scale. The geologic time scale divides Earth's history into units that reflect major changes in Earth and its life forms. During which eon did Earth form? What is the present era?

TABLE 3.2: DNA Similarities

Species	DNA Similarity with Species A
Species B	42%
Species C	85%
Species D	67%
Species E	91%

5. Describe the geologic time scale.

Resources



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3.2 Understanding Biodiversity

Understanding Biodiversity does not attempt to provide a complete review of biodiversity. For additional information about biodiversity, see the *Communities and Populations* chapter in the CK-12 Biology FlexBook® textbook at http://www.ck12.org/flexbook/book/2537 and the *Ecology and Human Actions* chapter in the CK-12 Biology I - Honors FlexBook® textbook at http://www.ck12.org/flexbook/book/829 .

"If names are not correct, language will not be in accordance with the truth of things." Confucius.

Biodiversity refers to the variety of life and its processes, including the variety of living organisms, the genetic differences among them, and the communities and ecosystems in which they occur. Scientists have identified about 1.9 million species alive today, each with their own unique scientific name. They are divided into the six kingdoms of life shown in the **Figure** 3.6. Scientists are still discovering new species. Thus, they do not know for sure how many species really exist today. Most estimates range from 5 to 30 million species.

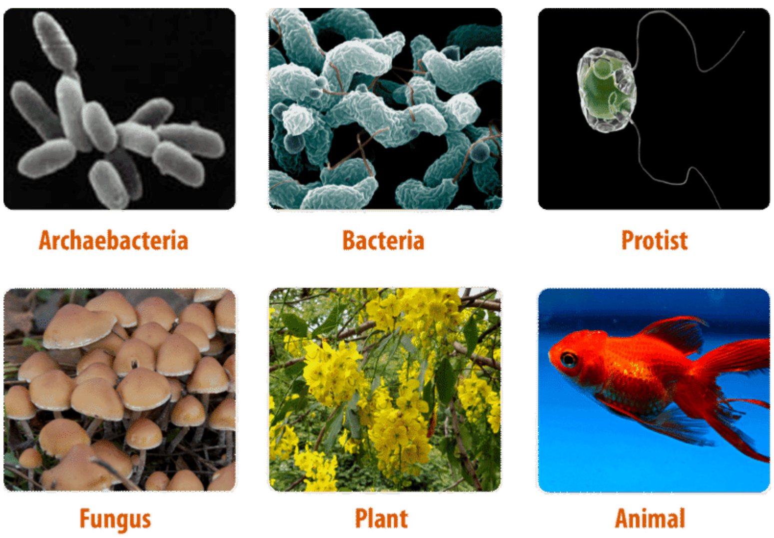

FIGURE 3.6
Diversity of life from Archaebacteria to Plants and Animals.

The Importance of Biodiversity

Human beings benefit in many ways from biodiversity. Biodiversity has direct economic benefits. It also provides services to entire ecosystems.

Economic Benefits of Biodiversity

The diversity of species provides humans with a wide range of economic benefits. Just a few of these are described below:

- Wild plants and animals maintain a valuable pool of genetic variation. This is important because many

domestic species are genetically uniform. This puts the domesticated species at great risk of dying out due to disease.
- Other organisms provide humans with many different products, including timber, fibers, adhesives, dyes, and rubber.
- Certain species may warn us of toxins in the environment. When the peregrine falcon nearly went extinct, for example, it warned us of the dangers of DDT.
- More than half of the most important prescription drugs come from wild species. Only a fraction of species have yet been studied for their medical potential. Therefore, declining biodiversity can indirectly harm human health.
- Other living things provide inspiration for engineering and technology. For example, the car design in the **Figure** 3.7 was based on the structure of a fish.

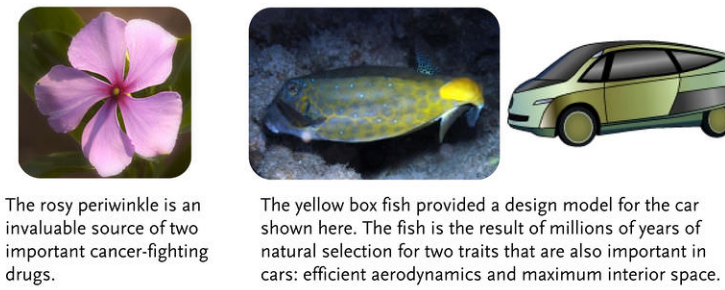

FIGURE 3.7
From flowers to fish, biodiversity benefits humans in many ways.

Ecosystem Services of Biodiversity

Biodiversity generally increases the productivity and stability of ecosystems. A large biodiversity helps ensure that at least some species will survive environmental change. It also provides many other ecosystem services. For example:

- Plants and algae maintain the atmosphere. During photosynthesis, they add oxygen and remove carbon dioxide.
- Plants help prevent soil erosion. They also improve soil quality when they decompose.
- Microorganisms purify water in rivers and lakes. They also return nutrients to the soil.
- Bacteria fix nitrogen as part of the nitrogen cycle and make the nitrogen available to plants. Other bacteria recycle the nitrogen from organic wastes and the remains of dead organisms.
- Insects and birds pollinate flowering plants, including crop plants.
- Natural predators control insect pests. They reduce the need for expensive pesticides, which may harm people and other organisms.

Why Study Biodiversity?

The economic services and benefits of biodiversity listed above are just a small sample of the reasons to study biodiversity. Every time a species goes extinct or an ecosystem is harmed, it can be argued that we are affected as well. So, as a species, we need to understand as much as we can about other species, especially the niche of other species and how they benefit their ecosystems. Benefits to humans are bound to result from the study of other species. See *Biodiversity* at http://vimeo.com/14105623 for additional information.

Millions of Unseen Species

A study released in August 2011 estimates that Earth has almost 8.8 million animal, plant, and fungi species, but we've only discovered less than a quarter of them. Recent newly discovered species have been very diverse: a psychedelic frogfish, a lizard the size of a dime, and even a blind hairy mini-lobster at the bottom of the ocean. There are potential benefits from these undiscovered species, which need to be found before they disappear from the planet. The study estimates that of the 8.8 million species, about 6.5 million would live on land and 2.2 million in the ocean. The research estimates there are 7.8 million animal species, followed by fungi with 611,000 and plants with just shy of 300,000 species. See http://news.yahoo.com/wild-world-millions-unseen-species-fill-earth-210051661.html for additional information.

If the 8.8 million estimate is correct, "those are brutal numbers," said Encyclopedia of Life executive director Erick Mata. "We could spend the next 400 or 500 years trying to document the species that actually inhabit our planet."

Biodiversity and Human Actions

Over 99 percent of all species that ever lived on Earth have gone extinct. Five mass extinctions are recorded in the fossil record. They were caused by major geologic and climatic events. Evidence shows that a **sixth mass extinction** is occurring now. Unlike previous mass extinctions, the sixth extinction is due to human actions.

Some scientists consider the sixth extinction to have begun with early hominids during the Pleistocene. They are blamed for over-killing big mammals such as mammoths. Since then, human actions have had an ever greater impact on other species. The present rate of extinction is between 100 and 100,000 species per year. In 100 years, we could lose more than half of Earth's remaining species.

Causes of Extinction

This is one of the most powerful birds in the world. Could it go extinct? The Philippine Eagle, also known as the Monkey-eating Eagle, is among the rarest, largest, and most powerful birds in the world. It is critically endangered, mainly due to massive loss of habitat due to deforestation in most of its range. Killing a Philippine Eagle is punishable under Philippine law by twelve years in jail and heavy fines.

The single biggest cause of extinction today is **habitat loss**. Agriculture, forestry, mining, and urbanization have disturbed or destroyed more than half of Earth's land area. In the U.S., for example, more than 99 percent of tall-grass prairies have been lost. Other causes of extinction today include:

- **Exotic species** introduced by humans into new habitats. They may carry disease, prey on native species, and disrupt food webs. Often, they can out-compete native species because they lack local predators. An example is described in the Brown Tree Snake **Figure** 3.8.
- Over-harvesting of fish, trees, and other organisms. This threatens their survival and the survival of species that depend on them.
- Global climate change, largely due to the burning of fossil fuels. This is raising Earth's air and ocean temperatures. It is also raising sea levels. These changes threaten many species.
- Pollution, which adds chemicals, heat, and noise to the environment beyond its capacity to absorb them. This causes widespread harm to organisms.
- Human overpopulation, which is crowding out other species. It also makes all the other causes of extinction more severe.

FIGURE 3.8

Brown Tree Snake. The brown tree snake is an exotic species that has caused many extinctions on Pacific islands such as Guam.

Effects of Extinction

The results of a study released in the summer of 2011 have shown that the decline in the numbers of large predators like sharks, lions, and wolves is disrupting Earth's ecosystem in all kinds of unusual ways. The study, conducted by scientists from 22 different institutions in six countries, confirmed the sixth mass extinction. The study states that this mass extinction differs from previous ones because it is entirely driven by human activity through changes in land use, climate, pollution, hunting, fishing, and poaching. The effects of the loss of these large predators can be seen in the oceans and on land.

- Fewer cougars in the western US state of Utah led to an explosion of the deer population. The deer ate more vegetation, which altered the path of local streams and lowered overall biodiversity.
- In Africa, where lions and leopard are being lost to poachers, there is a surge in the numbers of olive baboons who are transferring intestinal parasites to human who live nearby.
- In the oceans, industrial whaling led a change in the diets of killer whales, who eat more sea lion, seals, and otters and dramatically lowered those population counts.

The study concludes that the loss of big predators has likely driven many of the pandemics, population collapses, and ecosystem shifts the Earth has seen in recent centuries. See http://news.yahoo.com/loss-big-predators-disrupts-earth-ecosystem-study-181200945.html for additional information.

Disappearing Frogs

Around the world, frogs are declining at an alarming rate due to threats like pollution, disease and climate change. Frogs bridge the gap between water and land habitats, making them the first indicators of ecosystem changes. Meet the California researchers working to protect frogs across the state and across the world at http://www.kqed.org/quest/television/disappearing-frogs . Learn about the plight of the yellow-legged frog at http://www.kqed.org/quest/radio/plight-of-the-yellowlegged-frog .

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Nonnative Species

Scoop a handful of critters out of the San Francisco Bay and you'll find many organisms from far away shores. Invasive kinds of mussels, fish and more are choking out native species, challenging experts around the state to change the human behavior that brings them here. See http://www.kqed.org/quest/television/san-francisco-bay-invaders for more information.

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How You Can Help Protect Biodiversity

There are many steps you can take to help protect biodiversity. For example:

- Consume wisely. Reduce your consumption wherever possible. Re-use or recycle materials rather than throwing out and buying new. When you do buy something new, choose products that are energy efficient and durable.
- Avoid plastics. Plastics are made from petroleum and produce toxic waste.
- Go organic. Organically grown food is better for your health. It also protects the environment from pesticides and excessive nutrients in fertilizers.
- Save energy. Unplug electronic equipment and turn off lights when not in use. Take mass transit instead of driving.

Lost Salmon

Because of a sharp decline in their numbers, the entire salmon fishing season in the ocean off California and Oregon was canceled in both 2008 and 2009. At no other time in history has this salmon fishery been closed. The species in the most danger is the California coho salmon. Examine efforts to protect the coho in Northern California and explores the important role salmon play in the native ecosystem at http://www.kqed.org/quest/television/californias-lost-salmon and http://www.kqed.org/quest/television/coho-salmon-in-muir-woods .

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3.3 Mass Extinctions

Learning Objectives

- Define mass extinction.
- Give examples of mass extinctions.
- Describe the importance of the mass extinction dated at 65.5 million years ago.

What happened to the dinosaurs?

Most of the dinosaurs disappeared from Earth about 65 million years ago. This is probably the most famous example of a mass extinction. So how do you define a mass extinction?

Mass Extinctions

An organism goes extinct when all of the members of a species die out and no more members remain. **Extinctions** are part of natural selection. Species often go extinct when their environment changes, and they do not have the traits they need to survive. Only those individuals with the traits needed to live in a changed environment survive (Survival of the Fittest) (**Figure** 3.9).

Mass extinctions, such as the extinction of dinosaurs and many marine mammals, happened after major catastrophes such as volcanic eruptions and earthquakes (**Figure** 3.10).

Since life began on Earth, there have been several major mass extinctions. If you look closely at the geological time scale, you will find that at least five major mass extinctions have occurred in the past 540 million years. In each mass extinction, over 50% of animal species died. Though species go extinct frequently, a mass extinction in which such

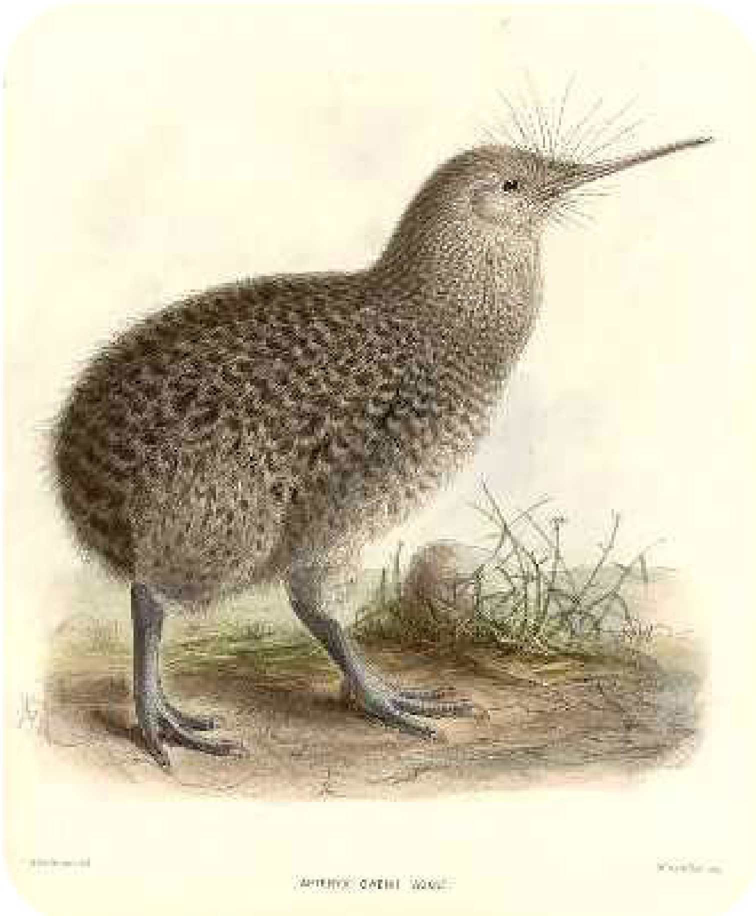

FIGURE 3.9
Humans have caused many extinctions by introducing species to new places. For example, many of New Zealand's birds have adapted to nesting on the ground. This was possible because there were no land mammals in New Zealand. Then Europeans arrived and brought cats, foxes, and other predators with them. Several of New Zealand's ground nesting birds, such as this flightless kiwi, are now extinct or threatened because of these predators.

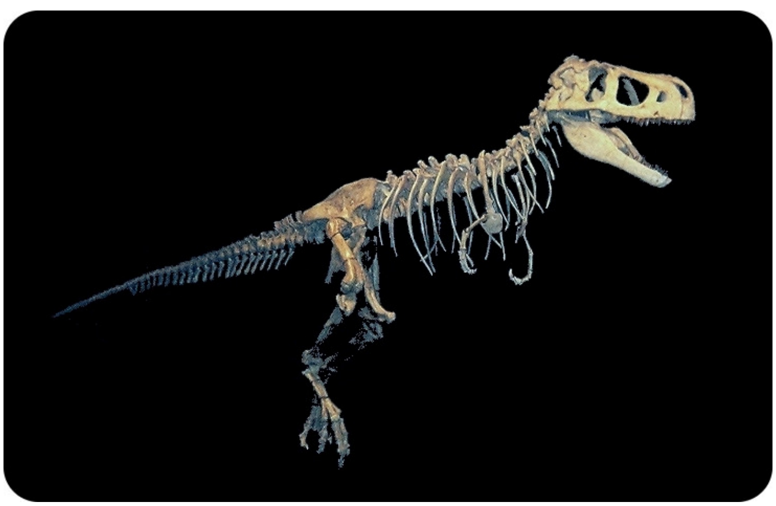

FIGURE 3.10
The fossil of Tarbosaurus, one of the land dinosaurs that went extinct during one of the mass extinctions.

a high percentage of species go extinct is rare. The total number of mass extinctions could be as high as 20. It is probable that we are currently in the midst of another mass extinction.

Two of the largest extinctions are described below:

- At the end of the Permian Period, it is estimated that about 99.5% of individual organisms went extinct! Up to 95% of marine species perished, compared to "only" 70% of land species. Some scientists theorize that the extinction was caused by the formation of **Pangaea,** or one large continent made out of many smaller ones. One large continent has a smaller shoreline than many small ones, so reducing the shoreline space may have caused much of the marine life to go extinct (**Figure** 3.11).

FIGURE 3.11

The supercontinent Pangaea encompassed all of today's continents in a single land mass. This configuration limited shallow coastal areas which harbor marine species. This may have contributed to the dramatic event which ended the Permian—the most massive extinction ever recorded.

- At the end of the Cretaceous Period, or 65 million years ago, all dinosaurs (except those which led to birds) went extinct. Some scientists believe a possible cause is a collision between the Earth and a comet or asteroid. The collision could have caused tidal waves, changed the climate, increased atmospheric dust and clouds, and reduced sunlight by 10-20%. A decrease in photosynthesis would have resulted in less plant food, leading to the extinction of the dinosaurs.

Evidence for the extinction of dinosaurs by asteroid includes an iridium-rich layer in the Earth, dated at 65.5 million years ago. Iridium is rare in the Earth's crust but common in comets and asteroids. Maybe the asteroid that hit the Earth left the iridium behind.

After each mass extinction, new species evolve to fill the habitats where old species lived. This is well documented in the fossil record.

Summary

- Extinctions, when a species entirely dies out, can happen when the environment changes, and the organisms do not have the traits they need to survive.
- Since life began on Earth, there have been at least five major massive extinctions.

Explore More

Use the resource below to answer the questions that follow.

- **Mass Extinctions - PBS** at http://www.pbs.org/wgbh/nova/earth/mass-extinction.html (13:14)

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1. What is a mass extinction? How many have occurred in the last 600 million years?
2. What are some of the reasons proposed for mass extinctions?
3. Which event wiped out 95% of animal species in the oceans? When did this occur?
4. How do scientists think the activity of the "Siberian Traps" changed the chemistry of the oceans?
5. How does the temperature of water affect how much gas can be dissolved in it?
6. How did the changing ocean environment lead to a mass extinction?

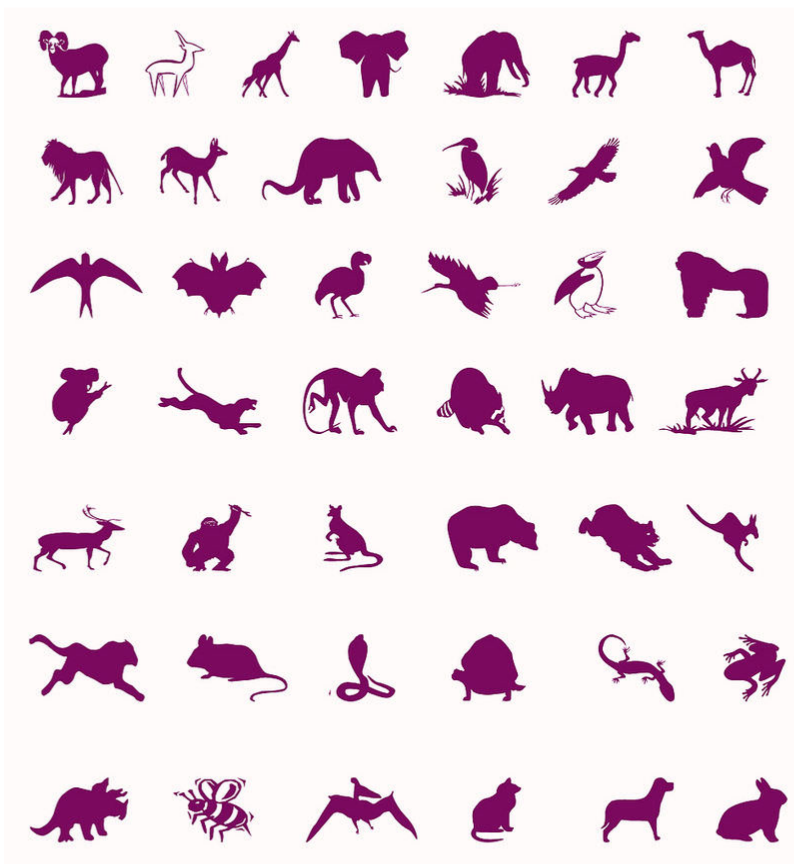
Review

1. Why do species sometimes go extinct?
2. What is a mass extinction?
3. What may have caused the mass extinction that killed the dinosaurs, and what is the evidence?

3.4 Phylogenetic Classification

Learning Objectives

- Define clade.
- Describe phylogenetic classification.
- Interpret a phylogenetic tree and cladogram.
- Distinguish phylogenetic classification from Linnaean classification.



Can two different species be related?

Of course they can. For example, there are many different species of mammals, or of one type of mammal, such as mice. And they are all related. In other words, how close or how far apart did they separate from a common ancestor during evolution? Determining how different species are evolutionarily related can be a tremendous task.

Phylogenetic Classification

Linnaeus classified organisms based on obvious physical traits. Basically, organisms were grouped together if they looked alike. After Darwin published his theory of evolution in the 1800s, scientists looked for a way to classify organisms that showed phylogeny. **Phylogeny** is the evolutionary history of a group of organisms theorized to be related. It is represented by a **phylogenetic tree**, like the one in **Figure** 3.12. The reason why the history is theoretical is because scientists do not know what the actual relationship was since they were not there. Rather, they theorize what the relationships were. Sometimes, scientists do not agree on the details because in those cases, they have an incomplete picture. Therefore, some ancient phylogenic classifications are theoretical, even so, scientists do their best.

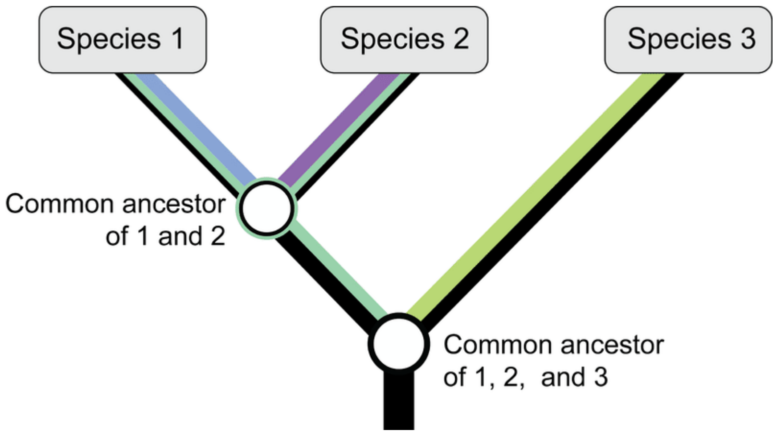


FIGURE 3.12

Phylogenetic Tree. This phylogenetic tree shows how three hypothetical species are related to each other through common ancestors. Do you see why Species 1 and 2 are more closely related to each other than either is to Species 3?

One way of classifying organisms that shows phylogeny is by using the clade. A **clade** is a group of organisms that includes an ancestor and all of its descendants. Clades are based on **cladistics**. This is a method of comparing traits in related species to determine ancestor-descendant relationships. Clades are represented by **cladograms**, like the one in **Figure** 3.13. This cladogram represents the mammal and reptile clades. The reptile clade includes birds. It shows that birds evolved from reptiles. Linnaeus classified mammals, reptiles, and birds in separate classes. This masks their evolutionary relationships.

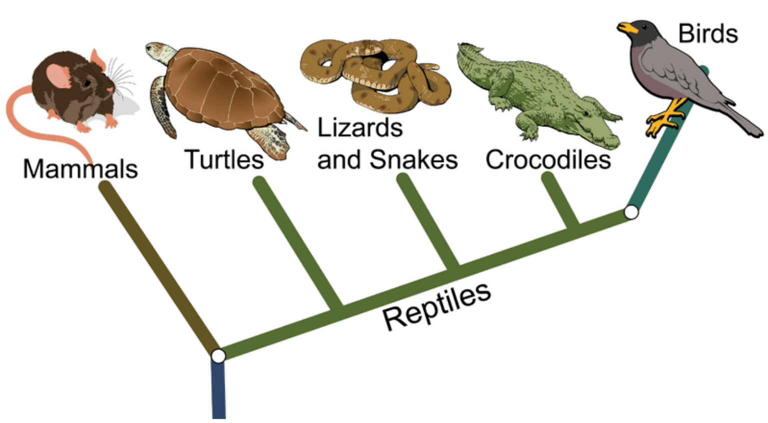


FIGURE 3.13

This cladogram classifies mammals, reptiles, and birds in clades based on their evolutionary relationships.

Summary

- Phylogeny is the evolutionary history of group of related organisms. It is represented by a phylogenetic tree that shows how species are related to each other through common ancestors.
- A clade is a group of organisms that includes an ancestor and all of its descendants. It is a phylogenetic classification, based on evolutionary relationships.

Explore More

Use this resource to answer the questions that follow.

- **Using trees for classification** at http://evolution.berkeley.edu/evolibrary/article/phylogenetics_04 .

1. What is phylogenetic classification?
2. Describe the advantages of phylogenetic classification.

Review

1. What is a clade?
2. What is cladistics, and what is it used for?
3. Explain why reptiles and birds are placed in the same clade.
4. Dogs and wolves are more closely related to each other than either is to cats. Draw a phylogenetic tree to show these relationships.

3.5 Living Species

Learning Objectives

- Explain the significance of homologous structures, analogous structures, and vestigial structures.
- Describe the meaning of similar DNA sequences between two species.

Is this evidence of evolution?

Take a close look at this gorilla hand. The similarities to a human hand are remarkable. Comparing anatomy, and characterizing the similarities and differences, provides evidence of evolution.

Evidence from Living Species

Just as Darwin did many years ago, today's scientists study living species to learn about evolution. They compare the anatomy, embryos, and DNA of modern organisms to understand how they evolved.

Comparative Anatomy

Comparative anatomy is the study of the similarities and differences in the structures of different species. Similar body parts may be homologies or analogies. Both provide evidence for evolution.

Homologous structures are structures that are similar in related organisms because they were inherited from a common ancestor. These structures may or may not have the same function in the descendants. **Figure** 3.14 shows the hands of several different mammals. They all have the same basic pattern of bones. They inherited this pattern from a common ancestor. However, their forelimbs now have different functions.

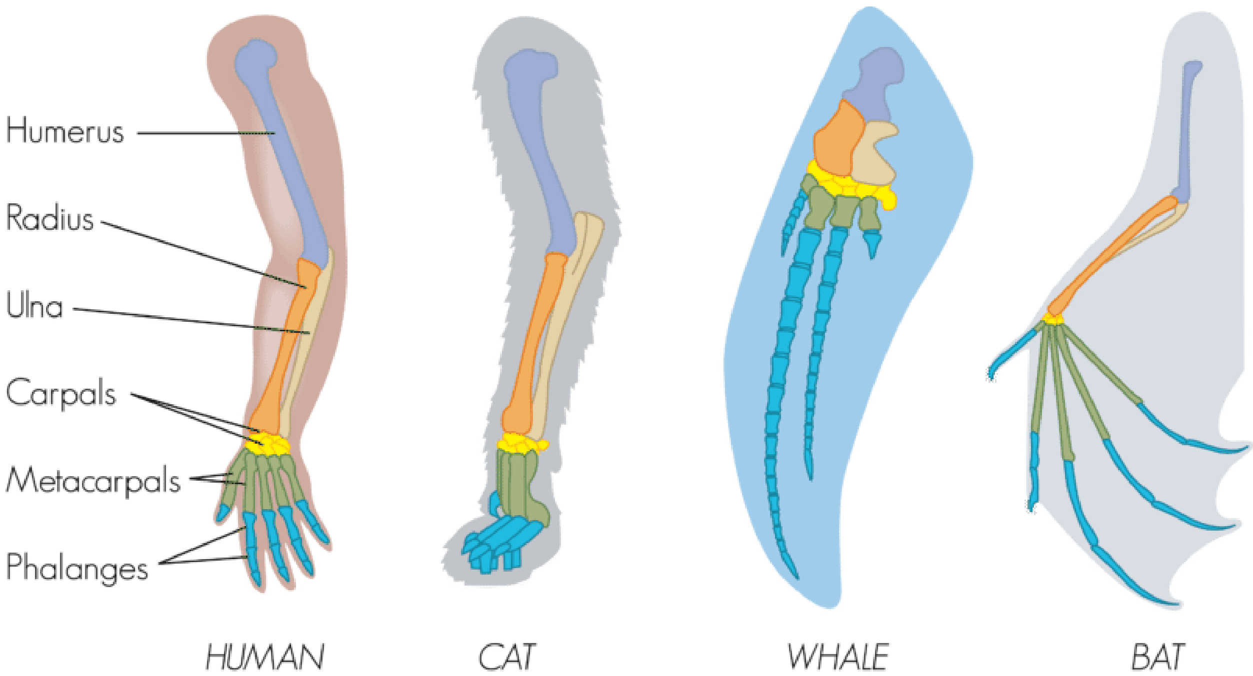
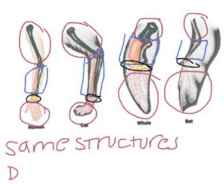


FIGURE 3.14
The forelimbs of all mammals have the same basic bone structure.



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Analogous structures are structures that are similar in unrelated organisms. The structures are similar because they evolved to do the same job, not because they were inherited from a common ancestor. For example, the wings of bats and birds, shown in **Figure** 3.15, look similar on the outside. They also have the same function. However, wings evolved independently in the two groups of animals. This is apparent when you compare the pattern of bones inside the wings.

Comparative Embryology

Comparative embryology is the study of the similarities and differences in the embryos of different species. Similarities in embryos are evidence of common ancestry. All vertebrate embryos, for example, have gill slits and tails. Most vertebrates, except for fish, lose their gill slits by adulthood. Some of them also lose their tail. In humans, the tail is reduced to the tail bone. Thus, similarities organisms share as embryos may be gone by adulthood.

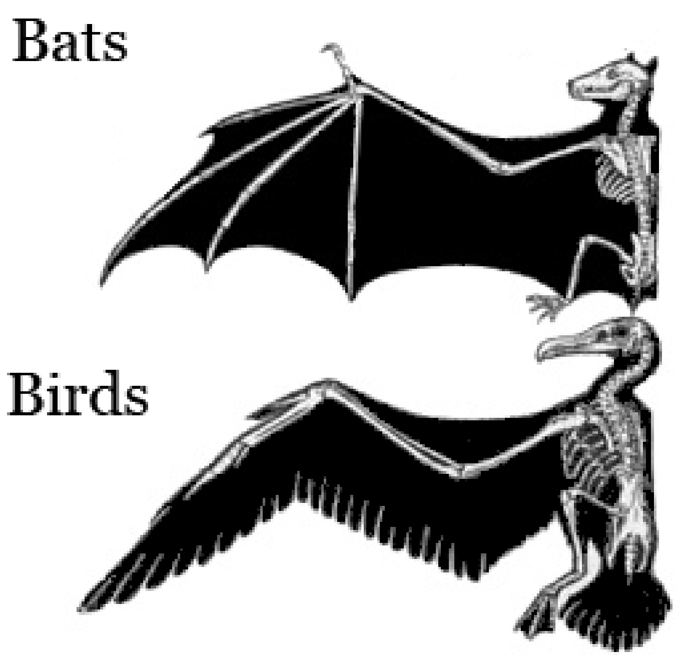
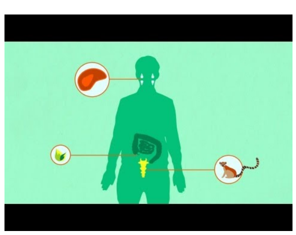


FIGURE 3.15
Wings of bats and birds serve the same function. Look closely at the bones inside the wings. The differences show they developed from different ancestors.

This is why it is valuable to compare organisms in the embryonic stage.

Vestigial Structures

Structures like the human tail bone and whale pelvis are called **vestigial structures**. Evolution has reduced their size because the structures are no longer used. The human appendix is another example of a vestigial structure. It is a tiny remnant of a once-larger organ. In a distant ancestor, it was needed to digest food. It serves no purpose in humans today. Why do you think structures that are no longer used shrink in size? Why might a full-sized, unused structure reduce an organism's fitness?



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Comparing DNA

Darwin could compare only the anatomy and embryos of living things. Today, scientists can compare their DNA. Similar DNA sequences are the strongest evidence for evolution from a common ancestor. More similarities in the

DNA sequence is evidence for a closer evolutionary relationship. Look at the cladogram in the **Figure** 3.16. It shows how humans and apes are related based on their DNA sequences.

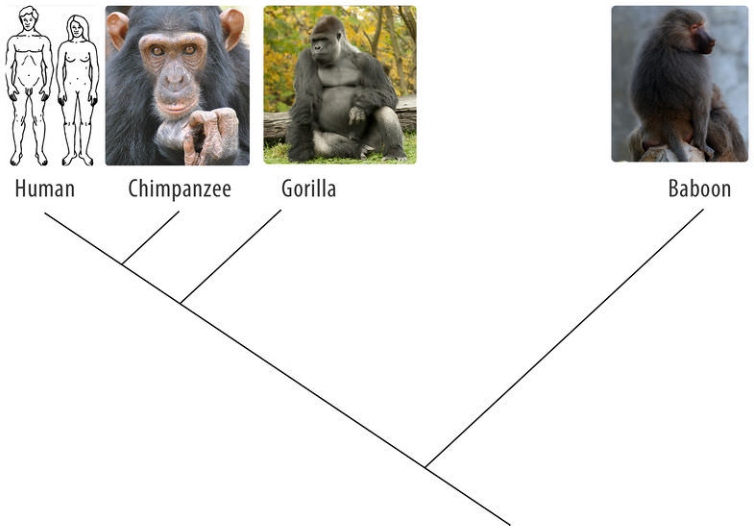

FIGURE 3.16
Cladogram of Humans and Apes. This cladogram is based on DNA comparisons. It shows how humans are related to apes by descent from common ancestors.

Summary

- Scientists compare the anatomy, embryos, and DNA of living things to understand how they evolved.
- Evidence for evolution is provided by homologous structures. These are structures shared by related organisms that were inherited from a common ancestor.
- Other evidence for evolution is provided by analogous structures. These are structures that unrelated organisms share because they evolved to do the same job.
- Comparing DNA sequences provided some of the strongest evidence of evolutionary relationships.

Review

1. What are vestigial structures? Give an example.
2. Compare homologous and analogous structures.
3. Why do vertebrate embryos show similarities between organisms that do not appear in the adults?
4. Humans and apes have five fingers they can use to grasp objects. Do you think these are analogous or homologous structures? Explain.
5. What is the strongest evidence of evolution from a common ancestor?

3.6 Glossary

Glossary

Clade, a group of organisms believed to have evolved from a common ancestor

Phylogenetic, A phylogenetic tree is a chart that shows believed descent of different species indicating the evolutionary relationship.

Ancestor, the organism from which its descendants came from.

Linnaeus, Carl Linnaeus was the inventor of the modern system for naming organisms.

Darwin, Charles Darwin author of "On the Origin of Species" which gave a naturalistic explanation for how selection could occur without intelligent action.

Cladistics, a method of classification based upon theorized evolutionary relationships.

Cladograms, a diagram showing the Cladistics (see above) of an organism.

Geologic, Geologic time scale is one which approaches the age of the earth as billions of years old.

Greenhouse. Greenhouse effect is when air is heated up due to the sun because the heat cannot escape due to the greenhouse walls or because certain gases trap more heat.

Extinction, when all the organisms of a certain species die it is an extinct species.

New Adaptations, new phenotypes (traits) .

Cell Specialization, the basis for complex life, where different cells do different jobs in an organism.

Multicellular, organisms made of many cells

Photosynthesis, the chemical process that plants use to convert sunlight into chemical energy by making sugars

Evolve, The change over time of organism as natural selection works on the species to change the traits of succeeding generations.

Amphibians, animals that lay eggs which hatch in the water and the individual creature later grows and changes until it can live on land.

Pollinate, when flowering plants share male sexual material it is carried in the pollen of flowers.

Evolution, the process of change over time in species as caused by natural selection.

Anatomy, the physical internal and external structure of a human or animal body.

Embryos, unformed offspring in a womb or an egg.

Comparative Anatomy, the process of comparing anatomy of different animals.

Homologous Structures, structures that are similar from different species and correspond to one another but serve different functions in different species.

Analogous Structures, Structures in a body that have the same appearance, structure or function but have evolved separately.

Vestigial Structures, structures that still exist but are of no purpose in a species.

Tetra pod Limbs, the limbs of creatures with four limbs.

Octopus Limbs, the limbs (tentacles) of an octopus.

Summary

LS 4-1, 4-3, Evolution focuses on past life forms and how they turned into present life forms. The history of life on Earth demonstrates how the first cells formed, turned into simple life forms, and then became more complex plants and animals. The studies of Charles Darwin have reshaped and influenced all aspects of biology. The myriad evidence of evolution demonstrates the importance of the theory of evolution by natural selection. Lastly, the current focus on evolution demonstrates that evolution is a continuous and ongoing process that continues today.

3.7 References

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16. Human: User:MrKimm/Wikimedia Commons; Chimpanzee: Afrika Force; Gorilla: Roger Luijten; Baboon: Birdseye Maple. Cladogram of humans, chimpanzees, gorillas, and babbons . Human: Public Domain; Chimpanzee, Gorilla, Baboon: CC BY 2.0

CHAPTER 4 Evolution Theory and Evidence That Supports it. MS LS 4-3

Chapter Outline

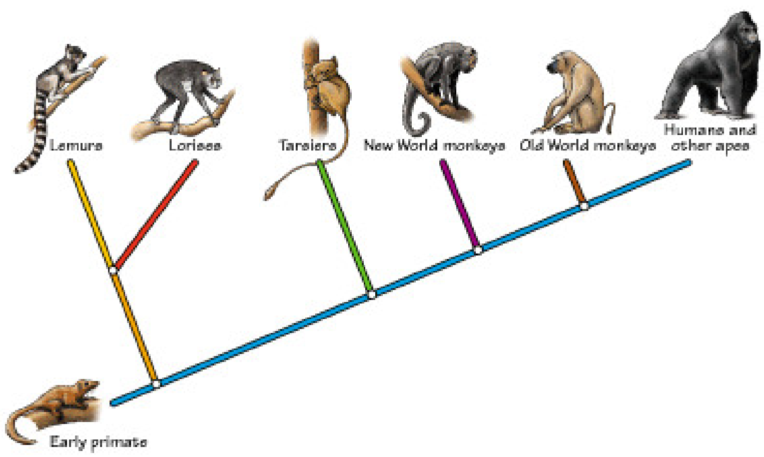


FIGURE 4.1
The phylogenetic tree shows the evolutionary relationships theorized by the maker of the tree.

INTRODUCTION

DISCIPLINARY CORE IDEA:

MS-LS 4-3 by the end of instruction, students should be able to answer a test which asks them to: **Look at diagrams and pictures of embryos and compare the development across several species to see if there are similarities in the embryos which are not visible in fully grown organisms.**

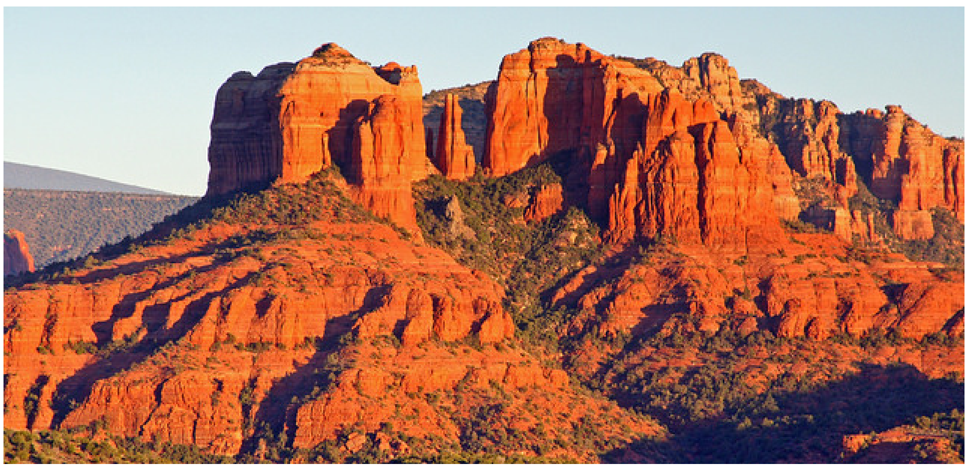
In this chapter we will focus on the use of embryos to support evolutionary theory.

Our story continues with a focus on how the different kinds of creatures came to be on the Earth - How do we have so much biodiversity?

4.1 Influences on Darwin

Learning Objectives

- Identify the influences of Lamarck, Lyell and Malthus on Darwin.
- Explain artificial selection.
- Describe the role of Alfred Russel Wallace in developing the theory of evolution.



How do structures like this form?

Cathedral Rock in Sedona, Arizona. Though Arizona was not on Darwin's itinerary, the work of others that saw and studied Earth's changing landscape influenced him. One geologist, Charles Lyell, proposed that gradual geological processes have shaped Earth's surface, inferring that Earth must be far older than most people believed. How else could structures like those shown here develop? If in fact Earth was much older then just 6,000 years, Darwin believed there would have been plenty of time for evolution to occur. In fact, a very long time period of Earth's history is REQUIRED for evolution as Darwin described it.

Influences on Darwin

Science, like evolution, always builds on the past. Darwin didn't develop his theory completely on his own. He was influenced by the ideas of earlier thinkers.

Earlier Thinkers Who Influenced Darwin

1. Jean Baptiste **Lamarck** (1744-1829) was an important French naturalist. He was one of the first scientists to propose that species change over time. However, Lamarck was wrong about how species change. His idea of the **inheritance of acquired characteristics** is incorrect. Traits an organism develops during its own life time cannot be passed on to offspring, as Lamarck believed.
2. Charles **Lyell** (1797-1875) was a well-known English geologist. Darwin took Lyell's book, *Principles of Geology,* with him on the *Beagle*. In the book, Lyell argued that gradual geological processes have gradually shaped Earth's surface. From this, Lyell inferred that Earth must be far older than most people believed.

3. Thomas **Malthus** (1766-1834) was an English economist. He wrote an essay titled *On Population*. In the essay, Malthus argued that human populations grow faster than the resources they depend on. When populations become too large, famine and disease break out. In the end, this keeps populations in check by killing off the weakest members.

Artificial Selection

These weren't the only influences on Darwin. He was also aware that humans could breed plants and animals to have useful traits. By selecting which animals were allowed to reproduce, they could change an organism's traits. The pigeons in **Figure** 4.2 are good examples. Darwin called this type of change in organisms **artificial selection**. He used the word "artificial" to distinguish it from natural selection.

FIGURE 4.2
Artificial Selection in Pigeons. Pigeon hobbyists breed pigeons to have certain characteristics. Both of the pigeons in the bottom row were bred from the common rock pigeon.

Wallace's Theory

Did you ever hear the saying that "great minds think alike?" It certainly applies to Charles Darwin and another English naturalist named Alfred Russel **Wallace**. Wallace lived at about the same time as Darwin. He also traveled to distant places to study nature. Wallace wasn't as famous as Darwin. However, he developed basically the same theory of evolution. While working in distant lands, Wallace sent Darwin a paper he had written. In the paper, Wallace explained his evolutionary theory. This served to confirm what Darwin already thought.

Summary

- Darwin was influenced by other early thinkers, including Lamarck, Lyell, and Malthus.

- Darwin was also influenced by his knowledge of artificial selection.
- Wallace's paper on evolution confirmed Darwin's ideas.

Explore More

Use this resource to answer the questions that follow.

- **People Who Influenced Charles Darwin** at http://evolution.about.com/od/Darwin/tp/People-Who-Influenced-Charles-Darwin.htm .

1. Briefly describe the influences on Darwin of the following individuals:
   a. Comte de Buffon,
   b. Erasmus Darwin,
   c. Georges Cuvier,
   d. James Hutton,
   e. Thomas Malthus.

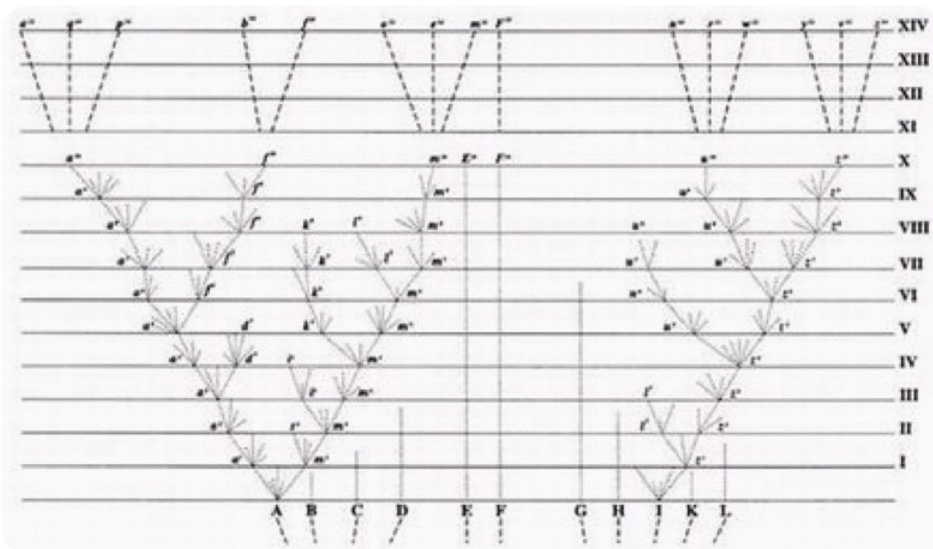
Review

1. What is the inheritance of acquired characteristics? What scientist developed this mistaken idea?
2. Who was Charles Lyell? How did he influence Darwin?
3. What is artificial selection? How does it work?
4. How did Alfred Russel Wallace influence Darwin?

4.2 Theory of Evolution by Natural Selection

Learning Objectives

- Define fitness and natural selection.
- Summarize Darwin's reasoning.
- Explain how a species can evolve through natural selection.



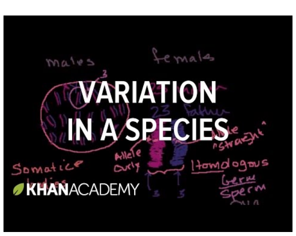
How do new species form?

This is the only illustration in Charles Darwin's 1859 book *On the Origin of Species*, showing his ideas describing the divergence of species from common ancestors.

Darwin's Theory of Evolution by Natural Selection

Darwin spent many years thinking about the work of Lamarck, Lyell, and Malthus, what he had seen on his voyage, and artificial selection. What did all this mean? How did it all fit together? It fits together in Darwin's theory of evolution by natural selection. It's easy to see how all of these influences helped shape Darwin's ideas.

For a discussion of the underlying causes of natural selection and evolution see http://www.youtube.com/watch?v=DuArVnT1i-E (19:51).



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Evolution of Darwin's Theory

It took Darwin years to form his theory of evolution by natural selection. His reasoning went like this:

1. Like Lamarck, Darwin assumed that species can change over time. The fossils he found helped convince him of that. *NOTE: the* **species** *changes - type of organism changes - individual organisms do NOT change over time (time means 000's of years or longer).*
2. From Lyell, Darwin saw that Earth and its life were very old. Thus, there had been enough time for evolution to produce the great diversity of life Darwin had observed.
3. From Malthus, Darwin knew that populations could grow faster than their resources. This "overproduction of offspring" led to a "struggle for existence," in Darwin's words.
4. From artificial selection, Darwin knew that some offspring have variations that occur by chance, and that can be inherited. In nature, offspring with certain variations might be more likely to survive the "struggle for existence" and reproduce. If so, they would pass their favorable variations to their offspring.
5. Darwin coined the term **fitness** to refer to an organism's relative ability to survive and produce fertile offspring. Nature selects the variations that are most useful. Therefore, he called this type of selection **natural selection**.
6. Darwin knew artificial selection could change domestic species over time. He inferred that natural selection could also change species over time. In fact, he thought that if a species changed enough, it might evolve into a new species.

Wallace's paper not only confirmed Darwin's ideas. It also pushed him to finish his book, *On the Origin of Species*. Published in 1859, this book changed science forever. It clearly spelled out Darwin's theory of evolution by natural selection and provided convincing arguments and evidence to support it.

Applying Darwin's Theory

The following example applies Darwin's theory. It explains how giraffes came to have such long necks (see **Figure** 4.3).

- In the past, giraffes had short necks. But there was chance variation in neck length. Some giraffes had necks a little longer than the average.
- Then, as now, giraffes fed on tree leaves. Perhaps the environment changed, and leaves became scarcer. There would be more giraffes than the trees could support. Thus, there would be a "struggle for existence."
- Giraffes with longer necks had an advantage. They could reach leaves other giraffes could not. Therefore, the long-necked giraffes were more likely to survive and reproduce. They had greater fitness.
- These giraffes passed the long-neck trait to their offspring. Each generation, the population contained more long-necked giraffes. Eventually, all giraffes had long necks.

As this example shows, chance variations may help a species survive if the environment changes. Variation among species helps ensure that at least one will be able to survive environmental change.

A summary of Darwin's ideas are presented in the video "Natural Selection and the Owl Butterfly" : http://www.youtube.com/watch?v=dR_BFmDMRaI (13:29).

MEDIA

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FIGURE 4.3

Giraffes feed on leaves high in trees. Their long necks allow them to reach leaves that other ground animals cannot.

KQED: Chasing Beetles, Finding Darwin

It's been over 150 years since Charles Darwin published *On the Origin of Species*. Yet his ideas remain as central to scientific exploration as ever, and has been called the unifying concept of all biology. Is evolution continuing today? Of course it is.

QUEST follows researchers who are still unlocking the mysteries of evolution, including entomologist David Kavanaugh of the California Academy of Sciences, who predicted that a new beetle species would be found on the Trinity Alps of Northern California. See http://www.kqed.org/quest/television/chasing-beetles-finding-darwin2 for more information.

It's rare for a biologist to predict the discovery of a new species. For his prediction, Kavanaugh drew inspiration from Darwin's own 1862 prediction. When Darwin observed an orchid from Madagascar with a foot-long nectar, he predicted that a pollinator would be found with a tongue long enough to reach the nectar inside the orchid's very thin, elongated nectar "pouch", though he had never seen such a bird or insect. Darwin's prediction was based on his finding that all species are related to each other and that some of them evolve together, developing similar **adaptations**. Darwin's prediction came true in 1903, when a moth was discovered in Madagascar with a long, thin proboscis, which it uncurls to reach the nectar in the orchid's nectar. In the process of feeding from the orchid, the moth serves as its pollinator. The moth was given the scientific name *Xanthopan morganii praedicta*, in honor of Darwin's prediction.

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As you view *Chasing Beetles, Finding Darwin,* focus on the following concepts:

1. the relationship between studying beetles and evolution,
2. the development of new species,

3. the relationship between genetic make-up of an organism and evolution,
4. the role of *beneficial* mutations,
5. the role of ”habitat islands”,
6. the selection for certain traits among breeders, such as pigeon breeders,
7. the importance of identifying new species.

Summary

- Darwin’s book *On the Origin of Species* clearly spells out his theory.
- Darwin’s book also provides evidence and logic to support that evolution occurs and that it occurs by natural selection.

Explore More

Explore More I

Use this resource to answer the questions that follow.

- **Charles Darwin Evolution** at http://darwin200.christs.cam.ac.uk/pages/index.php?page_id=d3 .

1. What did Darwin mean by "common descent?"
2. What did Darwin mean by "gradualism?"
3. What is meant by "super fecundity?"
4. What did Darwin say would happen to individuals of the same species in an environment of scarce resources?

Explore More II

- **Changes in the Environment** at http://www.concord.org/activities/changes-environment .

- **Natural Selection**

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Review

1. Define fitness.
2. Apply Darwin’s theory of evolution by natural selection to a specific case. For example, explain how Galápagos tortoises could have evolved saddle-shaped shells.
3. Explain how the writings of Charles Lyell and Thomas Malthus helped Darwin develop his theory of evolution by natural selection.
4. Discuss the role artificial selection had on Darwin’s theory.

4.3 Evidence for Evolution

Lesson Objectives

- Explain what fossils are, how they form, and how they are dated.
- Identify evidence for evolution provided by living organisms.
- Describe recent evolution by natural selection in Darwin's finches.

Lesson Vocabulary

- absolute dating
- fossil
- molecular clock
- paleontologist
- relative dating
- vestigial structure

Introduction

In his book *On the Origin of Species*, Darwin included a lot of evidence for evolution. Since then, much more evidence has accumulated. The evidence includes millions of fossils, like the one in **Figure** 4.4. It also includes detailed knowledge of living organisms.

What Are Fossils?

Fossils are the preserved remains or traces of organisms that lived during earlier ages. Remains that become fossils are generally the hard parts of organisms—mainly bones, teeth, or shells. Traces include any evidence of life, such as footprints like the dinosaur footprint in **Figure** 4.5. Fossils are like a window into the past. They provide direct evidence of what life was like long ago. A scientist who studies fossils to learn about the evolution of living things is called a **paleontologist**.

How Fossils Form

The soft parts of organisms almost always decompose quickly after death. That's why most fossils consist of hard parts such as bones. It's rare even for hard parts to remain intact long enough to become fossils. Fossils form when water seeps through the remains and deposits minerals in them. The remains literally turn to stone. Remains are more likely to form fossils if they are covered quickly by sediments.

FIGURE 4.4
Most of what we know about dinosaurs is based on fossils such as this one.

Once in a while, remains are preserved almost unchanged. For example, they may be frozen in glaciers. Or they may be trapped in tree resin that hardens to form amber. That's what happened to the wasp in **Figure** 4.6. The wasp lived about 20 million years ago, but even its fragile wings have been preserved by the amber.

How Fossils Are Dated

Fossils are useful for reconstructing the past only if they can be dated. Scientists need to determine when the organisms lived who left behind the fossils. Fossils can be dated in two different ways: absolute dating and relative dating.

- **Absolute dating** determines about how long ago a fossil organism lived. This gives the fossil an approximate age in years. Absolute dating is often based on the amount of carbon-14 or other radioactive element that remains in a fossil. You can learn how carbon-14 dating works by watching this short video:

http://www.scientificamerican.com/video/how-does-radiocarbon-dating-work-i2012-11-30/

FIGURE 4.5
Fossil footprint of a three-toed dinosaur

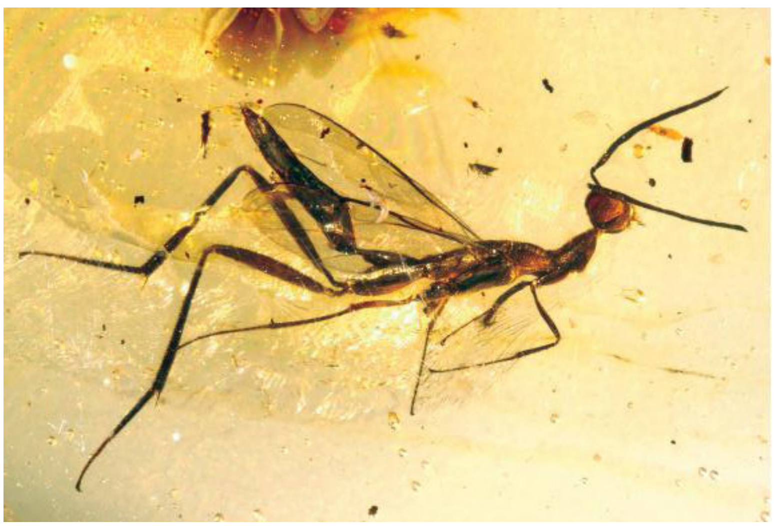

FIGURE 4.6
Wasp encased in amber

- **Relative dating** determines which of two fossils is older or younger than the other but not their age in years. Relative dating is based on the positions of fossils in rock layers. Lower rock layers were laid down earlier, so they are assumed to contain older fossils. This is illustrated in **Figure** 4.7.

Using Fossils to Understand Evolution

The evolution of whales is a good example of how fossils can help us understand evolution. Scientists have long known that mammals first evolved on land about 200 million years ago. It's been a mystery, however, how whales evolved. Whales are mammals that live completely in the water. Did they evolve from earlier land mammals? Or did they evolve from animals that already lived in the water?

Starting in the late 1970s, a growing number of fossils have allowed scientists to piece together the story of whale evolution. The fossils represent ancient, whale-like animals. They show that an ancient land mammal made its way

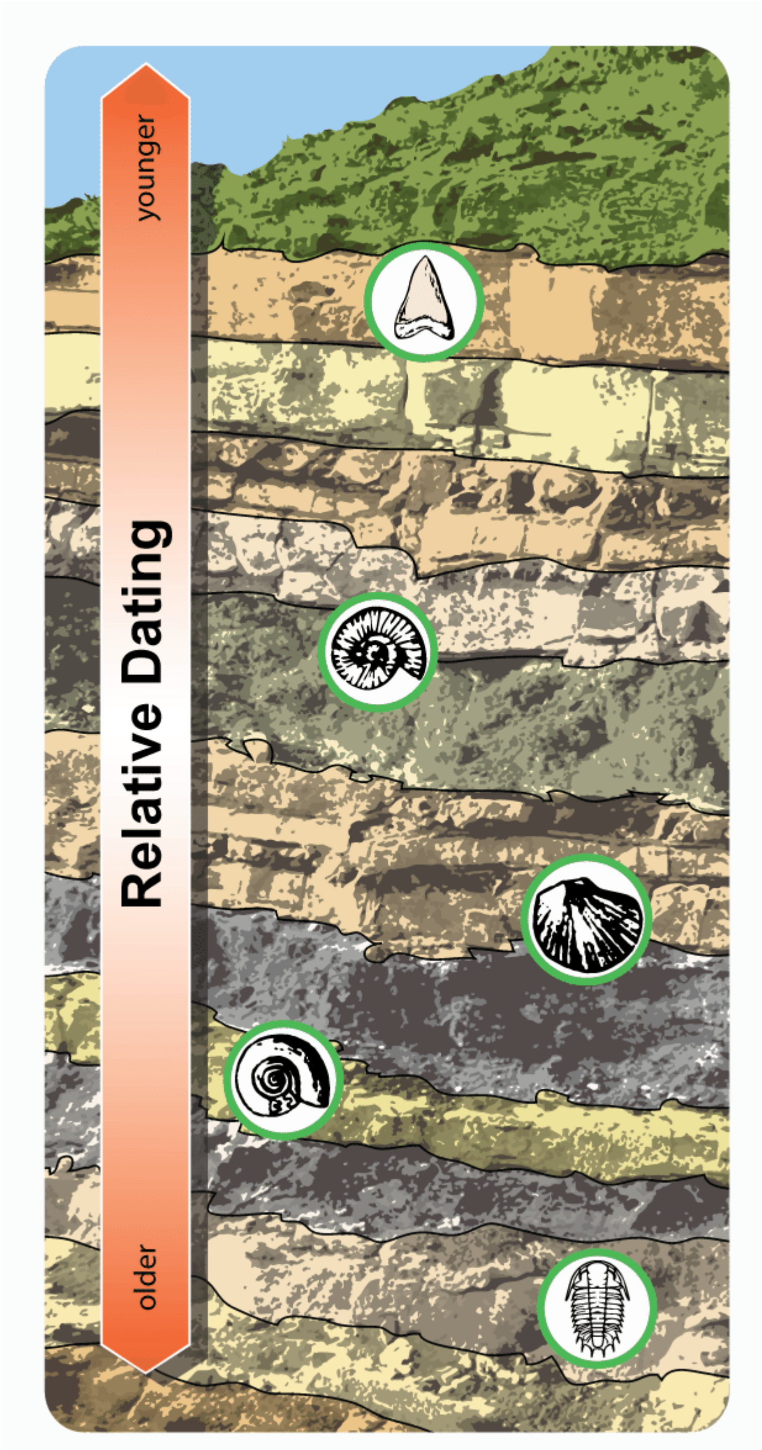

FIGURE 4.7
Fossils found in lower rock layers are generally older than fossils found in rock layers closer to the surface.

back to the sea more than 50 million years ago. It became the ancestor of modern whales. In doing so, it lost its legs and became adapted to life in the water.

In **Figure** 4.8 you can see an artist's rendition of such a whale ancestor. It had legs and could walk on land, but it was also a good swimmer. Watch this short video to learn more about the amazing story of whale evolution based on the fossils:

http://www.pbs.org/wgbh/evolution/library/03/4/l_034_05.html

FIGURE 4.8
This whale ancestor, called *Ambulocetus*, lived about 48 million years ago.

Evidence from Living Organisms

Scientists have learned a lot about evolution by comparing living organisms. They have compared body parts, embryos, and molecules such as DNA and proteins.

Comparing Body Parts

Comparing body parts of different species may reveal evidence for evolution. For example, all mammals have front limbs that look quite different and are used for different purposes. Bats use their front limbs to fly, whales use them to swim, and cats use them to run and climb. However, the front limbs of all three animals—as well as humans—have the same basic underlying bone structure. You can see this in **Figure** 4.9. The similar bones provide evidence that all four animals evolved from a common ancestor.

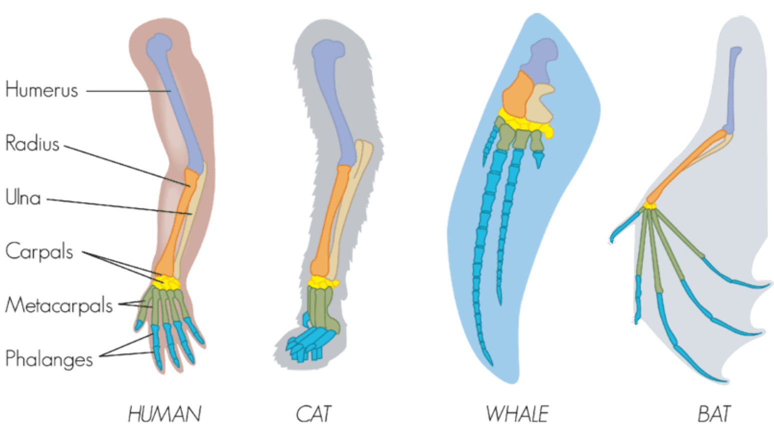

FIGURE 4.9
Front limb bones of different mammals

Vestigial Structures

Some of the most interesting evidence for evolution comes from **vestigial structures**. These are body parts that are no longer used but are still present in modern organisms. Examples in humans include tail bones and the appendix.

- Human beings obviously don't have tails, but our ancestors did. We still have bones at the base of our spine that form a tail in other, related animals, such as monkeys.

- The appendix is a tiny remnant of a once-larger organ. In a distant ancestor, it was needed to digest food. If your appendix becomes infected, a surgeon can remove it. You won't miss it because it no longer has any purpose in the human body.

Comparing Embryos

An embryo is an organism in the earliest stages of development. Embryos of different species may look quite similar, even when the adult forms look very different. Look at the drawings of embryos in **Figure** 4.10. They represent very early life stages of a chicken, turtle, pig, and human being. The embryos look so similar that it's hard to tell them apart. Such similarities provide evidence that all four types of animals are related. They help document that evolution has occurred.

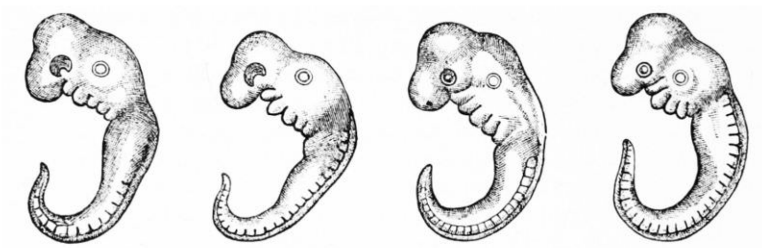

FIGURE 4.10
From left to right, embryos of a chicken, turtle, pig, and human being

Comparing Molecules

Scientists can compare the DNA or proteins of different species. If the molecules are similar, this shows that the species are related. The more similar the molecules are, the closer the relationship is likely to be. When molecules are used in this way, they are called **molecular clocks**. This method assumes that random mutations occur at a constant rate for a given protein or segment of DNA. Over time, the mutations add up. The longer the amount of time since species diverged, the more differences there will be in their DNA or proteins.

Table 4.1 compares the DNA of four different organisms with modern human DNA. The DNA of chimpanzees is almost 99 percent the same as the DNA of modern humans. This shows that chimpanzees are very closely related to us. We are less closely related to the other organisms in the table. It's no surprise that grapes, which are plants, are less like us than the animals in the table.

TABLE 4.1: Comparing DNA sequences

Organism	Similarity with Human DNA (percent the same)
Chimpanzee	98.8
Cow	85
Chicken	65
Honeybee	44
Grape	24

Observing Evolution in Action

The best evidence for evolution comes from actually observing changes in organisms through time. In the 1970s, biologists Peter and Rosemary Grant went to the Galápagos Islands to do fieldwork. They wanted to re-study

Darwin's finches. They spent the next 40 years on the project. Their hard work paid off. They were able to document evolution by natural selection taking place in the finches.

A period of very low rainfall occurred while the Grants were on the islands. The drought resulted in fewer seeds for the finches to eat. Birds with smaller beaks could eat only the smaller seeds. Birds with bigger beaks were better off. They could eat seeds of all sizes. Therefore, there was more food available to them. Many of the small-beaked birds died in the drought. More of the big-beaked birds survived and reproduced. Within just a couple of years, the average beak size in the finches increased. This was clearly evolution by natural selection.

Lesson Summary

- Fossils are the preserved remains or traces of organisms that lived long ago. They form mainly when minerals in water turn remains to stone. Fossils can be dated using methods such as carbon-14 dating or their positions in rock layers.
- Scientists have learned a lot about evolution from species that are living today. They have compared body parts, vestigial organs, embryos, and molecules in different species. Species that are the most similar in these ways are generally the most closely related.
- The best evidence for evolution is seeing it in action. An example is the work of Peter and Rosemary Grant. They documented recent evolution by natural selection in Darwin's finches.

Lesson Review Questions

Recall

1. Describe how fossils usually form.
2. What are vestigial structures? Give an example.

Apply Concepts

3. Apply the molecular clock concept to the data in the table below. Explain which of the three species in the table shared the most recent common ancestor with the human species.

TABLE 4.2: Human Percent DNA

Species	Percent of DNA that is the Same as Human DNA
African gorilla	98.4
Orangutan	97
Rhesus monkey	93

4.

Think Critically

4. Compare and contrast relative and absolute dating.
5. How did scientists use fossils to solve the mystery of whale evolution?
6. Explain why Peter and Rosemary Grant were eyewitnesses to evolution.

Points to Consider

Understanding how evolution occurs requires knowledge of genetics.

- How is variation in traits within a species related to genes?
- How would you define evolution in genetic terms?

4.4 Structural Evidence for Evolution

Learning Objectives

- Explain the evolutionary meaning of having a common ancestor.
- Discuss how vestigial structures and embryology support evolution theory.

Why do you have a tail bone?

If you look closely at a skeleton, you might notice a triangular bone at the end of the spinal column. This is your tailbone. Why would you have a tailbone when you don't have a tail? You have a tailbone because your ancient ancestors *did* have a tail. These sorts of "left-over" structures support the theory of evolution.

Structural Evidence

Even though two different species may not look similar, they may have similar internal structures that suggest they have a **common ancestor**. That means both evolved from the same ancestor organism a long time ago. Common ancestry can also be determined by looking at the structure of the organism as it first develops.

Vestigial Structures

Some of the most interesting kinds of evidence for evolution are body parts that have lost their use through evolution (**Figure** 4.11). For example, most birds need their wings to fly. But the wings of an ostrich have lost their original use. Structures that have lost their use through evolution are called **vestigial structures**. They provide evidence for evolution because they suggest that an organism changed from using the structure to not using the structure, or using it for a different purpose.

Penguins do not use their wings, known as flippers, to fly in the air. However, they do use them to move in the water. The theory of evolution suggests that penguins evolved to use their wings for a different purpose. A whale's pelvic bones, which were once attached to legs, are also vestigial structures. Whales are descended from land-dwelling ancestors that had legs.

Homologous structures are structures that have a common function and suggest common ancestry. For example, homologous structures include the limbs of mammals, such as bats, lions, whales, and humans, which all have a common ancestor. Different mammals may use their limbs for walking, running, swimming or flying. The method the mammal uses to move is considered a common function.

FIGURE 4.11
Moles live underground where they do not need eyes to find their way around. This mole's eyes are covered by skin. Body parts that do not serve their original function are vestigial structures.

Similar Embryos

Some of the oldest evidence of evolution comes from **embryology**, the study of how organisms develop. An embryo is an animal or plant in its earliest stages of development. This means looking at a plant or animal before it is born or hatched. Centuries ago, people recognized that the embryos of many different species have similar appearances.

The embryos of some species are even difficult to tell apart. Many of these animals do not differ much in appearance until they develop further.

Some unexpected traits can appear in animal embryos. For example, human embryos have gill slits just like fish! In fish they develop into gills, but in humans they disappear before birth. The presence of the gill slits suggests that a long time ago humans and fish shared a common ancestor.

The similarities between embryos suggests that these animals are related and have common ancestors. For example, humans did not evolve from chimpanzees. But the similarities between the embryos of both species suggest that we have an ancestor in common with chimpanzees. As our common ancestor evolved, humans and chimpanzees went down different evolutionary paths and developed different traits.

Summary

- Vestigial structures, or structures that have lost their use through evolution, are important evidence of evolution.
- Studying the embryos of organisms also provides evidence that two very different animals could have descended from a common ancestor.

Explore More

Use the resource below to answer the questions that follow.

- **Richard Dawkins Vestigial Organs The Wings of the Flightless Cormorant** at https://www.youtube.com/watch?v=3e5cs0PtuA4 .

1. Are all cormorants flightless?
2. What is the vestigial trait most obvious in the flightless cormorant?
3. How have these birds compensated for their inability to fly?

Review

1. What is a vestigial structure? Give an example.
2. How does embryology provide evidence for evolution?
3. Given an example of a structure that is present in human embryos, but has disappeared by birth.

4.5 Evolution Acts on the Phenotype

Learning Objectives

- Define carrier.
- Explain how an unfavorable allele is kept in the gene pool.

Would albinism be an advantage?

This rabbit is albino, meaning it lacks pigment in its skin, fur, and eyes. The same thing happens in other species, including humans. To most animals albinism would be a disadvantage since they need to blend into their environment to avoid predators or catch prey. How, then, does the gene that causes albinism stay in the gene pool?

Evolution Acts on the Phenotype

Natural selection acts on the **phenotype** (the traits or characteristics) of an individual. On the other hand, natural selection does not act on the underlying **genotype** (the genetic makeup) of an individual. For many traits, the homozygous genotype, *AA*, for example, has the same phenotype as the heterozygous *Aa* genotype. If both an *AA* and *Aa* individual have the same phenotype, the environment cannot distinguish between them. So natural selection cannot select for a homozygous individual over a heterozygous individual. Even if the "aa" phenotype is lethal, the recessive *a* allele, will be maintained in the population through heterozygous *Aa* individuals. Furthermore, the mating of two heterozygous individuals can produce homozygous recessive (*aa*) individuals. However, natural selection can and does differentiate between dominant and recessive phenotypes.

Carriers

Since natural selection acts on the phenotype, if an allele causes death in a homozygous individual, *aa*, for example, it will not cause death in a heterozygous *Aa* individual. These heterozygous *Aa* individuals will then act as **carriers** of the *a* allele, meaning that the *a* allele could be passed down to offspring. People who are carriers do not express the recessive phenotype, as they have a dominant allele. This allele is said to be kept in the population's gene pool. The **gene pool** is the complete set of genes and alleles within a population.

For example, Tay-Sachs disease is a recessive human genetic disorder. That means only individuals with the homozygous recessive genotype, *rr* will be affected. Affected individuals usually die from complications of the disease in early childhood, at an age too young to reproduce. The two parents are each heterozygous (*Rr*) for the Tay-Sachs gene; they will not die in childhood and will be carriers of the disease gene. This deadly allele is kept in the gene pool even though it does not help humans adapt to their environment. This happens because evolution acts on the phenotype, not the genotype (**Figure** 4.12).

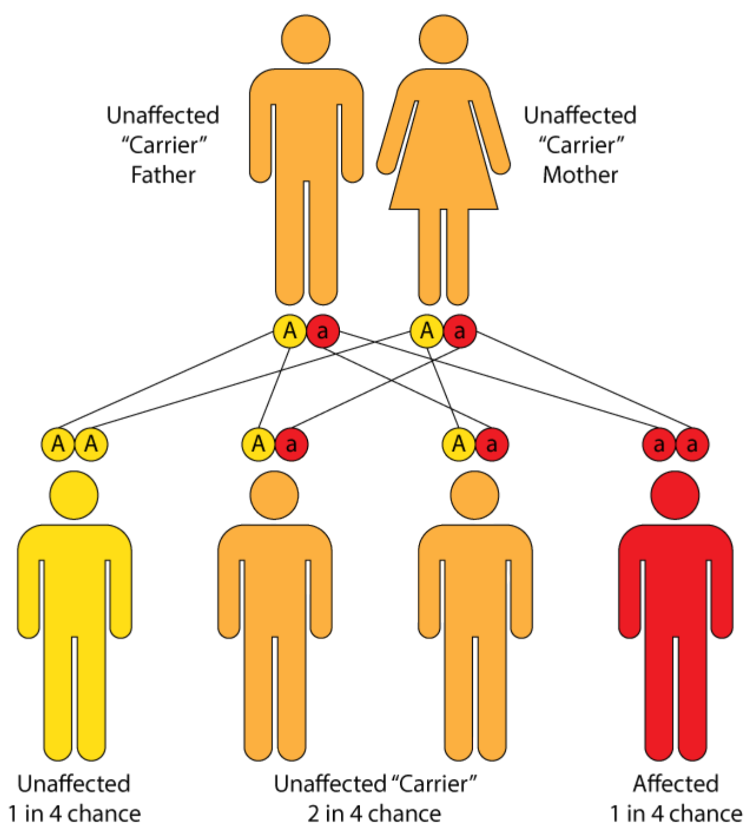

FIGURE 4.12
Tay-Sachs disease is inherited in the autosomal recessive pattern. Each parent is an unaffected carrier of the lethal allele.

Summary

- Natural selection acts on the phenotype (the traits or characteristics) of an individual, not on the underlying genotype.
- Carriers of a trait can show no symptoms of a recessive disease and, yet, still pass it on to their offspring.

Explore More

Use the resource below to answer the questions that follow.

- **Harmful Genes** at http://www.newton.dep.anl.gov/askasci/mole00/mole00460.htm .

1. What would happen if a harmful gene were dominant?
2. Give an example of a harmful recessive gene that provides carriers with an advantage.
3. How can a harmful gene "hide"?

Review

1. What's the difference between phenotype and genotype?
2. Does natural selection act on the genotype or phenotype?
3. Explain how a lethal recessive gene can stay in the gene pool.

4.6 Glossary

Glossary

Pollinate, when flowering plants share male sexual material it is carried in the pollen of flowers.

Evolution, the process of change over time in species as caused by natural selection.

Homo sapiens, the human species to which all people belong

Anatomy, the physical internal and external structure of a human or animal body.

Embryos, unformed offspring in a womb or an egg.

Comparative Anatomy, the process of comparing anatomy of different animals.

Homologous Structures, structures that are similar from different species and correspond to one another but serve different functions in different species.

Analogous Structures, Structures in a body that have the same appearance, structure or function but have evolved separately.

Vestigial Structures, structures that still exist but are of no purpose in a species.

Tetrapod Limbs, the limbs of creatures with four limbs.

Octopus Limbs, the limbs (tentacles) of an octopus.

4.7 References

1. Common rock pigeon: Image copyright Marketa Mark, 2014; Carrier pigeon: Image copyright guentermanaus, 2014; Fantail pigeon: Image copyright Ulrike Haberkorn, 2014. Artificial selection in pigeons to form the carrier pigeon and fantail pigeon . Used under licenses from Shutterstock.com
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9. Popular Science. Embryos of a chicken, turtle, pig, and human being . Public Domain
10. Image copyright Onyshchenko, 2014. A mole has vestigial eyes . Used under license from Shutterstock.com
11. Zachary Wilson. Tay-Sachs disease, with autosomal recessive inheritance . CC BY-NC 3.0

CHAPTER 5 Genetic Variation and Traits as Forces of Evolution LS 4-4

Chapter Outline

FIGURE 5.1
The two kittens have different genetic traits which chow up as different color patterns in their fur.

INTRODUCTION

DISCIPLINARY CORE IDEA:

MS-LS 4-4 By the end of instruction, students should be able to answer a test which asks them to: **Build an explanation based on evidence that shows how some individuals with certain genetically produced traits can survive AND reproduce better than others that don't have those traits.**

Various factor influence the traits of individuals. Those traits have direct impact on survival of specific individuals in a population and therefore affects the gene pool for the species as a whole. Over time these changes in the gene pool may affect the overall survivability of the species in a particular environment. below we can see how the forces that drive evolution can affect the traits which predominate in a species.

In this chapter we consider how differences between parents and offspring can add up to changes in certain kinds of organisms. For our story we are trying to get insight as to how these creatures seemed to change overtime, knowing the individual organisms did not change, but the change was always between generations if at all. We can then think about how this might affect us when we get to Mars.

5.1 Population Genetics

Learning Objectives

- Distinguish between microevolution and macroevolution.
- Define gene pool.
- Explain how to calculate allele frequencies.

Jeans vs. Genes. What's the difference?

Plenty. One you have for life, the other just lasts a few years. One is the basis for the passing of traits from one generation to the next. Some jeans you change frequently. But what happens when you change a gene's frequency? Essentially, evolution is a change in gene frequencies within a population.

Genes in Populations

Darwin knew that heritable variations are needed for evolution to occur. However, he knew nothing about Mendel's laws of genetics. Mendel's laws were rediscovered in the early 1900s. Only then could scientists fully understand the process of evolution. We now know that variations of traits are heritable. These variations are determined by different **alleles**. We also know that evolution is due to a change in alleles over time. How long a time? That depends on the scale of evolution.

- **Microevolution** occurs over a relatively short period of time within a population or species. The Grants observed this level of evolution in Darwin's finches (see the "Biogeography" concept).
- **Macroevolution** occurs over geologic time above the level of the species. The fossil record reflects this level of evolution. It results from microevolution taking place over many generations.

Remember that individuals do not evolve. Their **genes** do not change over time. The unit of evolution is the population. A **population** consists of organisms of the same species that live in the same area. In terms of evolution, the population is assumed to be a relatively closed group. This means that most mating takes place within the population. The science that focuses on evolution within populations is **population genetics**. It is a combination of evolutionary theory and Mendelian genetics.

Gene Pool

The genetic makeup of an individual is the individual's **genotype**. A population consists of many genotypes. Altogether, they make up the population's gene pool. The **gene pool** consists of all the genes of all the members of the population. For each gene, the gene pool includes all the different alleles for the gene that exist in the population. For a given gene, the population is characterized by the frequency of the different alleles in the gene pool.

Allele Frequencies

Allele frequency is how often an allele occurs in a gene pool relative to the other alleles for that gene. Look at the example in the **Table** 5.1. The population in the table has 100 members. In a sexually reproducing species, each member of the population has two copies of each gene. Therefore, the total number of copies of each gene in the gene pool is 200. The gene in the example exists in the gene pool in two forms, alleles A and a. Knowing the genotypes of each population member, we can count the number of alleles of each type in the gene pool. The table shows how this is done.

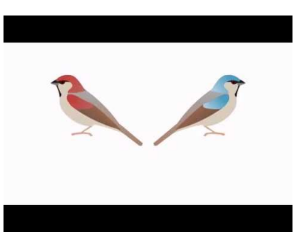
TABLE 5.1: Number of Alleles in a Gene Pool

Genotype	Number of Individuals in the Population with that Genotype	Number of Allele A Contributed to the Gene Pool by that Genotype	Number of Allele a Contributed to the Gene Pool by that Genotype
AA	50	$50 \times 2 = 100$	$50 \times 0 = 0$
Aa	40	$40 \times 1 = 40$	$40 \times 1 = 40$
aa	10	$10 \times 0 = 0$	$10 \times 2 = 20$
Totals	100	140	60

Let the letter p stand for the frequency of allele A. Let the letter q stand for the frequency of allele a. We can calculate p and q as follows:

- p = number of A alleles/total number of alleles = 140/200 = 0.7
- q = number of a alleles/total number of alleles = 60/200 = 0.3
- Notice that $p + q = 1$.

Evolution occurs in a population when allele frequencies change over time. What causes allele frequencies to change? That question was answered by Godfrey Hardy and Wilhelm Weinberg in 1908 (see the *Hardy-Weinberg Theorem* concept).



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Summary

- Microevolution occurs over a short period of time in a population or species. Macroevolution occurs over geologic time above the level of the species.
- The population is the unit of evolution.
- A population's gene pool consists of all the genes of all the members of the population.
- For a given gene, the population is characterized by the frequency of different alleles in the gene pool.

Review

1. Compare microevolution to macroevolution.
2. Why are populations, rather than individuals, the units of evolution?
3. What is a gene pool?
4. Assume that a population of 50 individuals has the following numbers of genotypes for a gene with two alleles, *B* and *b*: *BB* = 30, *Bb* = 10, and *bb* = 10. Calculate the frequencies of the two alleles in the population's gene pool.

5.2 Natural Selection

Learning Objectives

- Define natural selection.
- Explain the relationship between adaptations and natural selection.
- Describe when natural selection occurs.
- Explain the relationship between evolution and natural selection.

How is this deer mouse well adapted for life in the forest?

Notice how its dark coloring would allow the deer mouse to easily hide from predators on the darkened forest floor. On the other hand, deer mice that live in the nearby Sand Hills are a lighter, sand-like color. What caused the deer mice to be so well adapted to their unique environments? Natural selection.

Natural Selection

The theory of evolution by natural selection means that the inherited traits of a population change over time. **Inherited traits** are features that are passed from one generation to the next. For example, your eye color is an inherited trait. You inherited your eye color from your parents. Inherited traits are different from **acquired traits**, or traits that organisms develop over a lifetime, such as strong muscles from working out (**Figure** 5.2).

Natural selection explains how organisms in a population develop traits that allow them to survive and reproduce. Natural selection means that traits that offer an advantage will most likely be passed on to offspring; individuals with those traits have a better chance of surviving. Evolution occurs by natural selection.

FIGURE 5.2

Human earlobes may be attached or free. You inherited the particular shape of your earlobes from your parents. Inherited traits are influenced by genes, which are passed on to offspring and future generations. Things not influenced by genes are not passed on to your offspring. Natural selection only operates on traits like earlobe shape that have a genetic basis, not on traits that are acquired, like a summer tan.

Take the giant tortoises on the Galápagos Islands as an example. If a short-necked tortoise lives on an island with fruit located at a high level, will the short-necked tortoise survive? No, it will not, because it will not be able to reach the food it needs to survive. If all of the short necked tortoises die, and the long-necked tortoises survive, then, over time, only the long-necked trait will be passed down to offspring. All of the tortoises with long-necks will be "naturally selected" to survive. Organisms that are not well-adapted, for whatever reason, to their environment, will naturally have less of a chance of surviving and reproducing.

Every plant and animal depends on its traits to survive. Survival may include getting food, building homes, and attracting mates. Traits that allow a plant, animal, or other organism to survive and reproduce in its environment are called **adaptations**.

Natural selection occurs when:

1. There is some variation in the inherited traits of organisms within a species. Without this variation, natural selection would not be possible.
2. Some of these traits will give individuals an advantage over others in surviving and reproducing.
3. These individuals will be likely to have more offspring.

Imagine how in the Arctic, dark fur makes a rabbit easy for foxes to spot and catch in the snow. Therefore, white fur is a beneficial trait that improves the chance that a rabbit will survive, reproduce, and pass the trait of white fur on to its offspring (**Figure** 5.3). Through this process of natural selection, dark fur rabbits will become uncommon over time. Rabbits will adapt to have white fur. In essence, the selection of rabbits with white fur - the beneficial trait - is a natural process.

Why So Many Species?

Scientists estimate that there are between 5 million and 30 million species on the planet. But why are there so many? Different species are well-adapted to live and survive in many different types of environments. As environments change over time, organisms must constantly adapt to those environments. Diversity of species increases the chance that at least some organisms adapt and survive any major changes in the environment. For example, if a natural disaster kills all of the large organisms on the planet, then the small organisms will continue to survive.

FIGURE 5.3
The white fur of the Arctic hares may make it more difficult for fox and other predators to locate hares against the white snow.

Summary

- Evolution occurs by natural selection, the process by which organisms with traits that better enable them to adapt to their environment will tend to survive and reproduce in greater numbers. Evolution is due to differences in the survival and reproduction of individuals within a population.
- Natural selection occurs when there is some variation in the inherited traits, some of these traits will give individuals an advantage over others, and the individuals with certain traits will be more likely to have more offspring.

Explore More

Use the resource below to answer the questions that follow.

- **Sources of Variation** at http://learn.genetics.utah.edu/content/variation/sources/

1. Are all members of your family exactly alike? Are all members of a species exactly alike?
2. What is an important base of variation in species? Are all forms of a gene the same?
3. Give three examples of common mutations in DNA?
4. Do most mutations that are passed on to future generations come from the environment? What is the relationship between mutations and the environment?
5. How does recombination in sexually reproducing organisms ensure that every generation will have changes in the inherited DNA?
6. Describe the relationship between variation and natural selection.

Review

1. What's the difference between an acquired and inherited trait?
2. Define natural selection.
3. What is an adaptation?
4. What is required for natural selection to take place?
5. How many species are there on the planet?

5.3 Adaptation and Evolution of Populations

Learning Objectives

- Define adaptation.
- Explain mutations.

Why would an organism match its background? Wouldn't it be better to stand out?

An organism that blends with its background is more likely to avoid predators. If it survives, it is more likely to have offspring. Those offspring are more likely to blend into their backgrounds. This butterfly appears to be well adapted to its environment. It is less likely to be eaten by a bird than a butterfly that stands out against the tree.

Variation and Adaptation

Every organism is different from every other organism. Every organism's genes are different, too.

Variations

There are **variations** in the traits of a population. For example, there are lots of variations in the color of human hair. Hair can be blonde, brown, black, or even red. Hair color is a trait determined by genes.

Mutations

At some time in the past, a variation probably came from a mutation. A **mutation** is a random change in an organism's genes (**Figure** 5.4). Mutations are natural. Some are harmful, but many are neutral. If a mutation is harmful, the organism may not live to reproduce. If the mutation is beneficial, that organism may have a better chance to survive. An organism that survives is likely to have offspring. If it does, it may pass the mutation on to its offspring. The offspring may be more likely to survive.

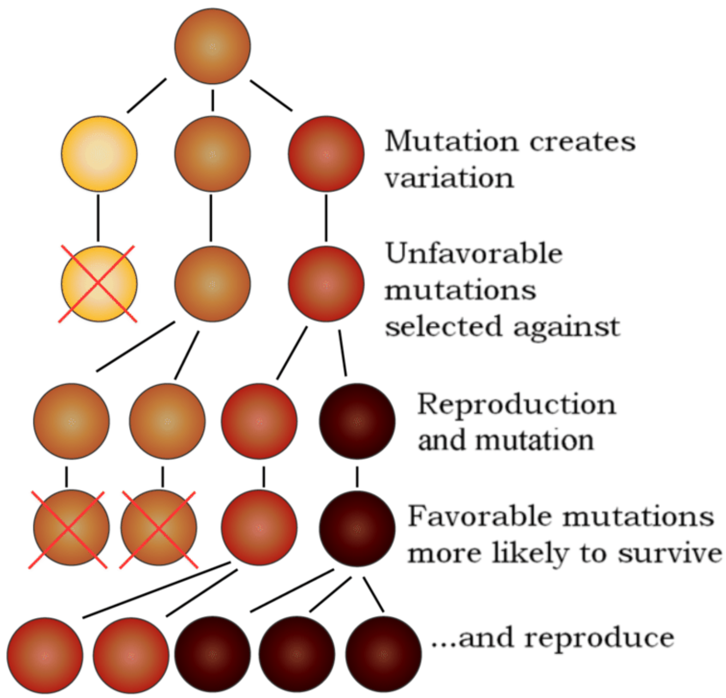


FIGURE 5.4
Genetic mutation is central to the creation of biological diversity.

Adaptations

Some of the characteristics an organism has may help it survive. These characteristics are called **adaptations**. Some adaptations are better than others.

Many adaptations protect organisms from the external environment (**Figure** 5.5).

FIGURE 5.5
Cacti have thick, water-retaining bodies that help them conserve water.

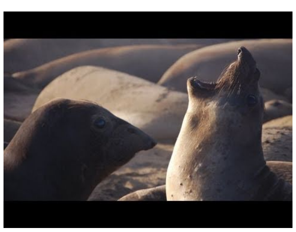
Other adaptations help an organism move or gather food. Reindeer have sponge-like hooves that help them walk on snowy ground without slipping and falling. Fish at the bottom of the ocean are tiny and use very little energy because there is very little food. Organisms have special features that help them avoid being eaten. Some plants have poisonous or foul-tasting substances in them that keep animals from eating them. Their brightly colored flowers serve as a warning. The same is true of some frogs, which can be poisonous (**Figure** 5.6)

FIGURE 5.6
Poison dart frogs have toxins in their skin. Their bright colors warn potential predators not to take a bite!

How Adaptations Develop

Adaptations develop this way. Think about a population of oak trees. Imagine that a fungus has arrived from Asia to North America. Most of the North American oak trees are killed by the fungus. But a few oak trees have a mutation that allows them to survive the fungus. Those oak trees are better adapted to the new environment than the others. Those trees have a better chance of surviving. They will probably reproduce. The trees may pass on the favorable mutation to their offspring. The other trees will die. Eventually, the population of oak trees will change. Most of the trees will have the trait to survive the fungus. This is an adaptation. Over time, traits that help an organism survive become more common. Traits that hinder survival eventually disappear.

Thousands of northern elephant seals—some weighing up to 4,500 pounds—make an annual migration to breed each winter at Año Nuevo State Reserve in California. Marine biologists are using high-tech tools to explore the secrets of these amazing creatures.



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Summary

- Different members of a population have different genes for the same trait.
- Some of these differences are due to mutations.
- Some traits allow an individual organism to be better adapted to its environment. That individual will be more likely to survive and to reproduce.

Review

1. How do adaptations develop?
2. What does it mean to say that an organism is well adapted to its environment?

3. What is a mutation?

5.4 Glossary

Glossary

adaptive radiation, the process by which a single species into many new species to fill available niches.

allele frequency, how often alleles show up in the gene pool

allele, the parts of genes from each parent.

biogeography, the study of how and why plants and animals live where they do.

bottleneck effect, a change in a gene pool that takes place when a population suddenly gets much smaller.

founder effect, when individuals with new mutations begin a new population with new genes.

gene flow, the change in allele frequencies which happens when individuals move in or out of a breeding population.

gene pool, all the alleles, of an individual or population.

gene, the section of dna that carries the code for a certain trait.

genetic drift, a random change in the allele frequency of a small population.

genotype, the exact kind of genes found in an individual, these genes produce the individuals traits (phenotype) or physical characteristics.

hardy -weinberg equilibrium, when allele frequencies changes due to random mutations cancel each other out so that no overall change in allele frequency changes a population.

hardy-weinberg theorem, founding principle of population genetics, it says that when there are no mutations changing the alleles in an overall population, and no gene drift, there are no new traits forming and no natural selection is taking place, so the species remains unchanged. this is called equilibrium and occurs only under the right condition according to this theory.

macroevolution, big changes in organisms through evolution - often into new organisms, it occurs over long periods of time.

microevolution, small changes in organisms -within a species, type of organism, it occurs over relatively shorter periods of time.

migration, when animals change from one location to another in large groups. migration occur at regular time intervals. some animals migrate at certain times of year, other migrate at certain times of day.

mutation, a change in trait due to a change in dna structure; the new structure creates different proteins with different results.

odds, how likely and event is to happen.

population genetics, the science of studying genes as the group (population) changes. often over evolutionary time.

population, all the organisms in a group, often living in the same area.

probability, the likelihood of something happening.

trait, a characteristic of an organism in its physical body, for example, brown eyes, tall, short, fur color, muscle size, type of heart (3 chambers or 4), etc.

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5.5 References

1. . Two Kittens.
2. Laura Guerin. Drawing of attached or free human earlobes, which is an inherited trait . CC BY-NC 3.0
3. U.S. Fish and Wildlife Service. A white Arctic hare in the snow . Public Domain
4. Hana Zavadska. An explanation of how adaptations develop . CC BY-NC 3.0
5. CK-12 Foundation - Miles Orchinik. Cacti have thick, water-retaining bodies that help them conserve water . CC BY-NC 3.0
6. Adrian Pingstone (Wikimedia: Arpingstone). Brightly colored poison dart frogs have toxins in their skin . Public Domain

CHAPTER 6 Where is the Earth, and How Do the Objects of the Solar System Compare MS ESS 1-3

Chapter Outline

INTRODUCTION

DISCIPLINARY CORE IDEA:

MS-ESS 1-3 By **the end of instruction, students should be able to answer a test which asks them to: Look at data to describe and compare the size and properties of objects in the solar system, include orbits, sizes, layers and surface features.**

Is Earth a planet?

Yes! No one doubts that Earth is a planet. But Earth is a lot different from the other planets in our solar system. The outer planets are huge and made of gas, like Jupiter. The inner planets are also different, like scorching-hot Venus. Earth is different because it has liquid water. It also has life! Life may be found on another planet or moon in our solar system. But it will not be intelligent life. We humans have looked around to know that! There was a planet that was really different from the other planets. That planet is no longer a planet. Pluto is now categorized as a dwarf planet. To decide what to do with Pluto, scientists had to decide what a planet is. We will look at some of the characteristics that make Earth a bona fide planet.

For our story to continue we take a look at where the Earth is in relation to other planets and solar system objects. We examine where the Earth is compared to Mars and begin to think about how to get there.

6.1 Milky Way

Learning Objectives

- Describe the characteristics of the Milky Way Galaxy and our solar system's location within it.

"The Milky Way is nothing else but a mass of innumerable stars planted together in clusters." — Galileo Galilei

It's sad that there is so much light pollution in most cities that many people have never seen the Milky Way. On a clear night away from lights the view is of a bright white river of stars. You don't need a telescope or even binoculars to see it. The view of the Milky Way is so bright because you're looking at the stars in your own galaxy.

The Milky Way Galaxy

The **Milky Way Galaxy**, which is our galaxy. The Milky Way is made of millions of stars along with a lot of gas and dust. It looks different from other galaxies because we are looking at the main disk from within the galaxy. Astronomers estimate that the Milky Way contains 200 to 400 billion stars.

Shape and Size

Although it is difficult to know what the shape of the Milky Way Galaxy is because we are inside of it, astronomers have identified it as a typical spiral galaxy containing about 200 billion to 400 billion stars (**Figure** 6.1).

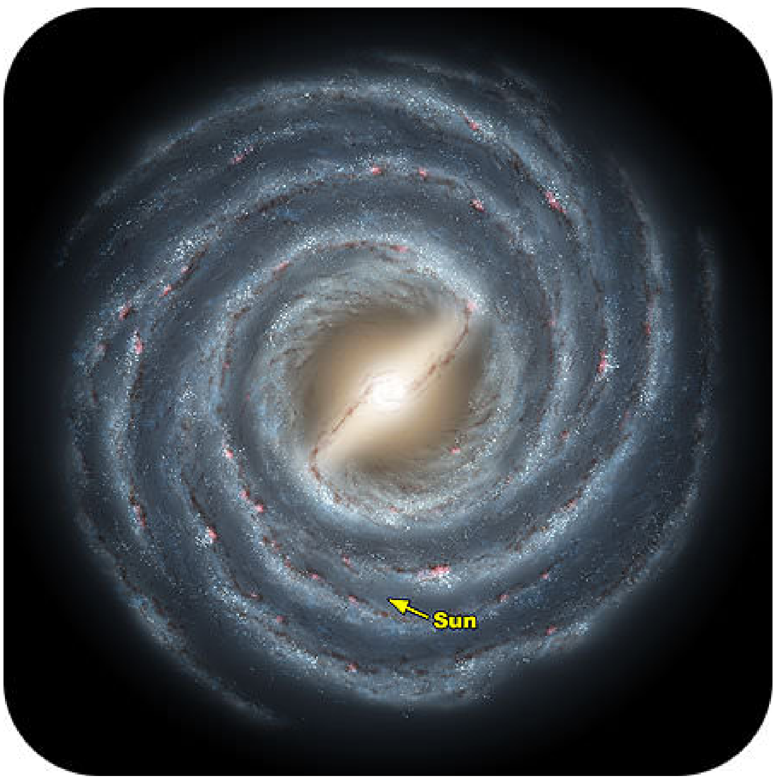


FIGURE 6.1
An artist's rendition of what astronomers think the Milky Way Galaxy would look like seen from above. The Sun is located approximately where the arrow points.

Like other spiral galaxies, our galaxy has a disk, a central bulge, and spiral arms. The disk is about 100,000 light-years across and 3,000 light-years thick. Most of the Galaxy's gas, dust, young stars, and open clusters are in the disk.

What evidence do astronomers find that lets them know that the Milky Way is a spiral galaxy?

1. The shape of the galaxy as we see it (**Figure** 6.2).

2. The velocities of stars and gas in the galaxy show a rotational motion.

3. The gases, color, and dust are typical of spiral galaxies.

The central bulge is about 12,000 to 16,000 light-years wide and 6,000 to 10,000 light-years thick. The central bulge contains mostly older stars and globular clusters. Some recent evidence suggests the bulge might not be spherical, but

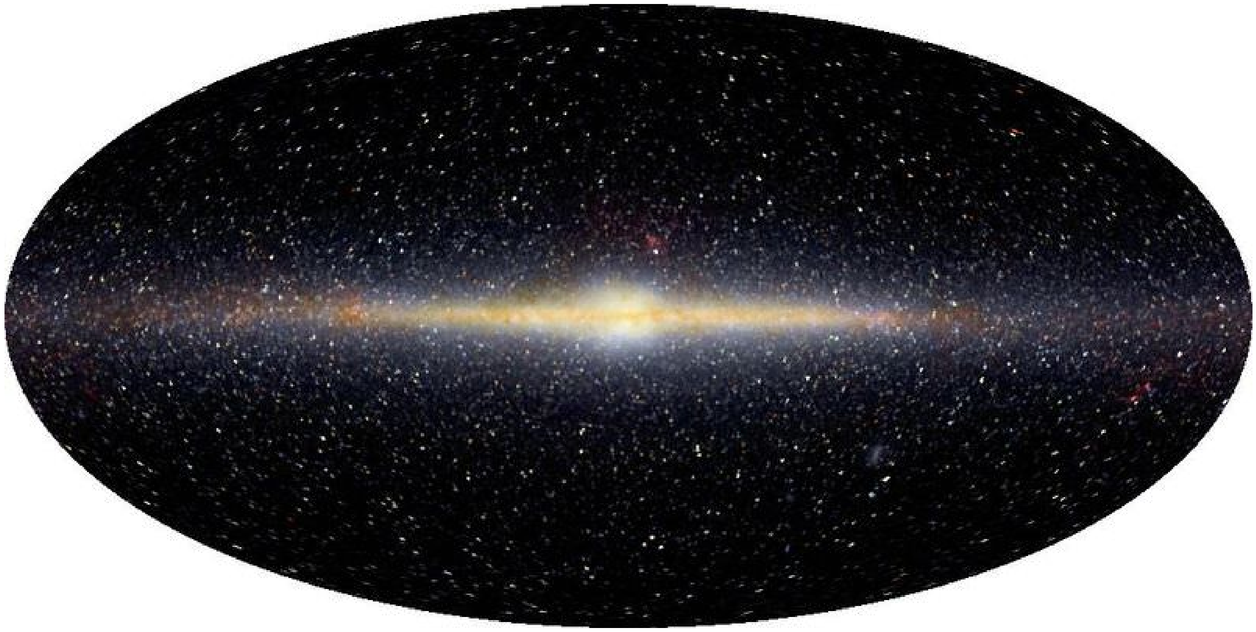


FIGURE 6.2
An infrared image of the Milky Way shows the long thin line of stars and the central bulge typical of spiral galaxies.

is instead shaped like a bar. The bar might be as long as 27,000 light-years long. The disk and bulge are surrounded by a faint, spherical halo, which also contains old stars and globular clusters. Astronomers have discovered that there is a gigantic black hole at the center of the galaxy.

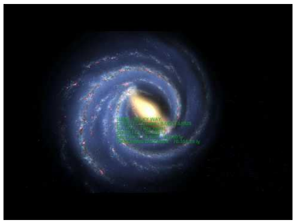
The Milky Way Galaxy is a big place. If our solar system were the size of your fist, the Galaxy's disk would still be wider than the entire United States!

Where We Are

Our solar system, including the Sun, Earth, and all the other planets, is within one of the spiral arms in the disk of the Milky Way Galaxy. Most of the stars we see in the sky are relatively nearby stars that are also in this spiral arm. We are about 26,000 light-years from the center of the galaxy, a little more than halfway out from the center of the galaxy to the edge.

Just as Earth orbits the Sun, the Sun and solar system orbit the center of the Galaxy. One orbit of the solar system takes about 225 to 250 million years. The solar system has orbited 20 to 25 times since it formed 4.6 billion years ago. Astronomers have recently discovered that at the center of the Milky Way, and most other galaxies, is a supermassive black hole, although a black hole cannot be seen.

This video describes the solar system in which we live. It is located in an outer edge of the Milky Way galaxy, which spans 100,000 light years.



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The Universe contains many billions of stars and there are many billions of galaxies. Our home, the Milky Way galaxy, is only one.

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Summary

- We view the Milky Way Galaxy from within so it looks like a river of stars.
- From outside the galaxy, the Milky Way would appear as a spiral.
- A supermassive black hole resides at the center of the galaxy, just like within most other galaxies.

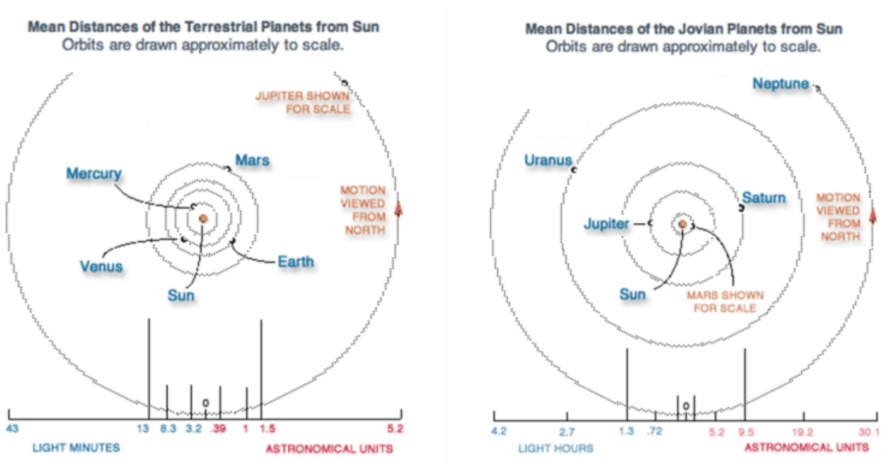
Review

1. Why do astronomers think that the Milky Way is a spiral galaxy?
2. Where is Earth within the Milky Way Galaxy?
3. What are some of the features found within the Milky Way Galaxy?

6.2 Planets of the Solar System

Learning Objectives

- Define astronomical unit.
- Describe the solar system's eight planets.



Can humans take a field trip through the solar system?

A field trip through the solar system would take a long time. It took 12 years for the Voyager spacecraft to get from Earth to Neptune. If a human was on board, he or she would probably want to come back! Fortunately, unmanned spacecrafts can send back images of far distant places in the solar system.

Solar System Objects

Astronomers now recognize eight planets (Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune), five dwarf planets (Ceres, Pluto, Makemake, Haumea, and Eris), more than 150 moons, and many, many asteroids and other small objects (**Figure** 6.3). These objects move in regular and predictable paths around the Sun.

Planet Sizes

The Sun is just an average star compared to other stars. But it is by far the largest object in the solar system. The Sun is more than 500 times the mass of everything else in the solar system combined! Listed below is data on the sizes of the Sun and planets relative to Earth (**Table** 6.1).

TABLE 6.1: Sizes of Solar System Objects Relative to Earth

Object	Mass (relative to Earth)	Diameter (relative to Earth)
Sun	333,000	109.2
Mercury	0.06	0.39
Venus	0.82	0.95

TABLE 6.1: (continued)

Object	Mass (relative to Earth)	Diameter (relative to Earth)
Earth	1.00	1.00
Mars	0.11	0.53
Jupiter	317.8	11.21
Saturn	95.2	9.41
Uranus	14.6	3.98
Neptune	17.2	3.81

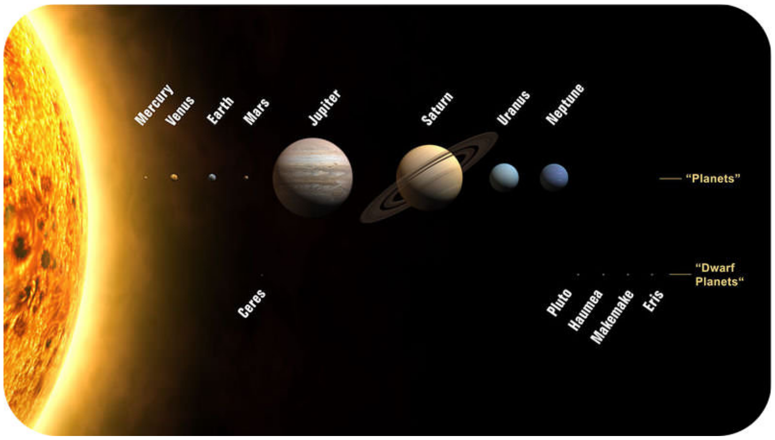


FIGURE 6.3
Relative sizes of the Sun, planets, and dwarf planets and their positions relative to each other are to scale. The relative distances are not to scale.

Distances in the Solar System

Distances in the solar system are often measured in **astronomical units** (AU). One astronomical unit is defined as the distance from Earth to the Sun. 1 AU equals about 150 million km (93 million miles). Listed below is the distance from the Sun to each planet in AU (**Table** 6.2). The table shows how long it takes each planet to spin once on its axis. It also shows how long it takes each planet to complete an orbit. Notice how slowly Venus rotates! A day on Venus is actually longer than a year on Venus!

TABLE 6.2: Distances to the Planets and Properties of Orbits Relative to Earth's Orbit

Planet	Average Distance from Sun (AU)	Length of Day (in Earth days)	Length of Year (in Earth years)
Mercury	0.39	56.84	0.24
Venus	0.72	243.02	0.62
Earth	1.00	1.00	1.00
Mars	1.52	1.03	1.88
Jupiter	5.20	0.41	11.86
Saturn	9.54	0.43	29.46
Uranus	19.22	0.72	84.01
Neptune	30.06	0.67	164.8

The Size and Shape of Orbits

Figure 6.4 shows the relative sizes of the orbits of the planets, asteroid belt, and Kuiper belt. In general, the farther away from the Sun, the greater the distance from one planet's orbit to the next. The orbits of the planets are not circular but slightly elliptical (**Figure** 6.4).

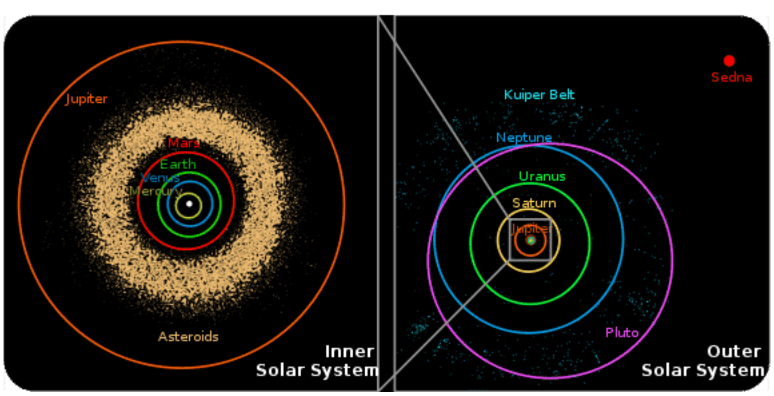


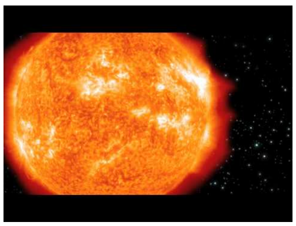
FIGURE 6.4
The relative sizes of the orbits of planets in the solar system. The inner solar system and asteroid belt is on the upper left. The upper right shows the outer planets and the Kuiper belt.

Review

1. What are the names of the planets and dwarf planets?
2. Where are the most massive planets? Where are the least massive planets?
3. What is an astronomical unit? Why is this unit used to measure distances in the solar system?

Explore More

Use the resource below to answer the questions that follow.



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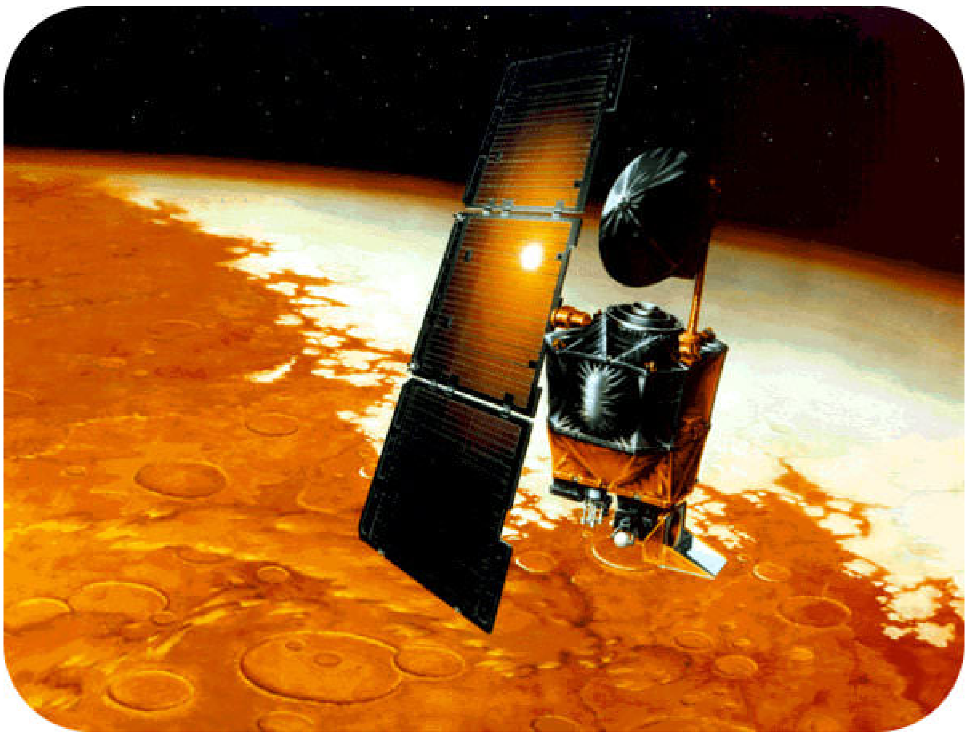
1. What did early astronomers believe about planet Earth?
2. How many planets did early astronomers know about?
3. What did Kepler discover?
4. How did our solar system form?
5. How many planets are in the solar system?
6. What is the Kuiper belt?
7. What is the Oort cloud?
8. What is found in the Oort cloud?
9. What is the outer boundary of the solar system?
10. Why are scientists interested in the other plants?

6.3 Inner versus Outer Planets

Learning Objectives

- Compare and contrast the inner and outer planets.



What's better than a field trip?

All of the inner planets are orbited by man-made satellites. Jupiter and Saturn have man-made satellites too. We can see what the planets look like from the photos they take. The satellites also carry instruments that collect a lot of important data. This is better than taking a field trip to such hostile places. You can learn a lot while sitting your own, very comfortable planet!

The Inner Planets

The four planets closest to the Sun—Mercury, Venus, Earth, and Mars—are the **inner planets** or **terrestrial planets** (**Figure** 6.5). They are similar to Earth. All are solid, dense, and rocky. None of the inner planets has rings. Compared to the outer planets, the inner planets are small. They have shorter orbits around the Sun and they spin more slowly. Venus spins backward and spins the slowest of all the planets.

All of the inner planets were geologically active at one time. They are all made of cooled igneous rock with inner iron cores. Earth has one big, round moon, while Mars has two very small, irregular moons. Mercury and Venus do not have moons.

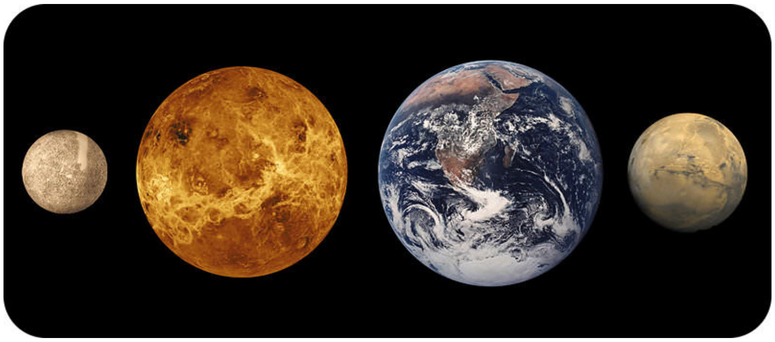


FIGURE 6.5
This composite shows the relative sizes of the four inner planets. From left to right, they are Mercury, Venus, Earth, and Mars.

The Outer Planets

Jupiter, Saturn, Uranus, and Neptune are the **outer planets** of our solar system. These are the four planets farthest from the Sun. The outer planets are much larger than the inner planets. Since they are mostly made of gases, they are also called **gas giants**. Pictured below are the relative sizes of the outer planets and the Sun (**Figure** 6.6)

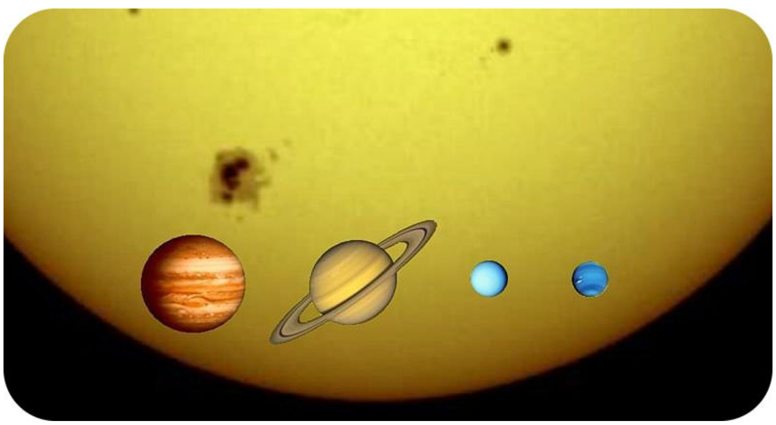


FIGURE 6.6
This image shows the four outer planets and the Sun, with sizes to scale. From left to right, the outer planets are Jupiter, Saturn, Uranus, and Neptune.

The gas giants are mostly made of hydrogen and helium. These are the same elements that make up most of the Sun. Astronomers think that most of the nebula was hydrogen and helium. The inner planets lost these very light gases. Their gravity was too low to keep them, and they floated away into space. The Sun and the outer planets had enough gravity to keep the hydrogen and helium.

All of the outer planets have numerous moons. They also have **planetary rings** made of dust and other small particles. Only the rings of Saturn can be easily seen from Earth.

Summary

- The four inner planets have slower orbits, slower spin, no rings, and they are made of rock and metal.
- The four outer planets have faster orbits and spins, a composition of gases and liquids, numerous moons, and rings.
- The outer planets are made of hydrogen and helium, so they are called gas giants.

Review

1. Describe the characteristics of the four inner planets.
2. Describe the characteristics of the four outer planets.
3. Why are the inner and outer planets so different from each other?

6.4 Moon

Learning Objectives

- Describe the characteristics of Earth's Moon.

Would you like to go on this field trip?

The most amazing "field trips" in human history took place in the Apollo program. Between 1969 and 1972, six manned spaceships landed on the Moon. Human astronauts walked on the Moon. They brought back soil and rock samples. No human has visited Earth's satellite since 1972. There is talk of someday returning, but there are no concrete plans.

Earth's Moon

The Moon is Earth's only natural satellite. The Moon is about one-fourth the size of Earth, 3,476 kilometers in diameter. Gravity on the Moon is only one-sixth as strong as it is on Earth. If you weigh 120 pounds on Earth, you would only weigh 20 pounds on the Moon. You can jump six times as high on the Moon as you can on Earth. The Moon makes no light of its own. Like every other body in the solar system, it only reflects light from the Sun.

Orbit

The Moon rotates on its axis once for every orbit it makes around Earth. What does this mean? This means that the same side of the Moon always faces Earth. The side of the Moon that always faces Earth is called the near side. The side of the Moon that always faces away from Earth is called the far side. From Earth, people have only seen the Moon's near side. The far side has only been seen by spacecraft and Apollo astronauts.

Atmosphere

The Moon has no atmosphere. With no atmosphere, the Moon is not protected from extreme temperatures. The average surface temperature during the day is approximately 107°C (225°F). Daytime temperatures can reach as high as 123°C (253°F). At night, the average temperature drops to -153°C (-243°F). The lowest temperatures measured are as low as -233°C (-397°F).

Lunar Surface

We all know what the Moon looks like. It's always looked the same during our lifetime. In fact, the Moon has looked the same to every person who has looked up at it for all time. Even the dinosaurs, trilobites, or cyanobacteria, should they have looked up at it, would have seen more-or-less the same thing. This is not true of Earth. Natural processes continually alter Earth's surface. Without these processes, would Earth's surface resemble the Moon's? The Moon does have more craters than it did in the long distant past, of course.

Even though we can't see it from Earth, the Moon has changed recently too. Astronauts' footprints are now on the Moon. They will remain unchanged for thousands of years, because there is no wind, rain, or living thing to disturb them. A falling meteorite could destroy them. Tiny micrometeorites bombard the Moon's surface and smooth it over time too.

Craters

The landscape of the Moon—its surface features—is very different from Earth. The lunar landscape is covered by **craters** caused by meteoroid impacts (**Figure** 6.7). (**Lunar** means relating to the Moon.) The craters are bowl-shaped basins on the Moon's surface. Because the Moon has no water, wind, or weather, the craters remain unchanged.

The Moon's coldest temperatures are found deep in the craters. The coldest craters are at the south pole on the Moon's far side. The Sun never shines on the bottoms of the deepest craters. These temperatures are amongst the coldest in our entire solar system.

FIGURE 6.7

Craters, like the one shown in this image, are found on the surface of the Moon.

Maria

When you look at the Moon from Earth, you notice dark and light areas. The **maria** are dark, solid, flat areas of lava (mostly basalt). Maria covers around 16% of the Moon's surface, mostly on the near side. The maria formed about 3.0 to 4.0 billion years ago, when the Moon was continually bombarded by meteoroids (**Figure** 6.8). Large meteorites broke through the Moon's newly formed surface. This eventually caused magma to flow out and fill the craters. Scientists estimate volcanic activity on the Moon ended about 1.2 billion years ago.

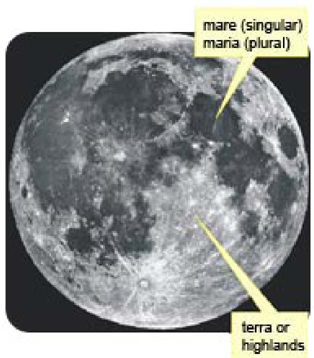


FIGURE 6.8
Maria (the dark areas) and terrae (the light areas) cover the Moon.

Terrae

The lighter parts on the Moon are called **terrae**, or highlands (**Figure** 6.8). They are higher than the maria and include several high mountain ranges. The rock that makes up the highlands is mostly composed of feldspar, which is lighter in color and crystallized more slowly than the maria. The rock looks light because it reflects more of the Sun's light.

The figure below shows the near and far sides of the Moon (**Figure** 6.9). They are different!

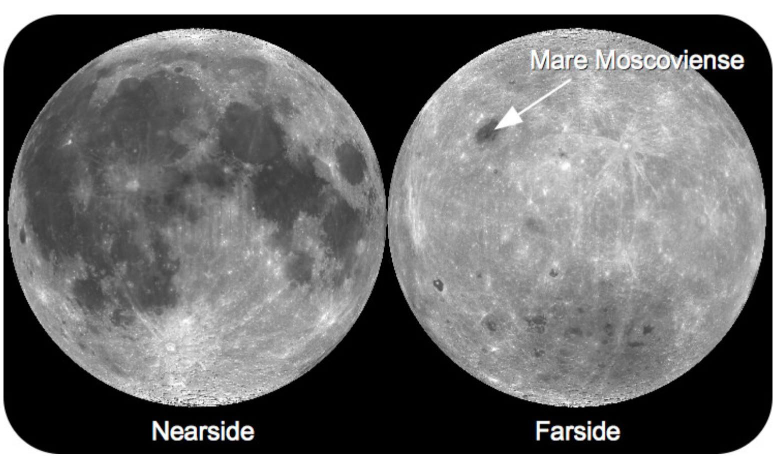


FIGURE 6.9
The Mare Moscoviense is one of the few maria, or dark, flat areas, on the far side.

The rocks of the terrae formed while the lunar magma ocean cooled just after the Moon formed. The maria formed later.

Water

There are no lakes, rivers, or even small puddles anywhere to be found on the Moon's surface. So there is no running water and no atmosphere. This means that there is no erosion. Natural processes continually alter Earth's surface. Without these processes, our planet's surface would be covered with meteorite craters just like the Moon. Many moons in our solar system have cratered surfaces.

NASA scientists have discovered a large number of water molecules mixed in with lunar dirt. There is also surface water ice in some of the frigid places that are always in shadow. Even though there is a very small amount of water, there is no atmosphere. Temperatures are extreme. So it comes as no surprise that there has not been evidence of life on the Moon.

Lunar Interior

Like Earth, the Moon has a distinct crust, mantle, and core. The crust is composed of igneous rock. This rock is rich in the elements oxygen, silicon, magnesium, and aluminum. On the near side, the Moon's crust is about 30 kilometers thick. On the far side, the crust is about 100 kilometers thick. The mantle is made of rock like Earth's upper mantle. The Moon has a small metallic core, perhaps 300 to 500 kilometers in diameter. The composition of the core is probably mostly iron with some sulfur and nickel. We learned this both from the rock samples gathered by astronauts and from spacecraft sent to the Moon.

Exploration

Humans have walked on only two planetary bodies: Earth and the Moon. The footprints the men left behind are the first signs of life ever on the Moon. Scientists learned a great deal about the Moon from the Apollo missions. The samples that were brought back have been studied in laboratories. We know an incredible amount about the Moon because of these samples. Having these rocks radically changed our thinking about the Moon.

The Moon is easily seen from Earth. Early astronomers used telescopes to study and map its surface. The Moon has also seen a great number of satellites, rovers, and orbiters. After all, it is relatively easy to get spacecraft to the satellite. Also, before humans could be safely sent to the Moon, many studies and experiments had to be completed.

Summary

- The Moon revolves around Earth as they orbit the Sun. The same side of Moon always faces Earth.
- The lunar surface has dark basalt maria. The light highlands are called terrae.
- The Moon has a crust, mantle, and core.
- The Moon has no atmosphere and only a very tiny amount of water.

Review

1. Why do we only see one side of the Moon from Earth?
2. What are the Moon's terrae like in structure and rock type?
3. How did the maria form?
4. In what form is water found on the Moon? In what form is it not found on the Moon?

Explore More

Use the resource below to answer the questions that follow.

MEDIA

Click image to the left or use the URL below.

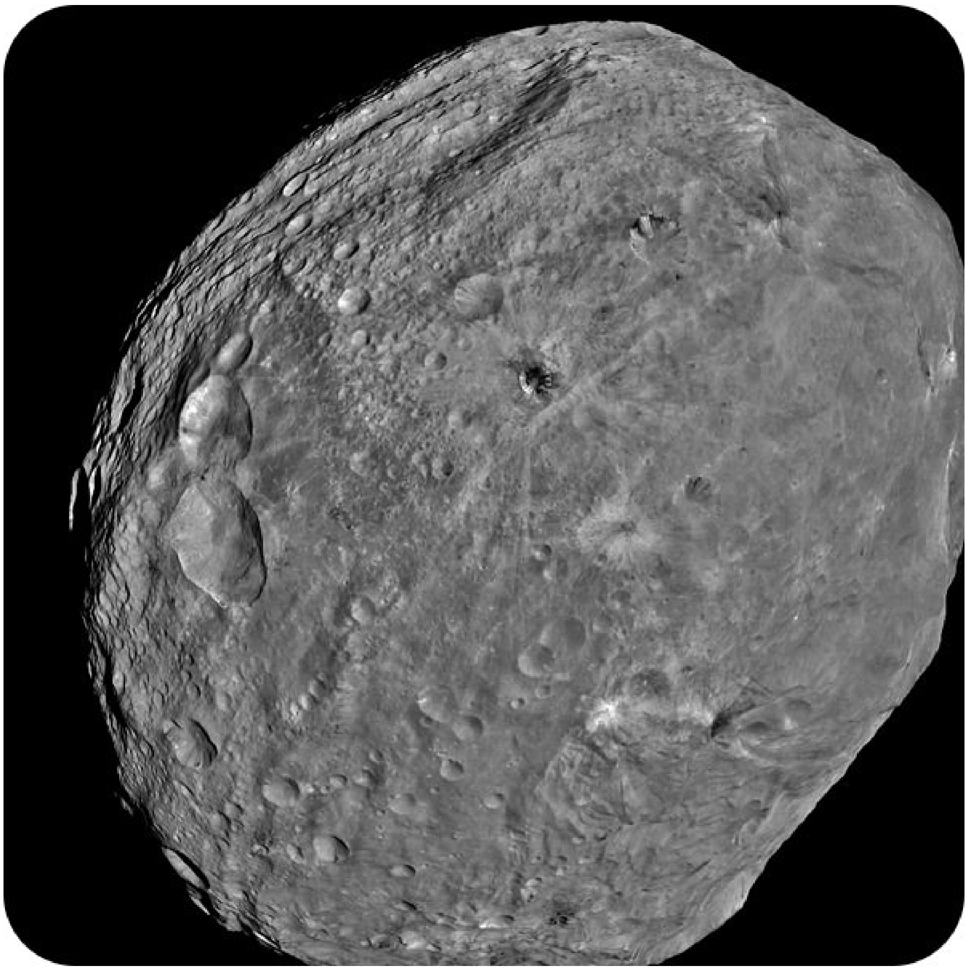
URL: http://www.ck12.org/flx/render/embeddedobject/10265

1. What is the Moon?
2. How far is the Moon from Earth? Where will it be relative to its current location 100 years from now?
3. What did Galileo prove about the Moon? How did he do that?
4. Where did the Moon come from?
5. What is the Moon like relative to Earth?
6. Why do we always see the same side of the Moon?
7. Describe the Moon's structure.
8. What are maria?
9. What are terrae?
10. What created the craters on the Moon?
11. If a small meteor went toward the Moon's surface and one the same size went toward Earth's surface, which would actually reach the surface and why?
12. If there is water on the Moon, how did it get there and where is it?
13. What is an eclipse?
14. What is a lunar eclipse?
15. What is a total solar eclipse?
16. Why is the Moon unique?
17. Who was the first person on the Moon?

6.5 Asteroids

Learning Objectives

- Describe asteroids and the asteroid belt.
- Explain what effects asteroids may have on Earth and other planets.



Is this rock an asteroid?

This rock is somewhat round. It is called asteroid Vesta, but it may actually be a protoplanet: too round to be an asteroid, not round enough to be a dwarf planet. This image was taken of Vesta as a spacecraft orbited it for a year. Scientists are interested in asteroids for many reasons. They are remnants from the early solar system. Asteroids sometimes cause mass extinctions.

Asteroids

After the Sun and planets formed, there was some material left over. These small chunks didn't get close enough to a large body to be pulled in by its gravity. They now inhabit the solar system as asteroids and comets.

Asteroids (**Figure** 6.10) are very small, irregularly shaped, rocky bodies. Asteroids orbit the Sun, but they are more like giant rocks than planets. Since they are small, they have features that are different from planets. Asteroids do not have enough gravity to become round. They are too small to have an atmosphere. With no internal heat, they are not geologically active.

An asteroid can only change due to a collision. A collision may cause the asteroid to break up. It may create craters on the asteroid's surface. An asteroid may strike a planet if it comes near enough to be pulled in by its gravity.

FIGURE 6.10
Asteroid Ida with its tiny moon Dactyl. The asteroid's mean radius is 15.7 km.

The Asteroid Belt

Hundreds of thousands of asteroids have been found in our solar system. They are still being discovered at a rate of about 5,000 new asteroids per month! The majority are located in between the orbits of Mars and Jupiter. This region is called the **asteroid belt** (**Figure** 6.11). There are many thousands of asteroids in the asteroid belt. Still, their total mass adds up to only about four percent of Earth's Moon.

Asteroids formed at the same time as the rest of the solar system. Although there are many in the asteroid belt, they were never able to form into a planet. Jupiter's gravity kept them apart.

Near-Earth Asteroids

Near-Earth asteroids have orbits that cross Earth's orbit. This means that they can collide with Earth. There are over 4,500 known near-Earth asteroids. Small asteroids do sometimes collide with Earth. An asteroid about 5-10 m in diameter hits about once per year. Five hundred to a thousand of the known near-Earth asteroids are much bigger. They are over 1 kilometer in diameter. When large asteroids hit Earth in the past, many organisms died. At times, many species became extinct in a mass extinction. Astronomers keep looking for near-Earth asteroids. They hope to predict a possible collision early so they can to try to stop it.

Asteroid Missions

Scientists are very interested in asteroids. Most are composed of material that has not changed since early in the solar system. Scientists can learn a lot from them about how the solar system formed. Asteroids may be important for space travel. They could be mined for rare minerals or for construction projects in space.

Scientists have sent spacecrafts to study asteroids. In 1997, the NEAR Shoemaker probe orbited the asteroid 433 Eros. The craft finally landed on its surface in 2001. The Japanese Hayabusa probe returned to Earth with samples of a small near-Earth asteroid in 2010. The U.S. Dawn mission spent a year in orbit around Vesta ending in August 2012.

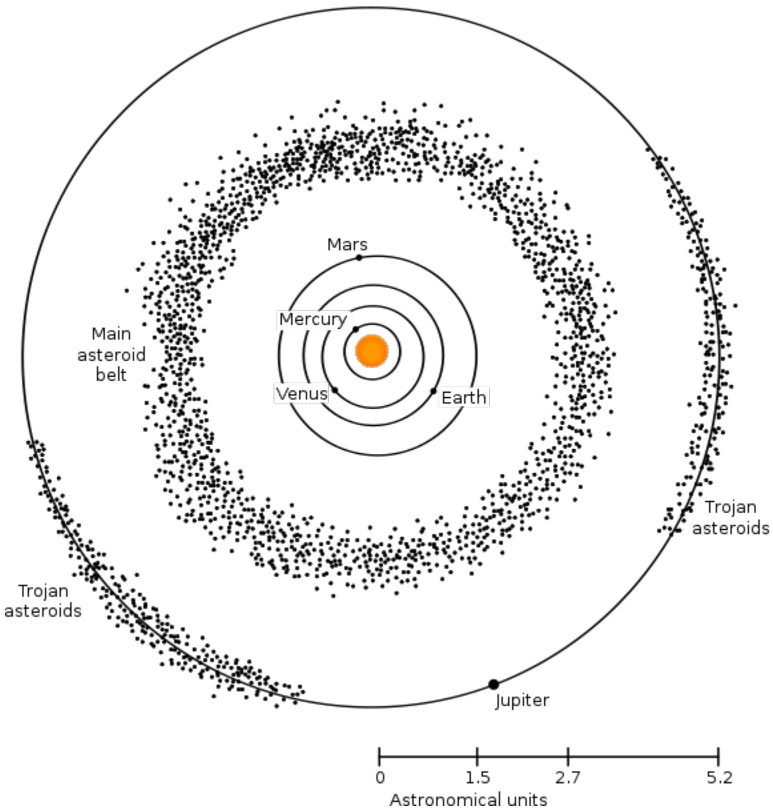
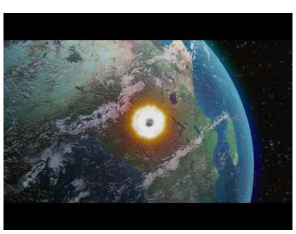


FIGURE 6.11
The asteroid belt is between Mars and Jupiter.

KQED: Asteroid Hunters

Thousands of objects, including comets and asteroids, are zooming around our solar system; some could be on a collision course with Earth. QUEST explores how these Near Earth Objects are being tracked and what scientists are saying should be done to prevent a deadly impact.



MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/114950

Summary

- Asteroids are small rocky bodies that orbit the Sun.
- Most asteroids reside in the asteroid belt, between Mars and Jupiter.
- Near-Earth asteroids are the ones most likely to strike Earth.

Review

1. What is the reason there is a belt of asteroids between Mars and Jupiter?
2. Why do scientists look for asteroids that might strike our planet?

3. What do scientists learn from missions to asteroids?

Explore More

Use the resource below to answer the questions that follow.

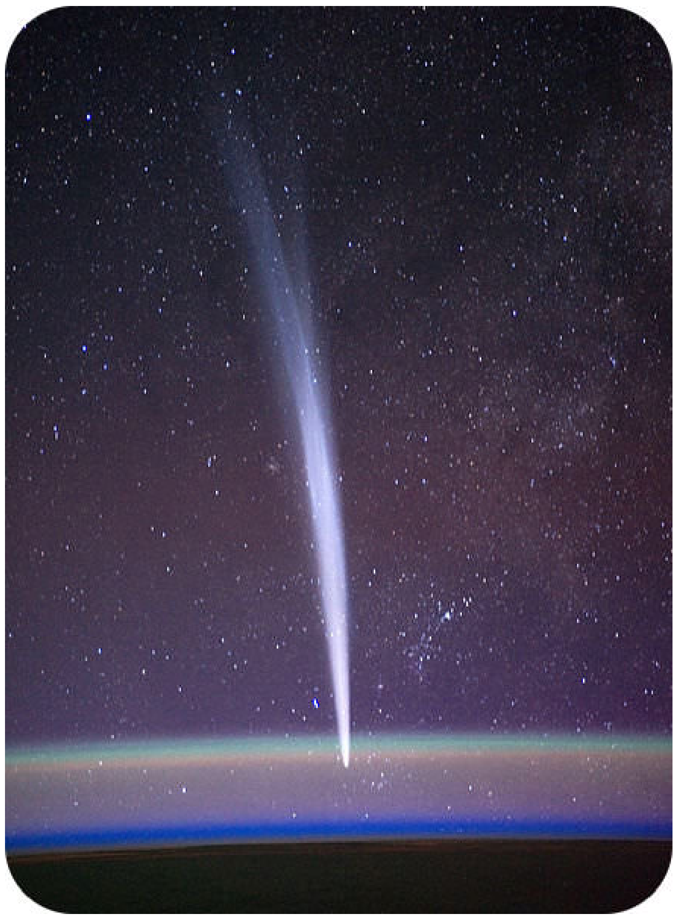
MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/58896

1. What percentage of near-Earth asteroids have been identified? What size?
2. Why is this identification important?
3. How many asteroids larger than 100 m are there, according to the new model?
4. How many asteroids larger than 100 m still need to be found?
5. Why is the infrared telescope better than a visible telescope at identifying near-Earth asteroids?

6.6 Comets

Learning Objectives

- Describe the characteristics of comets.
- Explain where comets come from.



Is this comet going to hit?

Astronauts on board the International Space Station witness incredible things. This photo of Comet Lovejoy was taken in December 2011. Although it looks like its going to strike Earth, it was not even visible from our planet by the naked eye. The comet is now traveling far out into space.

Comets

Comets are small, icy objects that have very elliptical orbits around the Sun. Their orbits carry them from the outer solar system to the inner solar system, close to the Sun. Early in Earth's history, comets may have brought water and other substances to Earth during collisions.

Comet tails form as the comet flies close to the Sun and the outer layers of ice melt and form a glowing coma. Particles streaming from the Sun push this gas and dust into a long tail. The tail always points away from the Sun. The coma is bright because it reflects light from the Sun (**Figure** 6.12). Comets appear for only a short time when they are near the Sun. They seem to disappear as they move back to the outer solar system.

FIGURE 6.12
Comet Hale-Bopp, also called the Great Comet of 1997. The comet has two visible tails: a bright, curved dust tail and a fainter, straight tail of ions (charged atoms) pointing directly away from the Sun.

The time between one appearance of a comet and the next is called the comet's period. Halley's comet, with a period of 75 years, will next be seen in 2061. The first mention of the comet in historical records may go back as much as two millennia.

Where Comets Come From

Short-period comets have periods of about 200 years or less. These comets come from a region beyond the orbit of Neptune called the **Kuiper belt** (pronounced "KI-per"). The Kuiper belt also contains asteroids and at least two dwarf planets.

Comets with periods as long as thousands or even millions of years come from a very distant region of the solar system. This region is called the Oort cloud. It is about 50,000-100,000 AU from the Sun (50,000-100,000 times the distance from the Sun to Earth).

Summary

- Comets are icy objects that have very elliptical orbits around the Sun.
- Comet tails form as ice vaporizes and glows in the Sun's light.
- Short-period comets come from the Kuiper belt beyond Neptune, and long-period comets come from the Oort cloud far out away from the Sun.

Review

1. Why do comets only have tails when they are near the Sun?
2. Where is the Kuiper belt, and what is found in it?
3. Why do most comets appear in regular, predictable time periods?
4. Where do long-period comets come from?

6.7 Meteors

Learning Objectives

- Define and describe meteors, meteoroids, and meteorites.
- Explain what makes a meteor shower.

Is this a comet?

When a meteor shoots through the atmosphere, it burns and glows. When we look up and see one, we call it a shooting star. In this image, the meteor looks like a comet. No need to go anywhere to see this. Just try to catch one of these meteor showers: the Perseids in mid-August or the Geminids in mid-December. Look for information on the dates and whether the Moon will not be lighting up the sky.

Meteors

If you look at the sky on a dark night, you may see a **meteor** (**Figure** 6.13). A meteor forms a streak of light across the sky. People call them shooting stars because that's what they look like. But meteors are not stars at all. The light you see comes from a small piece of matter burning up as it flies through Earth's atmosphere.

Meteoroids

Before these small pieces of matter enter Earth's atmosphere, they are called **meteoroids**. Meteoroids are as large as boulders or as small as tiny sand grains. Larger objects are called asteroids; smaller objects are interplanetary dust.

FIGURE 6.13
Meteors burning up as they fall through Earth's atmosphere.

Meteoroids sometimes cluster together in long trails. They are the debris left behind by comets. When Earth passes through a comet trail, there is a **meteor shower**. During a meteor shower, there are many more meteors than normal for a night or two.

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/58898

Meteorites

A meteoroid is dragged toward Earth by gravity and enters the atmosphere. Friction with the atmosphere heats the object quickly, so it starts to vaporize. As it flies through the atmosphere, it leaves a trail of glowing gases. The object is now a meteor. Most meteors vaporize in the atmosphere. They never reach Earth's surface. Large meteoroids may not burn up entirely in the atmosphere. A small core may remain and hit Earth's surface. This is called a **meteorite**.

Meteorites provide clues about our solar system. Many were formed in the early solar system (**Figure** 6.14). Some are from asteroids that have split apart. A few are rocks from nearby bodies like Mars. For this to happen, an asteroid smashed into Mars and sent up debris. A bit of the debris entered Earth's atmosphere as a meteor.

FIGURE 6.14
The Mars Rover, Opportunity, found a metal meteorite on the Red Planet.

Summary

- A meteor that strikes Earth's surface is a meteorite.
- Many meteorites are remnants of the earliest material that formed in the solar system.
- Shooting stars are meteors that burn up in Earth's atmosphere.

Review

1. Compare and contrast meteoroid, meteor, and meteorite.
2. What are meteorites important to scientists?
3. Why are meteors known as shooting stars?

6.8 Dwarf Planets

Learning Objectives

- Describe the characteristics of dwarf planets.
- Compare and contrast planets and dwarf planets.

What is, and what is not, a planet?

Pluto just didn't fit the criteria for a planet, so it was placed in a new category with others of its kind, dwarf planets. So what is a planet, and what is Pluto?

What is a Planet?

In 2006, the International Astronomical Union decided that there were too many questions surrounding what could be called a planet, and so refined the definition of a planet.

According to the new definition, a planet must:

- Orbit a star.
- Be big enough that its own gravity causes it to be shaped as a sphere.
- Be small enough that it isn't a star itself.
- Have cleared the area of its orbit of smaller objects.

Dwarf Planets

The **dwarf planets** of our solar system are exciting proof of how much we are learning about our solar system. With the discovery of many new objects in our solar system, astronomers refined the definition of a dwarf planet in 2006.

According to the IAU, a dwarf planet must:

- Orbit a star.
- Have enough mass to be nearly spherical.
- Not have cleared the area around its orbit of smaller objects.
- Not be a moon.

So dwarf planets are like planets except for one thing. They have not cleared their orbits of smaller objects. They do not have enough gravity to do this. There are five recognized dwarf planets in the solar system: Ceres, Pluto, Makemake, Haumea, and Eris.

Pluto

The reclassification of Pluto to the new category dwarf planet stirred up a great deal of controversy. How the classification of Pluto has evolved is an interesting story in science.

From the time it was discovered in 1930 until the early 2000s, Pluto was considered the ninth planet. When astronomers first located Pluto, the telescopes were not as good. Pluto and its moon, Charon, were seen as one much larger object (**Figure** 6.15). With better telescopes, astronomers realized that Pluto was much smaller than they had thought.

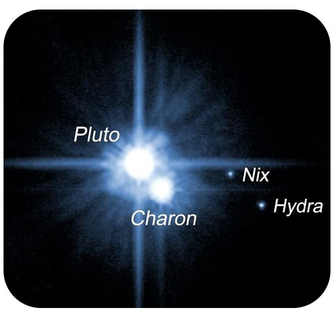


FIGURE 6.15
Pluto and its moon, Charon, are actually two objects.

Better technology also allowed astronomers to discover many smaller objects like Pluto that orbit the Sun. One of them, Eris, discovered in 2005, is even larger than Pluto.

Pluto was different in other ways. The outer planets are all gas giants. Pluto is small, icy, and rocky. Pluto has a diameter of about 2,400 km. It has only about one-fifth the mass of Earth's Moon. Pluto's orbit is tilted relative to the other planets. It's orbit is shaped like a long, narrow ellipse. Pluto's orbit sometimes even passes inside Neptune's orbit.

Pluto's orbit is in the Kuiper belt. With more than 200 million Kuiper belt objects, Pluto has failed the test of clearing other bodies out of its orbit.

From what you've read above, do you think Pluto should be called a planet? Why are people hesitant to take away Pluto's planetary status? Is Pluto a dwarf planet?

Pluto has three moons of its own. The largest, Charon, is big compared to Pluto. The Pluto-Charon system is sometimes called a double dwarf planet (**Figure** 6.15). Two smaller moons, Nix and Hydra, were discovered in 2005.

Pluto and the other dwarf planets, besides Ceres, are found orbiting out beyond Neptune.

Ceres

Ceres (**Figure** 6.16) is a rocky body that orbits the Sun. It could be an asteroid or a planet. Before 2006, Ceres was thought to be the largest asteroid. Is it an asteroid? Ceres is in the asteroid belt. But it is by far the largest object in the belt. Ceres has such high gravity that it is spherical.

Is Ceres a planet? Ceres only has about 1.3% of the mass of the Earth's Moon. Its orbit is full of other smaller bodies. Its gravity was not high enough to clear its orbit. Ceres fails the fourth criterion for being a planet. Ceres is now considered a dwarf planet, the closest to the Sun.

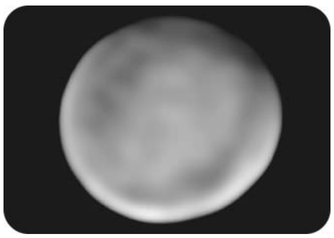


FIGURE 6.16
Ceres is a large spherical object in the asteroid belt.

Haumea

Haumea was named a dwarf planet in 2008. It is an unusual dwarf planet. The body is shaped like an oval! Haumea's longest axis is about the same as Pluto's diameter. Its shortest axis is about half as long. The body's orbit is tilted 28 degrees. Haumea is so far from the Sun that it takes 283 years to make one orbit (**Figure** 6.17).

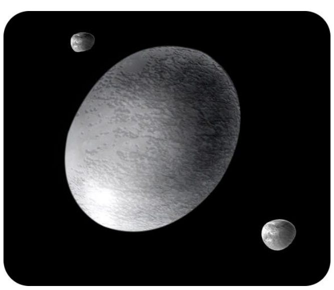


FIGURE 6.17
An artist's drawing of what Haumea and its moons might look like. The moons are drawn closer to Haumea than their actual orbits.

Haumea is the third-brightest Kuiper belt object. Haumea has two moons. Haumea's odd oval shape is probably caused by its extremely rapid rotation. It rotates in just less than 4 hours! Like other Kuiper belt objects, Haumea is covered by ice. Its density is similar to Earth's Moon, at 2.6 - 3.3 g/cm^3. This means that most of Haumea is rocky.

Haumea is part of a collisional family. This is a group of astronomical objects that formed from an impact. This family has Haumea, its two moons, and five more objects. All of these objects are thought to have formed from a collision very early in the formation of the solar system.

Makemake

Makemake is the third-largest and second-brightest dwarf planet we have discovered so far (**Figure** 6.18). Makemake is only 75 percent the size of Pluto. Its diameter is between 1300 and 1900 kilometers. The name comes from the mythology of the Eastern Islanders. Makemake was the god that created humanity. At a distance between 38.5 to 53 AU, this dwarf planet orbits the Sun in 310 years. Makemake is made of methane, ethane, and nitrogen ices.

FIGURE 6.18
Makemake is a dwarf planet.

Eris

Eris is the largest known dwarf planet in the solar system. It is 27 percent larger than Pluto.

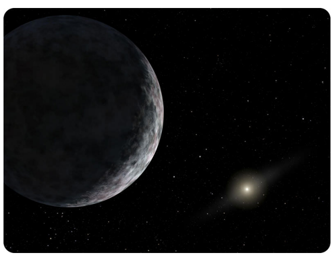


FIGURE 6.19
Eris is the largest known dwarf planet, but it's so far from the Sun that it wasn't discovered until 2005.

Like Pluto and Makemake, Eris is in the Kuiper belt. But Eris is about three times farther from the Sun than Pluto. Because of its distance, Eris was not discovered until 2005. Early on, it was thought that Eris might be the tenth planet. Its discovery helped astronomers realize that they needed a new definition of "planet." Eris has a small moon that orbits Eris once about every 16 days.

Astronomers know there may be other dwarf planets far out in the solar system. Look for Quaoar, Varuna, and Orcus to possibly be added to the list of dwarf planets in the future. We still have a lot to discover and explore!

Summary

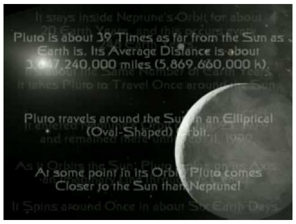
- There are currently five dwarf planets in our solar system: Pluto, Eris, Haumea, Makemake, and Ceres.
- Most dwarf planets are similar to planets, except that they haven't cleared their space of debris.
- Pluto was thought to be larger than it is because its large moon made the dwarf planet look bigger than it is.

Review

1. Why isn't Pluto still a planet? Why do some people still insist that it is?
2. Why did people think that Pluto was a planet in the decades after its discovery?
3. What are the characteristics of the other dwarf planets that have been recognized?

Explore More

Use the resource below to answer the questions that follow.



MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/1456

1. Who discovered Pluto? When?
2. When was Pluto demoted to a dwarf planet?
3. What is Pluto's diameter compared to Earth's?
4. Why don't scientists know much about Pluto?
5. What is odd about Pluto's orbit?
6. What are the names of some of Pluto's moons?
7. Why is the Pluto-Charon system different from the Earth-Moon system? (In other words, why is Earth a planet and Moon a satellite, but Pluto-Charon are more like a double planet or double dwarf planet?)
8. What spacecraft is on its way to Pluto? When will it get there?

6.9 Glossary

Apollo Program, NASA's program to land people on the moon. Apollo missions 11-17 landed on the moon, except Apollo 13 which had malfunctions.

asteroid belt, a region between mars and jupiter where many asteroids can be found.

asteroid, a rocky object that orbits the sun.

astronomical unit, the distance from the earth to the sun.

Ceres, a dwarf planet in the asteroid belt.

chromosphere, an irregular layer above the photosphere which has magnetic fields.

comet, a ball of ice and dust and frozen gas which orbits the sun. as it nears the sun, the gas can boil and make long tails visible without a telescope.

convective zone, the part of the sun where the heat is moved away from the core by convection.

core, the center of the sun where nuclear fusion is taking place. also, the center of a planet.

corona, the part of the sun's atmosphere that goes past the photosphere and can only seen during an eclipse. it is very hot and often has solar flares

coronal hole, a hole in the sun's corona where the temperature is lower and solar winds originate.

dwarf planet, a celestial body that is round due to gravity, but has not cleared out its orbital path.

dwarf planet, a large object that is round due to its own gravity which has not cleared out its orbital path.

ellipse (elliptical), the oval shape of orbits in the solar system.

Eris, a dwarf planet found in the Kuiper belt.

exoplanets, see extrasolar planet

extrasolar planets, planets that are outside of our solar system and orbit other stars.

flare (solar), see prominence

gas giants, a large planet with a thick atmosphere and no apparent solid surface. one of the four outer planets.

Haumea, a dwarf planet in the Kuiper belt.

igneous rock, a rock formed by cooling melted magma.

Kuiper Belt, a ring shaped region outside of Neptune's orbit where many object have been found including dozens of dwarf planets. Pluto is found in this region of space.

Makmake, a dwarf planet found in the Kuiper belt

maria, the low and relatively flat, darker parts of the moon's surface, from the latin word which means oceans

meteor, a rock that has entered the earth's atmosphere but has not yet struck the ground and may glow as it burns up in the atmosphere - it may not finish burning up before it hits the ground or leaves the atmosphere.

meteorite, a meteor after it has hit the ground.

meteoroid, a rocky object from a dust size to as large a s a dwarf planet which still orbits the sun.

orbit, the path of an object going around another object due to gravity.

photosphere, the part of the sun's we see - the apparent surface of the sun.

planet, a celestial body that has cleared out its orbital path of other objects and is round due to gravity

planet, a large object that orbits the sun, which is round due to its own gravity and has cleared out its orbital path of other objects which orbit the sun. it may have moons which orbit itself.

plasma, a very hot gas that glows from heat.

Pluto, a Dwarf plant about 50 AU from the sun. is one of two binary planets Pluto/Charon a dwarf planet binary system. Pluto is found in the Kuiper belt.

prominence, a cloud of plasma from the sun's surface held up by magnetic life of force.

prominence, a large eruption of plasma on the sun's surface, often called a solar flare.

radiative zone, the part of the sun where the heat is moved away from the core by radiation (escaping light)

solar system, the sun (or any star) and the planets and other objects that orbit it including comets, asteroids dust and dwarf planets.

solar eclipse, when the sun is blocked by the moon as seen from earth.

sunspots, parts of the sun's surface that are cooler (~5000^o compare to the normal 11,000^o) compared to the rest of the sun's surface.

terrae, a high or mountainous region of the moon, these are the brighter parts of the moon.

terrestrial planet, a rocky planet, one of the four inner planets.

Summary

This Concept deals with some Earth basics. Earth is a planet and has the characteristics of a planet. Like other planets, it is nearly round. This is because it has enough mass for its gravity to pull material into a round shape. Earth's gravity has also pulled in small objects, like asteroids. So the planet's orbit is cleared. Earth rotates on its axis and revolves around its star. As a result of its rotation, Earth has a day-night cycle. The tilt of its axis creates the seasons. Earth has layers from crust to mantle to core. The core is divided into a liquid outer core and a solid inner core. The liquid outer core has convection, which generates the magnetic field. The mantle is solid rock. The crust has two major types: continental and oceanic. The crust and uppermost mantle make up the lithosphere. Beneath the lithosphere is the asthenosphere. The lithosphere is brittle and will break. The asthenosphere can flow.

6.10 References

1. Courtesy of NASA/JPL-Caltech/R. Hurt (SSC). An artistic rendition of what the Milky Way Galaxy would look like from above . Public Domain
2. Courtesy of the COBE Project, DIRBE, NASA. An infrared image of the Milky Way shows the long thin line of stars and the central bulge typical of spiral galaxies. . Public Domain
3. User:Farry/Wikimedia Commons with images courtesy of NASA. The relative sizes of the Sun and planets in the Solar System . Public Domain
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6. User:Urhixidur/Wikipedia, using images from NSSDC. The relative sizes of the Sun, Jupiter, Saturn, Uranus, and Neptune . Public Domain
7. Courtesy of NASA. Craters on the surface of the moon . Public Domain
8. Courtesy of NASA. Maria and terrae cover the Moon . Public Domain
9. Courtesy of US Geological Survey/Arizona State University. The near and far side of the Moon . Public Domain
10. Courtesy of NASA/JPL, modified by Chzz. Picture of the asteroid Ida . Public Domain
11. User:Mizusumashi/Wikimedia Commons and User:Autiwa/Wikimedia Commons. Location of the asteroid belt between Mars and Jupiter . Public Domain
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13. Jared Tennant. Meteors burning up as they fall through Earth's atmosphere . CC BY 2.0
14. Courtesy of NASA/JPL/Cornell. The Mars Rover, Opportunity, found a metal meteorite on the Red Planet . Public Domain
15. Courtesy of H Weaver (JHU/APL), A Stern (SwRI), and the HST Pluto Companion Search Team. Pluto and its moon, Charon, are actually two objects . Public Domain
16. Courtesy of Dumas C et. al, NASA/JPL. Ceres is a large spherical object in the asteroid belt . Public Domain
17. Courtesy of Ann Feild (Space Telescope Science Institute), NASA. Drawing of the dwarf planet Haumea and its moons . Public Domain
18. Courtesy of Ann Feild (Space Telescope Science Institute), NASA. Drawing of the dwarf planet Makemake . Public Domain
19. Courtesy of NASA/JPL-Caltech. Drawing of the largest known dwarf planet Eris . Public Domain

CHAPTER 7 Patterns of Motion of the Earth and Moon and How it Affects the Earth ESS 1-1

Chapter Outline

INTRODUCTION

DISCIPLINARY CORE IDEA:

MS-ESS 1-1 By the end of instruction, students should be able to answer a test which asks them to: **Make and use a model of the Earth-sun-moon system to show the cyclic patterns of moon phases, eclipses and seasons.**

How well do humans know the solar system?

Humans have been exploring the solar system for centuries. Mostly we have used telescopes or simply our eyes. But the Sun, all of the planets, and many dwarf planets, asteroids and comets have been studied more closely. Spaceships have taken rovers, probes or other technologies to study these bodies. Sometimes a spacecraft just flies by to take a look. So while it's very difficult to get humans very far from Earth, our spacecraft have become our eyes. We know an incredible amount about the solar system compared with even a few decades ago. This is because of the tremendous spacecraft and the instruments they carry. In this concept, we will explore a small fraction of what scientists have learned about our solar system.

Our story continues as we figure out how to use the motion of the earth in our trip to Mars.

7.1 Lunar Phases

Can the Moon cast shadows?

Of course! A full moon is very bright. It is bright enough to cast shadows. If you are out away from city lights and the Moon is full you might cast your own Moon shadow.

The Phases of the Moon

The Moon does not produce any light of its own. It only reflects light from the Sun. The Moon has phases because it orbits around Earth. One orbit takes about 28 days. As the moon moves around Earth, different parts of it appear to be lit up by the Sun. The Moon sometimes appears fully lit and sometimes completely dark. Sometimes it is partially lit. The different appearances of the Moon are referred to as phases of the Moon (**Figure** 7.1).

A **full moon** occurs when the whole side facing Earth is lit. This happens when Earth is between the Moon and the Sun.

FIGURE 7.1
The moon's phases are a result of the moon's orbit around Earth.

About one week later, the Moon enters the quarter-moon phase. Only half of the Moon's lit surface is visible from Earth, so it appears as a half circle.

Another week later, the Moon moves between Earth and the Sun. The side of the Moon facing Earth is completely dark. This is called a **new moon**. Sometimes you can just barely make out the outline of the new moon in the sky. This is because some sunlight reflects off the Earth and hits the Moon.

One week after that, the Moon is in another quarter-moon phase. Finally, in one more week, the Moon is back to full.

Before and after the quarter-moon phases are the gibbous and crescent phases. During the **crescent** moon phase, the Moon is less than half lit. It is seen as only a sliver or crescent shape. During the **gibbous** moon phase, the Moon is more than half lit. It is not full. The Moon undergoes a complete cycle of phases about every 29.5 days.

Summary

- The appearance of the Moon from Earth has distinct phases.
- A full moon is completely lit; a new moon is completely dark.
- A gibbous moon is more than half lit; a crescent moon is less than half lit.

Explore More

Use the resource below to answer the questions that follow.

- **Phases of the Moon** at http://www.youtube.com/watch?v=nXseTWTZlks (3:15)

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/136806

1. Why does the moon have phases?
2. What are the four main phases of the moon? How long does it take to change from one to another?

3. What is the name for a moon that is less than half full? More than half full?
4. What is the name for a moon that is getting larger? Getting smaller?
5. What causes a lunar eclipse? Why doesn't a lunar eclipse occur during each full moon?

Review

1. Describe how the Sun, Moon, and Earth are aligned during a full moon.
2. Describe how the Sun, Moon, and Earth are aligned during a new moon.
3. Draw and label pictures of the Moon in its phases.

7.2 Lunar Eclipses

Learning Objectives

- Describe lunar eclipses.

Can you see a lunar eclipse?

Again, of course! Anyone with a view of the Moon can see a lunar eclipse. The next four total lunar eclipses predicted for North America will be on April 15, 2014, October 8, 2014, April 5, 2015, and September 28, 2015.

Lunar Eclipses

Sometimes a full moon moves through Earth's shadow. This is a **lunar eclipse** (**Figure** 7.2). During a total lunar eclipse, the Moon travels completely in Earth's umbra. During a partial lunar eclipse, only a portion of the Moon enters Earth's umbra. When the Moon passes through Earth's penumbra, it is a penumbral eclipse. Since Earth's shadow is large, a lunar eclipse lasts for hours.

Partial lunar eclipses occur at least twice a year, but total lunar eclipses are less common. The Moon glows with a dull red coloring during a total lunar eclipse (**Figure** 7.3).

Summary

- During a lunar eclipse, the full moon moves through Earth's shadow.
- Earth's shadow is large so lunar eclipses last longer than solar eclipses. They cover more area too.

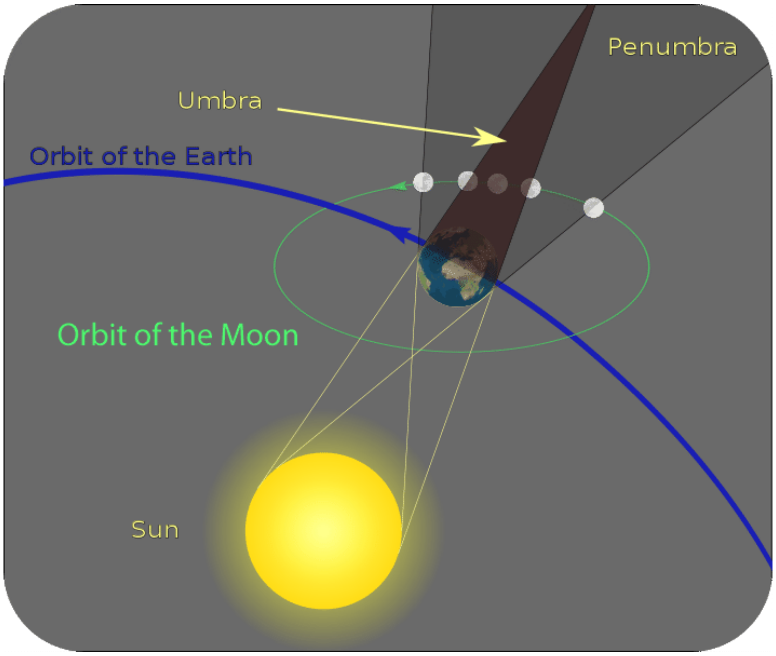


FIGURE 7.2
A lunar eclipse.

FIGURE 7.3
A lunar eclipse is shown in a series of pictures.

- The umbra is the part of the shadow in which light is completely blocked.
- The penumbra is the part of the shadow that is partially lit.

Review

1. What causes a lunar eclipse?
2. Why are you more likely to see a lunar eclipse than a solar eclipse?
3. When does a lunar eclipse occur?

7.3 Solar Eclipses

Learning Objectives

- Describe solar eclipses.

Can you see a solar eclipse?

Of course! This photo of a partial solar eclipse was taken on May 20, 2012 in Gilbert, Arizona. The maximum was 82% at that location. Further north people experienced totality. The next two eclipses in North America will be a partial on October 23, 2014 and a total on August 21, 2017. If you try to view an eclipse, be sure you use eye protection!

Solar Eclipses

When a new moon passes directly between the Earth and the Sun, it causes a **solar eclipse** (**Figure** 7.4). The Moon casts a shadow on the Earth and blocks our view of the Sun. This only happens if all three are lined up and in the same plane. This plane is called the ecliptic. The ecliptic is the plane of Earth's orbit around the Sun.

The Moon's shadow has two distinct parts. The **umbra** is the inner, cone-shaped part of the shadow. It is the part in which all of the light has been blocked. The **penumbra** is the outer part of Moon's shadow. It is where the light is only partially blocked.

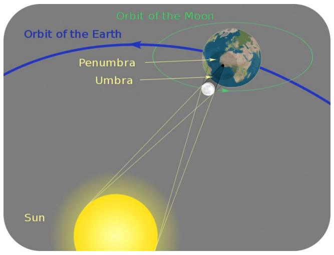


FIGURE 7.4
During a solar eclipse, the Moon casts a shadow on the Earth. The shadow is made up of two parts: the darker umbra and the lighter penumbra.

When the Moon's shadow completely blocks the Sun, it is a total solar eclipse (**Figure** 7.5). If only part of the Sun is out of view, it is a partial solar eclipse. Solar eclipses are rare events. They usually only last a few minutes. That is because the Moon's shadow only covers a very small area on Earth, and Earth is turning very rapidly.

Solar eclipses are amazing to experience. The light disappears so that it's like night, only strange. Birds may sing as they do at dusk. Stars become visible in the sky. It gets colder outside. Unlike at night, though, the Sun is out. So during a solar eclipse, it's easy to see the Sun's corona and solar prominences.

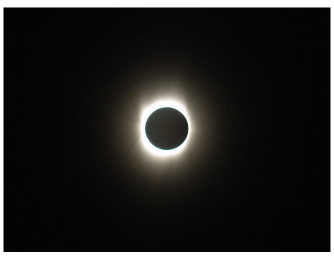


FIGURE 7.5
A photo of a total solar eclipse.

Summary

- During a solar eclipse, the new moon passes between Earth and Sun.
- The umbra is the part of the shadow in which light is completely blocked.
- The penumbra is the part of the shadow that is partially lit.

Review

1. What is a solar eclipse?
2. What causes a solar eclipse?
3. What is the relationship of the umbra and the penumbra?

7.4 Rotation of Earth

Learning Objectives

- Describe Earth's rotation on its axis.

What would you do if you were in Paris?

Take a view from the top of the Eiffel Tower? March up the stairs to eye the gargoyles at Notre Dame? Nibble on coffee and croissants in a sidewalk cafe? Visit Foucault's Pendulum in the Pantheon? Yes! When in Paris, don't forget to go to the Pantheon and visit this testament to Earth's rotation.

FIGURE 7.6
Foucault's Pendulum is at the Pantheon in Paris, France.

Foucault's Pendulum

In 1851, a French scientist named Léon Foucault took an iron sphere and hung it from a wire. He pulled the sphere to one side and then released it, as a pendulum. Although a pendulum set in motion should not change its motion, Foucault observed that his pendulum did seem to change direction relative to the circle below. Foucault concluded that Earth was moving underneath the pendulum. People at that time already knew that Earth rotated on its axis, but Foucault's experiment was nice confirmation.

Earth's Rotation

Imagine a line passing through the center of Earth that goes through both the North Pole and the South Pole. This imaginary line is called an **axis**. Earth spins around its axis, just as a top spins around its spindle. This spinning movement is called Earth's **rotation**.

An observer in space will see that Earth requires 23 hours, 59 minutes, and 4 seconds to make one complete rotation on its axis. But because Earth moves around the Sun at the same time that it is rotating, the planet must turn just a little bit more to reach the same place relative to the Sun. Hence the length of a day on Earth is actually 24 hours.

At the Equator, the Earth rotates at a speed of about 1,700 km per hour, but at the poles the movement speed is nearly nothing.

Day-Night Cycle

Earth rotates once on its axis about every 24 hours. To an observer looking down at the North Pole, the rotation appears counterclockwise. From nearly all points on Earth, the Sun appears to move across the sky from east to west each day. Of course, the Sun is not moving from east to west at all; Earth is rotating. The Moon and stars also seem to rise in the east and set in the west.

Earth's rotation means that there is a cycle of daylight and darkness approximately every 24 hours, the length of a day. Different places experience sunset and sunrise at different times and the amount of daylight and darkness also differs by location.

Shadows are areas where an object obstructs a light source so that darkness takes on the form of the object. On Earth, a shadow can be cast by the Sun, Moon, or (rarely) Mercury or Venus.

MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/186087

Summary

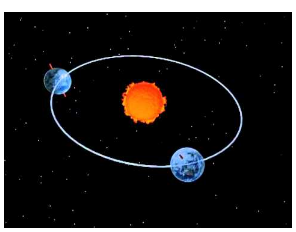
- Foucalt's pendulum shows that Earth moves beneath a swinging pendulum.
- Earth rotates on its axis every 24 hours.
- Earth rotates so that the Sun, Moon, and stars appear to travel from east to west each day.

Review

1. How does Foucalt's pendulum show that Earth rotates on its axis?
2. Why do the Sun, Moon, and stars appear to rise in the east and set in the west each day?
3. Why does a point on the Equator travel at a speed of 1,700 km per hour and a point at the poles not travel at all?

Explore More

Use these resources to answer the questions that follow.



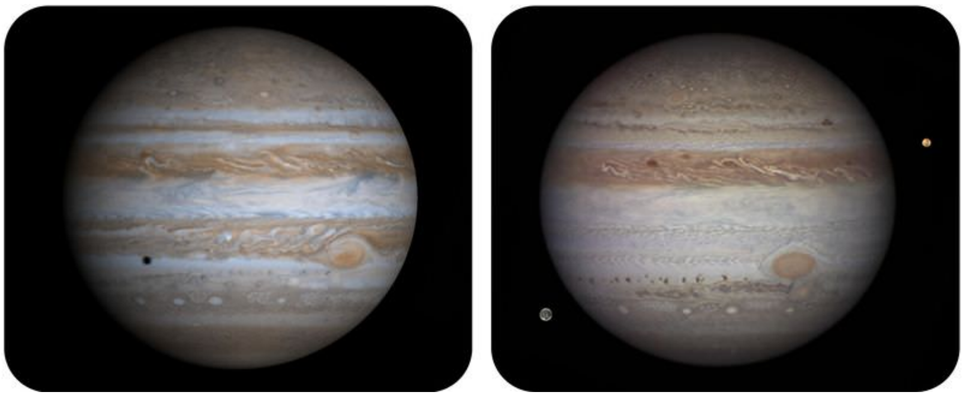
MEDIA
Click image to the left or use the URL below.
URL: http://www.ck12.org/flx/render/embeddedobject/177959

1. What is the tilt of Earth's axis of rotation?
2. How often does Earth rotate on its axis?
3. Under what circumstances is it summer in the Northern Hemisphere?
4. As Earth revolves around the Sun over 6 months, how much does the tilt of the axis of rotation change?
5. Under what circumstances is it summer in the Southern Hemisphere? At this time, what is the season in the Northern Hemisphere?
6. What is the wobble effect? How long is one cycle of this effect?
7. What will happen to the seasons in 13,000 years and why?

7.5 Revolutions of Earth

Learning Objectives

- Describe Earth's revolution around the Sun.



What kind of revolution are we talking about?

Copernicus caused a revolution. He said that Earth revolved around the Sun. With his telescope, Galileo found a lot of evidence for this. He could see moons orbiting Jupiter. If moons can orbit Jupiter, surely Earth can orbit the Sun. Yes? In the two images above, you can see Jupiter at two different times, showing moons in different places.

Earth's Revolution

Earth orbits a star. That star is our Sun. One **revolution** around the Sun takes 365.24 days. That is equal to one year. Earth stays in orbit around the Sun because of the Sun's gravity (**Figure** 7.7).

Earth's orbit is not a circle. It is a bit elliptical. So as we travel around the Sun, sometimes we are a little farther away from the Sun. Sometimes we are closer to the Sun.

Students sometimes think the slightly oval shape of our orbit causes Earth's seasons. That's not true! The seasons are due to the tilt of Earth's axis, as discussed in the previous concept.

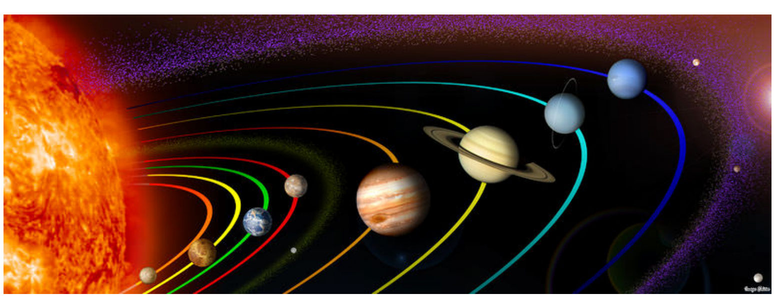


FIGURE 7.7
Earth and the other planets in the solar system make elliptical orbits around the Sun. The ellipses in this image are highly exaggerated.

The distance between the Earth and the Sun is about 93 million miles, or 150 million kilometers. Earth revolves around the Sun at an average speed of about 27 kilometers (17 miles) per second. Mercury and Venus are closer to the Sun, so they take shorter times to make one orbit. Mercury takes only about 88 Earth days to make one trip around the Sun. All of the other planets take longer amounts of time. The exact amount depends on the planet's distance from the Sun. Saturn takes more than 29 Earth years to make one revolution around the Sun. How old would you be if you were on Jupiter?

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/84537

Summary

- Earth's orbit around the Sun is somewhat elliptical.
- Earth's seasons are not caused by the shape of its orbit.
- Earth and the other planets of the solar system revolve around the Sun.

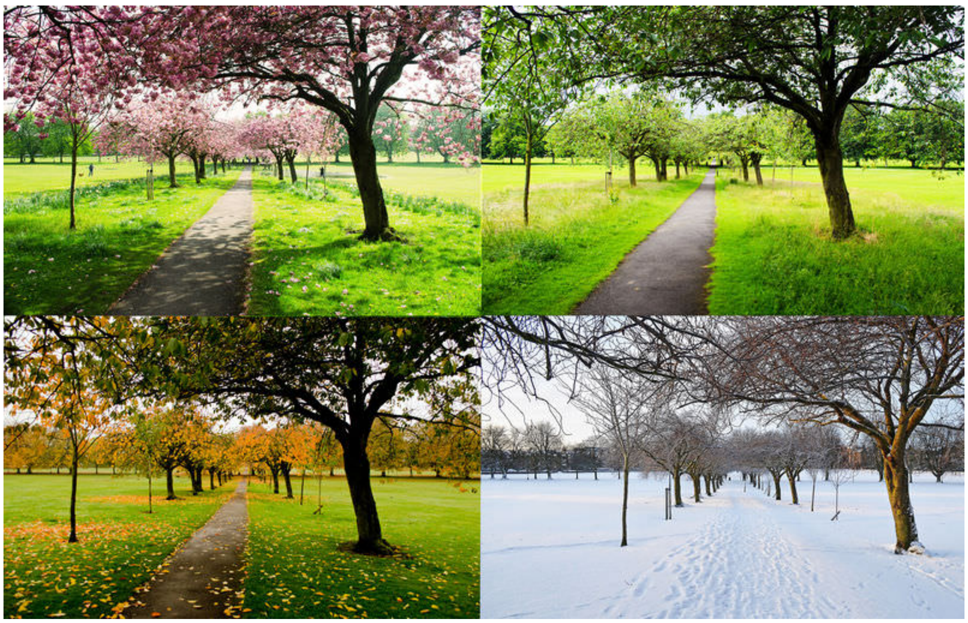
Review

1. How long does it take for Earth to make one revolution around the Sun?
2. Is Earth farther from the Sun in the winter and closer in the summer? Explain.
3. Describe Earth's orbit around the Sun. Describe the orbits of the other planets.

7.6 Seasons

Learning Objectives

- Explain why seasons occur.
- Define summer solstice, winter solstice, and equinox.



Do you like the seasons?

Do you live in a place with well-defined seasons? Do you appreciate the change of the seasons? In other words, are you happy that Earth's axis is tilted?

Earth's Seasons

Some people think that Earth is closer to the Sun in the summer and farther away from the Sun in the the winter. But that's not true! Why can't that be true? Because when it's summer in one hemisphere, it's winter in the other. So what does cause the seasons? The seasons are caused by the 23.5° tilt of Earth's axis. One hemisphere points more directly toward the Sun than the other hemisphere. As Earth orbits the Sun, the tilt of Earth's axis stays lined up with the North Star.

Solstice refers to the position of the Sun when it is closest to one of the poles. At equinox, the Sun is directly over the Equator.

Northern Hemisphere Summer

During summer in the Northern Hemisphere, the North Pole is tilted toward the Sun. The Sun's rays strike the Northern Hemisphere more directly (**Figure** 7.8). The region gets a lot of sunlight. **Summer solstice** is June 21 or 22. At that time, the Sun's rays hit directly at the Tropic of Cancer (23.5°N). This is the farthest north that the Sun will be directly overhead. Summer solstice in the Northern Hemisphere is winter solstice in the Southern Hemisphere.

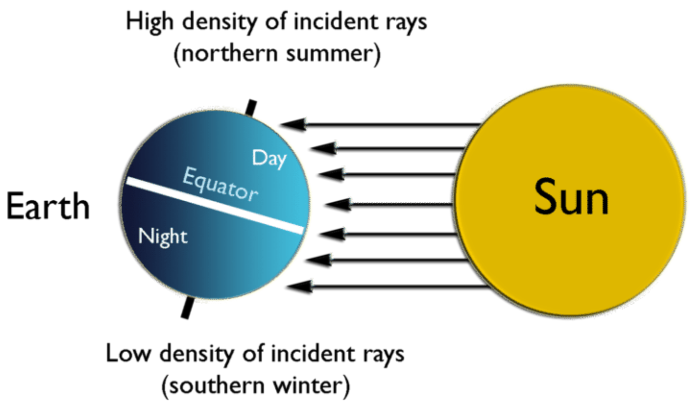


FIGURE 7.8
Summer solstice in the Northern Hemisphere.

Northern Hemisphere Winter

Winter solstice for the Northern Hemisphere happens on December 21 or 22. The North Pole of Earth's axis points away from the Sun (**Figure** 7.9). Light from the Sun is spread out over a larger area. With fewer daylight hours in winter, there is also less time for the Sun to warm the area. When it is winter in the Northern Hemisphere, it is summer in the Southern Hemisphere.

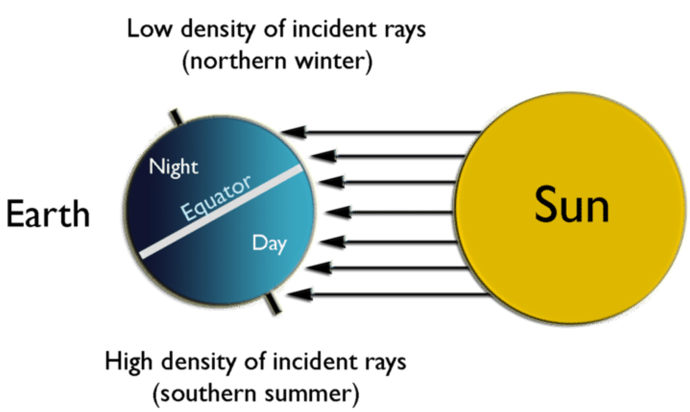


FIGURE 7.9
During summer in the Southern Hemisphere, the Sun's rays directly strike the Tropic of Capricorn (23.5°S). Sunlight is spread across a large area near the South Pole. No sunlight reaches the North Pole.

Equinox

Equinox comes halfway between the two solstices. At equinoxes, the Sun's rays shine most directly at the Equator (**Figure** 7.10). The daylight and nighttime hours are exactly equal on an equinox. The autumnal, or fall, equinox happens on September 22 or 23. The vernal, or spring, equinox happens March 21 or 22 in the Northern Hemisphere.

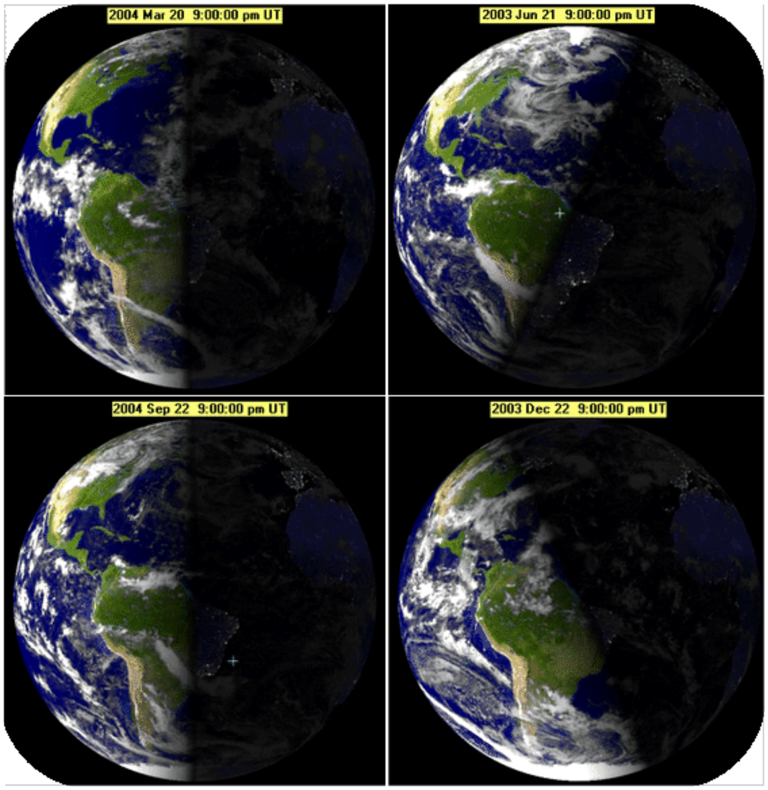


FIGURE 7.10
Where sunlight reaches on spring equinox, summer solstice, vernal equinox, and winter solstice. The time is 9:00 p.m. Universal Time, at Greenwich, England.

Summary

- Earth has seasons because of the (23.5°) tilt of its axis of rotation.
- In the Northern Hemisphere, at summer solstice the Sun is closest to the North Pole (around June 22). At winter solstice, the Sun is closest to the South Pole (around December 22). In the Southern Hemisphere, the names are changed.
- At equinox, the Sun is directly over the Equator. Autumnal equinox is around September 22. Spring equinox is around March 22.

Review

1. Imagine that it is summer solstice in the Northern Hemisphere. What is the date, and where is the Sun? What is happening in the Southern Hemisphere?
2. Describe why Earth has seasons.
3. What are equinoxes? When do they come?

Explore More

Use the resource below to answer the questions that follow.

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/1476

1. What causes Earth's seasons?
2. What is the longest day of the year in the Northern Hemisphere?
3. What occurs at the equinoxes?
4. What happens during the winter solstice?
5. When is it summer in the Southern Hemisphere?

7.7 Glossary

Apollo Program, NASA's program to land people on the moon. Apollo missions 11-17 landed on the moon, except Apollo 13 which had malfunctions.

core, the center of the sun where nuclear fusion is taking place. Also, the center of a planet.

day, when the Earth (rotates) spins around one complete turn on its axis.

ellipse (elliptical), the oval shape of orbits in the solar system.

igneous rock, a rock formed by cooling melted magma.

lunar eclipse, when the Earth blocks the sun's light going to the moon.

maria, the low and relatively flat, darker parts of the moon's surface, from the latin word which means oceans

month, when the moon revolves (orbits) the Earth one complete time.

orbit, the path of an object going around another object due to gravity.

phases of the moon, The different views of the moon as the lit/shadow side of the moon faces Earth.

planet, a celestial body that has cleared out its orbital path of other objects and is round due to gravity

planet, a large object that orbits the sun, which is round due to its own gravity and has cleared out its orbital path of other objects which orbit the sun. it may have moons which orbit itself.

revolution, when one solar system object complete one orbit, it has completed one revolution.

rotation, when an object spins around one complete time on its own axis.

season, the four seasons are summer, spring winter and fall. These occur due to the angle of tilt of the Earth'e axis toward the sun. As the angle changes throughout the year, the seasons change also. While the Earth is slightly closer at some times of year than at others, the Earth's orbit is very close to a circle so the angle of tilt matters MUCH more.

solar system, the sun (or any star) and the planets and other objects that orbit it including comets, asteroids dust and dwarf planets.

solar eclipse, when the sun is blocked by the moon as seen from earth.

terrae, a high or mountainous region of the moon, these are the brighter parts of the moon.

year, when the Earth (revolves) makes a complete trip around the sun.

solar eclipse, when the sun is blocked by the moon as seen from earth.

sunspots, parts of the sun's surface that are cooler (~5000^o compare to the normal 11,000^o) compared to the rest of the sun's surface.

terrae, a high or mountainous region of the moon, these are the brighter parts of the moon.

terrestrial planet, a rocky planet, one of the four inner planets.

Summary

At the center of the solar system is our star, the Sun. The Sun gets its power from the fusion of hydrogen and helium. The Sun has no solid parts, but it has layers. Much of what the Sun is made of is plasma. The Sun's surface features, like sunspots, can affect Earth. Eight planets orbit the Sun. The four nearest the Sun are small, dense, and rocky. The four farthest from the Sun are large and gaseous. Mercury is the smallest planet. It is closest to the Sun so it is extremely hot. Venus has a thick, atmosphere with a lot of carbon dioxide. The carbon dioxide gives the planet a large greenhouse effect so it is very hot. Earth, the third rock from the Sun, is the only one of the inner planets with a large moon. The Moon is the only body in the Universe, besides Earth, where humans have walked. The red planet, Mars, is the most Earth-like. The planet has volcanoes, channels where water once flowed and an enormous canyon. The four gas planets are Jupiter, Saturn, Uranus, and Neptune. They are made of hydrogen, helium, and some methane and other gases. All have rings and moons. The solar system also includes at least five dwarf planets. After decades as a planet, Pluto was recently made a dwarf planet. There are also asteroids, and comets. An object that strikes Earth is a meteorite. Increasing numbers of planets are now being found in other solar systems.

7.8 References

1. Flickr:OliBac. The phases of the moon . CC BY 2.0
2. User:Sagredo/Wikimedia Commons. The moon's position during a lunar eclipse . Public Domain
3. U.S. Navy photos by Mass Communication Specialist Seaman Joshua Valcarcel. A lunar eclipse is shown in a series of pictures . Public Domain
4. User:Sagredo/Wikimedia Commons. The moon's position during a solar eclipse . Public Domain
5. Alexandra Lord. Picture of a total solar eclipse . CC BY 2.0
6. User:Arnaud 25/Wikimedia Commons. Picture of Foucault's Pendulum in the Pantheon in Paris, France . Public Domain
7. Flickr:Image Editor. Planets in the solar system make elliptical orbits around the Sun . CC BY 2.0
8. Sam McCabe. Summer solstice in the Northern Hemisphere . CC BY-NC 3.0
9. Sam McCabe. Summer solstice in the Southern Hemisphere . CC BY-NC 3.0
10. Tom Ruen, Full Sky Observatory. Pictures of Earth during the spring equinox, summer solstice, vernal equ inox, and winter solstice . Public Domain

CHAPTER 8 How Gravity Affects the Motion of the Objects in the Solar System MS ESS 1-2, PS 2-4

Chapter Outline

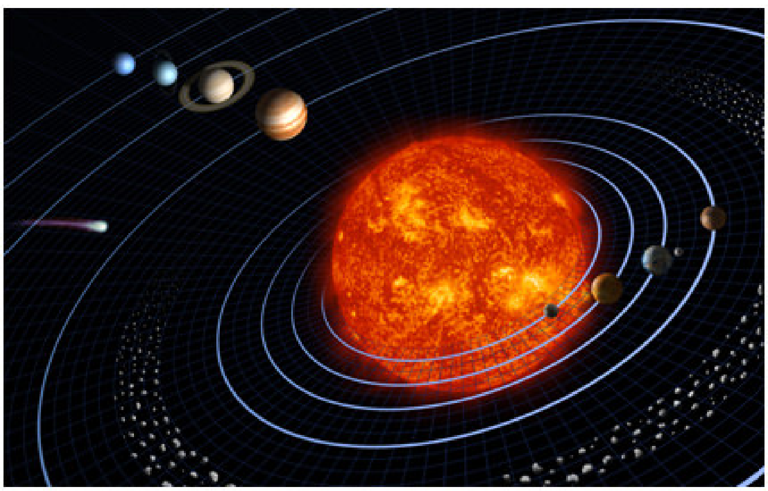


FIGURE 8.1
The image shows the imaginary lines which are the path a planet takes around the Sun. Those paths are called orbits.

INTRODUCTION

DISCIPLINARY CORE IDEA:

MS-ESS 1-2 By the end of instruction, students should be able to answer a test which asks them to: **Make and use a model that shows the place of gravity in the motions of orbits in the universe and the solar systems.**

Why do we have seasons? What is a month, a year, a day? How are all these connected? What are ocean tides, what causes them? How can we best understand them? In this chapter we will answer these questions.

We must learn to deal with gravity in our planned trip to Mars. Gravity will keep us on the Earth unless we use a space ship to go to Mars. Gravity will affect our journey to Mars and our landing when we get there. The lack of gravity will affect people's bodies and muscles and bones on the trip to Mars. Gravity is central to our story in this chapter.

8.1 Newton's Law of Gravity

Learning Objectives

- Describe Newton's law of universal gravitation, and explain why it was so important.
- Identify factors that affect the strength of gravity between two objects.

You may have heard a story about Isaac Newton coming up with the idea of gravity when an apple fell out of a tree and hit him in the head. The story isn't true, but seeing how things like apples fall to Earth helped Newton form his ideas about gravity, the force of attraction between things that have mass. Of course, people had known about the effects of gravity for thousands of years before Newton came along. After all, they constantly experienced gravity in their daily lives. They observed over and over again that things always fall toward the ground. However, it wasn't until Newton developed his law of gravity in the late 1600s that people knew gravity applies to everything in the universe that has mass.

Newton's Law of Universal Gravitation

Newton was the first one to suggest that gravity is universal and affects all objects in the universe. That's why Newton's law of gravity is called the **law of universal gravitation**. Universal gravitation means that the force that causes an apple to fall from a tree to the ground is the same force that causes the moon to keep moving around Earth. Universal gravitation also means that while Earth exerts a pull on you, you exert a pull on Earth. In fact, there is gravity between you and every mass around you—your desk, your book, your pen. Even tiny molecules of gas are attracted to one another by the force of gravity.

Q: Newton's law of universal gravitation had a huge impact on how people thought about the universe. Why do you think it was so important?

A: Newton's law was the first scientific law that applied to the entire universe. It explains the motion of objects not only on Earth but in outer space as well.

Factors That Influence the Strength of Gravity

Newton's law also states that the strength of gravity between any two objects depends on two factors: the masses of the objects and the distance between them.

- Objects with greater mass have a stronger force of gravity between them. For example, because Earth is so massive, it attracts you and your desk more strongly that you and your desk attract each other. That's why you and the desk remain in place on the floor rather than moving toward one another.
- Objects that are closer together have a stronger force of gravity between them. For example, the moon is closer to Earth than it is to the more massive sun, so the force of gravity is greater between the moon and Earth than between the moon and the sun. That's why the moon circles around Earth rather than the sun. You can see this in the **Figure** 8.2.

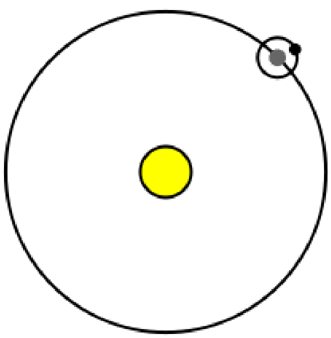


FIGURE 8.2

Summary

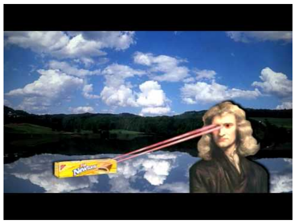
- Newton's law of universal gravitation states that the force of gravity affects everything with mass in the universe.
- Newton's law also states that the strength of gravity between any two objects depends on the masses of the objects and the distance between them.

Review

1. What is Newton's law of universal gravitation?
2. Describe the relationship between the masses of two objects and the force of gravity between them.
3. If two objects each have a mass of 10 kg, then the force of gravity between them
   a. is 100 kg.
   b. is constant.
   c. depends only on their masses.
   d. is greater when they are closer together.

Explore More

Watch the short video about Newton's law of gravity and then answer the questions below.



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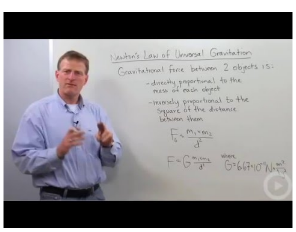
URL: http://www.ck12.org/flx/render/embeddedobject/1453

1. What equation did Newton use to represent the force of gravity between two objects? What does each letter in the equation stand for? Which letter stands for a value that never changes?
2. Based on the equation, how does the force of gravity between two objects change when the mass of one of the objects doubles?
3. If the distance between the two objects doubles, how does this affect the force of gravity between them?

Resources



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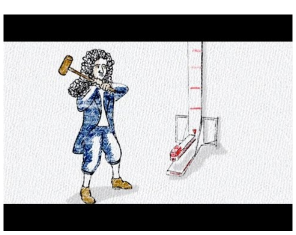

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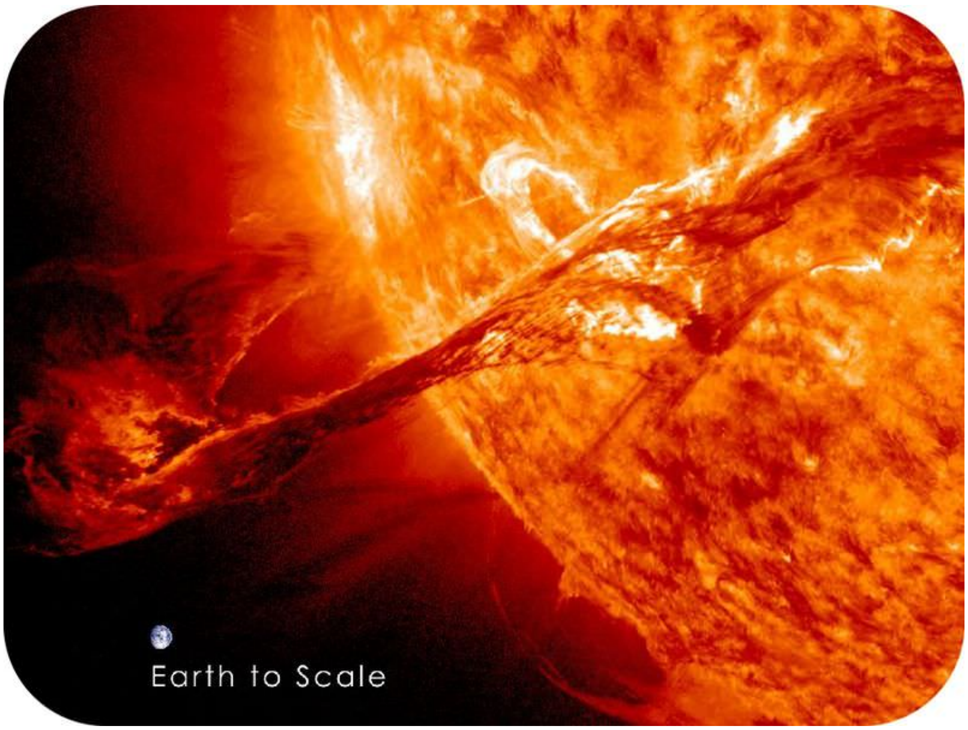
8.2 Orbital Motion

Learning Objectives

- Define orbital motion and explain why it occurs.
- Describe the orbits of Earth around the sun and the moon around Earth.



As you can see in this NASA photo, Earth is tiny compared with the massive sun. The sun's gravity is relatively strong because the force of gravity between two objects is directly proportional to their masses. Gravity between the sun and Earth pulls Earth toward the sun, but Earth never falls into the sun. Instead, it constantly revolves around the sun, making one complete revolution every 365 days.

Q: Why doesn't the sun's gravity pull Earth down to the surface of the sun?

A: Earth has enough forward velocity to partly counter the force of the sun's gravity.

What Is Orbital Motion?

Earth and many other bodies—including asteroids, comets, and the other planets—move around the sun in curved paths called orbits. Generally, the orbits are elliptical, or oval, in shape. You can see the shape of Earth's orbit in the **Figure** 8.3. Because of the sun's relatively strong gravity, Earth and the other bodies constantly fall toward the sun, but they stay far enough away from the sun because of their forward velocity to fall around the sun instead of into it. As a result, they keep orbiting the sun and never crash to its surface. The motion of Earth and the other bodies around the sun is called **orbital motion**. Orbital motion occurs whenever an object is moving forward and at the same time is pulled by gravity toward another object.

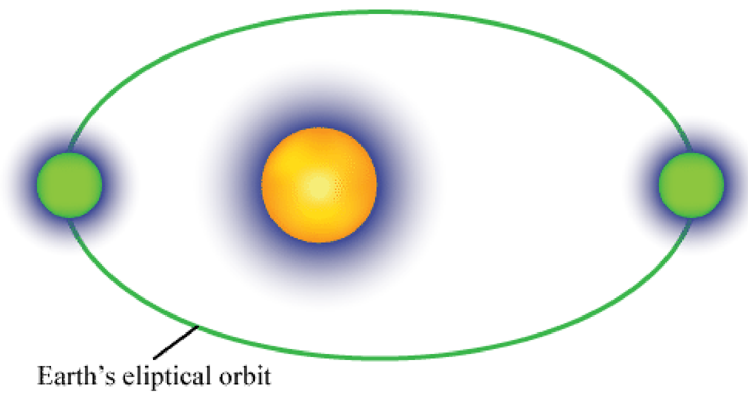


FIGURE 8.3

Orbital Motion of the Moon

Just as Earth orbits the sun, the moon also orbits Earth. The moon is affected by Earth's gravity more than it is by the gravity of the sun because the moon is much closer to Earth. The gravity between Earth and the moon pulls the moon toward Earth. At the same time, the moon has forward velocity that partly counters the force of Earth's gravity. So the moon orbits Earth instead of falling down to the surface of the planet.

The **Figure** 8.4 shows the forces involved in the moon's orbital motion around Earth. In the diagram, v represents the forward velocity of the moon, and a represents the acceleration due to gravity between Earth and the moon. The line encircling Earth shows the moon's actual orbit, which results from the combination of v and a.

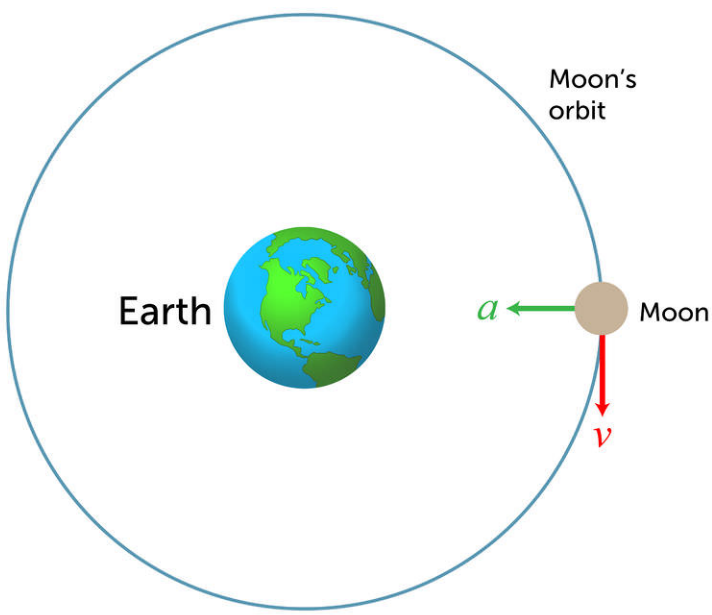


FIGURE 8.4

Summary

- Orbital motion occurs whenever an object is moving forward and at the same time is pulled by gravity toward another object.

- The forward velocity of the object combines with acceleration due to gravity toward the other object. The result is a circular or oval path called an orbit, in which one object keeps moving around the other.
- Because of the relatively great gravity of the sun, Earth orbits the sun. The moon orbits Earth rather than the sun because it is much closer to Earth.

Review

1. Define orbit and orbital motion, and explain why orbital motion occurs.
2. In addition to the moon, artificial satellites also orbit Earth. What factors do you think must be taken into account to ensure that a satellite keeps orbiting Earth rather than falling back to Earth's surface?
3. Earth is closer to nearby planets including Venus and Mars than it is to the sun. Why don't these other planets pull Earth toward them and cause it to veer off its orbit around the sun.

Resources

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MEDIA
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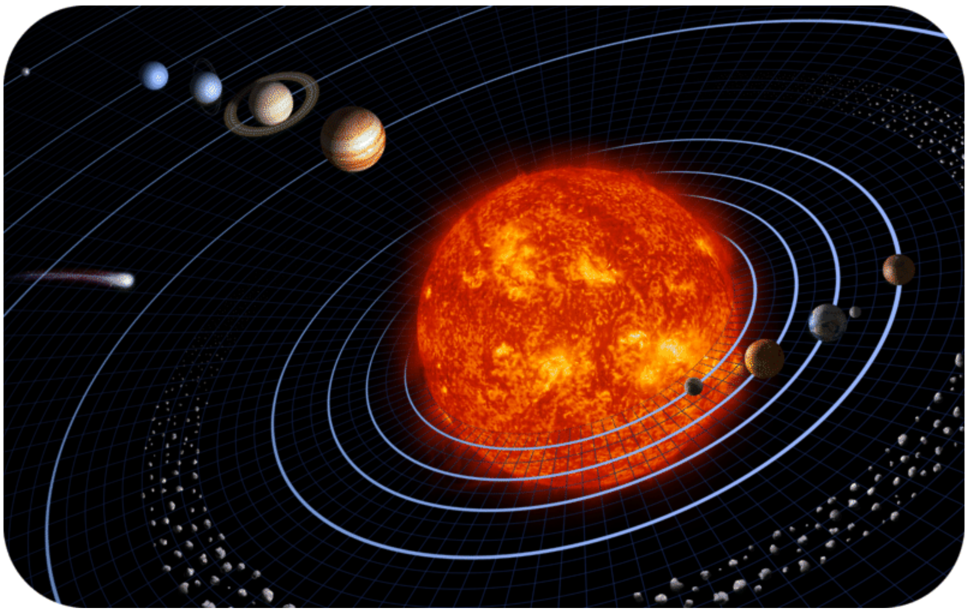
8.3 Planet Orbits in the Solar System

Learning Objectives

- Describe the size and shape of planetary orbits.



"Accordingly, since nothing prevents the earth from moving...

...I suggest that we should now consider also whether several motions suit it, so that it can be regarded as one of the planets. For, it is not the center of all the revolutions." - Nicolaus Copernicus

The Size and Shape of Orbits

Figure 8.5 shows the relative sizes of the orbits of the planets, asteroid belt, and Kuiper belt. In general, the farther away from the Sun, the greater the distance from one planet's orbit to the next. The orbits of the planets are not circular but slightly elliptical, with the Sun located at one of the foci (see opening image).

While studying the solar system, Johannes Kepler discovered the relationship between the time it takes a planet to make one complete orbit around the Sun, its "orbital period," and the distance from the Sun to the planet. If the orbital period of a planet is known, then it is possible to determine the planet's distance from the Sun. This is how astronomers without modern telescopes could determine the distances to other planets within the solar system.

How old are you on Earth? How old would you be if you lived on Jupiter? How many days is it until your birthday on Earth? How many days until your birthday if you lived on Saturn?

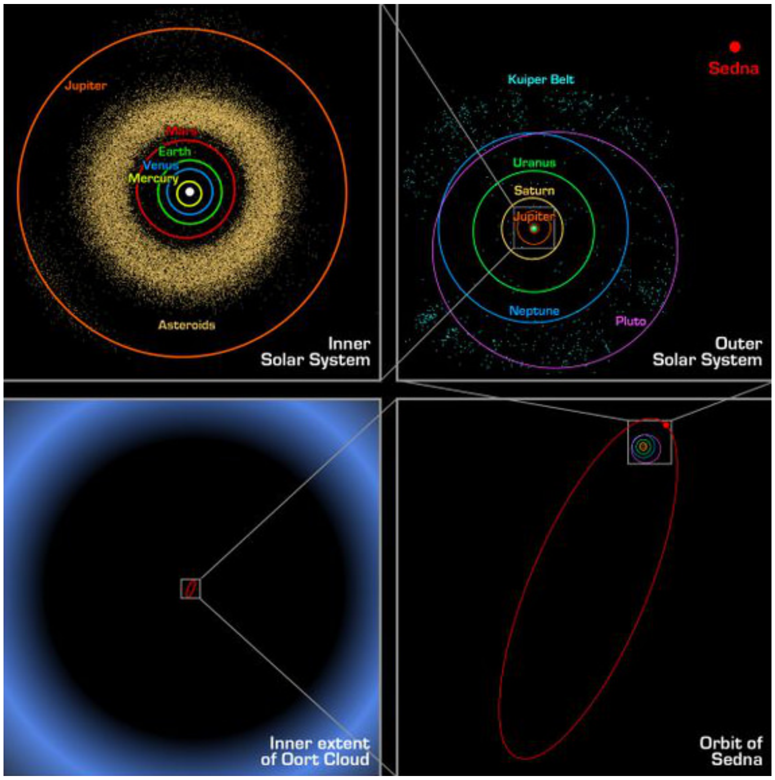


FIGURE 8.5
The relative sizes of the orbits of planets in the solar system. The inner solar system and asteroid belt is on the upper left. The upper right shows the outer planets and the Kuiper belt.

MEDIA
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URL: http://www.ck12.org/flx/render/embeddedobject/1467

Summary

- The eight planets orbit the Sun along slightly elliptical paths, with Sun located at one of the foci.
- Kepler discovered that by using a planet's orbital period, it is possible to determine its distance from the Sun.
- The farther the planets are from the Sun, the greater their distance from each other.

Review

1. When you look at the diagram of planet orbits, which planetoid (planet-like object) doesn't fit the criteria of a planet?
2. How did Johannes Kepler determine a planet's distance from the Sun?
3. Why would your age - the number of orbits you have made around the Sun - be different on a different planet? Would you be younger or older?

8.4 Glossary

dwarf Planet, A large object in space that orbits a star and is round due to gravity and has NOT cleared its orbital path of other large objects

elliptical galaxy, A galaxy with an oval (elliptical) shape

equinox, The days each when the day and night are of equal length of time due to the direction of the tile of the axis of the earth compared to the sun.

galaxy, a grouping of many stars in common orbit - Often billions of stars.

gravity, The force of attraction between any two masses (objects with mass)

irregular galaxy, A galaxy that has a shape that is neither elliptical or spiral.

lunar eclipse, The sun's light is blocked by the earth and the earth's shadow lands on the moon.

lunar Phase, The appearance of the moon as the shaded part of the moon becomes visible on earth.

milky way, The galaxy we live in.

orbit, The path of a planet or moon or other object as it goes around a star (sun) planet or moon.

orbital Motion,The motion of objects in an orbit.

penumbra, part of an eclipse shadow that has part o the shadow from the earth or moon.

planet, A large object in space that orbits a star and is round due to gravity and HAS cleared its orbital path of other large objects

revolution/revolve, One time around/To go around an object by orbiting it.

seasons, The change in weather due to the way that the earth faces the sun as it orbits the sun; these changes occur at the same time of year each year and therefore are also sections of the calendar year.

solar eclipse, When the sun's light is blocked by the moon and the moon's shadow lands on the earth.

spiral galaxy, A galaxy with a spiral shape

umbra, part of an eclipse shadow that has the full shadow from the earth or moon.

universe, all the galaxies and space and stars and planets in existence.

weight, The force of gravity on a mass near a planet

8.5 References

1. User:Tó campos/Wikipedia. The moon is much closer to the Earth than the sun . Public Domain
2. Zachary Wilson. Earth's orbit is elliptical . CC BY-NC 3.0
3. Christopher Auyeung and Laura Guerin. The moon orbits the earth . CC BY-NC 3.0
4. Courtesy of NASA/JPL-Caltech/R. Hurt. The relative sizes of the orbits of planets in the solar system . Public Domain

CHAPTER 9 Force and Motion MS PS 2-2

Chapter Outline

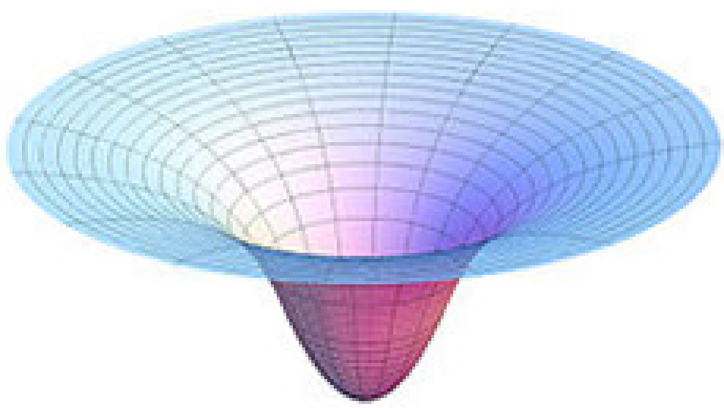


FIGURE 9.1
This is a drawing of a graph showing the calculated curvature of Space-Time by gravity near a planet according to Einstein's Theory of Relativity.

INTRODUCTION

DISCIPLINARY CORE IDEA:

MS-PS 2-4 By the end of instruction, students should be able to answer a test which asks them to: **Show how gravity is an attractive force ad depends on the masses of the objects based on evidence and logical statements and discussions.**

For our Story, we continue to explore gravity in more depth.

9.1 Force

Carson has been riding a scooter for almost as long as he can remember. As you can see, he's really good at it. He can even do tricks in the air. It takes a lot of practice to be able to control a scooter like this. Carson automatically applies just the right forces to control his scooter.

Defining Force

Force is defined as a push or pull acting on an object. There are several fundamental forces in the universe, including the force of gravity, electromagnetic force, and weak and strong nuclear forces. When it comes to the motion of everyday objects, however, the forces of interest include mainly gravity, friction, and applied force. Applied force is force that a person or thing applies to an object.

Q: What forces act on Carson's scooter?

A: Gravity, friction, and applied forces all act on Carson's scooter. Gravity keeps pulling both Carson and the scooter toward the ground. Friction between the wheels of the scooter and the ground prevent the scooter from sliding but also slow it down. In addition, Carson applies forces to his scooter to control its speed and direction.

Force and Motion

Forces cause all motions. Everytime the motion of an object changes, it's because a force has been applied to it. Force can cause a stationary object to start moving or a moving object to change its speed or direction or both. A change in the speed or direction of an object is called acceleration. Look at Carson's brother Colton in the **Figure**

9.2. He's getting his scooter started by pushing off with his foot. The force he applies to the ground with his foot starts the scooter moving in the opposite direction. The harder he pushes against the ground, the faster the scooter will go.

FIGURE 9.2

How much an object accelerates when a force is applied to it depends not only on the strength of the force but also on the object's mass. For example, a heavier scooter would be harder to accelerate. Colton would have to push with more force to start it moving and move it faster. You can explore the how force, mass, and acceleration are related by doing the activity at this URL:

http://www.harcourtschool.com/activity/newton/

Q: What units do you think are used to measure force?

A: The SI unit for force is the Newton (N). A **Newton** is the force needed to cause a mass of 1 kilogram to accelerate at 1 m/s^2, so a Newton equals 1 kg • m/s^2. The Newton was named for the scientist Sir Isaac Newton, who is famous for his laws of motion and gravity.

Force as a Vector

Force is a vector, or a measure that has both size and direction. For example, Colton pushes on the ground in the opposite direction that the scooter moves, so that's the direction of the force he is applies. He can give the scooter a strong push or a weak push. That's the size of the force. Like other vectors, a force can be represented with an arrow. You can see some examples in the **Figure** 9.3. The length of each arrow represents the strength of the force, and the way the arrow points represents the direction of the force.

Q: How could you use arrows to represent the forces that start Colton's scooter moving?

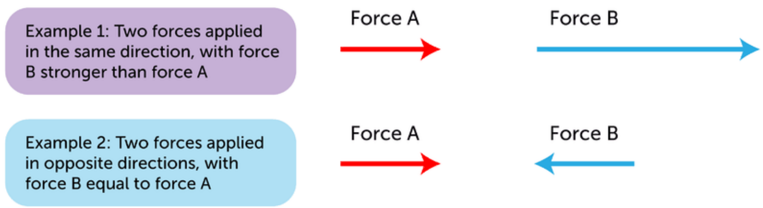


FIGURE 9.3

A: Colton pushes against the ground behind him (to the right in the **Figure** 9.2). The ground pushes back with equal force to the left, causing the scooter to move in that direction. Force arrows A and B in example 2 in the **Figure** 9.2) could represent these forces.

Summary

- Force is defined as a push or pull acting on an object. Forces include gravity, friction, and applied force.
- Force causes changes in the speed or direction of motion. These changes are called acceleration.
- The SI unit for force is the Newton (N).
- Force is a vector because it has both size and direction. Like other vectors, it can be represented by an arrow.

Explore More

Apply different types of forces to materials in the interactive animated lab at the following URL. Then answer the questions below.

http://www.pbs.org/wgbh/buildingbig/lab/forces.html

1. What is compression, and how does it affect materials?
2. What is tension? What is a real-life example?
3. Describe shear as a force.
4. What is torsion?

Review

1. What is force?
2. Relate force and motion.
3. What forces control the motion of everyday objects?
4. Identify and define the SI unit for force.
5. Draw a diagram to represent a foot kicking a resting soccer ball. Use arrows to represent the force applied to the ball and to show how the ball moves after it is kicked. To see an animation of this force and motion, go to the URL below.

http://www.3m.co.uk/intl/uk/3mstreetwise/pupils-force.htm

9.2 Combining Forces

It's boys against girls in this friendly tug of war. The two teams are pulling the rope in opposite directions. Which team do you think will win? It depends on which side pulls on the rope with the greatest force. As this example shows, more than one force may act on an object at the same time. Would it surprise you to learn that at least two different forces are acting on you as you read this article? Can you guess what they are?

Pulling Down and Pushing Up

One force acting on you—and all the other objects on Earth—is gravity. Look at the physics book in the **Figure** 9.4. Gravity pulls the book downward with a force of 20 Newtons. Why doesn't the book fall to the ground? The table pushes upward on the book with the same amount of force. The combined force, or **net force**, acting on the book is 0 Newtons. That's because upward and downward forces are balanced, so they cancel out.

Forces Acting in Opposite Directions

In general, whenever forces act on an object in opposite directions—like the book on the table—the net force is equal to the difference between the two forces. In other words, one force is subtracted from the other to calculate the net force. If the opposing forces are equal, or balanced, the net force is zero, as it is for the book. That's why the book doesn't fall to the ground but instead remains resting on the table. However, if the opposing forces are unbalanced, the net force is greater than zero, although it will be less than either of the individual forces. In this case, the object will move in the same direction as the net force.

Look at the dogs playing tug-of-war in the **Figure** 9.5. The dogs are pulling the rope in opposite directions, but one dog is pulling with more force than the other. The net force acting on the rope is 2 Newtons to the right, so the rope will move to the right.

Q: The boys in the **Figure** 9.6 are about to kick the soccer ball in opposite directions. What will be the net force on the ball? In which direction will the ball move?

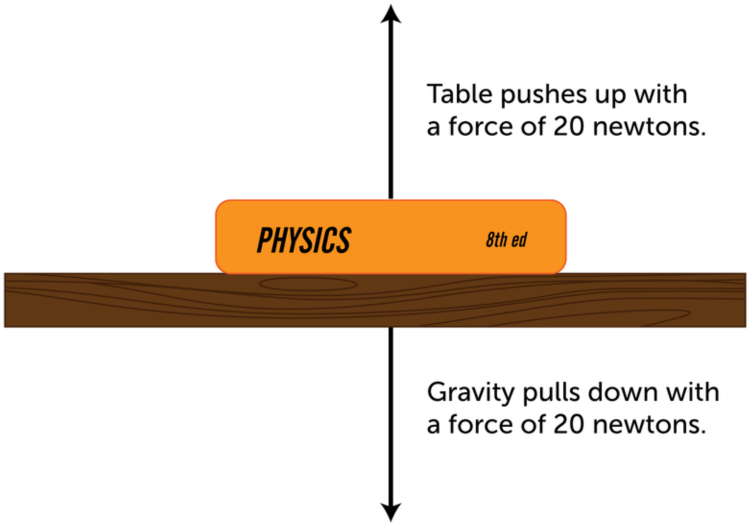


FIGURE 9.4

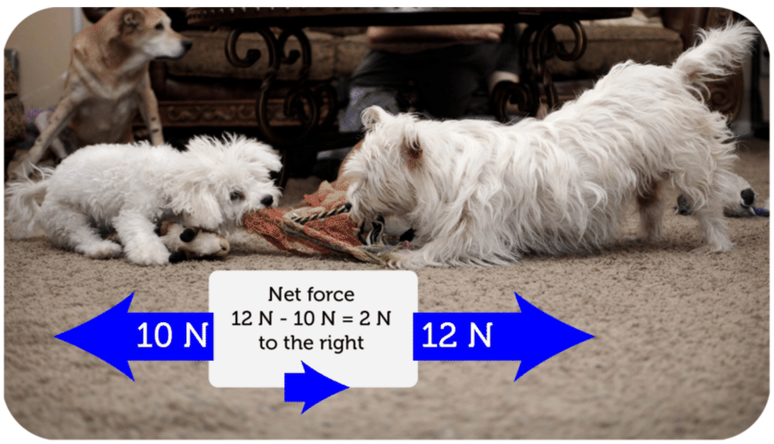


FIGURE 9.5

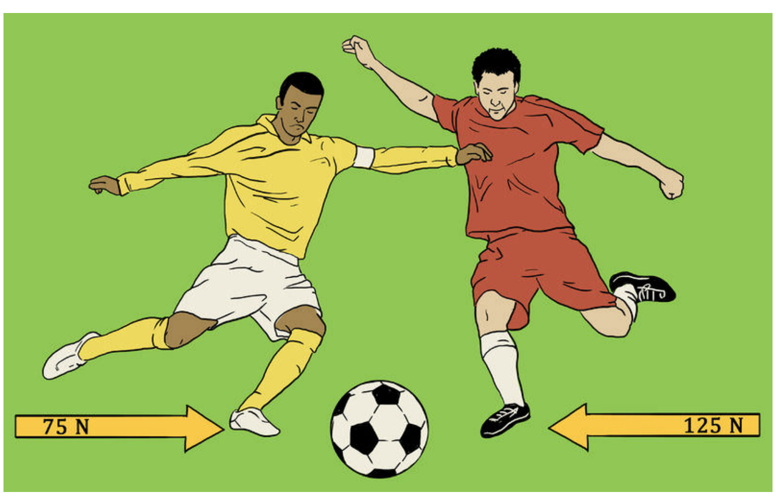
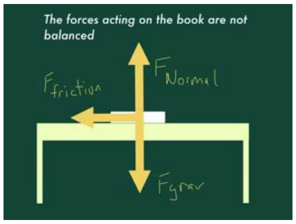


FIGURE 9.6

A: The net force on the ball will be 50 N to the left (125 N - 75 N = 50 N), so the ball will move to the left.



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Forces Acting in the Same Direction

If two forces act on an object in the same direction, the net force is equal to the sum of the two forces. This always results in a stronger force than either of the individual forces alone. In the **Figure** 9.7, after the man on the left picks up the couch, he will push the couch to the right with a force of 25 Newtons, and the man on the right will pull the couch to the right with a force of 20 Newtons. The net force on the couch is 45 Newtons to the right, so that's the way the couch will move.

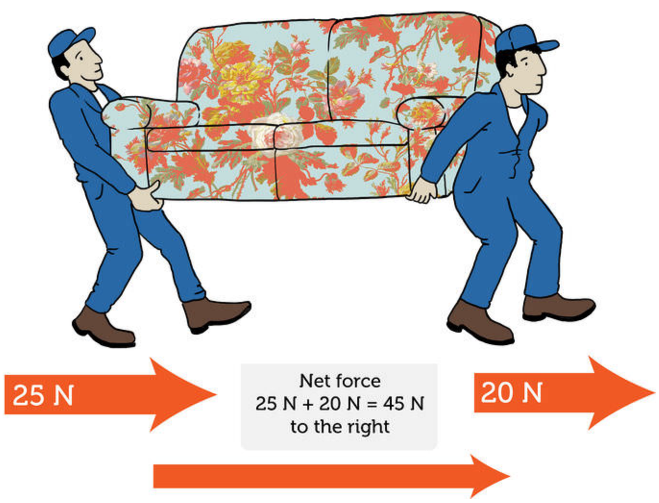

FIGURE 9.7

Summary

- The net force acting on an object is the combination of all of the individual forces acting on it.
- If two forces act on an object in opposite directions, the net force is the difference between the two forces. In this case, the net force is always greater than or equal to zero but less than either of the individual forces.
- If two forces act on an object in the same direction, the net force is the sum of the two forces. In this case, the net force is always greater than either of the individual forces.

Review

1. What is the net force acting on an object?
2. If an object has two forces acting on it, how can the net force equal 0?
3. Under what conditions does the net force acting on an object equal the sum of the individual forces?
4. What is the net force on the book in the **Figure** 9.8? If the book moves, in which direction will it move?

FIGURE 9.8

9.3 Motion

Learning Objectives

- Define motion.
- Explain how frame of reference is related to motion.

The wings of this hummingbird are moving so fast that they're just a blur of motion. You can probably think of many other examples of things in motion. If you can't, just look around you. It's likely that you'll see something moving, and if nothing else, your eyes will be moving. So you know from experience what motion is. No doubt it seems like a fairly simple concept. However, when you read this article, you'll find out that it's not quite as simple as it seems.

Defining Motion

In science, **motion** is defined as a change in position. An object's position is its location. Besides the wings of the hummingbird in the opening image, you can see other examples of motion in the **Figure** 9.9. In each case, the position of something is changing.

Q: In each picture in the **Figure** 9.9, what is moving and how is its position changing?

A: The train and all its passengers are speeding straight down a track to the next station. The man and his bike are racing along a curving highway. The geese are flying over their wetland environment. The meteor is shooting through the atmosphere toward Earth, burning up as it goes.

Frame of Reference

There's more to motion than objects simply changing position. You'll see why when you consider the following example. Assume that the school bus pictured in the **Figure** 9.10 passes by you as you stand on the sidewalk. It's

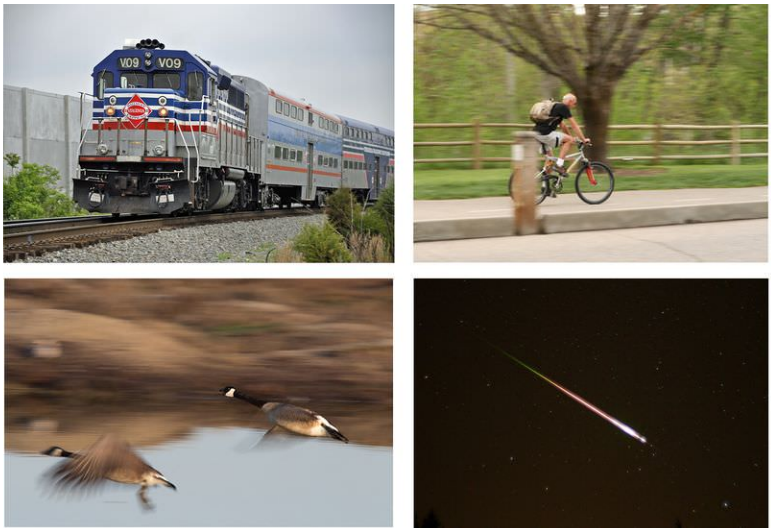

FIGURE 9.9

obvious to you that the bus is moving, but what about to the children inside the bus? The bus isn't moving relative to them, and if they look at the other children sitting on the bus, they won't appear to be moving either. If the ride is really smooth, the children may only be able to tell that the bus is moving by looking out the window and seeing you and the trees whizzing by.

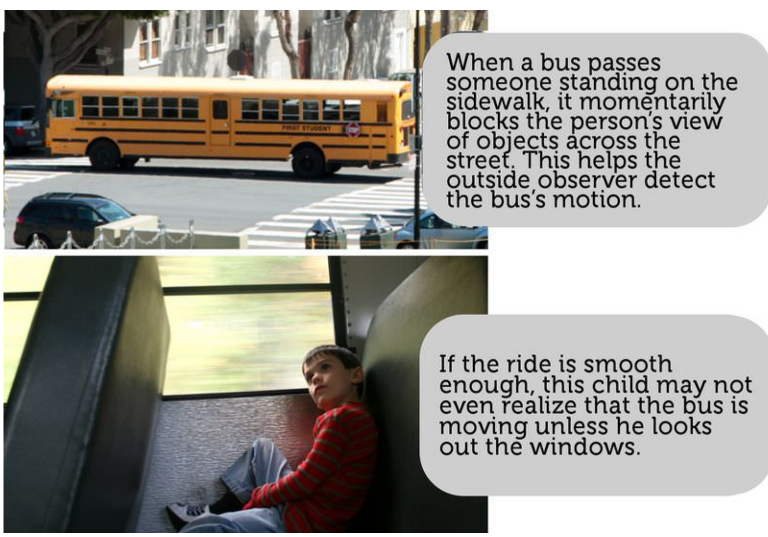

FIGURE 9.10

This example shows that how we perceive motion depends on our frame of reference. **Frame of reference** refers to something that is not moving with respect to an observer that can be used to detect motion. For the children on the bus, if they use other children riding the bus as their frame of reference, they do not appear to be moving. But if they use objects outside the bus as their frame of reference, they can tell they are moving.

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URL: http://www.ck12.org/flx/render/embeddedobject/5019

Q: What is your frame of reference if you are standing on the sidewalk and see the bus go by? How can you tell that the bus is moving?

A: Your frame of reference might be the trees and other stationary objects across the street. As the bus goes by, it momentarily blocks your view of these objects, and this helps you detect the bus' motion.

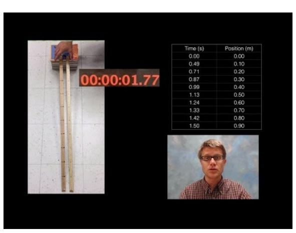
Summary

- Motion is defined as a change of position.
- How we perceive motion depends on our frame of reference. Frame of reference refers to something that is not moving with respect to an observer that can be used to detect motion.

Review

1. How is motion defined in science?
2. Describe an original example that shows how frame of reference influences the perception of motion.

Resources



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9.4 Newton's Second Law

Learning Objectives

- State Newton's second law of motion.
- Compare and contrast the effects of force and mass on acceleration.

These boys are racing around the track at Newton's Skate Park. The boy who can increase his speed the most will win the race. Tony, who is closest to the camera in this picture, is bigger and stronger than the other two boys, so he can apply greater force to his skates.

Q: Does this mean that Tony will win the race?

A: Not necessarily, because force isn't the only factor that affects acceleration.

Force, Mass, and Acceleration

Whenever an object speeds up, slows down, or changes direction, it accelerates. Acceleration occurs whenever an unbalanced force acts on an object. Two factors affect the acceleration of an object: the net force acting on the object and the object's mass. **Newton's second law of motion** describes how force and mass affect acceleration. The law states that the acceleration of an object equals the net force acting on the object divided by the object's mass. This can be represented by the equation:

$\text{Acceleration} = \frac{\text{Net force}}{\text{Mass}}$

or $a = \frac{F}{m}$

Q: While Tony races along on his rollerblades, what net force is acting on the skates?

A: Tony exerts a backward force against the ground, as you can see in the **Figure** 9.11, first with one skate and then with the other. This force pushes him forward. Although friction partly counters the forward motion of the skates, it is weaker than the force Tony exerts. Therefore, there is a net forward force on the skates.

FIGURE 9.11

Direct and Inverse Relationships

Newton's second law shows that there is a direct relationship between force and acceleration. The greater the force that is applied to an object of a given mass, the more the object will accelerate. For example, doubling the force on the object doubles its acceleration.

The relationship between mass and acceleration is different. It is an inverse relationship. In an inverse relationship, when one variable increases, the other variable decreases. The greater the mass of an object, the less it will accelerate when a given force is applied. For example, doubling the mass of an object results in only half as much acceleration for the same amount of force.

Q: Tony has greater mass than the other two boys he is racing (pictured in the opening image). How will this affect his acceleration around the track?

A: Tony's greater mass will result in less acceleration for the same amount of force.

Summary

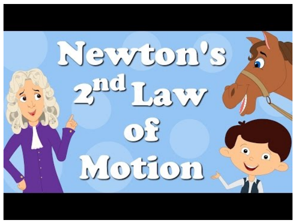
- Newton's second law of motion states that the acceleration of an object equals the net force acting on the object divided by the object's mass.
- According to the second law, there is a direct relationship between force and acceleration and an inverse relationship between mass and acceleration.

Review

1. State Newton's second law of motion.
2. How can Newton's second law of motion be represented with an equation?
3. If the net force acting on an object doubles, how will the object's acceleration be affected?
4. Tony has a mass of 50 kg, and his friend Sam has a mass of 45 kg. Assume that both friends push off on their rollerblades with the same force. Explain which boy will have greater acceleration.

Explore More

Use this resource to answer the questions that follow.



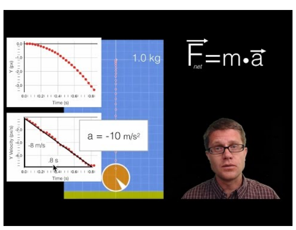
MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/177561

1. What is the rate of change of momentum?
2. How is force proportional to acceleration?
3. How is force proportional to mass?

Resources



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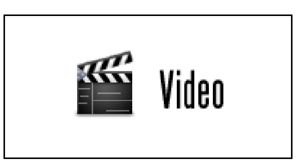

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9.5 Glossary

acceleration, The rate of change of velocity (or speed) acceleration = the change in velocity/the change in time or a = $\Delta V/\Delta T$ (ΔV means the ending velocity minus the starting velocity as done on a number line - so you subtract even if there are negative numbers)

anion, A negatively charged particle that is a group of one or more atoms.

cation, A positively charged particle that is a group of one or more atoms.

conduction, The process of electric charge traveling (flowing) through a physical object in a specific direction.

conservation of charge, The idea that electric charge is neither created nor destroyed. The total electric charge in a system remains unchanged.

electric charge, a property of certain particles of matter which can have a force that will attract (pull together) or repel (push away). The rule is as follows: Like charges repel opposite charges attract.

electric field, The mathematical description of how much the rate of force/distance electrical charge creates over an area or volume, how much potential electric energy there is in a particular volume.

electromagnetism, magnetism produced by electricity or the combination of electricity and magnetism into one mathematical idea/force.

force, is a push or a pull or the amount of the push or pull

friction, the force that opposes motion.

gravity has traditionally been defined as a force of attraction between things that have mass.

Law of universal gravitation, the law which described what is universally observed from the earth to the farthest seen galaxies. That all objects with mass attract all other objects with mass. The force of gravity is directly proportional to the product of the masses of the two objects and inversely proportional to the square of the distance between their centers of mass. The force of gravity follows this formula: $F = G\ m_1 m_2/d^2$. Where F is the force of gravity between the objects, m_1 and m_2 are the amounts of mass, and d is the distance between them.

magnetic fields, Similar to an electric field, A Mathematical description of the rate of force/distance a magnet causes in its location.

magnetic poles, One of the two ends of the magnet where its magnetic field enters the magnet.

magnets, An object with a property related to electric charges moving which also creates an attractive or repulsive force at a 90 degree angle to the charge movement.

mass, The amount of matter in an object.

polarization, separation of electric charges to create an electrical field.

right hand rule, If fingers on the right hand point in the direction of the magnetic field, then the thumb point in the direction of positive current flow (opposite direction of the flow of electricity)

static discharge, When the static charge is allowed to flow away and cancel itself with opposite charges.

static electricity, The buildup of charge on objects , because that charge can stay in one place it is called static (unmoving)

weight, The amount of force gravity exerts on a mass.

For

9.6 References

1. Image copyright Leah-Anne Thompson, 2013. Scooter rider pushing off the ground . Used under license from Shutterstock.com
2. Christopher Auyeung. Representation of a force using an arrow . CC BY-NC 3.0
3. Christopher Auyeung. This physics book is at rest because it has balanced forces . CC BY-NC 3.0
4. Mathew Cerasoli, modified by CK-12 Foundation. Tug of war illustrating the concept of net force . CC BY 2.0
5. Laura Guerin. Two soccer players illustrating the concept of net force . CC BY-NC 3.0
6. Laura Guerin. Workers illustrating the concept of net force . CC BY-NC 3.0
7. Chris Down/Tango project(book), Arman Cagle (arrow), modified by CK-12 Foundation. Practice problem illustrating the concept of net forces . Public Domain
8. Train: John H. Gray; Bike: Flickr:DieselDemon; Geese: Don McCullough; Meteor: Ed Sweeney (Flickr:Navicore). Examples of moving objects . CC BY 2.0
9. Bus: Flickr:torbakhopper; Children: Flickr:woodleywonderworks. We perceive motion based on our frame of reference . CC BY 2.0
10. Uploaded by User:Shizhao/Wikimedia Commons. Skater exerting force . CC BY 2.5

CHAPTER 10 Gravity, Electric and Magnetic Fields in Physical Science PS 2-3, PS 2-5

Chapter Outline

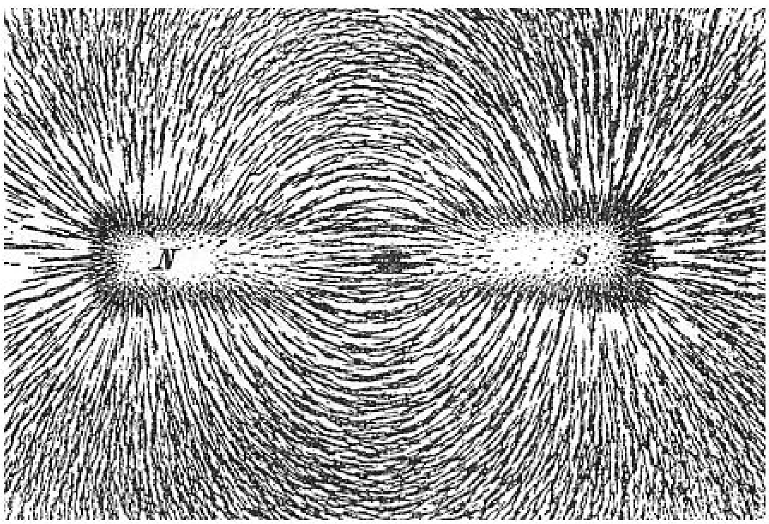


FIGURE 10.1

The image shows iron filings (small bits of iron) shaped into a pattern as they are dropped on a white paper above a magnet. Scientist imagine lines that follow the shape of the filings and mathematically calculate them, calling it a magnetic field.

INTRODUCTION

DISCIPLINARY CORE IDEA:

MS-PS 2-5 By the end of instruction, students should be able to answer a test which asks them to: **Do experiments that provide evidence that fields exist between objects and exert forces over a distance even though objects do not touch.**

How will we use electric and magnetic fields in our trip to Mars? Our Story helps us look at electricity and magnetism. There is of course another role, the magnetic field of the Earth and Mars Before and after we leave Earth.

http://www.space.dtu.dk/english/Research/Universe_and_Solar_System/magnetic_field

10.1 Magnets

The train in this photo is called a maglev train. The word *maglev* stands for "magnetic levitation." Magnets push the train upward so it hovers, or levitates, above the track without actually touching it. This eliminates most of the friction acting against the train when it moves. Other magnets pull the train forward along the track. Because of all the magnets, the train can go very fast. It can fly over the tracks at speeds up to 480 kilometers (300 miles) per hour! What are magnets and how do they exert such force? In this article, you'll find out.

Magnetic Poles

A **magnet** is an object that attracts certain materials such as iron. You're probably familiar with common bar magnets, like the one shown in the **Figure** 10.2. Like all magnets, this bar magnet has north and south **magnetic poles**. The red end of the magnet is the north pole and the blue end is the south pole. The poles are regions where the magnet is strongest. The poles are called north and south because they always line up with Earth's north-south axis if the magnet is allowed to move freely. (Earth's axis is the imaginary line around which the planet rotates.)

Q: What do you suppose would happen if you cut the bar magnet pictured in the **Figure** 10.2 along the line between the north and south poles?

A: Both halves of the magnet would also have north and south poles. If you cut each of the halves in half, all those pieces would have north and south poles as well. Pieces of a magnet always have both north and south poles no matter how many times you cut the magnet.

Magnetic Force and Magnetic Field

The force that a magnet exerts on certain materials, including other magnets, is called **magnetic force**. The force is exerted over a distance and includes forces of attraction and repulsion. North and south poles of two magnets attract each other, while two north poles or two south poles repel each other. A magnet can exert force over a

FIGURE 10.2

distance because the magnet is surrounded by a **magnetic field**. In the **Figure** 10.3, you can see the magnetic field surrounding a bar magnet. Tiny bits of iron, called iron filings, were placed under a sheet of glass. When the magnet was placed on the glass, it attracted the iron filings. The pattern of the iron filings shows the lines of force that make up the magnetic field of the magnet. The concentration of iron filings near the poles indicates that these areas exert the strongest force. You can also see how the magnetic field affects the compasses placed above the magnet.

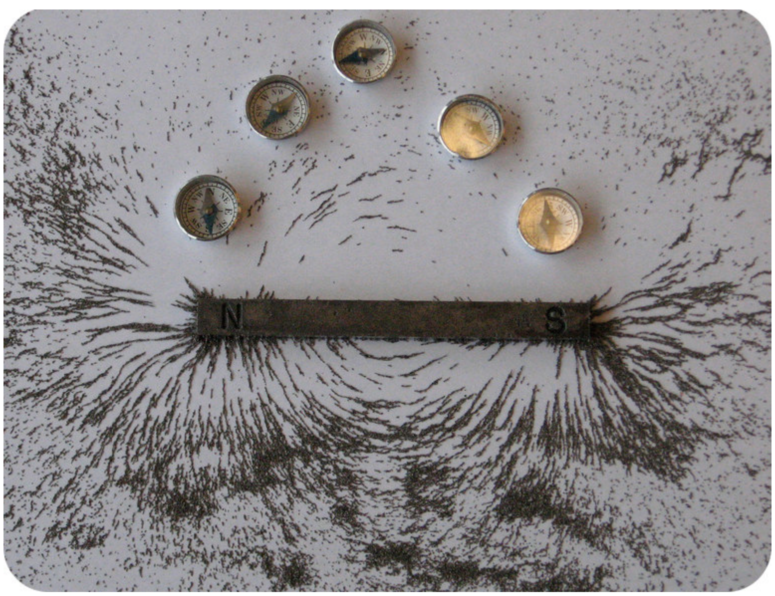


FIGURE 10.3

When two magnets are brought close together, their magnetic fields interact. You can see how they interact in the **Figure** 10.4. The lines of force of north and south poles attract each other whereas those of two north poles repel each other.

Electromagnetism

Electromagnetism is magnetism produced by an electric current. When electric current flows through a wire, it creates a magnetic field that surrounds the wire in circles. You can see this in the diagram below. Note that electric

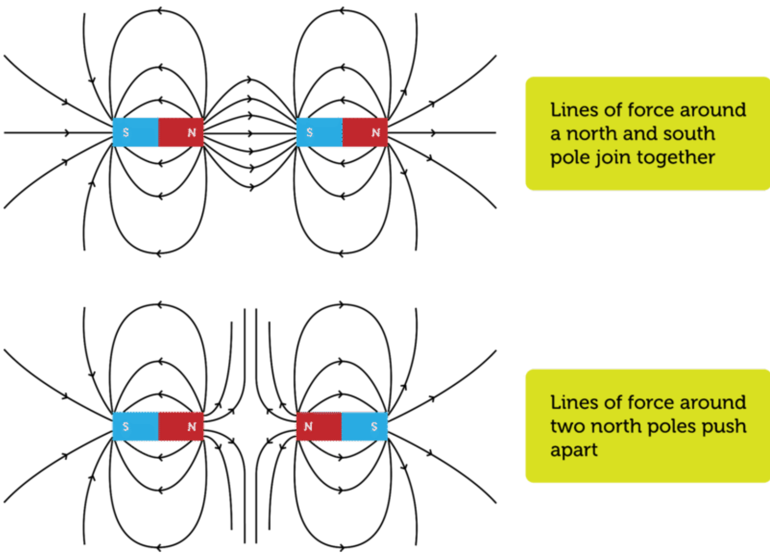


FIGURE 10.4

current is conventionally shown moving from positive to negative electric potential, as in this diagram. However, electrons in current actually flow in the opposite direction, from negative to positive potential.

Q: If more current flows through a wire, how might this affect the magnetic field surrounding the wire?

A: With more current, the magnetic field is stronger.

http://www.ck12.org/physics/Magnetic-Fields/lecture/Magnetic-Field-from-Electrical-Current/?referrer=featured_content

Summary

- A magnet is an object that attracts certain materials such as iron. All magnets have north and south magnetic poles. The poles are regions where the magnet is strongest.
- The force that a magnet exerts is called magnetic force. The force is exerted over a distance and includes forces of attraction and repulsion. A magnet can exert force over a distance because the magnet is surrounded by a magnetic field.

Review

1. What is a magnet?
2. Describe the magnetic poles of a bar magnet.
3. Explain why a magnet can exert force over a distance.
4. Sketch two bar magnets that are arranged so their magnetic fields attract each other. Label the magnetic poles, and add arrows to represent lines of force between the two magnets.

10.2 Earth Is a Magnet

Did you ever use a compass like the one in this picture? Even if you've never used a compass, you probably know that the needle of a compass always points north. That's because a compass needle is magnetized, so it is attracted by a magnet.

Q: What magnet attracts a compass needle?

A: A compass needle is attracted by magnet Earth. It always points north because Earth acts as a giant magnet.

Earth's Magnetic Poles

Imagine a huge bar magnet passing through Earth's axis, as in the **Figure** 10.5. This is a good representation of Earth as a magnet. Like a bar magnet, Earth has north and south magnetic poles. A **magnetic pole** is the north or south end of a magnet, where the magnet exerts the most force.

Two North Poles

Although the needle of a compass always points north, it doesn't point to Earth's north geographic pole. Find the north geographic pole in the **Figure** 10.6. As you can see, it is located at 90° north latitude. Where does a compass needle point instead? It points to Earth's north magnetic pole, which is located at about 80° north latitude. Earth also has two south poles: a south geographic pole and a south magnetic pole.

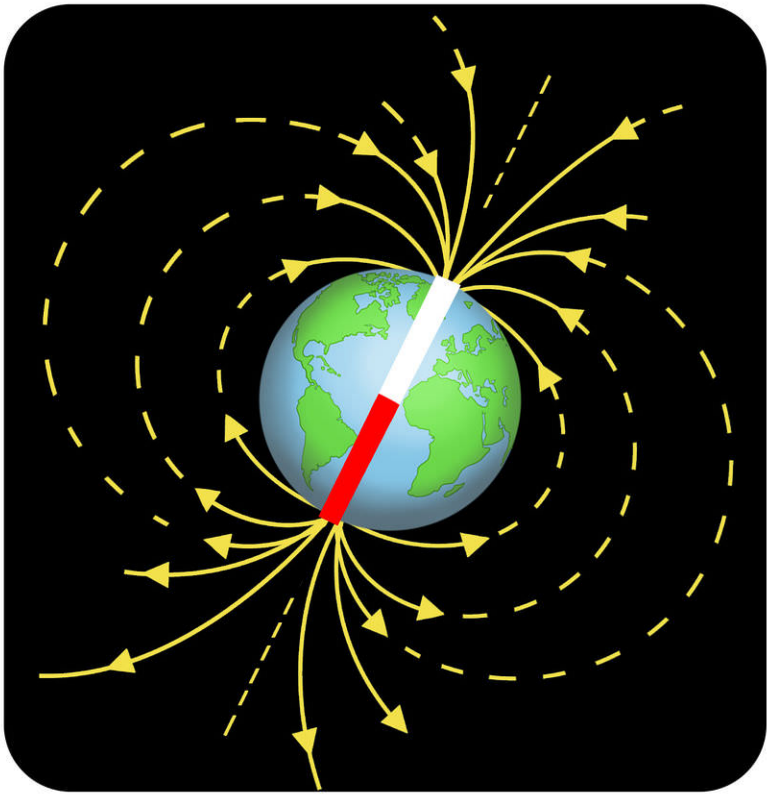


FIGURE 10.5

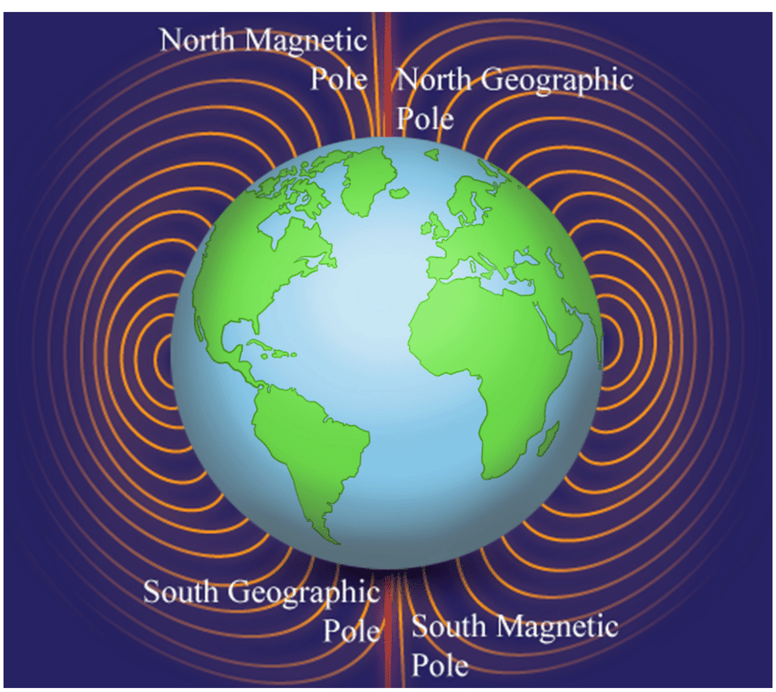


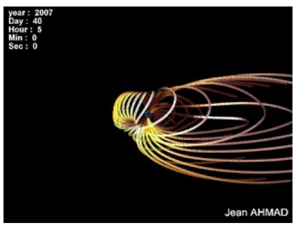
FIGURE 10.6

Q: The north end of a compass needle points toward Earth's north magnetic pole. The like poles of two magnets repel each other, and the opposite poles attract. So why doesn't the north end of a compass needle point to Earth's south magnetic pole instead?

A: The answer may surprise you. The compass needle actually does point to the south pole of magnet Earth. However, it is called the north magnetic pole because it is close to the north geographic pole. This naming convention was adopted a long time ago to avoid confusion.

Earth's Magnetic Field

Like all magnets, Earth has a magnetic field. Earth's magnetic field is called the **magnetosphere**. You can see a model of the magnetosphere in the **Figure** 10.7. It is a huge region that extends outward from Earth in all directions. Earth exerts magnetic force over the entire field, but the force is strongest at the poles, where lines of force converge.



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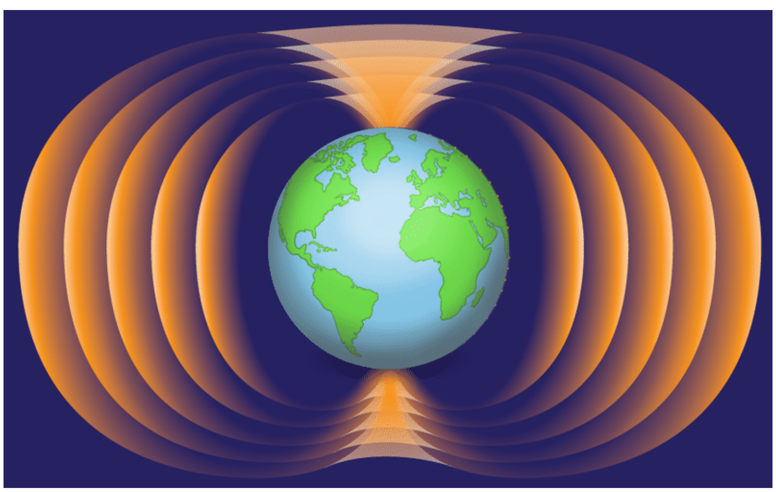


FIGURE 10.7

Summary

- Earth acts as a giant magnet with magnetic poles and a magnetic field over which it exerts magnetic force.
- Earth has north and south magnetic poles like a bar magnet. Earth's magnetic poles are not the same as the geographic poles.
- Earth's magnetic field is called the magnetosphere. It is strongest at the poles.

Review

1. How does Earth act as a bar magnet?
2. The compass in a car shows that the car is moving north. Does this mean that the car is moving toward 90° north latitude? Why or why not?
3. Describe the magnetosphere.

10.3 Electric Charge and Electric Force

Learning Objectives

- Define electric charge.
- Describe electric forces between charged particles.

A lightning bolt is like the spark that gives you a shock when you touch a metal doorknob. Of course, the lightning bolt is on a *much* larger scale. But both the lightning bolt and spark are a sudden transfer of electric charge.

Introducing Electric Charge

Electric charge is a physical property of particles or objects that causes them to attract or repel each other without touching. All electric charge is based on the protons and electrons in atoms. A proton has a positive electric charge, and an electron has a negative electric charge. In the **Figure** 10.8, you can see that positively charged protons (+) are located in the nucleus of the atom, while negatively charged electrons (-) move around the nucleus.

Electric Force

When it comes to electric charges, opposites attract, so positive and negative particles attract each other. You can see this in the **Figure** 10.9. This attraction explains why negative electrons keep moving around the positive nucleus of the atom. Like charges, on the other hand, repel each other, so two positive or two negative charges push apart. This is also shown in the diagram. The attraction or repulsion between charged particles is called **electric force**. The strength of electric force depends on the amount of electric charge on the particles and the distance between them. Larger charges or shorter distances result in greater force.

Q: How do positive protons stay close together inside the nucleus of the atom if like charges repel each other?

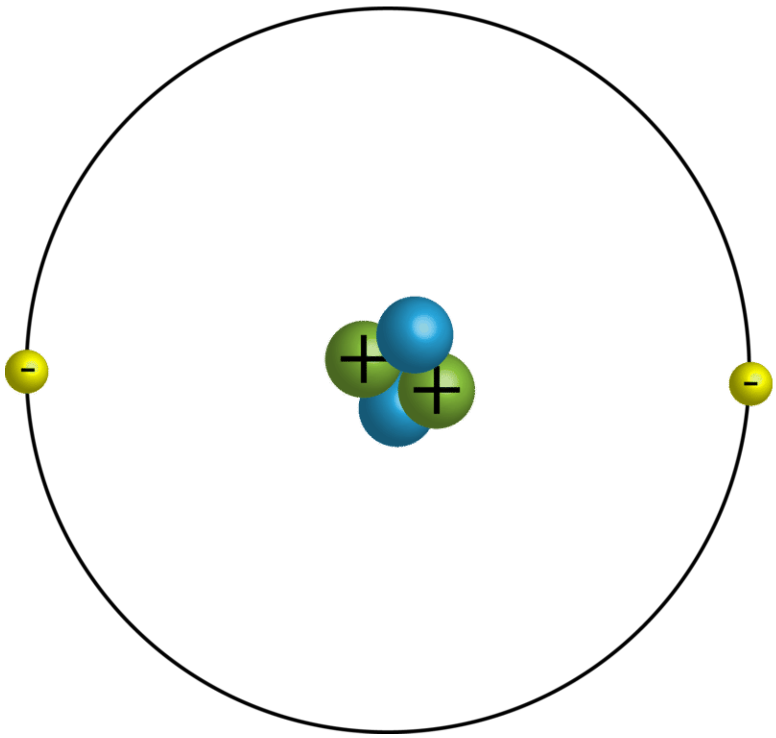


FIGURE 10.8

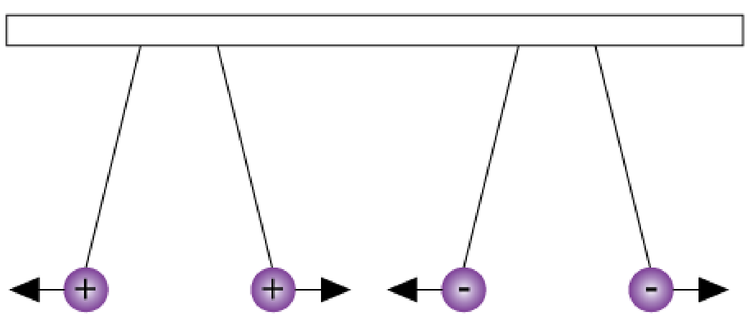


FIGURE 10.9

A: Other, stronger forces in the nucleus hold the protons together.

Summary

- Electric charge is a physical property of particles or objects that causes them to attract or repel each other without touching.
- Particles that have opposite charges attract each other. Particles that have like charges repel each other. The force of attraction or repulsion is called electric force.

Review

1. What is electric charge?
2. Make a simple table summarizing electric forces between charged particles.

10.4 Electric Fields

Learning Objectives

- Describe the electric field around a charged particle.
- Explain how electric fields of two charged particles interact.

Halt! This science fiction image shows a human hand surrounded by a green force field. It's supposed to represent an electric field generated by a hand. What is an electric field? Read on to find out.

What Is an Electric Field?

An **electric field** is a space around a charged particle where the particle exerts electric force on other charged particles. Because of their force fields, charged particles can exert force on each other without actually touching. Electric fields are generally represented by arrows, as you can see in the **Figure** 10.10. The arrows show the direction of electric force around a positive particle and a negative particle.

Interacting Electric Fields

When charged particles are close enough to exert force on each other, their electric fields interact. This is illustrated in the **Figure** 10.11. The lines of force bend together when particles with different charges attract each other. The lines bend apart when particles with like charges repel each other.

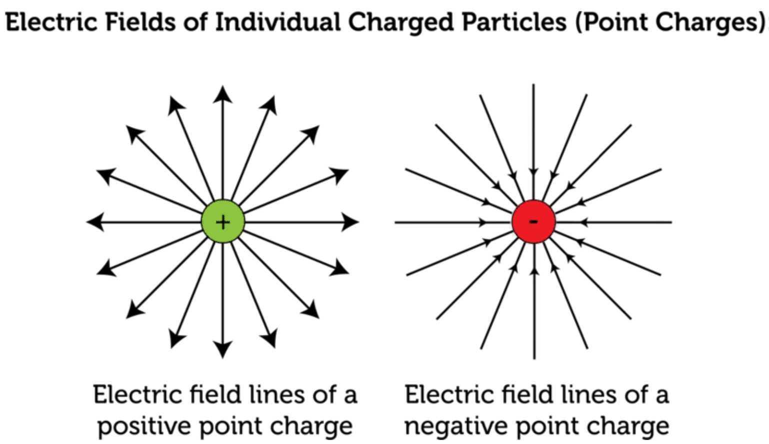


FIGURE 10.10

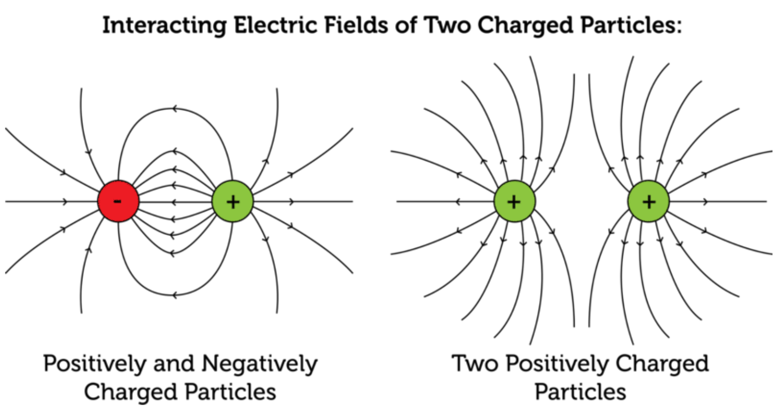


FIGURE 10.11

Note: +q = positive charge and -q = negative charge

Q: What would the lines of force look like around two negative particles?

A: They would look like the lines around two positive particles, except the arrows would point toward, rather than away from, the negative particles.

Summary

- An electric field is a space surrounding a charged particle where the particle exerts electric force.
- When charged particles are close enough to exert force on each other, their electric fields interact. Particles with opposite charges attract each other. Particles with like charges repel each other.

Review

1. What is an electric field?
2. Create a sketch showing how the electric fields of two negatively charged particles interact.

10.5 Glossary

acceleration, the rate of change of velocity of an object, sometimes the rate of change of speed is used.

average speed, the total distance over the total time.

Balanced forces, Forces that act in opposite directions on the same object and have the same magnitude (amount)

direction, the way in which motion takes place, the alignment of motion; as a mathematical description direction is often the sign value of the number line. for example, motion to the left can be thought of as motion in the negative direction, while motion to the right can be thought of as motion in the positive direction.

distance, the amount of change in position, sometimes from beginning to end, sometimes along the path taken (if it is not a straight path.

force, A push or pull in a certain direction.

frame of reference, The place or location you choose to think of as stopped so you can compare the motion of other objects.

instantaneous speed, The speed at a single moment in time.

mass, the amount of matter in a object

motion, a change in position over a time period

net force, The sum of forces. forces can add in the same direction or in opposite directions, or in different directions depending on which forces act on one object at the same time. When forces are in the same direction or opposite direction they add like positive and negative numbers on a number line.

Newton's First law of motion, an object at rest stays at rest, an object in motion stays in the same motion unless acted on by a net force.

Newton's second law of motion, force equals mass times acceleration, or F=ma. this can be rewritten using algebra as a= F/m or m= F/a, the equations have describe the same thing, they are mathematically identical equations.

Newton's third law, for every force on an object, there is an equal force in the opposite by the object on what pushed it. This is often said as: "For every action there is an equal and opposite reaction."

speed, the rate of motion distance/time, or S=D/T. If we talk about instantaneous speed, we will be talking about speed over a very short time range, if we talk about average speed, the amount of time will be relatively large. It is also the slope of a line on a distance vs. time graph.

Unbalances forces, When forces act in opposite directions and do NOT have the same magnitude (amount) and do not completely cancel out. Think about a game of tug of war - one side pulls harder and wins.

vector, a quantity which has BOTH amount and direction at the same time. The word for amount is usually replaced by the word magnitude. so vectors have magnitude and direction. common vectors include velocity (speed in a certain direction) and force.

10.6 References

1. Image copyright MilanB, 2014. Bar magnet . Used under license from Shutterstock.com
2. Marc Spooner. Iron fillings attracted to a bar magnet . CC BY 2.0
3. Christopher Auyeung. Magnetic field lines formed by bringing two magnets close to each other . CC BY-NC 3.0
4. Laura Guerin. Schematic illustrating how earth is a magnet . CC BY-NC 3.0
5. Laura Guerin. Earth has two north poles, geographic north and magnetic north . CC BY-NC 3.0
6. Laura Guerin. Earth's magnetosphere . CC BY-NC 3.0
7. Christopher Auyeung. Location of charges in an atom . CC BY-NC 3.0
8. Zachary Wilson. Like charges repel each other . CC BY-NC 3.0
9. Christopher Auyeung. Point charge electric field . CC BY-NC 3.0
10. Christopher Auyeung. Field lines of two close charges . CC BY-NC 3.0

CHAPTER 11 Waves MS PS 4-1, PS 4-2, PS 4-3

Chapter Outline

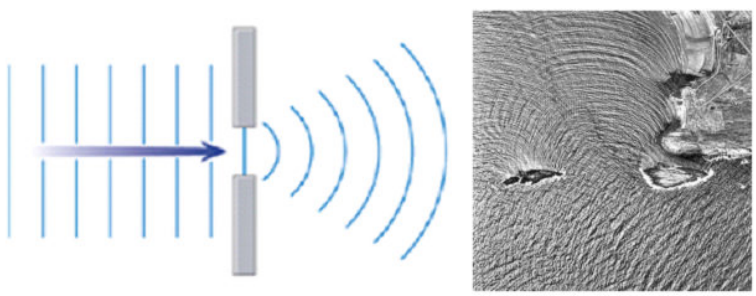


FIGURE 11.1
The image shows a drawing if diffraction, and a photo of diffraction occurring in nature. Diffraction is one of several behaviors of waves. Diffraction is how waves bend around corners and edges instead of just going straight through them.

INTRODUCTION

DISCIPLINARY CORE IDEA:

MS-PS 4-2 By the end of instruction, students should be able to answer a test which asks them to: **Create and use a model to show wave properties of reflection, absorption, and transmission through various materials.**

For our Story, we learn about waves, electromagnetic waves, light radio, microwaves are the kinds of waves we will use to communicate with Earth and other space ships on our way to Mars.

11.1 Visible Light and Matter

Learning Objectives

- Describe how visible light interacts with matter.
- Compare and contrast transparent, translucent, and opaque matter.

A mime is an actor who uses movement and facial expressions rather than words to communicate with an audience. The mime in this picture is using a mirror to apply stage makeup that will accentuate her features so she can communicate more expressively. When light strikes a mirror, it is reflected back from the shiny surface. The reflected light forms an image of whatever is in front of the mirror. Reflection is just one way that visible light may interact with matter.

Reflection

Reflection of light occurs when light bounces back from a surface that it cannot pass through. Reflection may be regular or diffuse.

- If the surface is very smooth, like a mirror, the reflected light forms a very clear image. This is called regular, or specular, reflection. In the **Figure** 11.2, the smooth surface of the still water in the pond on the left reflects light in this way.

- When light is reflected from a rough surface, the waves of light are reflected in many different directions, so a clear image does not form. This is called diffuse reflection. In the **Figure** 11.2, the ripples in the water in the picture on the right cause diffuse reflection of the blooming trees.

FIGURE 11.2

Transmission

Transmission of light occurs when light passes through matter. As light is transmitted, it may pass straight through matter or it may be refracted or scattered as it passes through.

- When light is refracted, it changes direction as it passes into a new medium and changes speed. The straw in the **Figure** 11.3 looks bent where light travels from water to air. Light travels more quickly in air than in water and changes direction.

FIGURE 11.3

- **Scattering** occurs when light bumps into tiny particles of matter and spreads out in all directions. In the **Figure** 11.4, beams of light from car headlights are shining through fog. The light is scattered by water droplets in the air, giving the headlights a “halo” appearance.

FIGURE 11.4

Q: What might be another example of light scattering?

A: When light passes through smoky air, it is scattered by tiny particles of soot.

Absorption

Light may transfer its energy to matter rather than being reflected or transmitted by matter. This is called **absorption**. When light is absorbed, the added energy increases the temperature of matter. If you get into a car that has been sitting in the sun all day, the seats and other parts of the car's interior may be almost too hot to touch, especially if they are black or very dark in color. That's because dark colors absorb most of the sunlight that strikes them.

Q: In hot sunny climates, people often dress in light-colored clothes. Why is this a good idea?

A: Light-colored clothes absorb less light and reflect more light than dark-colored clothes, so they keep people cooler.

Classifying Matter in Terms of Light

Matter can be classified on the basis of its interactions with light. Matter may be transparent, translucent, or opaque. An example of each type of matter is pictured in the **Figure** 11.5.

- **Transparent** matter is matter that transmits light without scattering it. Examples of transparent matter include air, pure water, and clear glass. You can see clearly through transparent objects, such as the top panes of the window 11.5, because just about all of the light that strikes them passes through to the other side.

- **Translucent** matter is matter that transmits light but scatters the light as it passes through. Light passes through translucent objects but you cannot see clearly through them because the light is scattered in all directions. The frosted glass panes at the bottom of the window 11.5 are translucent.
- **Opaque** matter is matter that does not let any light pass through it. Matter may be opaque because it absorbs light, reflects light, or does some combination of both.

Examples of opaque objects are objects made of wood, like the shutters in the **Figure** 11.6. The shutters absorb most of the light that strikes them and reflect just a few wavelengths of visible light. The glass mirror 11.6 is also opaque. That's because it reflects all of the light that strikes it.

FIGURE 11.5

FIGURE 11.6

Summary

- Reflection of light occurs when light bounces back from a surface that it cannot pass through. If the surface is very smooth, the reflected light forms an image.
- Transmission of light occurs when light passes through matter. As light is transmitted, it may pass straight through matter or it may be refracted or scattered by matter.
- Absorption of light occurs when light transfers its energy to matter rather than being reflected or transmitted

by matter. The temperature of matter increases with the added energy.
- Matter can be classified as transparent, translucent, or opaque depending on how it interacts with light.

Review

1. Describe three ways that light can interact with matter.
2. Transmitted light may be refracted or scattered. When does each process occur?
3. Why does matter increase in temperature when it absorbs light?
4. Compare and contrast transparent, translucent, and opaque matter.

11.2 Wavelength

Learning Objectives

- Define wavelength.
- Describe the wavelength of transverse and longitudinal waves.
- Relate wavelength to the energy of a wave.

Nobody really has such colorful eyes! The colors were added digitally after the photo was taken. They represent all the different colors of light. Light is a form of energy that travels in waves. Light of different colors has different wavelengths.

Defining Wavelength

Wavelength is one way of measuring the size of waves. It is the distance between two corresponding points on adjacent waves, and it is usually measured in meters. How it is measured is a little different for transverse and longitudinal waves.

- In a transverse wave, particles of the medium vibrate up and down at right angles to the direction that the wave travels. The wavelength of a transverse wave can be measured as the distance between two adjacent crests, or high points, as shown in the **Figure** 11.7.

- In a longitudinal wave, particles of matter vibrate back and forth in the same direction that the wave travels. The wavelength of a longitudinal wave can be measured as the distance between two adjacent compressions, as shown in the **Figure** 11.8. Compressions are the places where particles of the medium crowd close together as the energy of the wave passes through.

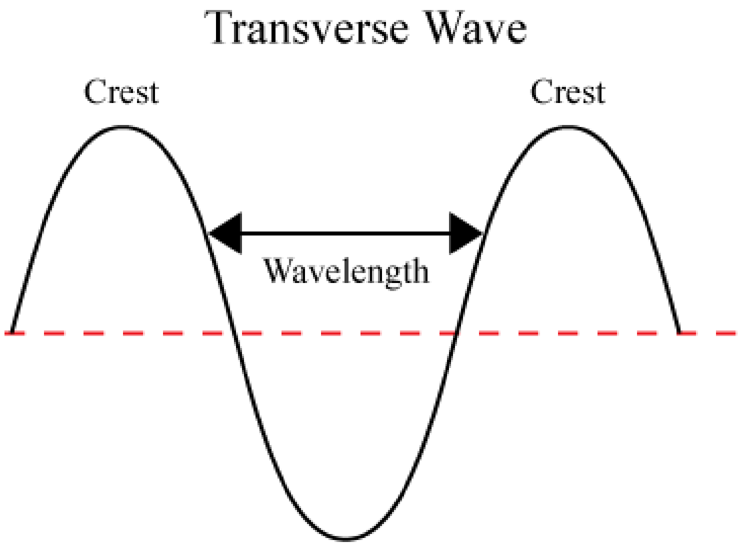


FIGURE 11.7

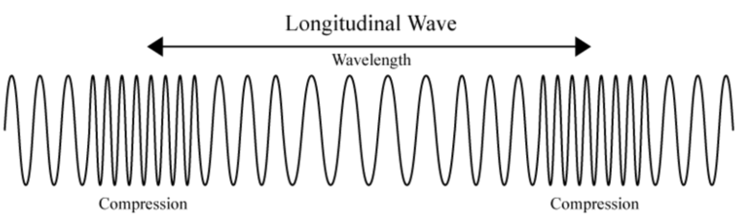


FIGURE 11.8

Wavelength and Wave Energy

The wavelength of a wave is related to the wave's energy. Short-wavelength waves have more energy than long-wavelength waves of the same amplitude. (Amplitude is a measure of how far particles of the medium move up and down or back and forth when a wave passes through them.) You can see examples of transverse waves with shorter and longer wavelengths in the **Figure** 11.9.

Q: Of all the colors of visible light, red light has the longest wavelength and violet light has the shortest wavelength. Which color of light has the greatest energy?

A: Violet light has the greatest energy because it has the shortest wavelength.

Summary

- Wavelength is one way of measuring the size of waves. It is the distance between two corresponding points on adjacent waves, usually measured in meters.
- The wavelength of a transverse wave can be measured as the distance between two adjacent crests. The wavelength of a longitudinal wave can be measured as the distance between two adjacent compressions.
- Short-wavelength waves have more energy than long-wavelength waves of the same amplitude.

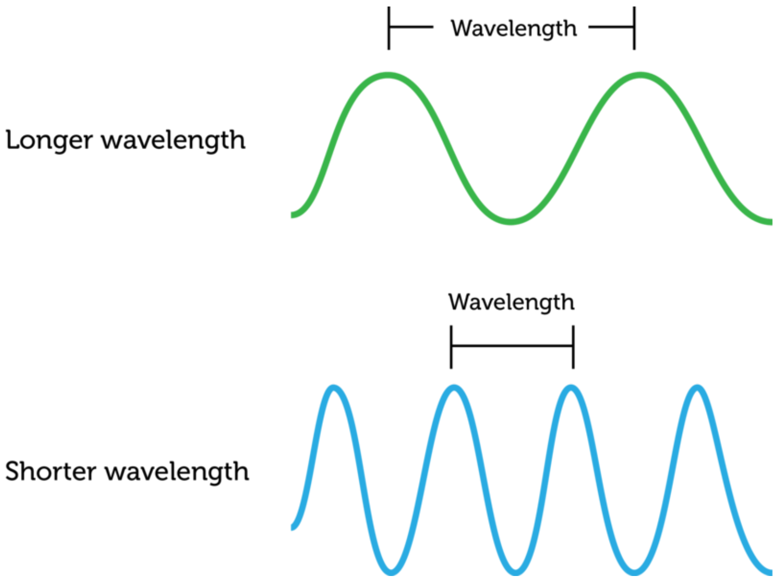
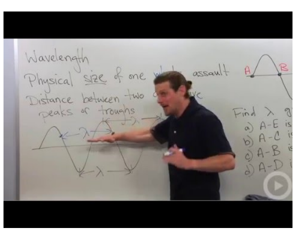


FIGURE 11.9

Review

1. What is the wavelength of a wave?
2. Draw a simple transverse wave and label the wavelength.

Resources



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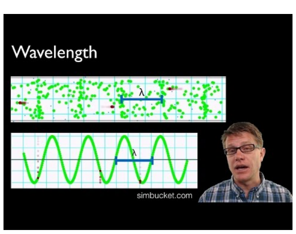

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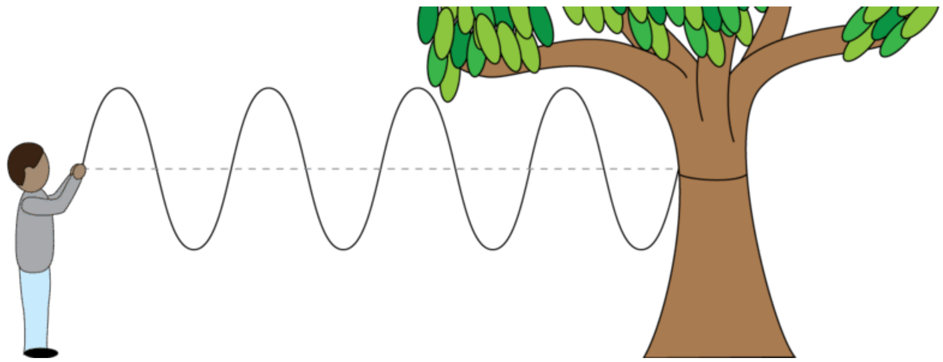
11.3 Wave Frequency

Learning Objectives

- Define wave frequency.
- Identify the SI unit for wave frequency.
- Explain how wave frequency is related to the energy of a wave.



Imagine making transverse waves in a rope, like the person in the sketch above. You tie one end of the rope to a tree or other fixed point, and then you shake the other end of the rope up and down with your hand. You can move the rope up and down slowly or quickly. How quickly you move the rope determines the frequency of the waves.

What Is Wave Frequency?

The number of waves that pass a fixed point in a given amount of time is **wave frequency**. Wave frequency can be measured by counting the number of crests (high points) of waves that pass the fixed point in 1 second or some other time period. The higher the number is, the greater the frequency of the waves. The SI unit for wave frequency is the **hertz (Hz)**, where 1 hertz equals 1 wave passing a fixed point in 1 second. The **Figure** 11.10 shows high-frequency and low-frequency transverse waves.

Q: The wavelength of a wave is the distance between corresponding points on adjacent waves. For example, it is the distance between two adjacent crests in the transverse waves in the diagram. Infer how wave frequency is related to wavelength.

A: Waves with a higher frequency have crests that are closer together, so higher frequency waves have shorter wavelengths.

Wave Frequency and Energy

The frequency of a wave is the same as the frequency of the vibrations that caused the wave. For example, to generate a higher-frequency wave in a rope, you must move the rope up and down more quickly. This takes more energy, so a higher-frequency wave has more energy than a lower-frequency wave with the same amplitude. You can see examples of different frequencies in the **Figure** 11.11 (Amplitude is the distance that particles of the medium move when the energy of a wave passes through them.)

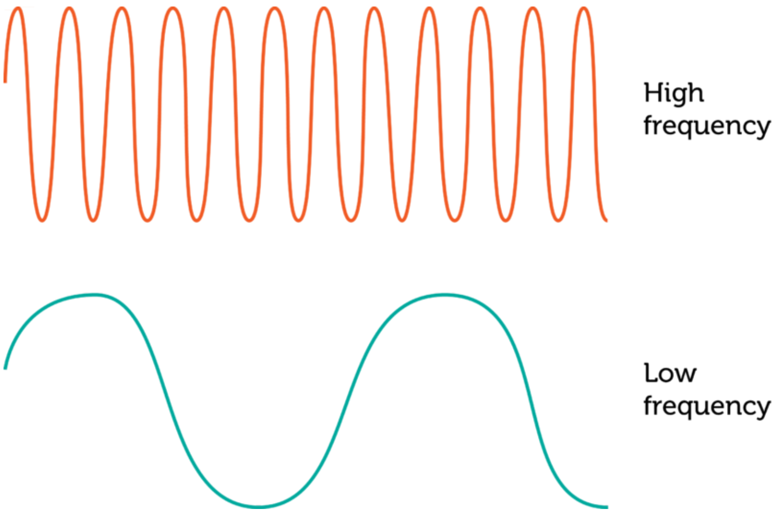


FIGURE 11.10

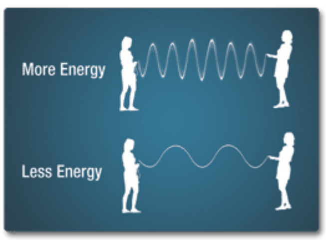


FIGURE 11.11

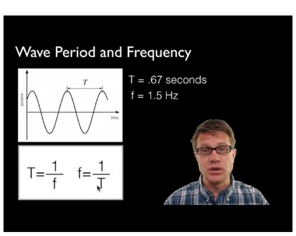
Summary

- Wave frequency is the number of waves that pass a fixed point in a given amount of time.
- The SI unit for wave frequency is the hertz (Hz), where 1 hertz equals 1 wave passing a fixed point in 1 second.
- A higher-frequency wave has more energy than a lower-frequency wave with the same amplitude.

Review

1. What is wave frequency?
2. What is the SI unit for wave frequency?
3. Assume that 10 waves pass a fixed point in 5 seconds. What is the frequency of the waves in hertz?
4. Relate wave frequency to the energy of waves.

Resources



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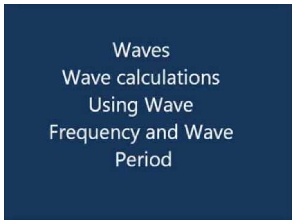

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11.4 Wave Amplitude

Learning Objectives

- Define wave amplitude.
- State how to measure the amplitude of transverse and longitudinal waves.
- Explain what determines the amplitude of a wave.

On a windy day, moving air particles strike these flags and transfer their energy of motion to particles of fabric. The energy travels through the fabric in waves. You can see the waves rippling through the brightly colored cloth. The windier the day is, the more vigorously the flags wave.

What's the Matter?

Waves that travel through matter—such as the fabric of a flag—are called mechanical waves. The matter they travel through is called the medium. When the energy of a wave passes through the medium, particles of the medium move. The more energy the wave has, the farther the particles of the medium move. The distance the particles move is measured by the wave's amplitude.

What Is Wave Amplitude?

Wave amplitude is the maximum distance the particles of the medium move from their resting positions when a wave passes through. The resting position of a particle of the medium is where the particle would be in the absence of a wave. The **Figure** 11.12 show the amplitudes of two different types of waves: transverse and longitudinal waves.

- In a transverse wave, particles of the medium move up and down at right angles to the direction of the wave. Wave amplitude of a transverse wave is the difference in height between the crest and the resting position. The crest is the highest point particles of the medium reach. The higher the crests are, the greater the amplitude of the wave.
- In a longitudinal wave, particles of the medium move back and forth in the same direction as the wave. Wave amplitude of a longitudinal wave is the distance between particles of the medium where it is compressed by the wave. The closer together the particles are, the greater the amplitude of the wave.

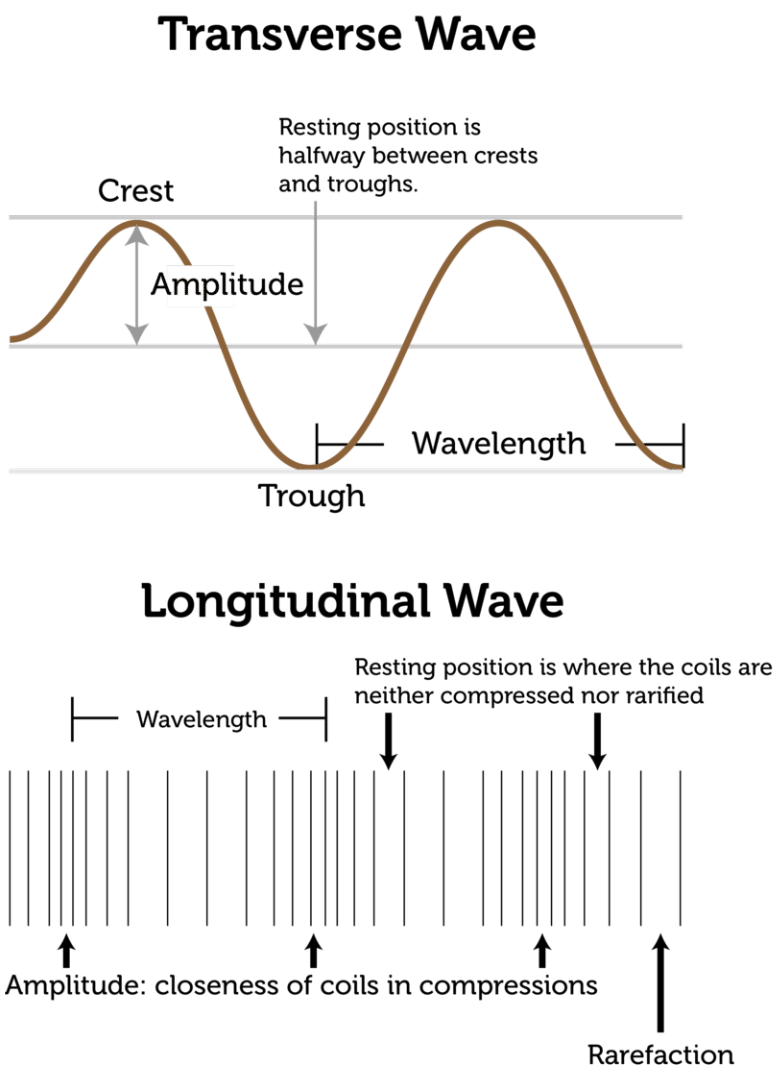


FIGURE 11.12

Q: What do you think determines a wave's amplitude?

A: Wave amplitude is determined by the energy of the disturbance that causes the wave.

Energy and Amplitude

A wave caused by a disturbance with more energy has greater amplitude. Imagine dropping a small pebble into a pond of still water. Tiny ripples will move out from the disturbance in concentric circles. The ripples are low-amplitude waves with very little energy. Now imagine throwing a big boulder into the pond. Very large waves will be generated by the disturbance. These waves are high-amplitude waves and have a great deal of energy.

Summary

- Wave amplitude is the maximum distance the particles of the medium move from their resting positions when a wave passes through.
- Wave amplitude of a transverse wave is the difference in height between a crest and the resting position. Wave amplitude of a longitudinal wave is the distance between particles of the medium where it is compressed by the wave.
- Wave amplitude is determined by the energy of the disturbance that causes the wave. A wave caused by a disturbance with more energy has greater amplitude.

Review

1. Define wave amplitude.
2. What is the amplitude of the transverse wave modeled in the **Figure** 11.13 if the height of a crest is 3 cm above the resting position of the medium?

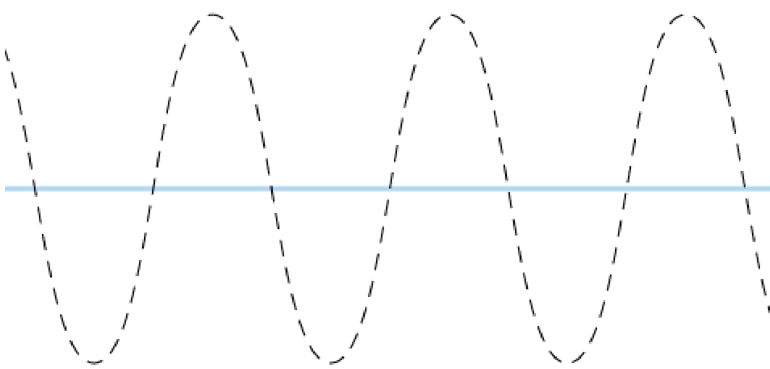


FIGURE 11.13

3. Which of these two longitudinal waves in the **Figure** 11.14 has greater amplitude?

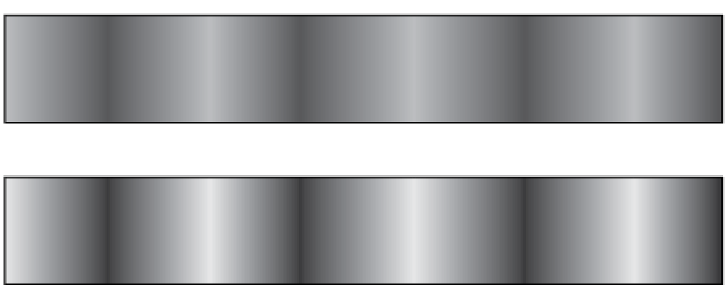
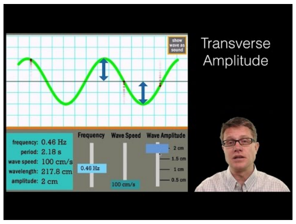


FIGURE 11.14

4. Relate wave amplitude to wave energy.

Resources



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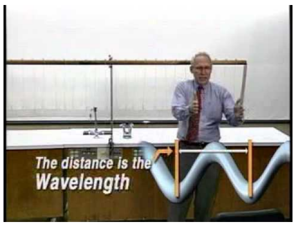

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11.5 Sound Waves

Learning Objectives

- Define sound.
- Describe sound waves and how they are generated.
- Identify media through which sound waves can travel.

Crack! Crash! Thud! That's what you'd hear if you were in the forest when this old tree cracked and came crashing down to the ground. But what if there was nobody there to hear the tree fall? Would it still make these sounds? This is an old riddle. To answer the riddle correctly, you need to know the scientific definition of sound.

Defining Sound

In science, **sound** is defined as the transfer of energy from a vibrating object in waves that travel through matter. Most people commonly use the term sound to mean what they hear when sound waves enter their ears. The tree above generated sound waves when it fell to the ground, so it made sound according to the scientific definition. But the sound wasn't detected by a person's ears if there was nobody in the forest. So the answer to the riddle is both yes and no!

How Sound Waves Begin

All sound waves begin with vibrating matter. Look at the first guitar string on the left in the **Figure** 11.15. Plucking the string makes it vibrate. The diagram below the figure shows the wave generated by the vibrating string. The moving string repeatedly pushes against the air particles next to it, which causes the air particles to vibrate. The vibrations spread through the air in all directions away from the guitar string as longitudinal waves. In longitudinal waves, particles of the medium vibrate back and forth parallel to the direction that the waves travel.

Q: If there were no air particles to carry the vibrations away from the guitar string, how would sound reach the ear?

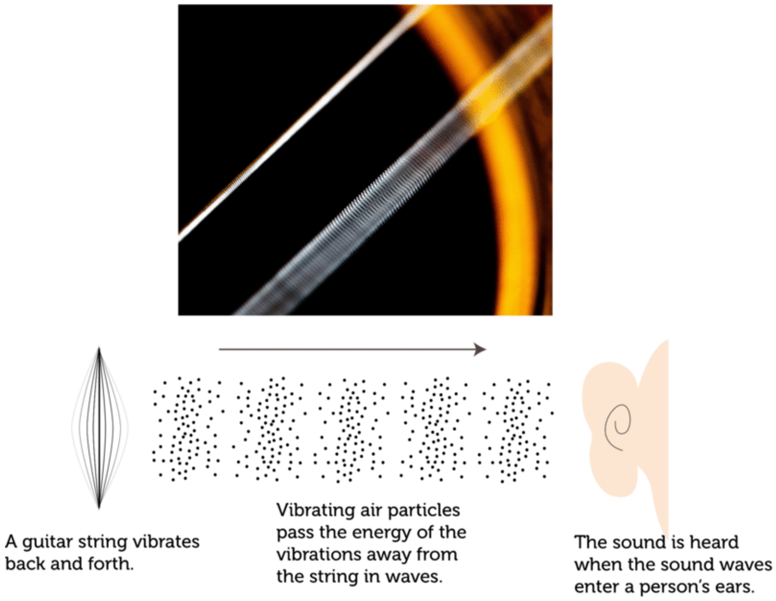

FIGURE 11.15

A: It wouldn't unless the vibrations were carried by another medium. Sound waves are mechanical waves, so they can travel only though matter and not through empty space.

A Ticking Clock

The fact that sound cannot travel through empty space was first demonstrated in the 1600s by a scientist named Robert Boyle. Boyle placed a ticking clock in a sealed glass jar. The clock could be heard ticking through the air and glass of the jar. Then Boyle pumped the air out of the jar. The clock was still ticking, but the ticking sound could no longer be heard. That's because the sound couldn't travel away from the clock without air particles to pass the sound energy along.

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Sound Waves and Matter

Most of the sounds we hear reach our ears through the air, but sounds can also travel through liquids and solids. If you swim underwater—or even submerge your ears in bathwater—any sounds you hear have traveled to your ears through the water. Some solids, including glass and metals, are very good at transmitting sounds. Foam rubber and heavy fabrics, on the other hand, tend to muffle sounds. They absorb rather than pass on the sound energy.

Q: How can you tell that sounds travel through solids?

A: One way is that you can hear loud outdoor sounds such as sirens through closed windows and doors. You can also hear sounds through the inside walls of a house. For example, if you put your ear against a wall, you may be able to eavesdrop on a conversation in the next room—not that you would, of course.

Summary

- In science, sound is defined as the transfer of energy from a vibrating object in waves that travel through matter.
- All sound waves begin with vibrating matter. The vibrations generate longitudinal waves that travel through matter in all directions.
- Most sounds we hear travel through air, but sounds can also travel through liquids and solids.

Review

1. How is sound defined in science? How does this definition differ from the common meaning of the word?
2. Hitting a drum, as shown in the **Figure** 11.16, generates sound waves. Create a diagram to show how the sound waves begin and how they reach a person's ears.

FIGURE 11.16

3. How do you think earplugs work?

11.6 Intensity and Loudness of Sound

Learning Objectives

- Define intensity of sound and relate it to loudness.
- Compare decibel levels of different sounds.
- Identify factors that affect sound intensity.

A friend whispers to you in a voice so soft that she has to lean very close so you can hear what she's saying. Later that day, your friend shouts to you from across the gymnasium. Now her voice is loud enough for you to hear her clearly even though she's several meters away. Obviously, sounds can vary in loudness.

It's All About Energy

Loudness refers to how loud or soft a sound seems to a listener. The loudness of sound is determined, in turn, by the intensity of the sound waves. **Intensity** is a measure of the amount of energy in sound waves. The unit of intensity is the **decibel (dB)**.

Decibel Levels

The **Figure** 11.17 shows decibel levels of several different sounds. As decibel levels get higher, sound waves have greater intensity and sounds are louder. For every 10-decibel increase in the intensity of sound, loudness is 10 times greater. Therefore, a 30-decibel "quiet" room is 10 times louder than a 20-decibel whisper, and a 40-decibel light rainfall is 100 times louder than the whisper. High-decibel sounds are dangerous. They can damage the ears and cause loss of hearing.

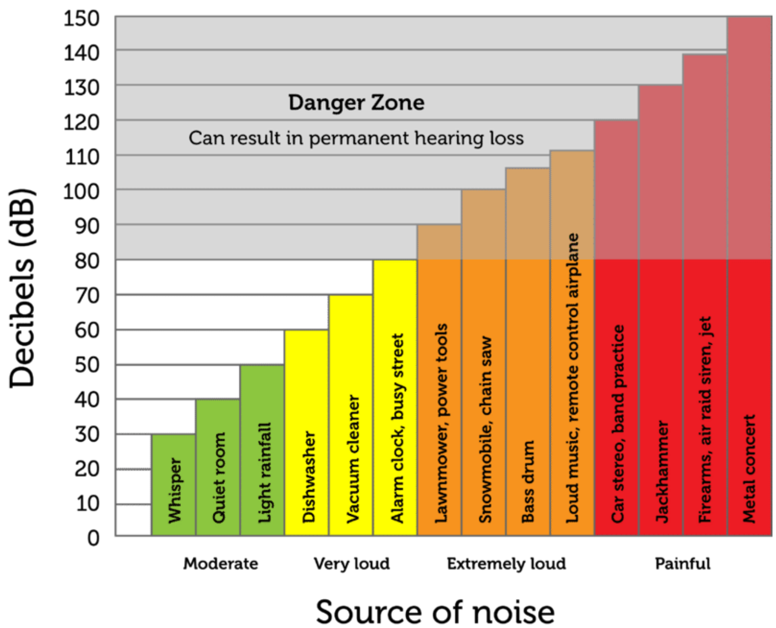

FIGURE 11.17

Q: How much louder than a 20-decibel whisper is the 60-decibel sound of a vacuum cleaner?

A: The vacuum cleaner is 10,000 times louder than the whisper!

Amplitude and Distance

The intensity of sound waves determines the loudness of sounds, but what determines intensity? Intensity results from two factors: the amplitude of the sound waves and how far they have traveled from the source of the sound.

- Amplitude is a measure of the size of sound waves. It depends on the amount of energy that started the waves. Greater amplitude waves have more energy and greater intensity, so they sound louder.
- As sound waves travel farther from their source, the more spread out their energy becomes. You can see how this works in the **Figure** 11.18. As distance from the sound source increases, the area covered by the sound waves increases. The same amount of energy is spread over a greater area, so the intensity and loudness of the sound is less. This explains why even loud sounds fade away as you move farther from the source.

Q: Why can low-amplitude sounds like whispers be heard only over short distances?

A: The sound waves already have so little energy that spreading them out over a wider area quickly reduces their intensity below the level of hearing.

Summary

- Loudness refers to how loud or soft a sound seems to a listener. The loudness of sound is determined, in turn, by the intensity, or amount of energy, in sound waves. The unit of intensity is the decibel (dB).
- As decibel levels get higher, sound waves have greater intensity and sounds are louder. For every 10-decibel increase in the intensity of sound, loudness is 10 times greater.
- Intensity of sound results from two factors: the amplitude of the sound waves and how far they have traveled from the source of the sound.

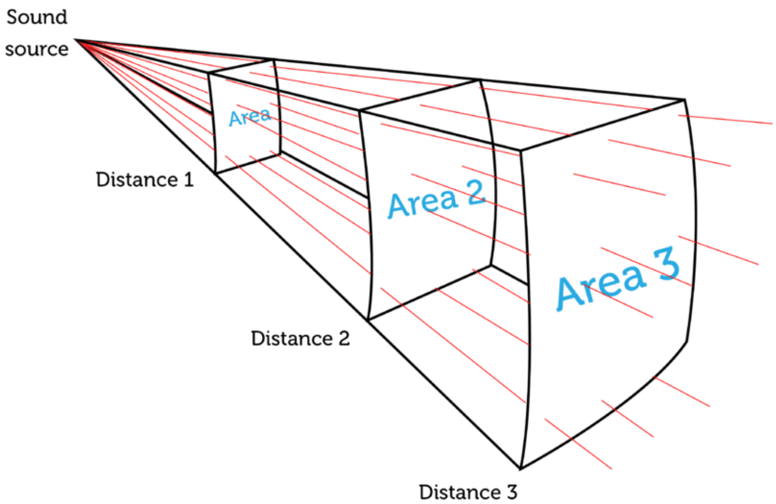

FIGURE 11.18
This diagram represents just a small section of the total area of sound waves spreading out from a source. Sound waves actually travel away from the source in all directions.

Review

1. Define loudness and intensity of sound. How are the two concepts related?
2. What is the unit of intensity of sound?
3. At what decibel level do sounds start to become harmful to the ears and hearing?
4. Relate amplitude and distance to the intensity and loudness of sound.

Resources

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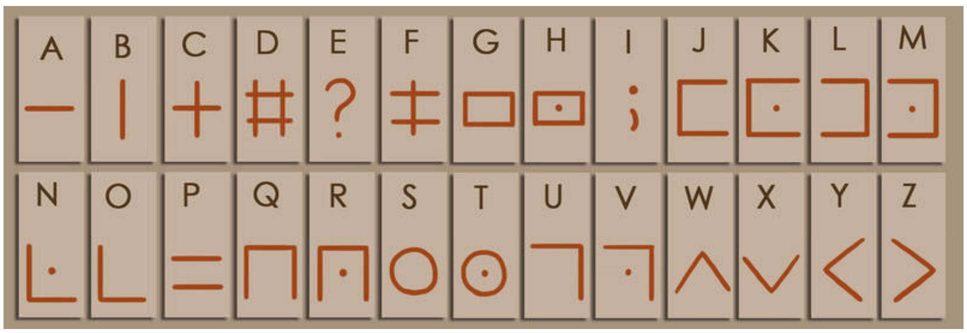
11.7 Analog and Digitized Signals

Learning Objectives

- Define electronic signal and electronics.
- Compare and contrast analog and digital signals.

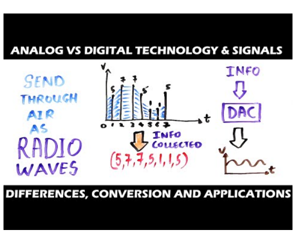


Did you ever make a secret code by assigning each letter of the alphabet a unique symbol? The code shown above is believed to have been used by George Washington to send secret messages during the American Revolutionary War. A different type of code can be sent with electric current.

Q: How do you think electric current can be used to encode messages?

A: The short answer is by changing the voltage in an electric circuit. Keep reading to learn more.

Electronic Messages



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Electric devices, such as lights and household appliances, change electric current to other forms of energy. For example, an electric stove changes electric current to thermal energy. Other common devices, such as mobile phones and computers, use electric current for another purpose: to encode information. A message encoded this way is called an **electronic signal**, and the use of electric current for this purpose is called **electronics**.

To encode a message with electric current, the voltage is changed rapidly, over and over again. Voltage is a difference in electric potential energy that is needed in order for electric current to flow. There are two different ways voltage can be changed, resulting in two different types of electronic signals, called analog signals and digital signals.

Analog Signals

Analog signals consist of continuously changing voltage in an electric circuit. The **Figure** 11.19 represents analog signals. These were the first electronic signals to be invented. They were used in early computers and other early electronic devices. Analog signals are subject to distortion and noise, so they aren't used as often anymore. They are used mainly in microphones and some mobile phones to encode sounds as electronic signals.

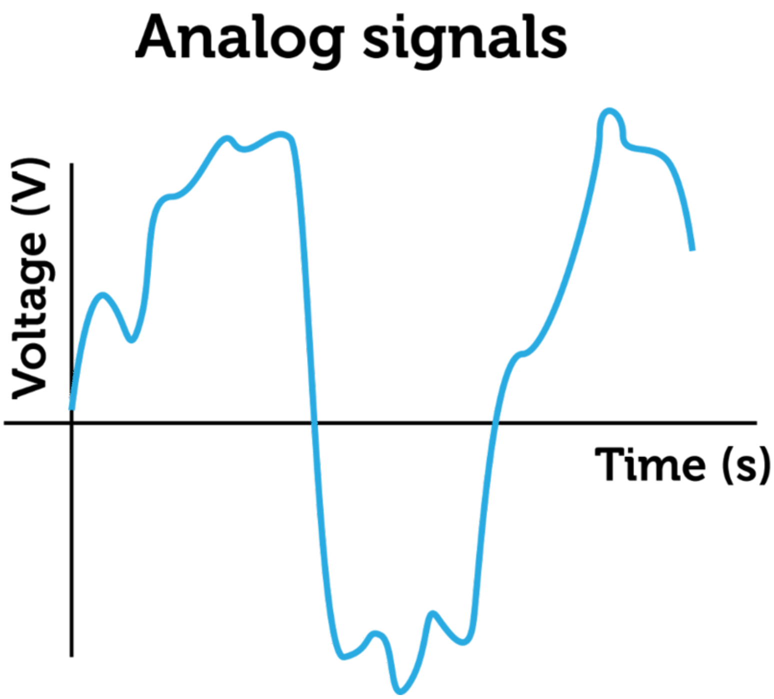

FIGURE 11.19

Digital Signals

Today, most electronic signals are digital signals. Digital signals consist of rapid pulses of voltage that repeatedly switch the current off and on. The **Figure** 11.20 represents digital signals. This type of signal encodes information as a string of 0's (current off) and 1's (current on). This is called a binary ("two-digit") code. The majority of modern electronic devices, including computers and many mobile phones, encode data as digital signals. Compared with analog signals, digital signals are easier to transmit and more accurate.

Summary

- A message encoded by changing the voltage of an electric current is called an electronic signal. The use of electric current for this purpose is known as electronics.
- Electronic signals may be analog or digital signals. Analog signals consist of continuously changing voltage in an electric circuit. Digital signals, which are the main type of signals used today, consist of rapid pulses of voltage that repeatedly switch the current off and on.

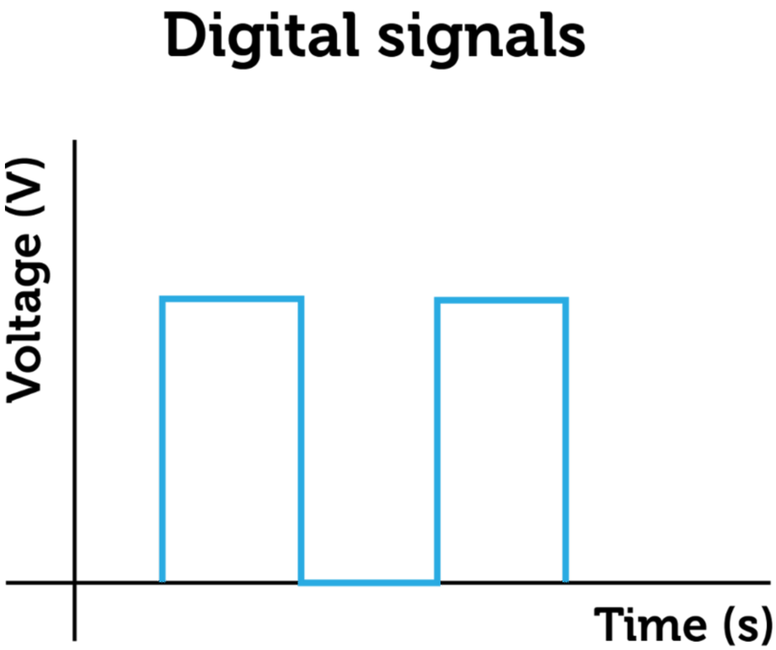

FIGURE 11.20

Review

1. What is an electronic signal?
2. Define electronics.
3. Create a table comparing and contrasting analog and digital signals.

11.8 Glossary

Amplitude, see WAVE AMPLITUDE

Compressions, the squeezing action of wave energy, especially sound

Concave Lens, a lens that causes parallel waves of light to come to spread apart as it passes through the lens

Concave Mirror, a mirror that causes parallel waves of light to come together as it reflects off the mirror

Convex Lens, a lens that causes parallel waves of light to come to together as it passes through the lens

Convex Mirror, a mirror that causes parallel waves of light to spread apart as it reflects off the mirror

Crest, the highest displacement location of a surface wave (usually water wave)

Decibel, 1/10 of a Bell, a measurement of sound intensity

Diffraction, the process where a wave spreads out as it goes past an edge or corner. Often producing recognizable patterns.

Diffuse Reflection when incoming parallel waves of light DO NOT remain parallel after reflection

Disturbance, the temporary moving of particles of matter from their original position by the energy of a wave.

Electromagnetic Radiation, light waves regardless of frequency/wavelength (color) - changes in the magnetic and electrical fields in space or matter.

Electromagnetic Spectrum, the full range of possible frequencies of electromagnetic radiation (light)

Electromagnetic Waves, the waves of ELECTROMAGNETIC RADIATION.

Frequency, see WAVE FREQUENCY

Intensity, The amplitude or amount of sound or light energy

Law Of Reflection, angle of incidence equals angle of reflection, the angle of the light wave motion compared to the surface on which it reflects remains the same as it runs into (has incidence) with the surface to when it leaves (reflects) from the surface.

Lens, a construct that changes the angle of light as the light passes though it The angel is changed in such a way as to have a FOCAL POINT

Longitudinal, where the disturbance of the medium is in the same/opposite direction as the wave motion.

Matter, something that has mass and takes up volume

Mechanical Wave, a disturbance in matter that transfers energy through that same matter.

Medium, the matter which carries or transmits a mechanical wave

Particles, the pieces of matter disturbed in a mechanical wave

Rarefactions, the stretching action of wave energy, especially sound

Reflection, when a wave "bounces" and is returned at the boundary (edge) of a medium.

Refraction, when the boundary of a medium changes the angle of the path of a wave due to change in medium

Regular Reflection, when incoming parallel waves of light remain parallel after reflection

Sound, mechanical waves in matter which can often be heard. Sound in air and water is transmitted as longitudinal waves with compression and rarefaction of the medium. In solids , sound has both longitudinal waves and transverse waves.

Standing Waves, waves in a fixed position on a physical object or area

Surface Wave, a disturbance in the surface between two different media.

Surface Waves, waves along a surface

Transverse, where the disturbance of the medium is perpendicular (90 degree angle) to the motion of the wave

Troughs, The low point of a surface wave (usually water wave)

Wave Amplitude, the distance the particles/medium move(s) when disturbed by a wave, the height of a wave.

Wave Frequency, the number of disturbances per second of a wave, the rate of disturbances.

Wave Interference, when wave amplitudes add up in a medium

Wave Speed, the speed at which wave energy moves through a medium.

Wavelength, the distance between waves in a medium, peak to peak, tough to trough or beginning to beginning of disturbance.

11.9 References

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CHAPTER 12 Energy MS PS 3-1, MS PS 3-2, MS PS 2-1,

Chapter Outline

INTRODUCTION

DISCIPLINARY CORE IDEA:

MS-PS 3-1 By the end of instruction, students should be able to answer a test which asks them to:**Make graphs and read graphs to explain, and describe the details of math relationships of mass, kinetic energy an velocity of an object.**

The surfer in this photo is dwarfed by the immense wave he's riding, yet he's managing to use the incredible energy of the wave for a thrilling ride. Ocean waves like this one carry a huge amount of energy. Do you know what energy is? Can you identify other forms of energy besides ocean waves? In this unit, you'll learn a lot about energy, including how it makes modern life possible—even if you never ride a surfboard!

What speed will we need to get to in order to be able to leave earth? How will we stop when we get to Mars? we need to consider the relationship between energy and speed for our trip to Mars in our Story.

12.1 Kinetic Energy

Learning Objectives

- Define kinetic energy.
- Show how to calculate the kinetic energy of a moving object.

What could these four photos possibly have in common? Can you guess what it is? All of them show things that have kinetic energy.

Defining Energy

Energy is defined in science as the ability to move matter or change matter in some other way. Energy can also be defined as the ability to do work, which means using force to move an object over a distance . When work is done, energy is transferred from one object to another. For example, when the boy in the **Figure** below uses force to swing the racket, he transfers some of his energy to the racket.

FIGURE 12.1

Q: It takes energy to play tennis. Where does this boy get his energy?

A: He gets energy from the food he eats.

Defining Kinetic Energy

Kinetic energy is the energy of moving matter. Anything that is moving has kinetic energy—from atoms in matter to stars in outer space. Things with kinetic energy can do work. For example, the spinning saw blade in the photo above is doing the work of cutting through a piece of metal.

Calculating Kinetic Energy

The amount of kinetic energy in a moving object depends directly on its mass and velocity. An object with greater mass or greater velocity has more kinetic energy. You can calculate the kinetic energy of a moving object with this equation:

$\text{Kinetic Energy (KE)} = \frac{1}{2}\text{mass} \times \text{velocity}^2$

This equation shows that an increase in velocity increases kinetic energy more than an increase in mass. If mass doubles, kinetic energy doubles as well, but if velocity doubles, kinetic energy increases by a factor of four. That's because velocity is squared in the equation.

Let's consider an example. The **Figure** 12.2 shows Juan running on the beach with his dad. Juan has a mass of 40 kg and is running at a velocity of 1 m/s. How much kinetic energy does he have? Substitute these values for mass and velocity into the equation for kinetic energy:

$\text{KE} = \frac{1}{2} \times 40\text{ kg} \times (1\frac{\text{m}}{\text{s}})^2 = 20\text{ kg} \times \frac{\text{m}^2}{\text{s}^2} = 20\text{ N} \cdot \text{m, or } 20\text{ J}$

Notice that the answer is given in joules (J), or N • m, which is the SI unit for energy. One joule is the amount of energy needed to apply a force of 1 Newton over a distance of 1 meter.

What about Juan's dad? His mass is 80 kg, and he's running at the same velocity as Juan (1 m/s). Because his mass is twice as great as Juan's, his kinetic energy is twice as great:

$\text{KE} = \frac{1}{2} \times 80\text{ kg} \times (1\frac{\text{m}}{\text{s}})^2 = 40\text{ kg} \times \frac{\text{m}^2}{\text{s}^2} = 40\text{ N} \cdot \text{m, or } 40\text{ J}$

Q: What is Juan's kinetic energy if he speeds up to 2 m/s from 1 m/s?

A: By doubling his velocity, Juan increases his kinetic energy by a factor of four:

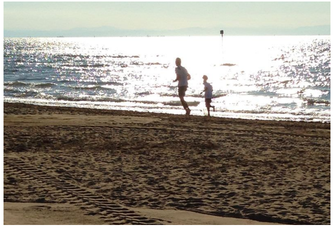

FIGURE 12.2

$$KE = \frac{1}{2} \times 40 \text{ kg} \times (2\frac{\text{m}}{\text{s}})^2 = 80 \text{ kg} \times \frac{\text{m}^2}{\text{s}^2} = 80 \text{ N} \cdot \text{m, or } 80 \text{ J}$$

Summary

- Kinetic energy (KE) is the energy of moving matter. Anything that is moving has kinetic energy.
- The amount of kinetic energy in a moving object depends directly on its mass and velocity. It can be calculated with the equation: $KE = \frac{1}{2}\text{mass} \times \text{velocity}^2$.

Review

1. What is kinetic energy?
2. The kinetic energy of a moving object depends on its mass and its
   a. volume.
   b. velocity.
   c. distance.
   d. acceleration.
3. The bowling ball in the **Figure** 12.3 is whizzing down the bowling lane at 4 m/s. If the mass of the bowling ball is 7 kg, what is its kinetic energy?

FIGURE 12.3

Resources

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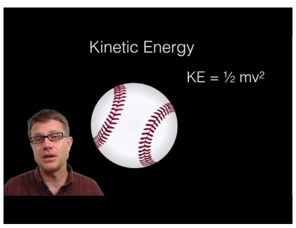

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12.2 Speed

Learning Objectives

- Define speed, and give the SI unit for speed.
- Show how to calculate average speed from distance and time.
- Describe instantaneous speed.
- Show how to calculate distance or time from speed when the other variable is known.

Did you ever play fast-pitch softball? If you did, then you probably have some idea of how fast the pitcher throws the ball. For a female athlete like the one in the opening image, the ball may reach a speed of 120 km/h (about 75 mi/h). For a male athlete, the ball may travel even faster. A fast-pitch pitcher uses a "windmill" motion to throw the ball. This is a different technique than other softball pitches, and it explains why the ball travels so fast.

Introducing Speed

How fast or slow something moves is its **speed**. Speed determines how far something travels in a given amount of time. The SI unit for speed is meters per second (m/s). Speed may be constant, but often it varies from moment to moment.

Average Speed

Even if speed varies during the course of a trip, it's easy to calculate the average speed by using this formula:

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

For example, assume you go on a car trip with your family. The total distance you travel is 120 miles, and it takes 3 hours to travel that far. The average speed for the trip is:

$$\begin{aligned} \text{speed} &= \frac{120 \text{ mi}}{3 \text{ h}} \\ &= 40 \text{ mi/h} \end{aligned}$$

Q: Terri rode her bike very slowly to the top of a big hill. Then she coasted back down the hill at a much faster speed. The distance from the bottom to the top of the hill is 3 kilometers. It took Terri $\frac{1}{4}$ hour to make the round trip. What was her average speed for the entire trip? (*Hint*: The round-trip distance is 6 km.)

A: Terri's speed can be calculated as follows:

$$\begin{aligned} \text{speed} &= \frac{6 \text{ km}}{0.25 \text{ h}} \\ &= 24 \text{ km/h} \end{aligned}$$

Instantaneous Speed

When you travel by car, you usually don't move at a constant speed. Instead you go faster or slower depending on speed limits, traffic lights, the number of vehicles on the road, and other factors. For example, you might travel 65 miles per hour on a highway but only 20 miles per hour on a city street (see the pictures in the **Figure** 12.4.) You might come to a complete stop at traffic lights, slow down as you turn corners, and speed up to pass other cars. Therefore, your speed at any given instant, or your instantaneous speed, may be very different than your speed at other times. Instantaneous speed is much more difficult to calculate than average speed.

FIGURE 12.4
Cars race by in a blur of motion on an open highway but crawl at a snail's pace when they hit city traffic.

Calculating Distance or Time from Speed

If you know the average speed of a moving object, you can calculate the distance it will travel in a given period of time or the time it will take to travel a given distance. To calculate distance from speed and time, use this version of the average speed formula given above:

distance = speed × time

For example, if a car travels at an average speed of 60 km/h for 5 hours, then the distance it travels is:

distance = 60 km/h × 5 h = 300 km

To calculate time from speed and distance, use this version of the formula:

$$\text{time} = \frac{\text{distance}}{\text{speed}}$$

Q: If you walk 6 km at an average speed of 3 km/h, how much time does it take?

A: Use the formula for time as follows:

$$\begin{aligned}\text{time} &= \frac{\text{distance}}{\text{speed}}\\ &= \frac{6\ \text{km}}{3\ \text{km/h}}\\ &= 2\ \text{h}\end{aligned}$$

Summary

- How fast or slow something moves is its speed. The SI unit for speed is meters per second (m/s).
- Average speed is calculated with this formula:

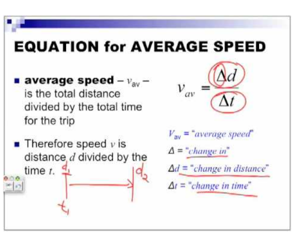
$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

- Speed may be constant, but often it varies from moment to moment. Speed at any given instant is called instantaneous speed. It is much more difficult to calculate than average speed.
- Distance or time can be calculated by solving the average speed formula for distance or time.

Review

1. What is speed?
2. If you walk 3 kilometers in 30 minutes, what is your average speed in kilometers per hour?
3. Compare and contrast instantaneous and average speed.
4. What distance will a truck travel in 3 hours at an average speed of 50 miles per hour?

Resources



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12.3 Potential Energy

Learning Objectives

- Define potential energy.
- Show how to calculate gravitational potential energy.
- Describe elastic potential energy.
- Identify other forms of potential energy.

This diver has just jumped up from the end of the diving board. After she dives down and is falling toward the water, she'll have kinetic energy, or the energy of moving matter. But even as she is momentarily stopped high above the water, she has energy. Do you know why?

Stored Energy

The diver has energy because of her position high above the pool. The type of energy she has is called potential energy. **Potential energy** is energy that is stored in a person or object. Often, the person or object has potential energy because of its position or shape.

Q: What is it about the diver's position that gives her potential energy?

A: Because the diver is high above the water, she has the potential to fall toward Earth because of gravity. This gives her potential energy.

Gravitational Potential Energy

Potential energy due to the position of an object above Earth's surface is called gravitational potential energy. Like the diver on the diving board, anything that is raised up above Earth's surface has the potential to fall because of gravity. You can see another example of people with gravitational potential energy in the **Figure** 12.5.

FIGURE 12.5

Gravitational potential energy depends on an object's weight and its height above the ground. It can be calculated with the equation:

Gravitational potential energy (GPE) = weight $\times$ height

Consider the little girl on the sled, pictured in the **Figure** 12.5. She weighs 140 Newtons, and the top of the hill is 4 meters higher than the bottom of the hill. As she sits at the top of the hill, the child's gravitational potential energy is:

GPE = 140 N $\times$ 4 m = 560 N • m

Notice that the answer is given in Newton • meters (N • m), which is the SI unit for energy. A Newton ● meter is the energy needed to move a weight of 1 Newton over a distance of 1 meter. A Newton • meter is also called a joule (J).

Q: The gymnast on the balance beam pictured in the **Figure** 12.5 weighs 360 Newtons. If the balance beam is 1.2 meters above the ground, what is the gymnast's gravitational potential energy?

A: Her gravitational potential energy is:

GPE = 360 N $\times$ 1.2 m = 432 N • m, or 432 J

Elastic Potential Energy

Potential energy due to an object's shape is called elastic potential energy. This energy results when an elastic object is stretched or compressed. The farther the object is stretched or compressed, the greater its potential energy is. A point will be reached when the object can't be stretched or compressed any more. Then it will forcefully return to its original shape.

Look at the pogo stick in the **Figure** 12.6. Its spring has elastic potential energy when it is pressed down by the boy's weight. When it can't be compressed any more, it will spring back to its original shape. The energy it releases will push the pogo stick—and the boy—off the ground.

Q: The girl in the **Figure** 12.7 is giving the elastic band of her slingshot potential energy by stretching it. She's holding a small stone against the stretched band. What will happen when she releases the band?

A: The elastic band will spring back to its original shape. When that happens, watch out! Some of the band's elastic potential energy will be transferred to the stone, which will go flying through the air.

Other Forms of Potential Energy

All of the examples of potential energy described above involve movement or the potential to move. The form of energy that involves movement is called mechanical energy. Other forms of energy also involve potential energy, including chemical energy and nuclear energy. Chemical energy is stored in the bonds between the atoms of

FIGURE 12.6

FIGURE 12.7

compounds. For example, food and batteries both contain chemical energy. Nuclear energy is stored in the nuclei of atoms because of the strong forces that hold the nucleus together. Nuclei of radioactive elements such as uranium are unstable, so they break apart and release the stored energy.

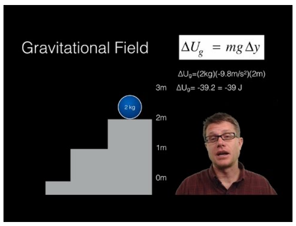
Summary

- Potential energy is energy that is stored in a person or object.
- Gravitational potential energy is due to the position of an object above Earth's surface. The object has the potential to fall due to gravity. Gravitational potential energy depends on an object's weight and its height above the ground (GPE = weight x height).
- Elastic potential energy is due to an object's shape. It results when an elastic object is stretched or compressed. The more it is stretched or compressed, the greater its elastic potential energy is.
- Chemical energy and nuclear energy are other forms of potential energy.

Review

1. What is potential energy?
2. Compare and contrast gravitational and elastic potential energy, and give an example of each.
3. The diver on the diving board in the opening picture weighs 500 Newtons. The diving board is 5 meters above the ground. What is the diver's gravitational potential energy?
4. Why does food have potential energy?

Resources



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12.4 Newton's Third Law

Learning Objectives

- State Newton's Third Law of Motion.
- Describe action and reaction forces.
- Explain why action and reaction forces are not balanced forces.

This is a sketch of Jerod on his skateboard. He's on his way to Newton's Skate Park. When he pushes his foot against the ground, what happens next? He moves on his skateboard in the opposite direction. How does this happen?

Action and Reaction

Newton's third law of motion explains how Jerod starts his skateboard moving. This law states that every action has an equal and opposite reaction. This means that forces always act in pairs. First an action occurs—Jerod pushes against the ground with his foot. Then a reaction occurs—Jerod moves forward on his skateboard. The reaction is always equal in strength to the action but in the opposite direction.

Q: If Jerod pushes against the ground with greater force, how will this affect his forward motion?

A: His action force will be greater, so the reaction force will be greater as well. Jerod will be pushed forward with more force, and this will make him go faster and farther.

Equal and Opposite Forces

The forces involved in actions and reactions can be represented with arrows. The way an arrow points shows the direction of the force, and the size of the arrow represents the strength of the force. Look at the skateboarders in the

Figure 12.8. In the top row, the arrows represent the forces with which the skateboarders push against each other. This is the action. In the bottom row, the arrows represent the forces with which the skateboarders move apart. This is the reaction. Compare the top and bottom arrows. They point in different directions, but they are the same size. This shows that the reaction forces are equal and opposite to the action forces.

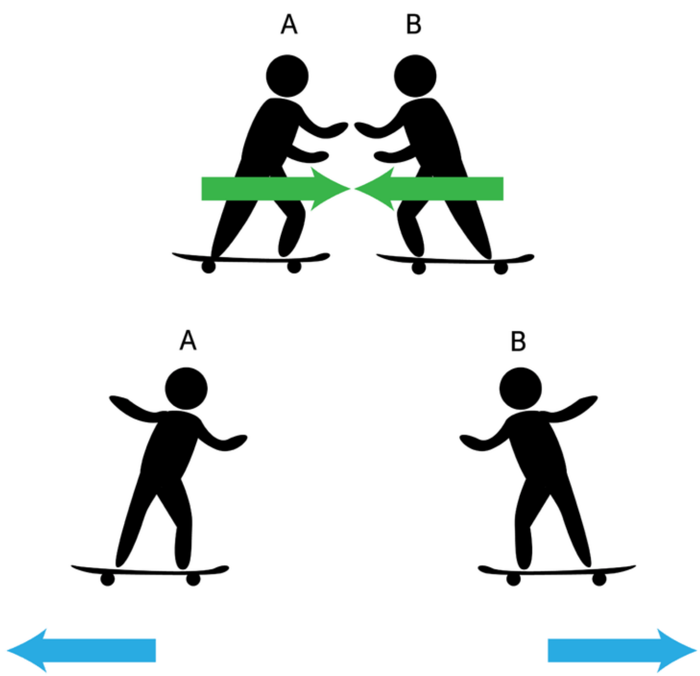

FIGURE 12.8

Equal and Opposite but Not Balanced

Because action and reaction forces are equal and opposite, you might think they would cancel out, as balanced forces do. But you would be wrong. Balanced forces are equal and opposite forces that act on the same object. That's why they cancel out. Action-reaction forces are equal and opposite forces that act on different objects, so they don't cancel out. In fact, they often result in motion. Think about Jerod again. He applies force with his foot to the ground, whereas the ground applies force to Jerod and the skateboard, causing them to move forward.

Q: Actions and reactions occur all the time. Can you think of an example in your daily life?

A: Here's one example. If you lean on something like a wall or your locker, you are applying force to it. The wall or locker applies an equal and opposite force to you. If it didn't, you would go right through it or else it would tip over.

Summary

- Newton's third law of motion states that every action has an equal and opposite reaction. This means that forces always act in pairs.
- Action and reaction forces are equal and opposite, but they are not balanced forces because they act on different objects so they don't cancel out.

Review

1. State Newton's third law of motion.

2. Describe an example of an action and reaction. Identify the forces and their directions.
3. Explain why action and reaction forces are not balanced forces.

Explore More

Watch this video about Newton's third law of motion, and then answer the questions below.

MEDIA

Click image to the left or use the URL below.

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1. Outline the action and reaction demonstrated by the astronauts in the video. Why does wearing the battery pack affect the motion of the astronaut named Alexander?
2. Describe an example of Newton's cradle.
3. How do space vehicles apply action and reaction forces to blast off?

Resources

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12.5 Glossary

Conservation of energy, the idea that says in a closed system energy is not created or destroyed, it can only change form.

Energy conservation, saving energy by not using it.

Energy, The ability to do work

Forms of energy, energy can exist in any one of these fundamental forms: motion (kinetic)/heat, electrical/magnetic, gravitational (height), nuclear, light, sound, mechanical waves, chemical or information. Energy can change between force without being lost.

Kinetic energy, the energy of motion

Potential energy, energy which is stored and can be used

Work, a force acting through a distance in the same direction as the distance it travels

Summary

This unit introduces energy and energy resources. Different forms of energy—including thermal and sound energy—are described. The unit also explains how energy travels in waves, how light energy behaves, and how we use light to see. Electricity and magnetism, and the relationship between them, are explored as well.

12.6 References

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5. Flickr: lobo235. This pogo stick stores energy in its spring . CC BY 2.0
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7. Christopher Auyeung. These skaters are demonstrating Newton's third law of motion . CC BY-NC 3.0

CHAPTER 13 Molecular Biology and Genetics LS 3-1

Chapter Outline

INTRODUCTION

DISCIPLINARY CORE IDEA:

MS-LS 3-1 By the end of instruction, students should be able to answer a test which asks them to: **Create a model that explains why changes to genes on chromosomes makes changes in proteins that can be good, bad, or neutral to and organisms structure and function.**

Why is heredity so important?

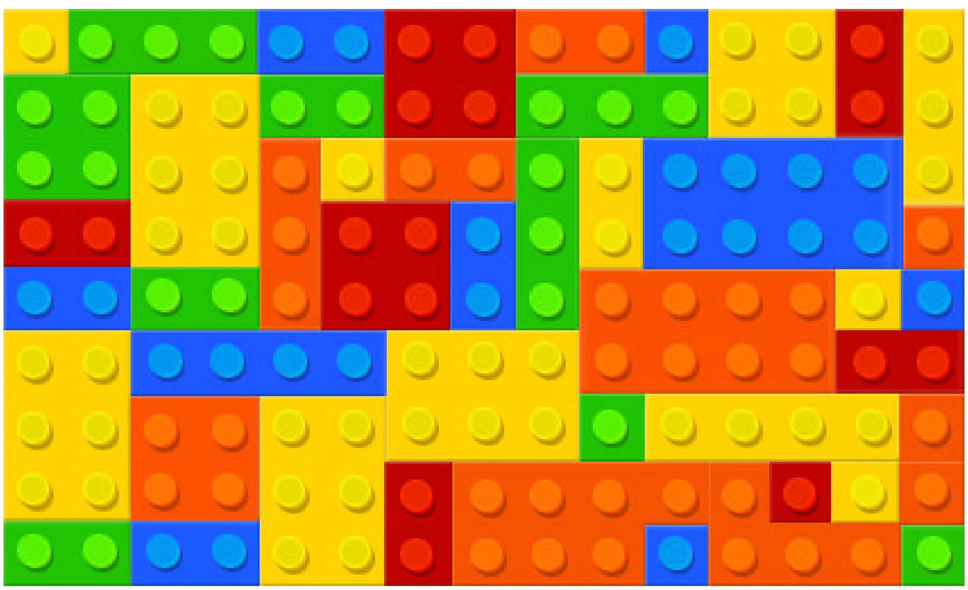
Genetics is the study of inheritance. Inheritance is the passing of traits from parents to offspring. How are these traits "passed"? Through DNA, which is the genetic material of all organisms. This concept will focus on genetics, inheritance, and DNA.

When we get to Mars, we will have a limited gene supply for our Story. We need to have enough genetic diversity to ensure a good gene pool for plants, animals and people, we should understand basic genetics. Also we may want to take smaller animals and plants that have the gene to grow big plants and animals when we arrive. Smaller animals would require less food on our trip. Smaller plant take up less space on the trip and when we first arrive. and we have limited space and infra structure.

13.1 Protein Synthesis and Gene Expression

Learning Objectives

- Define gene.
- Describe the purpose of protein synthesis.
- Explain the meaning of gene expression.
- Summarize the relationship between DNA, amino acids, and proteins.



How do you build a protein?

Your body needs proteins to create muscles, regulate chemical reactions, transport oxygen, and perform other important tasks in your body. But how are these proteins built? They are made up of units called amino acids. Just like there are only a few types of blocks in a set, there are a limited number of amino acids. But there are many different ways in which they can be combined.

Introduction to Protein Synthesis

A monomer is a molecule that can bind to other monomers to form a polymer. **Amino acids** are the monomers of a protein. The DNA sequence contains the instructions to place amino acids into a specific order.

When the amino acid monomers are assembled in that specific order, proteins are made, a process called **protein synthesis.** In short, DNA contains the instructions to create proteins. But DNA does not directly make the proteins. Proteins are made on the ribosomes in the cytoplasm, and DNA (in an eukaryotic cell) is in the nucleus. So the cell uses an RNA intermediate to produce proteins.

Each strand of DNA has many separate sequences that code for a specific protein. Insulin is an example of a protein made by your cells (**Figure** 13.1). Units of DNA that contain code for the creation of a protein are called **genes**.

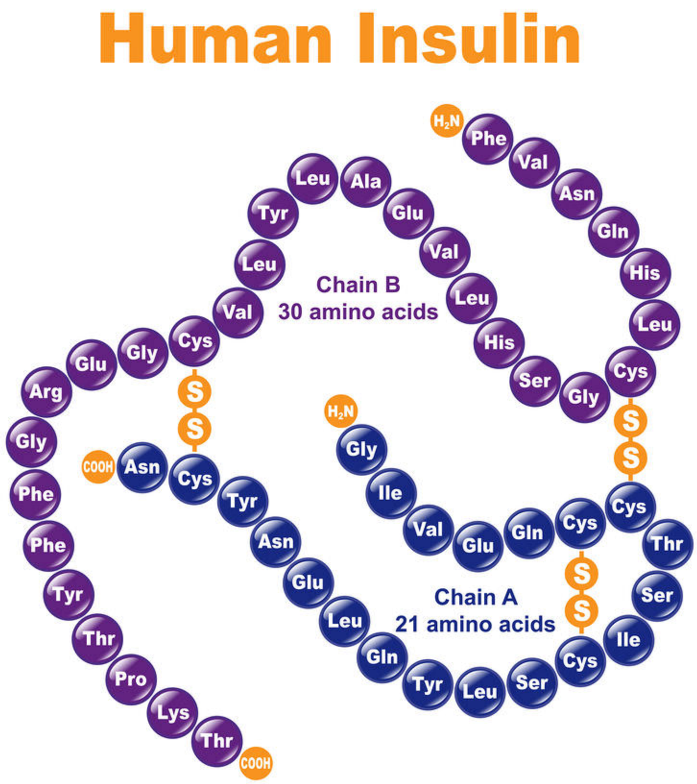


FIGURE 13.1

Insulin. Each blue or purple bead represents a different amino acid. Just 20 different amino acids are arranged in many different combinations to make thousands of proteins.

Cells Can Turn Genes On or Off

There are about 22,000 genes in every human cell. Does every human cell have the same genes? Yes. Does every human cell make the same proteins? No. In a multicellular organism, such as us, cells have specific functions because they have different proteins. They have different proteins because different genes are expressed in different cell types (which is known as **gene expression**).

Imagine that all of your genes are "turned off." Each cell type only "turns on" (or expresses) the genes that have the code for the proteins it needs to use. So different cell types "turn on" different genes, allowing different proteins to be made. This gives different cell types different functions.

Once a gene is expressed, the protein product of that gene is usually made. For this reason, gene expression and protein synthesis are often considered the same process.

Summary

- DNA contains the instructions to assemble amino acids in a specific order to make protein.

- Each cell type only "turns on" (or expresses) the genes that have the code for the proteins it needs to use.
- Gene expression and protein synthesis are usually considered the same molecular process.

Explore More

1. What is the cell structure used in the assembly of proteins?
2. What is the molecule that delivers the amino acids?
3. What ends protein synthesis?

Review

1. What is a gene?
2. What is an amino acid?
3. If every human cell has the same genes, how can they look and function so differently?
4. What is the relationship between DNA and proteins?

13.2 Protein Synthesis and Mutations

Lesson Objectives

- Identify the structure and functions of RNA.
- Describe the genetic code and how to read it.
- Explain how proteins are made.
- List causes and effects of mutations.

Lesson Vocabulary

- codon
- genetic code
- mutagen
- mutation
- protein synthesis
- RNA (ribonucleic acid)
- transcription
- translation

Introduction

Blueprints, like those pictured in **Figure** 13.2, contain the instructions for building a house. Your cells also contain "blueprints." They are encoded in the DNA of your chromosomes.

DNA, RNA, and Proteins

DNA and RNA are nucleic acids. DNA stores genetic information. RNA helps build proteins. Proteins, in turn, determine the structure and function of all your cells. Proteins consist of chains of amino acids. A protein's structure and function depends on the sequence of its amino acids. Instructions for this sequence are encoded in DNA.

In eukaryotic cells, chromosomes are contained within the nucleus. But proteins are made in the cytoplasm at structures called ribosomes. How do the instructions in DNA reach the ribosomes in the cytoplasm? RNA is needed for this task.

Comparing RNA with DNA

RNA stands for ribonucleic acid. RNA is smaller than DNA. It can squeeze through pores in the membrane that encloses the nucleus. It copies instructions in DNA and carries them to a ribosome in the cytoplasm. Then it helps build the protein.

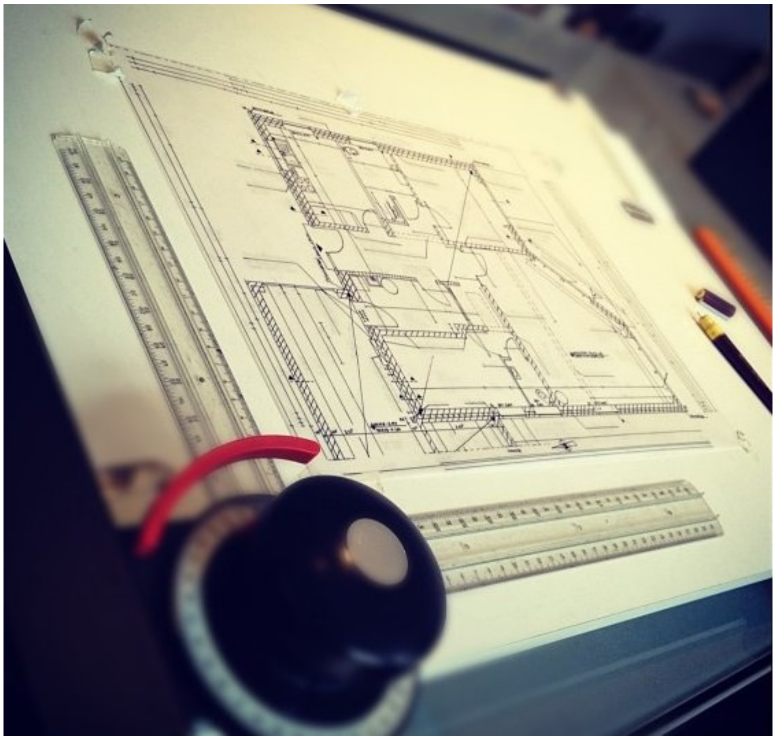


FIGURE 13.2
Blueprints for a house

RNA is not only smaller than DNA. It differs from DNA in other ways as well. It consists of one nucleotide chain rather than two chains as in DNA. It also contains the nitrogen base uracil (U) instead of thymine (T). In addition, it contains the sugar ribose instead of deoxyribose. You can see these differences in **Figure** 13.3.

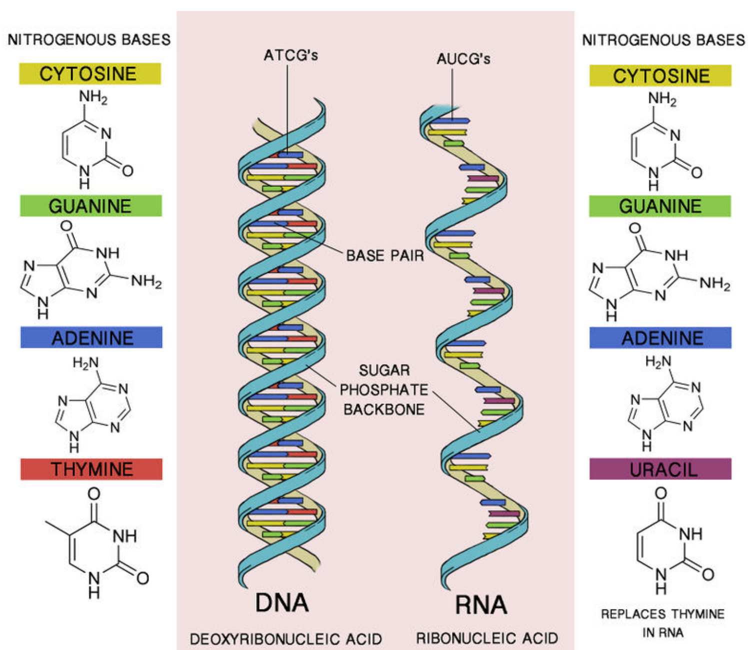


FIGURE 13.3
Comparison of RNA and DNA

Types of RNA

There are three different types of RNA. All three types are needed to make proteins.

- Messenger RNA (mRNA) copies genetic instructions from DNA in the nucleus. Then it carries the instructions to a ribosome in the cytoplasm.
- Ribosomal RNA (rRNA) helps form a ribosome. This is where the protein is made.
- Transfer RNA (tRNA) brings amino acids to the ribosome. The amino acids are then joined together to make the protein.

The Genetic Code

How is the information for making proteins encoded in DNA? The answer is the genetic code. The genetic code is based on the sequence of nitrogen bases in DNA. The four bases make up the "letters" of the code. Groups of three bases each make up code "words." These three-letter code words are called codons. Each codon stands for one amino acid or else for a start or stop signal.

There are 20 amino acids that make up proteins. With three bases per codon, there are 64 possible codons. This is more than enough to code for the 20 amino acids plus start and stop signals. You can see how to translate the genetic code in **Figure** 13.4. Start at the center of the chart for the first base of each three-base codon. Then work your way out from the center for the second and third bases.

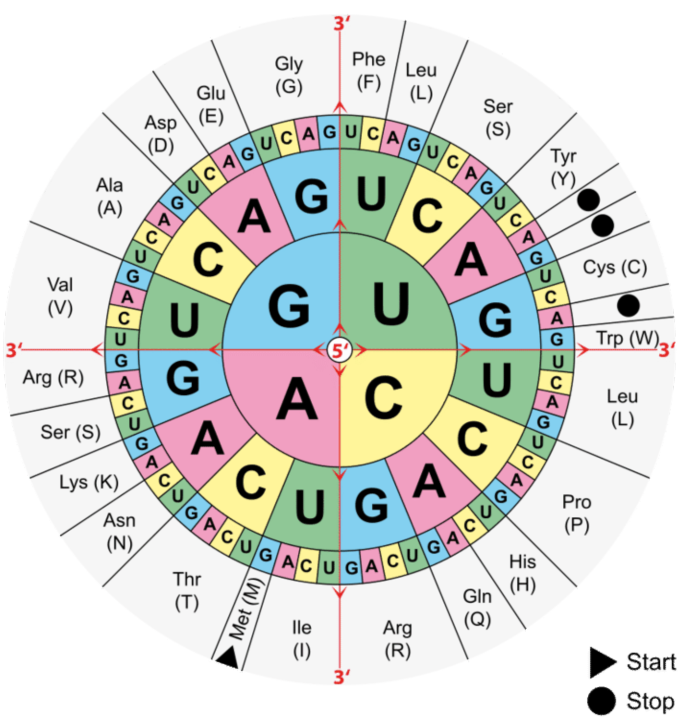


FIGURE 13.4
Translating the genetic code

Find the codon AUG in **Figure** 13.4. It codes for the amino acid methionine. It also codes for the start signal. After an AUG start codon, the next three letters are read as the second codon. The next three letters after that are read as the third codon, and so on. You can see how this works in **Figure** 13.5. The figure shows the bases in a molecule of RNA. The codons are read in sequence until a stop codon is reached. UAG, UGA, and UAA are all stop codons. They don't code for any amino acids.

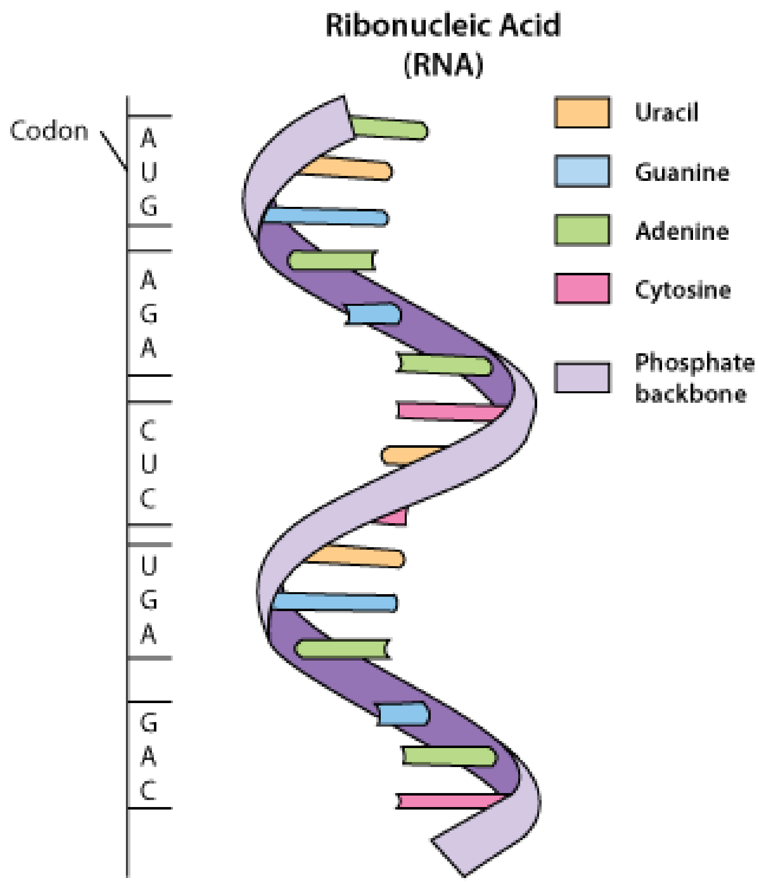


FIGURE 13.5
How the genetic code is read

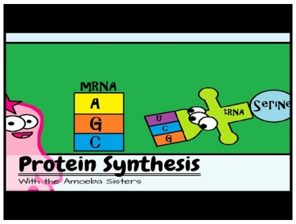
Characteristics of the Genetic Code

The genetic code has three other important characteristics.

- The genetic code is the same in all living things. This shows that all organisms are related by descent from a common ancestor.
- Each codon codes for just one amino acid (or start or stop). This is necessary so the correct amino acid is always selected.
- Most amino acids are encoded by more than one codon. This is helpful. It reduces the risk of the wrong amino acid being selected if there is a mistake in the code.

Protein Synthesis

The process in which proteins are made is called protein synthesis. It occurs in two main steps. The steps are transcription and translation. Watch this video for a good introduction to both steps of protein synthesis: http://www.youtube.com/watch?v=h5mJbP23Buo .



MEDIA

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Transcription: DNA → RNA

Transcription is the first step in protein synthesis. It takes place in the nucleus. During transcription, a strand of DNA is copied to make a strand of mRNA. How does this happen? It occurs by the following steps, as shown in **Figure** 13.6.

1. An enzyme binds to the DNA. It signals the DNA to unwind.
2. After the DNA unwinds, the enzyme can read the bases in one of the DNA strands.
3. Using this strand of DNA as a template, nucleotides are joined together to make a complementary strand of mRNA. The mRNA contains bases that are complementary to the bases in the DNA strand.

FIGURE 13.6

Transcription step of protein synthesis

Translation is the second step in protein synthesis. It is shown in **Figure** 13.7. Translation takes place at a ribosome in the cytoplasm. During translation, the genetic code in mRNA is read to make a protein. Here's how it works:

1. The molecule of mRNA leaves the nucleus and moves to a ribosome.
2. The ribosome consists of rRNA and proteins. It reads the sequence of codons in mRNA.
3. Molecules of tRNA bring amino acids to the ribosome in the correct sequence.
4. At the ribosome, the amino acids are joined together to form a chain of amino acids.
5. The chain of amino acids keeps growing until a stop codon is reached. Then the chain is released from the ribosome.

Mutations

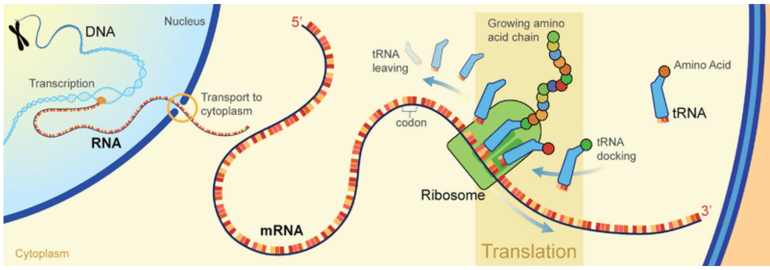


FIGURE 13.7
Translation step of protein synthesis

FIGURE 13.8

Would a mutation make you a superhero?

In the comic books, a mutation can give a person superpowers. Do you think this really happens? In real life, a mutation can be beneficial, or it can harm an organism. For example, beneficial mutations lead to evolution, and harmful mutations can lead to diseases like cancer . A mutation, however, is not going to turn you into a superhero!

Mutations

The process of DNA replication is not always 100% accurate. Sometimes the wrong base is inserted in the new strand of DNA. This wrong base could become permanent. A permanent change in the sequence of DNA is known as a **mutation**. Small changes in the DNA sequence are usually **point mutations**, which is a change in a single nucleotide. Once DNA has a mutation, that mutation will be copied each time the DNA replicates. After cell division , each resulting cell will carry the mutation.

A mutation may have no effect. However, sometimes a mutation can cause a protein to be made incorrectly. A defect in the protein can affect how well the protein works, or whether it works at all. Usually the loss of a protein function is detrimental to the organism.

In rare circumstances, though, the mutation can be beneficial. Mutations are a mechanism for how species evolve. For example, suppose a mutation in an animal's DNA causes the loss of an enzyme that makes a dark pigment in the animal's skin. If the population of animals has moved to a light colored environment, the animals with the mutant gene would have a lighter skin color and be better camouflaged. So in this case, the mutation is beneficial.

Causes of Mutations

Mutations have many possible causes. Some mutations occur when a mistake is made during DNA replication or transcription. Other mutations occur because of environmental factors. Anything in the environment that causes a mutation is known as a **mutagen**. Examples of mutagens are shown in **Figure** 13.9. They include ultraviolet rays in sunlight, chemicals in cigarette smoke, and certain viruses and bacteria.

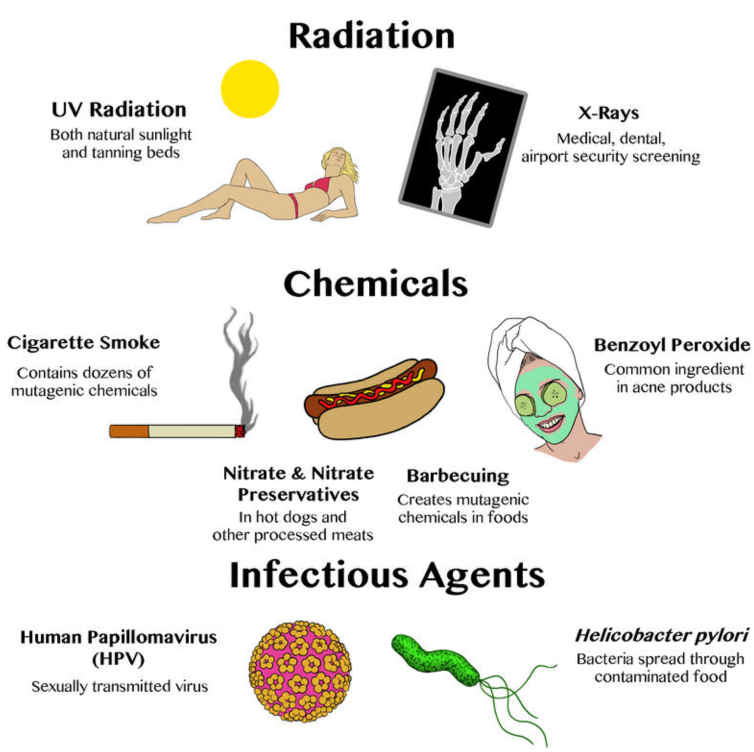


FIGURE 13.9
Examples of mutagens

Effects of Mutations

Many mutations have no effect on the proteins they encode. These mutations are considered neutral. Occasionally, a mutation may make a protein even better than it was before. Or the protein might help the organism adapt to a new environment. These mutations are considered beneficial. An example is a mutation that helps bacteria resist antibiotics. Bacteria with the mutation increase in numbers, so the mutation becomes more common. Other mutations are harmful. They may even be deadly. Harmful mutations often result in a protein that no longer can do its job. Some harmful mutations cause cancer or other genetic disorders.

Mutations also vary in their effects depending on whether they occur in gametes or in other cells of the body.

- Mutations that occur in gametes can be passed on to offspring. An offspring that inherits a mutation in a gamete will have the mutation in all of its cells.
- Mutations that occur in body cells cannot be passed on to offspring. They are confined to just one cell and its daughter cells. These mutations may have little effect on an organism.

Types of Mutations

The effect of a mutation is likely to depend as well on the type of mutation that occurs.

- A mutation that changes all or a large part of a chromosome is called a chromosomal mutation. This type of mutation tends to be very serious. Sometimes chromosomes are missing or extra copies are present. An example is the mutation that causes Down syndrome. In this case, there is an extra copy of one of the chromosomes.
- Deleting or inserting a nitrogen base causes a frameshift mutation. All of the codons following the mutation are misread. This may be disastrous. To see why, consider this English-language analogy. Take the sentence "The big dog ate the red cat." If the second letter of "big" is deleted, then the sentence becomes: "The bgd oga tet her edc at." Deleting a single letter makes the rest of the sentence impossible to read.
- Some mutations change just one or a few bases in DNA. A change in just one base is called a point mutation. **Table** 13.1 compares different types of point mutations and their effects.

TABLE 13.1: Types of point mutations

Type	Description	Example	Effect
Silent	mutated codon codes for the same amino acid	CAA (glutamine) → CAG (glutamine)	none
Missense	mutated codon codes for a different amino acid	CAA (glutamine) → CCA (proline)	variable
Nonsense	mutated codon is a premature stop codon	CAA (glutamine) → UAA (stop)	serious

Lesson Summary

- DNA encodes instructions for proteins. RNA copies the genetic code in DNA and carries it to a ribosome. There, amino acids are joined together in the correct sequence to make a protein.
- The genetic code is based on the sequence of nitrogen bases in DNA. A code "word," or codon, consists of three bases. Each codon codes for one amino acid or for a *Protein synthesis is the process in which proteins are made. In the first step, called transcription, the genetic code in DNA is copied by RNA. In the second step,

called translation, the genetic code in RNA is read to make a protein.
- A mutation is a change in the base sequence of DNA or RNA. Environmental causes of mutations are called mutagens. The effects of a mutation depend on the type of mutation and whether it occurs in a gamete or body cell.

Lesson Review Questions

Recall

1. What are three types of RNA? What role does each type play in protein synthesis?
2. Describe the genetic code and its characteristics.
3. Give an overview of the transcription step of protein synthesis. Where does it take place?
4. What is a mutation? What are some causes of mutations?

Apply Concepts

5. Use Figure 13.4 to translate the following sequence of RNA bases into a chain of amino acids: AUGUACCC-CACAGACUAA.

Think Critically

6. Compare and contrast RNA and DNA.
7. Explain what happens during the translation step of protein synthesis.
8. Why is a single base insertion or deletion likely to drastically change how the rest of the genetic code is read?

Points to Consider

Offspring generally resemble their parents. This is true even when the offspring are not genetically identical to the parents.

- Can you apply your knowledge of reproduction and protein synthesis to explain why offspring and parents have similar traits?

13.3 Glossary

allele, a variant (type) of a gene

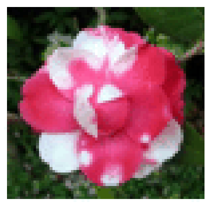
anticodon, The set of three amino acids in a group on tRNA which matches the codon

biotechnology, the use of technology to improve the breeding of plants animals or other organism by changing its genetic makeup.

chromosomal mutation, Mutations due to segments of DNA being copied improperly. Thes include deletion, duplication, inversion (the strand get copied backwards, and translocation, the strand get placed out of order.

chromosomes, one of the sections of DNA passed on to the offspring. Humans have 23 chromosomes.

codominance, Where BOTH traits share expression at the same time. The flower shows codominance of color, Both color traits.



codon, The set of three amino acids in a group on mRNA

DNA, Deoxyribonucleic acid - the molecule that holds the information for the cell.

dominance, when one trait is expressed in place of a second trait in the same offspring. the parents each giving one of the traits.

dominant, when one gene (allele) wins (dominates) the combination of gene.

gametes, the sex cells that pass on traits and form the offspring.

gene expression, The result of a particular gene in the organism - what the gene does.

genetic disorders, Disorders/ disease caused by mutation of certain genes.

genotype, The actual genetic makeup of a cell or organism

Gregor Mendel, The priest who studied pea plants and gave the first explanation for inheritance of traits. Punnett Squares were developed to show how traits can be inherited. Mendel's rules work with single allele/single gene traits.

heterozygous, Two of the same allele

homozygous, Two different alleles

incomplete dominance, a way that genes share dominance and a mixture of each trait results. Example is that a white and red flower produce a pink flower.

law of segregation, the rule that says that when male or female sex cells are produced each carries with it one of the two factors for creating the gene. It is represented by each of the letters on a Punnett Square

mitosis, When a cell divides, the process is called mitosis.

mutation, a permanent change in the DNA sequence of a gene.

pedigree, evidence of the breeding of an animal which shows if it purebred or not.

phenotype, The traits that result from the genotype due to dominance and the way the alleles combine

point mutation, deletion of a single base pair in the DNA sequence

polygenic traits, where a trait is expressed based upon more than one allele at the same time. Eye color is one example of a polygenic trait.

protein synthesis, When Protiens are made from the mRNA

Punnett square, a diagram for determining the probability of inherited traits based upon the dominant and recessive genes. May include single genes or multiple genes.

recombinant DNA, the result of a transgenic operation to create an organism with new DNA

RNA, Ribonucleic acid - the molecule which is used to copy the DNA sections for creation of a protein.

s phase, the part of the cell cycle where DNA is Replicated (copied)

sex-linked trait, traits that are expressed because the trait is carried on Y (male) or X (female) (sex determining) chromosome. Colorblindness is one example.

trait, a noticeable result from a genotype or genetic combination of alleles.

transcription, The name of the process where RNA is made.

transgenic, an organism that has had its DNA altered by human action.

translation, The process of "reading" the mRNA to make a protein strand.

Summary

LS 3-1Molecular Biology and Genetics focuses on DNA and how proteins are made, and how genetic information is passed from one generation to the next. DNA is the genetic material, which is the material passed from parents to offspring. It also contains the information used to make RNA. RNA leaves the nucleus and, together with a ribosome, makes proteins. Beginning with Mendel's pea plants, genetics has become one of the most important fields of biology. Human genetics affects many, if not every, field of medicine. Technologies associated with genetics are involved in developing products to make our lives better but have raised a number of ethical, legal, and social issues.

13.4 References

1. Image copyright spline_x, 2014. Amino acid sequence of insulin . Used under license from Shutterstock.com
2. Thomas Teichert. Blueprints are like DNA . CC BY 2.0
3. Laura Guerin. Comparison of RNA and DNA . CC BY-NC 3.0
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6. National Human Genome Research Institute. Transcription step of protein synthesis . Public Domain
7. Mariana Ruiz Villarreal (LadyofHats) for the CK-12 Foundation. Translation step of protein synthesis . CC-BY-NC 3.0
8. Laura Guerin. Examples of mutagens . CC BY-NC 3.0

CHAPTER 14 Artificial Selection: Animal Husbandry, Farming and Biotechnology LS 4-5

Chapter Outline

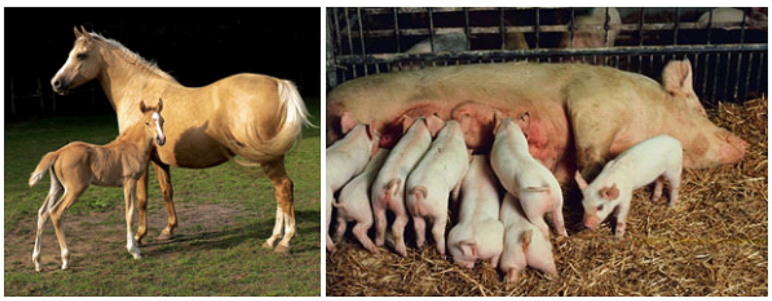


FIGURE 14.1
Farmers use many breeding methods to get the best offspring for their herds. They use similar techniques for growing better plants. They choose which animals and plants are allowed to breed together and hopefully produce offspring which are as good or better than their parents.

INTRODUCTION

DISCIPLINARY CORE IDEA:

MS-LS 4-5 By the end of instruction, students should be able to answer a test which asks them to: **Research the techniques of biotechnology and farming and animal husbandry and show how these are used in artificial selection for desired traits.**

When we arrive at Mars in our Story we will need to raise animals and plants for food and clothing we ought to know how to best breed them.

14.1 Biotechnology in Agriculture

Learning Objectives

- Define transgenic crop.
- Explain how biotechnology can be used in agriculture.

Have you ever eaten genetically engineered foods?

Most likely, yes. The majority of the corn in the United States is genetically engineered. Corn syrup is used to sweeten many things, like this soft drink. Corn is also fed to the cows that provided this hamburger.

Biotechnology in Agriculture

Biotechnology is changing the genetic makeup of living things to make a useful product. Biotechnology has led scientists to develop useful applications in agriculture and food science. These include the development of **transgenic** crops. In transgenic crops, genes are placed into plants to give the crop a beneficial trait. Benefits include:

- Improved yield from crops.
- Increased resistance of crops to environmental stresses.
- Increased nutritional qualities of food crops.
- Improved taste, texture or appearance of food.
- Reduced dependence on fertilizers, insecticides, and other chemicals.

Crops are obviously dependent on environmental conditions. Drought can destroy crop yields, as can too much rain and floods. But what if crops could be developed to withstand these harsh conditions?

Biotechnology will allow the development of crops containing genes that will help them to withstand harsh conditions. For example, drought and salty soil are two significant factors affecting how well crops grow. But there are crops that can withstand these harsh conditions. Why? Probably because of that plant's genetics. So scientists are studying plants that can cope with these extreme conditions. They hope to identify and isolate the genes that control these beneficial traits. The genes could then be transferred into more desirable crops, with the hope of producing the same traits in those crops.

Thale cress (**Figure** 14.2), a species of ***Arabidopsis*** (*Arabidopsis thaliana*), is a tiny weed that has been extensively studied. It is often used for plant research because it is very easy to grow, and its DNA has been mapped. Scientists have identified a gene from this plant, At-DBF2, that gives the plant resistance to some environmental stresses. When this gene is inserted into tomato and tobacco cells, the cells were able to withstand environmental stresses like salt, drought, cold, and heat far better than ordinary cells. If these results prove successful in larger trials, then At-DBF2 genes could help in engineering crops that can better withstand harsh environments.

FIGURE 14.2
Thale cress (*Arabidopsis thaliana*).

Recombinant DNA

FIGURE 14.3

Can we alter DNA ?

You might think that DNA is stable and unchangeable. For the most part you are right. However, there are new technologies that allow us to alter the DNA of humans and other organisms.

Recombinant DNA is the combination of DNA from two different sources. For example, it is possible to place a human gene into bacterial DNA. Recombinant DNA technology is useful in gene cloning and in identifying the function of a gene.

Recombinant DNA technology can also be used to produce useful proteins , such as insulin. To treat diabetes , many people need insulin. Previously, insulin had been taken from animals. Through recombinant DNA technology, bacteria were created that carry the human gene which codes for the production of insulin. These bacteria become tiny factories that produce this protein. Recombinant DNA technology helps create insulin so it can be used by humans.

Summary

- Genetic alteration can be used to change many different phenotypes of plants.
- Transgenic crops have extra genes that were placed into them to give the crop a beneficial trait.
- In the future, crops may be genetically altered to withstand harsh conditions.

Explore More

Use the resource below to answer the questions that follow.

- **How Do You Disable A Gene** at http://www.youtube.com/watch?v=QEbVpj7EbwU (6:19)

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/57299

1. What approach do scientists use to disable genes in *Arabidopsis*? How does this work?
2. What do scientists use to insert DNA into *Arabidopsis*?
3. Can scientists insert whole genes into a plant's genome?
4. How are the *Araidopsis* mutants valuable to botanists in general?

Review

1. What is a transgenic plant?
2. What are three examples of how biotechnology might be used in agriculture?

14.2 Biotechnology and Bioethics

Lesson Objectives

- Identify methods and uses of biotechnology.

Lesson Vocabulary

- biotechnology
- gene therapy
- genetically modified organism (GMO)
- genetic disorder
- genome

Introduction

The science of genetics has come a long way since Mendel's laws were rediscovered in 1900. There have been many advances in genetics. One of the most impressive advances was sequencing the human genome.

Biotechnology

Treating genetic disorders is one use of biotechnology. **Biotechnology** is the use of technology to change the genetic makeup of living things for human purposes. It's also called genetic engineering. Besides treating genetic disorders, biotechnology is used to change organisms so they are more useful to people.

Methods in Biotechnology

Biotechnology uses a variety of methods, but some are commonly used in many applications. A common method is the polymerase chain reaction. Another common method is gene cloning.

- The polymerase chain reaction is a way of making copies of a gene. It uses high temperatures and an enzyme to make new DNA molecules. The process keeps cycling to make many copies of a gene.

- Gene cloning is another way of making copies of a gene. A gene is inserted into the DNA of a bacterial cell. **Figure** 14.4 shows how this is done. Bacteria multiply very rapidly by binary fission. Each time a bacterial cell divides, the inserted gene is copied.

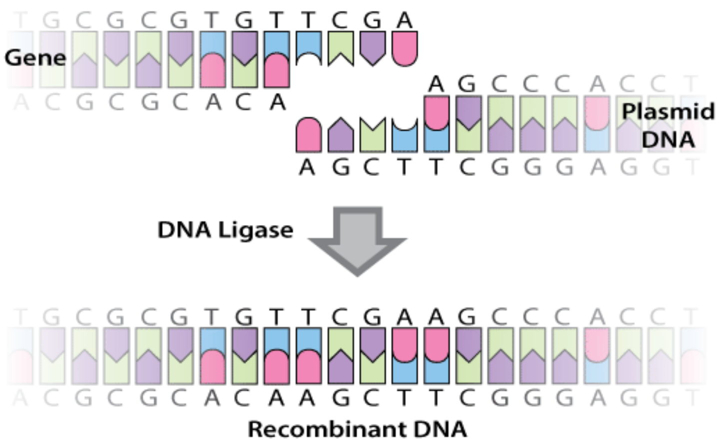


FIGURE 14.4

The enzyme DNA ligase joins together a gene and bacterial (plasmid) DNA. The DNA that results is called recombinant DNA.

Uses of Biotechnology

Biotechnology has many uses. It is especially useful in medicine and agriculture. Biotechnology is used to

- treat genetic disorders. For example, copies of a normal gene might be inserted into a patient with a defective gene. This is called **gene therapy**. Ideally, it can cure a genetic disorder.
- create **genetically modified organisms (GMOs)**. Many GMOs are food crops such as corn. Genes are inserted into plants to give them desirable traits. This might be the ability to get by with little water. Or it might be the ability to resist insect pests. The modified plants are likely to be healthier and produce more food. They may also need less pesticide.
- produce human proteins. Insulin is one example. This protein is needed to treat diabetes. The human insulin gene is inserted into bacteria. The bacteria reproduce rapidly. They can produce large quantities of the human protein. You can see another example in **Figure** 14.5.

Concerns about Biotechnology

Biotechnology has many benefits. Its pros are obvious. It helps solve human problems. However, biotechnology also raises many concerns. For example, some people worry about eating foods that contain GMOs. They wonder if GMOs might cause health problems. The person in **Figure** 14.6 favors the labeling of foods that contain GMOs. That way, consumers can know which foods contain them and decide for themselves whether to eat them.

Another concern about biotechnology is how it may affect the environment. Negative effects on the environment have already occurred because of some GMOs. For example, corn has been created that has a gene for a pesticide. The corn plants have accidentally cross-pollinated nearby milkweeds. Monarch butterfly larvae depend on milkweeds for food. When they eat milkweeds with the pesticide gene, they are poisoned. This may threaten the survival of the monarch species as well as other species that eat monarchs. Do the benefits of the genetically modified corn outweigh the risks? What do you think?

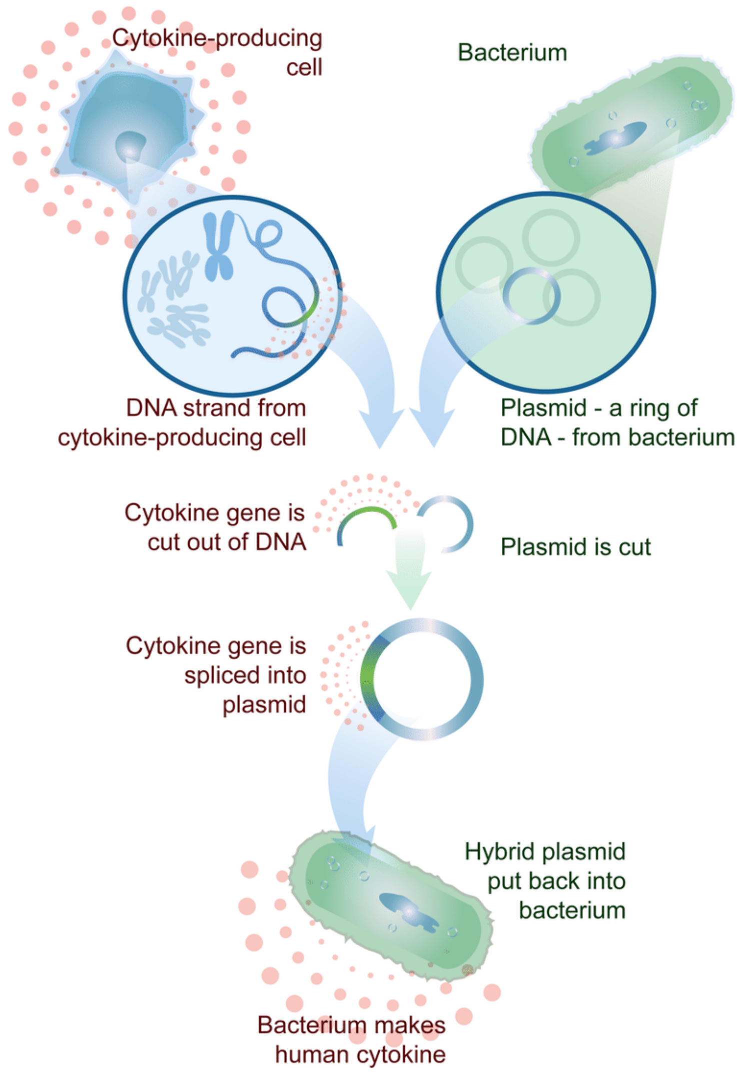


FIGURE 14.5
Bacteria are modified to produce the human protein cytokine. This is a protein that helps fight infections.

Lesson Summary

- Sequencing the human genome has increased our knowledge of genetic disorders. These are diseases caused by mutations. They may be caused by single gene mutations or the failure of chromosomes to separate correctly during meiosis.
- Biotechnology is the use of technology to treat genetic disorders or change organisms so they are more useful to people. Methods include gene cloning. Applications include gene therapy and genetically modified food crops.

Lesson Review Questions

Recall

1. Define genome.

FIGURE 14.6
Chances are that some of the foods you eat contain GMOs. However, they may not be labeled that way.

Apply Concepts

2. Pedigrees show that a certain genetic disorder passes from mothers to about half of their sons or from fathers to all of their daughters. Only males are actually affected by the disorder. What type of disorder is it?

Think Critically

3. Compare and contrast the polymerase chain reaction and gene cloning.

4. Weigh the pros and cons of using biotechnology to produce genetically modified organisms.

Points to Consider

Biotechnology can be used to artificially change the genetic makeup of organisms in a species.

1. How can the genetic makeup of a species change naturally?
2. What might be the outcome of this type of change?

14.3 Glossary

agrochemicals, chemicals used to protect plants from attack or used as fertilizers for plants or hormones used to cause animals to grow a certain way.

autosomal chromosome, a chromosome that is not relate to the sex of an animal

pedigree, The family relations of a particular individual animal often used to show it is a pure bred animal, commonly written on a pedigree chart.

recombinant DNA, The use of laboratory techniques to create a new DNA molecule and place the new molecule in a species to produce a new species.

sex-linked chromosome, a chromosome that is passed on ONLY by the male or female animal.

transgenic crop, crops with recombinant DNA

yield, the amount of crop produced per acre or hectare.

Human breeding methods

14.4 References

1. Quentin Groom. Picture of thale cress, which is used for genetic research . Public Domain
2. Zachary Wilson. DNA Ligase helps to create recombinant DNA . CC BY-NC 3.0
3. Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation. Bacteria can be modified to produce useful p roteins . CC BY-NC 3.0
4. Daniel Goehring. Some people favor the labeling of foods that contain GMOs. . CC-BY 2.0

CHAPTER 15 Ecology and Resources ESS 3-4

Chapter Outline

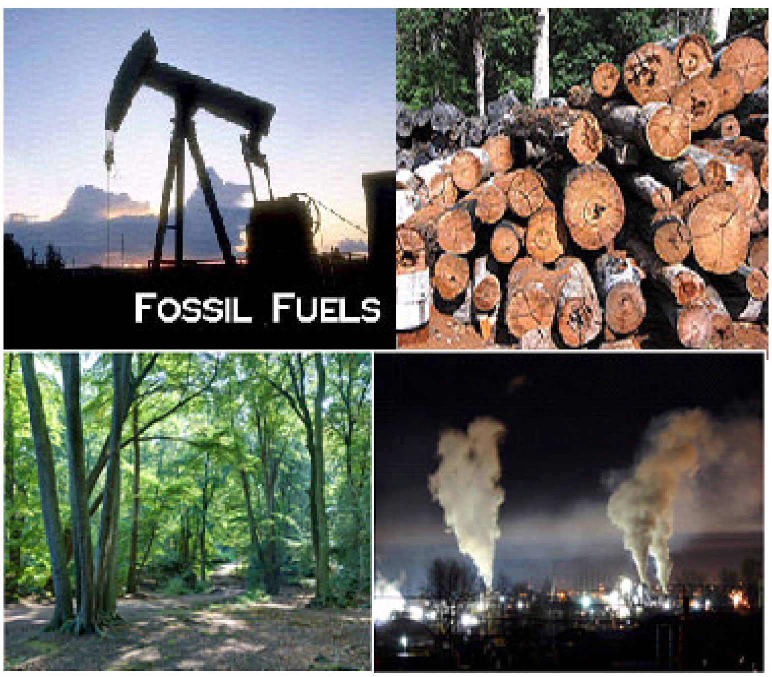


FIGURE 15.1

People use resources from nature and when we do, we often leave behind pollution or have other effects on the natural environment. Some of those actions lead to preservation of nature and some lead to destruction of nature. People consume resources and impact our environment.

INTRODUCTION

DISCIPLINARY CORE IDEA:

MS-ESS 3-4 By the end of instruction, students should be able to answer a test which asks them to: **Show from evidence how as human population increases, the amount natural resources used also increases and how the average person's use of these resources impacts the environment.**

In this chapter we learn how human activity and the human population as a whole can affect its own environment. We learn about how increasing population means increasing use of natural resources. We also learn about ways to use fewer resources. There is much discussion about the causes of changes in the environment and the solutions to resource use. What some see as a problem, others see as a benefit. People do not all agree on what to do or how to think about the growth in human population worldwide. As is typical of things that become part of politics, the truth is hard to see. People's personal lives are being affected on a large scale by decisions about how people should interact with their environment. Also, there is a great deal of money at stake as the large populations have the power to purchase goods and services, food and resources. This purchasing power affects economies, governments and individuals. How we interact with our environment and how we affect it is the topic of this chapter.

Both here on Earth and when we get to Mars, we will have limited resources. For our Story we need to understand how to manage and plan for how to use the resources.

15.1 Global Change

How do the activities of humans affect the environment on a continental and worldwide scale?

Human activities have led to continental and even worldwide changes in the environment. The result is called **global change**, because the changes occur on a huge scale over the entire globe called Earth. Often, the direct causes of these changes are not immediately clear. For example, traces of pesticides can be found in the snow at the North Pole even though humans do not use pesticides anywhere near there. The pesticides somehow traveled thousands of miles through the atmosphere from places where farmers used them to control agricultural pests. In this section you will explore two major examples of global change-acid rain and global warming (the cause of global warming is not clear, many studies show it is NOT related to greenhouse gas emissions - it may simply be the natural climate cycle of the earth over thousands of years) or a combination of greenhouse gases and the natural changes in the Earth's orbit and angle toward the sun.

Chief Seattle, as translated by Dr. Henry Smith

"Whatever befalls the Earth befalls the sons of the earth. Man did not weave the web of life; he is merely a strand in it. Whatever he does to the web, he does to himself. . ."

The Earth Speaks

Acid Rain

One of the problems created by excessive energy use in North America is **acid rain.** What is acid rain? How is it formed? How can rain be acidic? What can be done to prevent its formation?

Did You Know?

A better name for acid rain is acid precipitation, because snow as well as rain can be acidic. An even better name is acid deposition, because it also includes dry particles that can fall out of the atmosphere and combine with water to form acids.

Rain, in most cases, is naturally acidic. But sometimes it contains impurities that can make it highly acidic. **Acidity** is the amount of acid in a substance. Measuring the acidity of a liquid is measuring of one property of that liquid.

You probably know other measurements of the properties of a liquid, such as its temperature, volume, and weight. Acidity is measured in terms of pH, much like temperature is measured in degrees. Vinegar, lemon juice, and cola are some examples of acidic liquids that you know. The opposite of acidity is alkalinity (al-ka-LIHN-ih-tee). Shampoo and milk are examples of alkaline liquids.

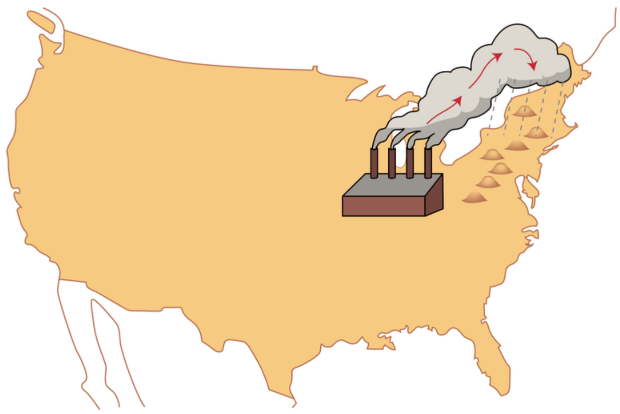


Figure 10.1 The sources of acid rain may be located far from where the acid rain has the most damaging effects.

Did You Know?

The most acidic rain ever measured in the mountains of the eastern United States was 2,000 times more acidic than unpolluted rain. That means it was like lemon juice falling from the sky!

Sulfur dioxide and nitrogen oxides are gases in the atmosphere. These gases can mix with water in the atmosphere. When enough of these gases mix with water, they change into sulfuric and nitric acids. The acids mix with water vapor and fall to earth when it rains. Sulfur dioxide is a chemical with molecules that are made up of one atom of sulfur and two atoms of oxygen. Sulfur dioxide is written SO_2 in scientific shorthand. Nitrogen oxides are chemicals with molecules made of one atom of nitrogen and one or two molecules of oxygen. Scientific shorthand for nitrogen oxides is NO_x. The X indicates either one or two atoms of oxygen.

What Do You Think?

How would you solve the problems caused by acid rain in the Northeastern United States? Would your solution be fair to the people in the Midwest? Would it be fair to the people in the Northeast? Explain your reasoning.

How do sulfur dioxide and nitrogen oxides get into the atmosphere? Most come from the smokestacks of power plants and factories and the tailpipes of automobiles. SO_2 and NO_x are released as byproducts when fossil fuels such as gasoline or coal are burned. SO_2 and NO_x in the air can drift hundreds of miles before falling out of the sky as acid rain. For this reason, many of the places suffering the effects of acid rain are not necessarily near the source of the pollution, as shown in Figure 10.1.

Did You Know?

Acid rain affects land organisms and water organisms. The needles of evergreen trees can be damaged by acid rains.

Acid rain tends to acidify the lakes and rivers on which it falls. Many aquatic organisms are affected by the acidity of the water in which they live. Acid rain has caused the decline of fish populations in lakes in the Adirondack Mountains of New York and in the rivers in Nova Scotia. Some insects such as water boatmen can live in lakes with a wide range of acidities. Other organisms such as fresh water mussels are very sensitive to acidity and can live only in fairly neutral waters. The bar graph in Figure 10.2 on page 64 compares how much acidity some different organisms are able to tolerate.

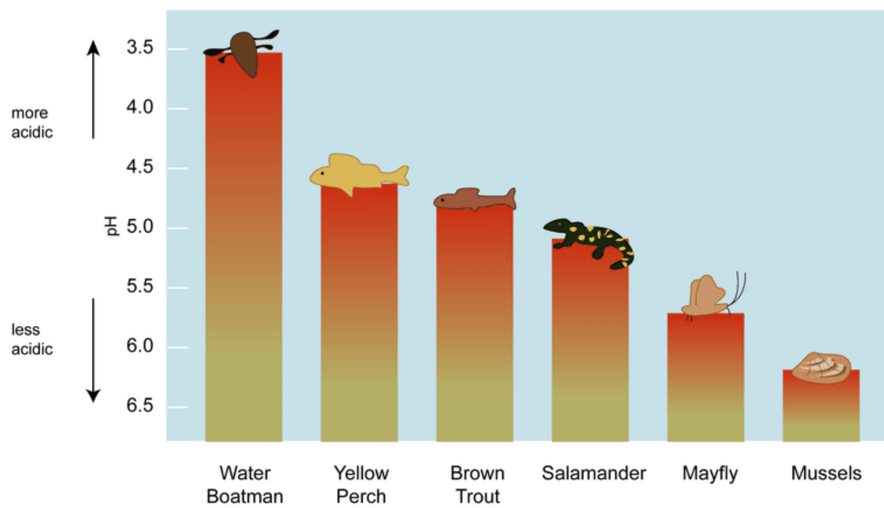


Figure 10.2 Different aquatic organisms can tolerate different amounts of lake acidity. The shaded bars on this graph show the range of acidities in which these organisms can live.

Apply Your KNOWLEDGE

Suppose you found a water boatman, a salamander, and a may fly while you were exploring a stream. What would you guess the pH of the stream would be? If you found only water boatmen in a second stream, would you guess that the second stream has a higher or lower pH than the first? (Hint: Look at Figure 10.2 and make sure that you notice that pH gets lower as you go up the vertical axis.)

Acid rain washes away calcium that normally cycles in forests. When this happens, calcium isn't available in the food chain, and birds can't get the calcium they need to make strong eggshells. As a result, birds living in areas with heavy acid rain are more likely to lay thin, fragile eggs. The fragile eggs break when the birds try to sit on them to keep them warm.

Journal Writing

Which of the effects of global warming do you think is more dangerous to humans: sea levels rising or rainfall patterns changing? Why? Should people who are not directly affected by these global warming effects do anything to decrease greenhouse gases? Why or why not?

Limiting the release of sulfur dioxide and nitrogen oxides would reduce the problem of acid rain. This can be done in several ways. For example, using more fuel-efficient automobiles and installing scrubbers that clean smokestack emissions will reduce the release of harmful gases. These changes sound easy but often are not done because they are expensive. Also, the people who suffer the effects of acid rain are often not the ones who cause the problems. Most of the pollution that causes acid rain in the northeastern United States actually comes from big Midwestern cities such as Chicago, Detroit, Cleveland, and Pittsburgh. So people in the Northeast have to convince people in the Midwest to burn their fossil fuels more wisely, even though the Midwest people don't benefit directly. In fact, it may cost them more money!

Another problem you've probably heard about on the news is global warming. You read a little about global warming on page 24. **Global warming** is the continuing increase of Earth's temperature. If the present trend continues over the next hundred years, the average temperature of the earth's atmosphere may become warmer than it has been for the past million years. Although this change doesn't sound that bad, even a small increase in temperature could lead to some large changes. Melting ice caps can increase ocean waters and cause flooding of low-lying areas near the ocean. Global warming can increase the length of the hurricane season. Also, global warming can increase the amount of rain in some areas and decrease the amount of rain in others. Although most places will become warmer, weather patterns may change so that a few could become cooler.

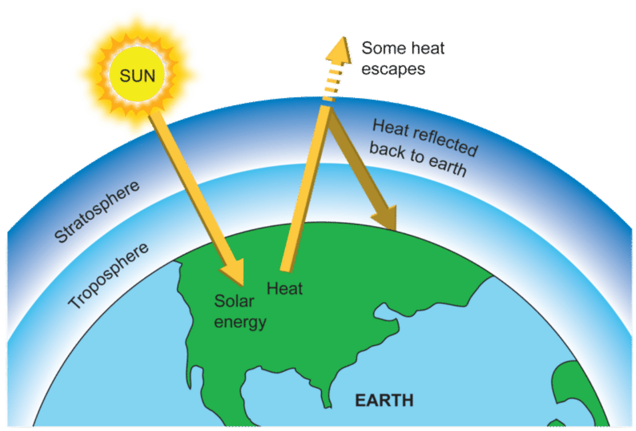


Figure 10.3 Greenhouse gases trap the sun's energy in the Earth's atmosphere.

Many scientists think global warming is likely to happen because humans have added excessive amounts of carbon dioxide to the atmosphere by burning fossil fuels. Methane, one of the components of natural gas and a large part of gases released by cow farts is another greenhouse gas. Gases called **CFCs** (chlorinated fluorocarbons) found in some air conditioners and refrigerators also are being released into the atmosphere and these may be affecting the ozone layer - letting in more harmful sunlight. Carbon dioxide and methane are greenhouse gases that have the ability to trap heat in the atmosphere. Many scientists believe that these gases are affecting our environment, but not all scientists agree.

Did You Know?

Sometimes simple changes can stop the production of substances that can harm the environment. One disk-drive factory in California was the single largest source of CFC-113 emissions in the United States in 1987 because it used CFC-113 to clean circuit boards. Now, the company simply dunks the circuit boards in soapy water and blow-dries them. This is a good example of a corporation seeing a problem and finding a solution to the problem. It's important for other corporations, individuals, and groups of people to do the same type of problem solving.

Remember that greenhouse gases trap heat in the atmosphere. This process of trapping heat is similar to the way that glass keeps the sun's heat trapped in automobiles and greenhouses. Normally, energy from the sun reaches Earth, warms it, and then some bounces back to space. But when greenhouse gases are in the atmosphere, the heat that would normally bounce out into space is trapped and stays to warm the atmosphere. This process, sometimes called the **greenhouse effect**, is shown in Figure 10.3. Many scientists thought this would be the cause of global warming as we are measuring it. Yet recent studies are showing greenhouse gases are not likely to be the only cause of global climate change. More work is needed to see if the cause can be determined.

What are some of the possible effects of global warming? One of the most dramatic effects would be the rise in sea levels. Because water takes up more room when it is warmer, the volume of the world's oceans will increase. Scientists predict that sea levels around the world will rise anywhere from 0.2 meters to 2.2 meters. Many low-lying areas near the ocean would be permanently flooded. For example, most of the Florida Keys and the Everglades would be completely underwater!

Another likely effect of global warming would be a change in precipitation patterns. Some places that receive a lot of rain now could dry up, while others that don't get much rain now could be flooded! Currently, scientists predict that the central United States will be much drier. This region is sometimes called the nation's "breadbasket." But continued global warming could make the area too dry even to grow wheat.

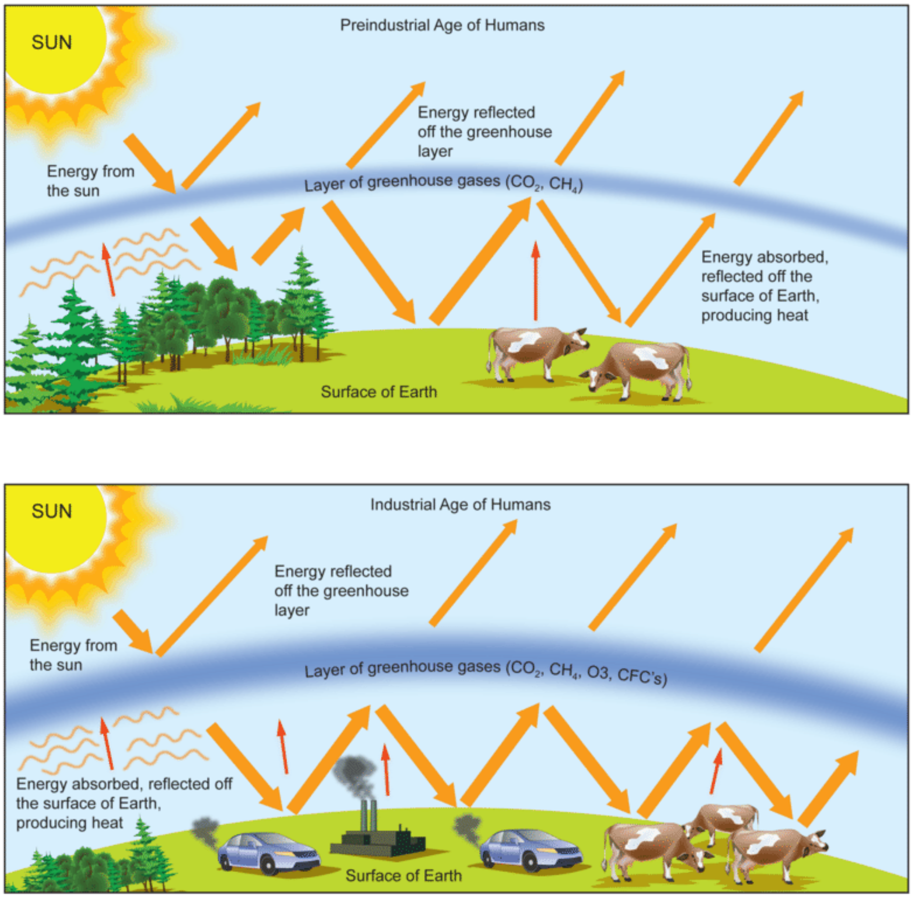


Figure 10.4 Greenhouse gases have increased significantly during the industrial age.

Did You Know?

Carbon dioxide is responsible for about 71% of the greenhouse effect. Every year people in the U.S. add at least 1.5 billion tons (1.36 billion metric tons) of carbon dioxide to the atmosphere by burning fossil fuels.

Many scientists think that one way to prevent global warming is to reduce the amount of greenhouse gases that human activities put into the atmosphere, again some disagree. This could be done by reducing the amount of fossil fuels burned and, perhaps, replace them with fuels that don't produce carbon dioxide. Scientists are now looking at ways to use hydrogen-based fuels and solar energy to achieve this goal. Global warming may not be affected at all by greenhouse gases. It may be that the Sun is producing more heat and that the angle of the earth is changing enough to shift the balance of heating and cooling. More work needs to be done. In the mean time, some scientists feel that reducing greenhouse gases will help, some feel it will not help.

Activity 10-1: Feeling the Heat: The Greenhouse Effect

Introduction

There is evidence that human activities are causing the Earth's average temperature to rise at a slow but steady rate, Scientists have called this phenomenon the *global warming*. Many scientist think this was due to the *greenhouse* *effect* where greenhouse gases trap heat in the atmosphere others are still looking for the cause. What exactly is the greenhouse effect? What causes it? What are its consequences? Are there possible solutions?

Materials

- Glass bowls or containers of various sizes
- Lamp
- Dirt
- Ice
- Water
- Colored paper
- Thermometers
- Activity Report

Procedure

Step 1 Discuss the following questions, Write your responses on your Activity Report.

- Why do scientists think gases such as CO_2 trap heat in the atmosphere?
- Will increased CO_2 in the atmosphere cause an increase in global temperature? Explain.
- How is the greenhouse effect expected to influence your life? Human life in general? The environment?

Step 2 Design and create physical models of Earth under two different conditions-without high levels of greenhouse gases and with high levels of greenhouse gases.

- What part(s) of your physical model represents “normal” levels of greenhouse gases? What part(s) represents high levels?
- How does changing your model’s “atmosphere” affect other parts of your model, such as air temperature?
- How can you change parts of your model such as temperature to lessen the effects of a rise in greenhouse gases?

Step 3 Discuss the following questions, Write your responses on your Activity Report.

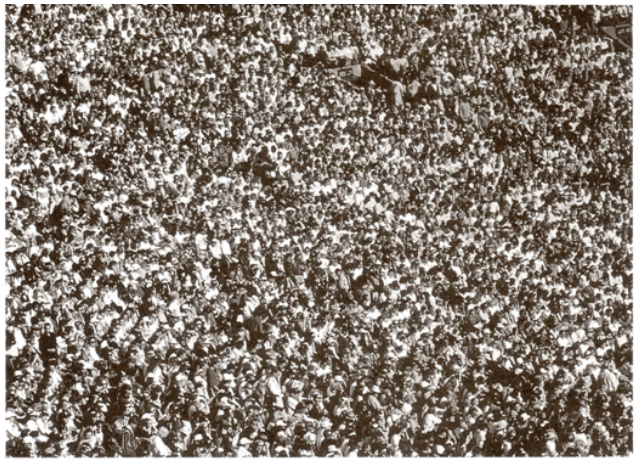
- How closely does your model represent real life?
- In what ways could your model be improved?

Step 4 Use your model to create a presentation to teach the class about the greenhouse effect. Your presentation should include its causes, consequences, and possible solutions. Use the responses on your Activity Report to begin developing your presentation.

Review Questions

1. What causes acid rain?
2. Does acid rain affect only the people who live near its source?
3. What is global warming?

15.2 Human Population Growth



How do humans affect other species?

How do you and other humans fit into the environment? Are humans separate from the environment? Do they compete with other species for resources? Let's find out!

Chief Seattle, as translated by Dr. Henry Smith

"You must teach your children that the ground beneath their feet is the ashes of our grandfathers. So that they will respect the land, tell your children that the earth is rich with the lives of our kin. Teach your children what we have taught our children-that the earth is our mother. Whatever befalls the earth, befalls the sons of the earth."

The Earth Speaks

How do you think ecologists use the term population? Do they mean the people in your town? Do they mean the people in the world-what about all the frogs in a pond or the trees in a watershed? Actually, if you answered yes to all of those examples, you are correct! A **population** is all of the organisms of a certain type living in a certain area at a certain time. Most often, people think only of human populations. But ecologists may study the populations of any type of organism.

Let's talk about the population of people living in Pellston, which is a small town in Michigan. The size of the human population in the town can do only three things: It can go up. It can go down. Or it can remain the same. What are ways to increase the number of people in Pellston? People living in Pellston can have children or people from elsewhere can move to the town. Moving into an area is called **immigration** (ih-muh-GRAY-shun). What are some ways to decrease the number of people in Pellston? People can die or people can move away. Moving away from an area is called **emigration** (eh-muh-GRAY-shun). Those four occurrences-birth, death, immigration, and emigration-cause the size of any population anywhere to change.

Did You Know?

According to the World Bank, half of the population in developing countries will be under 15 years of age by the year 2000. That means that more than 600 million jobs will be needed in those countries in the next few years.

It is important to remember that population size means only the number of individual organisms. For example, the number of individuals who actually live in Pellston is constantly changing. People are moving there and people are leaving. Babies are being born and people are dying. However, the number of people in Pellston seems to stay around 530. That is the population size listed on the sign posted at the outskirts of town.

Apply Your KNOWLEDGE

What is the population size of your class? Your school? Your town?

In many ways, Pellston is like other places in the world because its population can change. However, Pellston is not typical because its population remains pretty stable. A population is stable when the number of births and the number of people immigrating in is balanced by the number of deaths and the number of people emigrating out. Most human populations are growing. A population grows if more people are born or immigrate into the area than die or emigrate out. Some human populations are shrinking. Populations shrink if more people die or emigrate from the area than are born or immigrate into the area.

Now let's look at a human population that is a bit bigger than Pellston's-the world's population. In 1997, the world's human population was over 5.9 billion. But it hasn't always been that large. Look at the graph in Figure 9.1 on page 57.

The graph shows the approximate growth of the world's population since 8000 B.C. Notice how the line wobbles up and down but basically stays flat from 8000 B.C. until after 1000 A.D. After 1000 A.D., the population starts to increase dramatically. The graph shows that it took thousands of years for the human population to reach 1 billion, another 130 years to reach 2 billion, another 30 years to reach 3 billion, another 15 years to reach 4 billion, and another 12 years to reach 5 billion! This pattern is alarming because it shows that it is taking less and less time for humans to add another billion people to the world's population.

What Do You Think?

How many people do you think the world needs? Did we have enough in 1900? In 1950? Do we still need more people? Explain your reasoning.

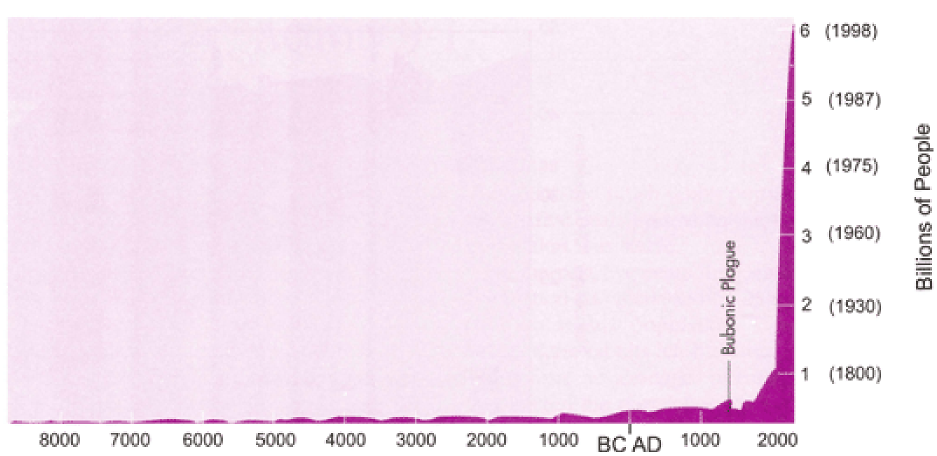


Figure 9.1 This graph shows how the world human population has grown. The years shown in brackets along the right side indicate when the population reached the numbers along the vertical axis.

What is happening with the world's human population as shown in Figure 9.1? You may remember that populations grow only if the birthrate increases, the death rate decreases, or more people immigrate into the population. Immigration and emigration are not involved when studying the world's human population. That's pretty obvious since people aren't moving away from Earth. So what occurrences are affecting population increase in our world? More babies are being born and fewer people are dying.

Ecologists who keep track of human populations are called **demographers** (dem-OG-rah-fers). Demographers tell us that the most dramatic change in the world population has been the result of fewer people dying. Advances in medicine, sanitation, and food production have allowed people to live longer and to have children who also live longer and eventually have more children.

Mexico is one example of a country whose population size has been greatly affected by these changes. Approximately 40 people in 1,000 died each year around 1920. This number shows the **mortality rate**, or death rate. By 1990, the mortality rate had greatly decreased. Only 6 people in 1,000 died each year. So, on average, 34 more people out of 1,000 are now surviving, living, and having children every year. Contrast this change with what has happened with the **birthrate.** The birthrate is the number of children born each year. In 1920, approximately 40 babies were born per 1000 people. In 1990, approximately 30 babies per 1,000 people were born.

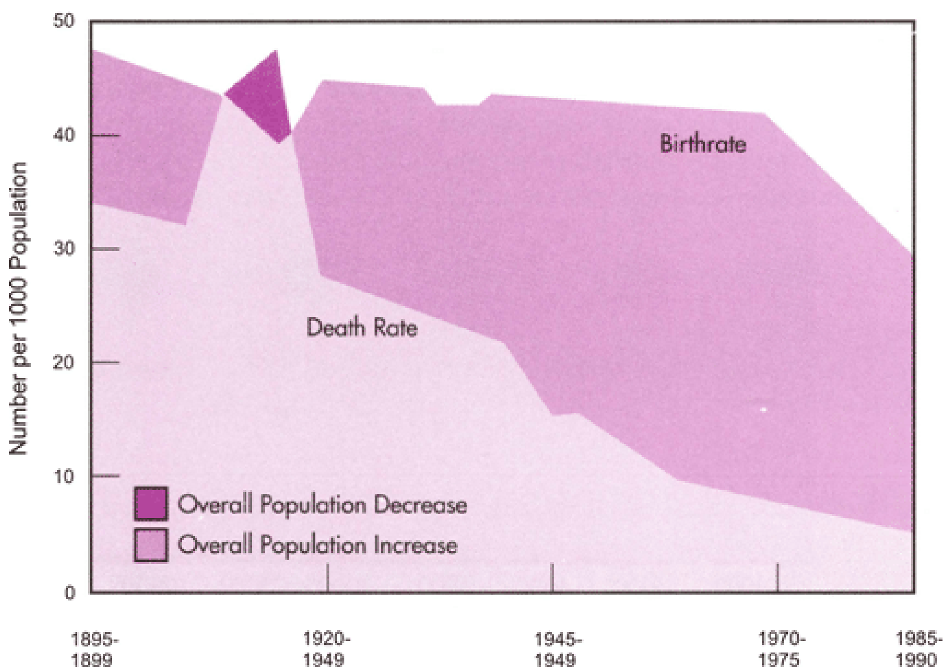


Figure 9.2 Birth-and Death Rates in Mexico, 1895-1990.

The mortality rate and birthrate combine to affect population growth. For example, approximately the same number of people were being born as were dying in Mexico around 1915. That kept the population stable. But many more people are being born than are dying now. As a result, the population is growing.

Did You Know?

Today's physicians effectively treat diseases that once killed hundreds of thousands of people. Furthermore, fewer children are dying right after birth. For example, in the past a woman in Kenya who gave birth to eight children could expect only four to survive beyond infancy. Today a woman in a similar situation would probably see most of her children survive to have children of their own.

One way of thinking about population growth is to calculate the **doubling time** of a population. The doubling time is the amount of time it takes for a population to double in size. Most developed countries such as the United States and most European countries are growing slowly and have long doubling times. For example, demographers predict that the population of the United States will double in about 89 years. Most developing countries such as many countries in Africa, Asia, and South America are growing more quickly than developed countries. So developing countries have short doubling times. The average doubling time for many developing countries is approximately 34 years. That may seem like a long time to you. But 34 years really isn't a long time. Just think: In 34 years a developing country will need twice as many houses, twice as much energy, and twice as much food as it does now. This growth is bound to cause some problems. Imagine what would happen if the number of people in your neighborhood doubled. Where would you put the extra apartments, houses, roads, grocery stores, schools, and everything else people need to live?

Graph of total world population:

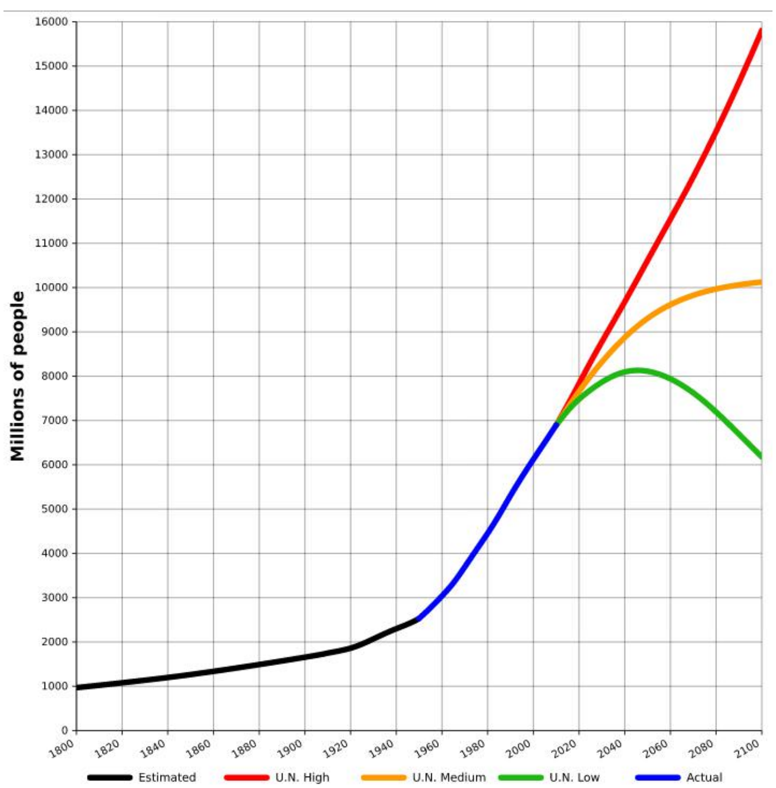


FIGURE 15.2

World human population estimates from 1800 to 2100, based on "high", "medium" and "low" United Nations projections in 2010 (colored red, orange and green) and US Census Bureau historical estimates (in black). From UN Projections 2015. https://esa.un.org/unpd/wpp/dataquery/

Introduction

Brush rabbits live throughout the state of California. In order to survive, brush rabbits need dense, brushy areas for their nests. They also need grasslands and meadows for grazing in the spring and summer. In the fall and winter, they need leaves, twigs, buds, and bark. If the rabbits have the food, water, shelter, and space they need, they will keep reproducing. They can produce about three litters per year, with three or four bunnies per litter. Their predators-bobcats and coyotes-keep the population in check. When all of these factors are in balance, the brush rabbit population remains relatively stable. In this activity you investigate how changes in resources can affect the brush rabbit population.

Materials

- Pencils
- Data Sheet: Graph A
- Data Sheet: Graph B
- Resource
- Activity Report
- Graph paper (optional)

Procedure

Step 1 Using the information given below, complete the Data Sheet for Graph A.

Population Growth Information for Graph A

In one habitat, the brush rabbit population has been growing steadily. The rabbits have enough food and water. They also have enough space and brush cover for their nests. While the bobcat population has remained stable, the population of one of their predators-the coyote-has been decreasing over the past five years. Farmers have been trapping coyotes to protect their chickens, and some of the coyotes have been killed.

The following assumptions give you numbers for the brush rabbit and coyote populations for the last five years. Use this information to fill out the Data Sheet for Graph A.

Assumptions

- The estimated brush rabbit population was 250 rabbits five years ago when the coyote population was stable.
- Over the past five years the estimated rabbit population has increased by 25 rabbits per year over the original population.
- None of the rabbits left the area.
- There were no shortages of essential resources that limited the population.

Step 2 Using the information given below, complete the Data Sheet for Graph B.

Population Growth Information for Graph B

Use the same brush rabbit habitat described above. But assume that the coyote population was reduced to zero and that hunters have killed all but three bobcats. This drastic change in the predator population has resulted in the brush rabbit population doubling each year for five years, starting with year one.

The following assumptions give you numerical information for the brush rabbit and coyote population for the last five years. Use this information to fill out the Data Sheet for Graph B.

Assumptions

- The brush rabbit population doubled every year from year one to year five.
- The number of brush rabbits five years ago was 250.
- None of the rabbits left the area.
- There were no shortages of essential resources that limited the population.

Step 3 Use your completed graphs to answer the questions on the Activity Report.

Did You Know?

People living in the United States consume more resources than people living in most other countries do. We also produce more waste by processing all those resources.

Population Growth and Resource Use

The number of people is just one part of the story of human population growth. The other part is how people use the resources that are available to them. For example, as a person living in the United States, during your lifetime you will probably consume;

- a number of calories equal to that contained in 100,000 hamburgers, 2 million French fries, 50,000 chocolate shakes, 50,000 apples, and 4,000 gumdrops,
- 500,000 gallons (2,272,500 liters) of water just to shower
- 1 ton of soap (0.9 metric ton)
- enough energy to drive a car around the world 1,500 times
- 150 trees for wood and paper
- tons of metals, cloth, plastics, and glass

A typical person living in a developing country would use far less of all of these products.

It can be hard to compare the resources used by people in different countries. For example, you may eat hamburgers or other meat several times a week, while a student in India may never eat meat. Ecologists have tackled this problem by trying to reduce all comparisons to the amount of energy used by people in different parts of the world.

One way to measure energy is to measure the number of calories in food or fuel. Another unit used to measure the amount of energy in something is a **gigajoule** (GIG-uh-jool). A joule is equal to 0.24 calories, and *giga* means 'one billion'. Ecologists have calculated that the average person living in the United States uses about 300 gigajoules of energy each year to do everything from heating their homes, to growing the food they eat, to traveling. The average person living in Mexico uses about 50 gigajoules each year. The average person living in Nigeria uses less than 10 gigajoules of energy per year.

Apply Your KNOWLEDGE

How many calories are there in 300 gigajoules?

People in developed countries such as the United States use about 10 times as much energy per person as people in many developing countries. For example, farmers in developing nations may use only human muscle power and a few domestic animals to work their fields. In contrast, farmers in developed countries use machines and products that consume a lot of energy such as tractors, loaders, combines, fertilizers, and pesticides.

The difference in energy use shows how differently the various people around the world use resources. One person in the United States uses about 6 times as many resources in a year as one person in Mexico, and about 100 times as many resources as one person in Nigeria. In other words, you can raise one child in the United States or 100 children in Nigeria with the same amount of resources.

Journal Writing

Suppose you wanted to reduce the amount of resources that humans consumed in an area.

- Explain one strategy to keep the number of people in the area from growing.
- Explain one strategy to reduce the amount of resources that each person used.

Which countries would you advise to use each strategy?

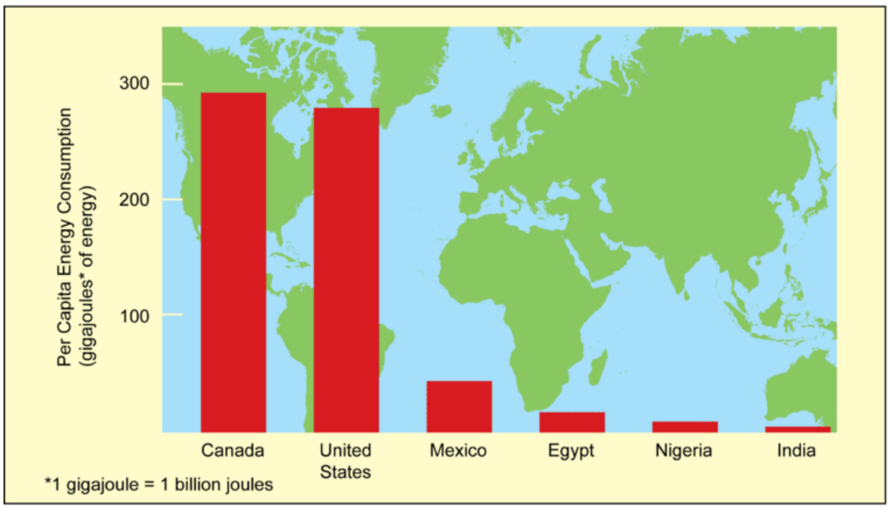


Figure 9.3 Compare the average energy use per person in these six countries.

These energy comparisons show that it doesn't matter only how many people live in an area. It also matters how they use their resources. Ecologists estimate that humans are using about 40 percent of the world's **terrestrial net primary productivity.** Terrestrial net primary productivity is a name for all of the sun's energy that is trapped and stored by all of the plants on the Earth's land surfaces during photosynthesis. Remember how all energy can be ultimately traced back to the sun?

Population growth and the use of resources are the keys to many environmental problems we have. More people use more and more resources. This increasing use is depleting our supply of important resources. And the more resources we use, the more waste and pollution we are dumping into the environment.

Apply Your KNOWLEDGE

Suppose that the world's population doubles in 40 years, and energy consumption rates remain the same. What percentage of the world's net primary productivity will be used by humans in 40 years? What percentage will be left over for all of the other living things on Earth?

Review Questions

1. What is a population? What are four ways in which its size may change?

2. Suppose the doubling time for a population of algae in a pond is 24 hours. Also suppose the pond is now at capacity for algae. How long ago was the pond only half full of algae? How long ago was the pond one fourth full of algae?
3. Is the size of the world's human population growing or shrinking? Is it doing this at a constant rate?
4. Do 100 people living in developing countries such as Nigeria have the same impact on the environment as 100 people living in the United States? Explain your answer.

15.3 Recycling in Human Communities

How can humans cycle their resources?

You've seen how materials cycle and recycle throughout biological communities. It is very important that we all remember the saying in Section 4: "You can't ever really throw anything away. There is no 'away'!" What is on Earth now, stays on Earth. So we need to be careful how we use and reuse our resources. This section will help you discover some ways we can reuse and recycle our resources.

Sigurd Olson

"Awareness is becoming acquainted with the environment, no matter where one happens to be."

quoted in *The Earth Speaks*

It has taken humans a long time to figure out that we need to do what biological communities have always done. Like biological communities, we need to recycle the materials that allow all living organisms on Earth to grow and survive. People in the United States are realizing that, when they throw things "away" they are merely putting them someplace else-usually where they don't have to see them. Unfortunately, most of the things that people throw away end up in a landfill somewhere. These items have been removed from their normal cycles and dumped so they are no longer serving any useful purpose.

What happens when you throw a piece of paper in the garbage can in your classroom? Does it magically disappear? No! If your school is typical of most schools in the United States, your paper goes on a very long and complicated journey.

Did You Know?

People in the United States produce 154 million tons of garbage every year-enough to fill the New Orleans Superdome from top to bottom twice a day-every day!

Let's follow that paper on its journey. First, your paper travels from the garbage can in your classroom to the custodian's garbage. Eventually it's dumped into the school's dumpster. The paper and everything else with it in the dumpster is picked up by a community garbage truck. The truckload of garbage is driven to a transfer station and emptied into an even bigger garbage truck. When the bigger garbage truck is full, it is driven to a clay-lined landfill where its load of garbage is emptied. At a typical sanitary landfill, the garbage is covered with soil or crushed rock at the end of each day. A landfill is covered with a clay cap when it's full so that rainwater can't get in. Rainwater must be kept out, because it could leach out chemicals from the garbage that might contaminate the groundwater beneath the landfill.

Figure 6.1 Throwing a piece of paper into a garbage can is just the first step of many until it is sealed in a landfill.

What Do You Think?

What sources of energy are used in the process of throwing away a piece of paper? Do you think that the energy sources are being used wisely? Explain your answer.

Does that sound like a long trip to you? Well, it is. And that piece of paper doesn't just take up space. No, disposing of that piece of paper also requires the work of many people. The school custodian, two garbage truck drivers, the people who work at the transfer station, the bulldozer operator at the landfill, and many other people are involved! And there's another problem with the way that paper was disposed of. That paper resource can't be used again. The paper was wasted when it could have been recycled and used again.

Landfills end the long trip your trash takes. There is no "cycle" for things put in a landfill. Many people think that landfills are wonderful places where garbage decomposes, and is turned into soil by decomposers such as worms and microbes. Unfortunately, that is not the case. Decomposers need water, sunlight, and air to decompose things quickly. The clay cap put on landfills to prevent groundwater contamination keeps out water, sunlight, and air. As a result, very little decomposition happens.

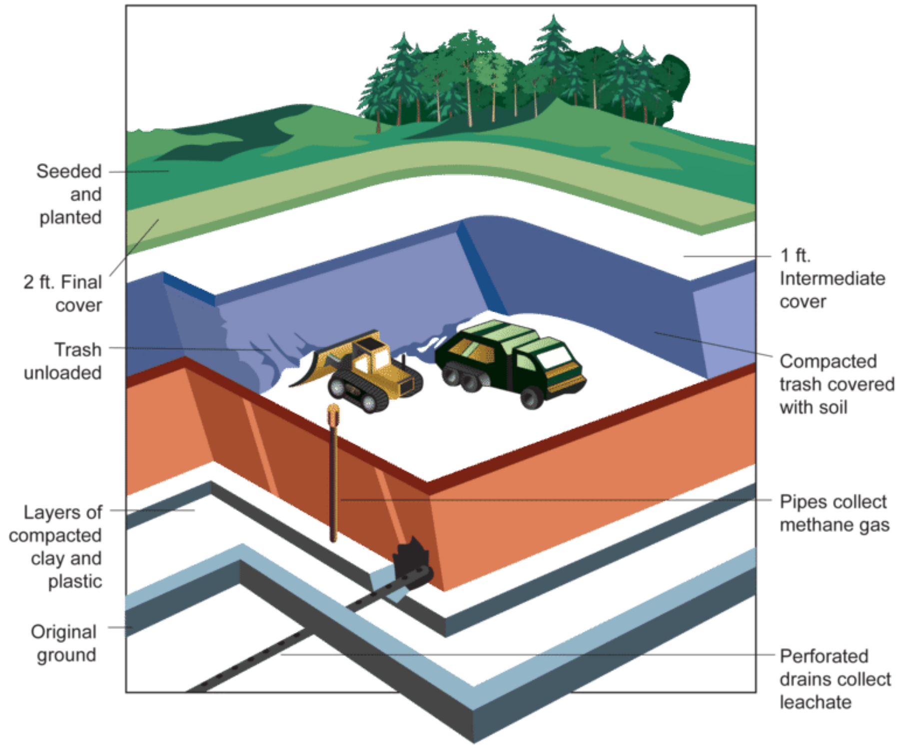


Figure 6.2 A landfill is more than a simple hole in the ground. What do you think are some of the things in this landfill that keep garbage from decomposing?

Draw a Paper Cycle Think about a pine tree in a forest. The paper in your notebook probably came from such a tree. Paper can be thought of as a resource that flows through the environment just as water, nitrogen, or carbon does. Is this flow a cycle? Draw a path showing the flow of paper from its source to where it ends up. How would the flow of paper in your drawing change if you lived in a community that recycles paper products? Add this to your drawing.

One self-named garbologist-William Rathje-has made a career of excavating (or digging up) landfills to see what actually happens to garbage in a landfill. He has found that newspapers do not decompose. So he regularly uses them to estimate the age of the garbage where he is digging. How do you think Mr. Rathje uses newspapers to estimate the age of the garbage? He has found hot dogs that look as if he could eat them. (But he doesn't, of course!) He has found five-year-old heads of lettuce that look no worse than lettuce that has been sitting in a refrigerator for a couple of weeks. But the hot dog and the lettuce were disposed of long ago. His discoveries have shown that little decomposition takes place in a landfill. Figure 6.2 illustrates how a landfill is constructed. You can see from the illustration that the clay and plastics used to enclose the landfill actually help to keep the garbage from decomposing quickly.

Apply Your KNOWLEDGE

What do you think happens to paper bags in a landfill?

Activity 6-1: What's in Your Garbage and Where Does It Go?

Introduction

What is in your garbage can? How many items in your garbage could be reused or recycled? Recent research indicates that people in the United States are creating more garbage than ever before. In this activity you analyze the types of things you throw away and where they go after you throw them away. Then you determine how you might reduce the amount of garbage generated.

Materials

- A bag of typical garbage
- Scale
- Tape measure
- Paper and pencil
- Plastic bags
- Cardboard box
- Gloves
- Calculator (optional)
- Activity Report

Procedure

Step 1 Weigh the bag of garbage on the scale and record this information on your Activity Report.

Step 2 Empty the bag of garbage into a cardboard box and record the volume of the garbage on your Activity Report. The volume can be determined by using the following equation. Volume = (length of box) $\times$ (width of box) $\times$ (height of garbage in box)

Step 3 Assume that this bag of garbage was produced in one day. Calculate the volume and weight of garbage produced by this household for a 30-day period. What would be the volume and weight of garbage produced during one year? Show your work and record the information on your Activity Report.

Step 4 Look at the garbage and discuss with your group how you could sort the garbage into categories such as plastic, paper, aluminum, and whatever other categories you can identify. Put the gloves on and sort the garbage into piles.

Step 5 Now remove all the materials that could be reused, recycled, or composted. List these items on your Activity Report. Then write how you think they could be reused or recycled.

Step 6 Calculate the volume and weight of the garbage after you have removed all of the items that could be reused or recycled. What would be the volume and weight for a 30-day period? What would be the volume for one year? Show your work and record the information on your Activity Report.

Step 7 Now choose one of the items you separated from the garbage because it could be recycled. Make a list on your Activity Report of the people who would handle it and the places it could travel on its recycling journey.

Here's another saying for you to remember. *"Reduce, Reuse, Recycle!"* We can partially avoid the problems landfills present by following this slogan. By following those three steps, in that specific order, we can significantly lower the amount of garbage that is thrown away. Let's examine each step, one at a time.

Mini-Activity

Overpackaging How can you change the amount of refuse that goes into a landfill? You can reduce the amount of waste you create by buying products that have less packaging or recyclable packaging. Bring in examples of products you think are overpackaged. Propose alternative packaging methods. Create a commercial to convince your Classmates that your alternative packaging method is better than the existing method. You may want to include posters or models to illustrate your point.

Reduce

Reduce is the most important step because it is much easier to not make garbage than it is to dispose of it once it is made. Reducing the amount of materials we use helps in several ways. Energy isn't wasted in making the product. Time and energy aren't wasted in transporting the product to you. And time, energy, and space aren't wasted in taking it away as garbage to bury it in a landfill.

Let's look at a good example of a product whose use can be reduced or totally eliminated. Grocery stores use a lot of paper bags. Why chop down a tree, turn it into paper, and fashion the paper into a bag, just so you can take your groceries home from the store and throw the bag away? It's just as easy to use cloth grocery bags that can be washed and reused. Try to think of some other ways you can reduce the use of paper bags or eliminate their use altogether. Surprisingly, the people who work on solutions to the problems of landfills often ignore this strategy. Perhaps it is too simple. What do you think?

Journal Writing

Select a packaged item from home or school that you think is overpackaged. Write a letter to the company that produced the item and suggest alternative packaging ideas.

Reuse

Reuse resources, products, and materials. The next easiest step in reducing the wastes that go to landfills is to reuse the things you have. For example, you can take the grocery bags with you the next time you go shopping, and reuse them. You can also save the bag you got at the grocery store and use it to take your lunch to school. You accomplish two goals at once! You are reducing the amount of disposable items that you are using by not buying manufactured lunch bags, and you are reusing bags that you already have!

Did You Know?

One dollar out of every eleven dollars that people in the United States spend on food goes for packaging. In fact, we spent more on the packaging for our food last year than American farmers received in net income.

Recycle

The last step is not the easiest step, but is very important to conservation and keeping our Earth healthy. *Recycle* the wastes you produce. This task is harder than reducing or reusing products. Recyclable items have to go through several steps and processes. Recycled wastes have to be taken to a recycling collection center. From there they are transported to a recycling plant and remanufactured into new products. Then the new products are returned to a store for someone to buy again. Think about it. You can recycle a paper bag by taking it to a recycling center. There it can be prepared for a paper recycling plant. The paper bag is turned into a new paper product and sold again. It seems a lot simpler and more considerate to our environment to not have picked up the bag in the first place.

Most Common Recyclables

- Newspapers
- White office paper
- Corrugated cardboard
- Magazines not coated with clay (not glossy)
- Aluminum cans
- Steel cans
- Glass (must be sorted by color)
- Plastics are coded. (See Figure 6.4.)

Figure 6.3 You usually have to sort recyclable items when you prepare them for recycling.

Recycling is an important option for reducing the amount of waste you send to a landfill. Many communities in the United States have recycling programs that can handle most of your household wastes. The most commonly recycled materials are aluminum, steel, glass, newspapers, office paper, and some plastics.

Did You Know?

It takes an entire forest (over 500,000 trees) to supply people in the United States with their Sunday newspapers every week. Newspapers take up almost 25 percent of the room in a typical landfill in the United States!

In order for wastes to be recycled, they have to be sorted into their different types. You can't turn a garbage can full of assorted garbage into recycled paper. But you can turn a stack of newspapers into recycled paper. Some cities collect recyclable materials all mixed up together, and the materials are then sorted mechanically or by people. However, most cities with recycling programs require that the people who are throwing things away do the sorting. Perhaps you have separate bins for bottles, cans, and paper in your kitchen because you recycle already.

Did You Know?

- Making aluminum products from recycled aluminum cans uses 90% less energy than making aluminum products from scratch.
- The energy saved from recycling one glass bottle could light a 60 Watt bulb for four hours.
- Recycled plastic can be used to make products such as plastic lumber and fiberfill sleeping bag insulation.

Recycling your wastes can be simple and fun. But before you start setting up bins and sorting everything from foil balls to toothpaste tops, you should check with your local recycling program. The people at the recycling program probably want you to sort your recyclables in a very specific way. Their goal is to have you sort the recyclables in a way that is useful for the people in your area who use those recyclables to make new products.

The world of recycling changes constantly. Your community might recycle some of the above-mentioned things, all of these things, or maybe even more than what was described here. Be sure to check with your local recycling program so that you can save energy, save resources, and keep your local landfill from filling up quite as fast.

Figure 6.4 Plastics are coded 1-7. Objects coded 1 are easy to recycle. Objects coded 2-6 are increasingly harder to recycle. Objects coded 7 cannot be recycled at all. Mixing the coded objects can spoil an entire batch at a recycling plant.

Apply Your KNOWLEDGE

Name ten things that are thrown away but aren't on the list of most common recyclables.

There is one type of material you may be able to recycle completely in your own home. Yard waste, such as grass clippings and leaves, are **biodegradable** (by-oh-dee-GRAY-duh-bul) materials. Biodegradable means that decomposers can turn them into soil fairly easily. You can recycle yard wastes by building a compost pile in your yard.

Review Questions

1. Why do people who work on waste disposal say that there is no "away"?
2. What are the three steps you can follow to limit the amount of garbage that you send to a landfill?
3. Why is it important to properly sort items for recycling?
4. What is meant by biodegradable? Give two examples of biodegradable items, and explain why each is biodegradable.

15.4 Energy Conservation

Learning Objectives

- Define conservation.
- List ways to conserve energy in transportation.
- Give tips for conserving energy at home.

You won't see this car on the road, at least not yet. It's a concept car that was developed by a major automaker. Instead of burning gasoline, it runs on hydrogen gas. Using hydrogen for fuel doesn't produce pollution, and it doesn't depend on nonrenewable fossil fuels. New technologies like this car may one day help solve our energy resource problems. But even without new technologies such as this, there are many ways we can help solve the problems right now.

Conserving Energy

Everyone can reduce their use of energy resources and the pollution the resources cause by conserving energy. **Conservation** means saving resources by using them more efficiently, using less of them, or not using them at all. You can read below about some of the ways you can conserve energy on the road and in the home.

Conserving Energy in Transportation

Much of the energy used in the U.S. is used for transportation. You can conserve transportation energy in several ways. For example, you can:

- plan ahead to avoid unnecessary trips.
- take public transit such as subways (see **Figure** 15.3) instead of driving.
- drive an energy-efficient vehicle when driving is the only way to get there.

FIGURE 15.3

Q: What are some other ways you could save energy in transportation?

A: You could carpool to save transportation energy. Even if you carpool with just one other person, that's one less vehicle on the road. For short trips, you could ride a bike or walk to you destination. The extra exercise is another benefit of using your own muscle power to get where you need to go.

Conserving Energy at Home

Many people waste energy at home, so a lot of energy can be saved there as well. What can you do to conserve energy? You can:

- turn off lights and unplug appliances and other electrical devices when not in use.
- use energy-efficient light bulbs and appliances.
- turn the thermostat down in winter and up in summer.

FIGURE 15.4

Q: How can you tell which light bulbs and appliances use less energy?

A: One way is to look for this ENERGY STAR® logo (**Figure** 15.5).

FIGURE 15.5

Summary

- Conservation means saving resources by using them more efficiently, using less of them, or not using them at all.
- Everyone can reduce their use of energy resources and the pollution the resources cause by taking steps to conserve energy.
- There are several simple ways to conserve energy in transportation and at home.

Review

1. What is energy conservation?
2. Describe one practical way that you could save transportation energy in your own life.
3. Draw a sketch of a house in which energy is being wasted. Then explain how energy could be conserved instead.

Resources

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/187434

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/187436

15.5 Glossary

abiotic, non-living materials

acidity, the amount of acid in a substance.

acid rain, precipitation containing impurities that can make it highly acidic.

aerobic respiration, a chemical process that uses oxygen and produces water and carbon dioxide. it stores energy in the form of ATP.

aesthetics, things pertaining to beauty.

biodegradable, materials that decomposers can break down fairly easily.

biological community, all the organisms living together in a specific area.

biological diversity, the variety of life at all levels of organization that exists in an area.

biotic, those things that are alive or were recently alive.

birth rate, the number of children born each year.

calorie, the amount of energy it takes to raise the temperature of one gram of water one degree celsius. (the calories used to describe food are actually k calories or 1,000 calories.)

camouflage, the color, markings, body shape, or behavior that helps an animal or plant hide in its surroundings.

carbonification, the process by which dead plants and/or animals are turned into coal, oil, or natural gas.

carnivores, animals that eat only other animals. some plants are also considered carnivores because they "eat" insects.

carrying capacity, the number of organisms that a habitat can support indefinitely.

CFCS, (chlorinated fluorocarbons) gases formerly used in air conditioners and refrigerators that are also being released into the atmosphere.

community, a group of organisms that live in the same place.

competition, what happens when one organism uses a resource in a way that prevents other organisms from using it.

consumers, organisms that get energy by eating other organisms.

cycle, a chain of events that happens regularly and has no distinct beginning or end.

decomposers, organisms that break down dead matter.

dehydrate, to dry up.

demographers, ecologists who study human populations.

diversity, variety

doubling time, the amount of time it takes for a population to double in size.

ecological pyramid, a snapshot of the amount of energy or number of individuals at different levels of a food web in a specific location.

ecologists, scientists who study the distribution and abundance of organisms in-the environment.

emigration, moving away from an area.

endangered, a species that is threatened with becoming extinct.

environment, the physical, chemical, and biotic (living) factors that you affect and that affect you.

ethics, a set of moral principles or values.

evaporate, change into water vapor.

extinct, a species of which all members have died.

food chain, a description of the path by which energy moves from the sun to plants and animals.

food web, a diagram that shows how food chains in a community are related and interlinked.

fossil fuels, coal, oil, and gas that are made up of the remains of ancient plants and animals.

genes, structures in almost every living cell that carry genetic information from one generation to the next.

giga, a prefix meaning one billion.

gigajoule, a unit used to measure energy.

global change, any worldwide change in the environment.
global warming, a warming trend around the world that is caused by an increase of greenhouse gases such as carbon dioxide in the atmosphere.
greenhouse effect, the trapping of heat in earth's atmosphere due to the presence of gases such as carbon dioxide.
greenhouse gas, gases that trap heat from the sun in the atmosphere, much like glass traps the heat of the sun in a greenhouse.
groundwater, water within the earth that supplies wells and springs.
habitat, the physical place where a plant or animal usually lives.
herbivores, organisms that eat only plants.
host organism, an organism that is used as food by a parasitic organism without the host being killed.
human community, all of the people who live around you and help you live where you do.
immigration, moving into an area.
joule, 0.24 calories.
melanin, a pigment that gives color to hair, skin, and eyes.
mimicry, a method of protection in which one species or organism looks like another species.
mortality rate, death rate
mutualism, two species helping each other out.
nature reserves, protected areas for wildlife and plants.
niche, the full range of biotic and abiotic conditions under which a particular species can live and reproduce.
omnivores, organisms that eat both plants and animals.
open water, water on the surface of earth.
organism, a complete and whole living thing.
parasite, an organism that feeds off another organism without killing it immediately.
photosynthesis, a process in which a plant uses sunlight, water, and carbon dioxide to produce sugar and release oxygen.
population, all of the individuals of a species living in a certain area at a certain time.
precipitation, rain, snow, sleet, hail
predation, an interaction in which one organism kills and eats another.
producers, organisms that make sugars through photosynthesis.
proximate cause, an action that happens right before an event and that causes the event to happen.
recycle, use materials over again, thus saving resources and energy.
resource, a substance, object, or space needed by an organism to live, grow, and reproduce.
species, a group of organisms that are so much alike that they can reproduce and make others like themselves.
terrestrial net primary productivity, a name for all of the sun's energy that is trapped and stored by all of the plants on earth's land surfaces during photosynthesis.
ultimate cause, an action that starts a series of events.
watershed, the area of land drained by a stream or river.

As you can see, the chapter covers a great deal of information which affect decisions by governments and individuals. We need to give a great deal of thought to how we will handle our responsibility to care for the place we live. We must continue to use science to search for truth and not be swayed by purely political arguments, commercials and political speeches. We must find the truth and then decide on responsible, compassionate action.

15.6 References

1. Cem K. (iyiinsan) and Doğa. Subways help conserve transportation energy . CC BY 2.0
2. Image copyright Steve Cukrov, 2014. Energy efficient light switch . Used under license from Shutterstock.com
3. Courtesy of the U.S. Environmental Protection Agency. Energy Star logo . Public Domain