8th Grade Science

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CHAPTER 1 Standard I: Matter

Chapter Outline

Why Science?

Many students equate science to learning vocabulary terms, labeling pictures, and memorizing facts. Science by nature is much more inclusive and loosely defined. Have you ever asked yourself questions about your surroundings and wondered how or why they are happening? This is science. Science works best when driven by curiosity and innovation. In order for you to experience science in its fullest sense you must take it beyond the textbook and into your everyday experience, but in order to be meaningful there are certain guidelines that can help us. Science is not constrained to 8th Grade Integrated Science, but there are **crosscutting concepts** threaded throughout all scientific disciplines. These include:

- Patterns: The pattern of indicators used to determine if a chemical or physical change has taken place or the pattern of a wave's wavelength in relation to the energy in the wave.
- Cause and effect: Mechanism and explanation: Cause and effect relationships are demonstrated when heat is added or removed from H_2O and changes in particle motion, density, temperature and states of matter are observed.
- Scale, proportion, and quantity: Determining the proportions of a lever allows one to calculate its mechanical advantage.
- Systems and system models: Making models increases student understanding of chemical reactions, roller-coasters, the rock cycle and a food web.
- Energy and matter: Flows, cycles, and conservation: The conservation energy and matter is demonstrated in each unit in eighth grade. Matter is conserved and energy flows in chemical and physical changes, the rock cycle, all forms of motion and through living systems. Potential and kinetic energy and the rock cycle are cyclical.
- Structure and function: The structure of a wave relates to how it can be absorbed, reflected or transmitted through different substances. The physical and chemical properties of a substance determine how they are used in everyday life.
- Stability and change: Changes in an ecosystem affect the stability of that environment and its ability to support the life forms in it.

When studying any specific scientific discipline you should attempt to keep these crosscutting concepts in mind in order to gain a better perspective of the world as whole and the nature of science. Included in the concepts are the skills and practices that a scientist utilizes. When asking questions about the natural world there are certain skills and practices that can help you be generate better conclusions, explanations and inferences. These practices include:

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data

- Using mathematics and computational thinking
- Constructing explanations and designing solutions
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

While these practices and crosscutting concepts are crucial to your overall success in science, in order to be most meaningful they do need some context. This is where the study of disciplinary core ideas are most impactful. If you study **8th Grade Integrated Science** or any other scientific discipline without the cross cutting concepts and scientific practices then you limit yourself to fact memorization and miss how these concepts relate to our everyday life and our society as a whole. Studying individual scientific disciplines are the vehicle for understanding crosscutting concepts and acquiring scientific skills. When individual disciplines are studied within the context of practices and crosscutting concepts they become more meaningful and more impactful.

Standard 1: Students will understand the nature of changes in matter.

Objective 1: Describe the chemical and physical properties of various substances.

1. Differentiate between chemical and physical properties.
2. Classify substances based on their chemical and physical properties (e.g., reacts with water, does not react with water, flammable or nonflammable, hard or soft, flexible or nonflexible, evaporates or melts at room temperature).
3. Investigate and report on the chemical and physical properties of a particular substance.

Objective 2: Observe and evaluate evidence of chemical and physical change.

1. Identify observable evidence of a physical change (e.g., change in shape, size, phase).
2. Identify observable evidence of a chemical change (e.g., color change, heat or light given off, change in odor, gas given off).
3. Observe and describe chemical reactions involving atmospheric oxygen (e.g., rust, fire, respiration, photosynthesis).
4. Investigate the effects of chemical change on physical properties of substances (e.g., cooking a raw egg, iron rusting, polymerization of a resin).

Objective 3: Investigate and measure the effects of increasing or decreasing the amount of energy in a physical or chemical change, and relate the kind of energy added to the motion of the particles.

1. Identify the kinds of energy (e.g., heat, light, sound) given off or taken in when a substance undergoes a chemical or physical change.
2. Relate the amount of energy added or taken away from a substance to the motion of molecules in the substance.
3. Measure and graph the relationship between the states of water and changes in its temperature.
4. Cite evidence showing that heat may be given off or taken in during a chemical change (e.g., striking a match, mixing vinegar and antacid, mixing ammonium chloride and water).
5. Plan and conduct an experiment, and report the effect of adding or removing energy on the chemical and physical changes.

Objective 4: Identify the observable features of chemical reactions.

1. Identify the reactants and products in a given chemical change and describe the presence of the same atoms in both the reactants and products.
2. Cite examples of common significant chemical reactions (e.g., photosynthesis, respiration, combustion, rusting) in daily life.

3. Demonstrate that mass is conserved in a chemical reaction (e.g., mix two solutions that result in a color change or formation of a precipitate and weigh the solutions before and after mixing).
4. Experiment with variables affecting the relative rates of chemical changes (e.g., heating, cooling, stirring, crushing, concentration).

Research and report on how scientists or engineers have applied principles of chemistry to an application encountered in daily life (e.g., heat-resistant plastic handles on pans, rust-resistant paints on highway bridges).

1.1 Does Matter?

Objectives

- Differentiate between chemical and physical properties.
- Classify substances based on their chemical and physical properties.
- Investigate and report on the chemical and physical properties of a particular substance.

What is Matter?

Both you and a speck of dust consist of atoms of **matter** - (anything that has atoms and takes up space). So does the ground beneath your feet. In fact, everything you can see, touch, taste, and smell is made of **matter**. Things that aren't matter are forms of energy, such as light, heat, and sound. Although forms of energy are not matter, the air and other substances they travel through are. So what is matter?

Matter is defined as anything that has **mass -** (amount of matter in an object) and **volume -** (amount of space taken up by an object).

Mass

The amount of **mass** in an object is commonly measured with a balance. A digital balance is shown in the figure. The Standard International (SI or metric) unit for mass is the kilogram (Kg), but for smaller masses grams (g) are often used instead.

FIGURE 1.1
This balance shows one way of measuring mass.

Physical Properties of Matter

Matter has many properties. Properties are characteristics that describe matter. Physical properties - (properties of matter that can be measured or observed without matter changing the substance) are typically things you can detect with your senses. For example, whether a given substance normally exists as a solid, liquid, or gas is a physical property. Consider water, it is a liquid at room temperature, but frozen water (ice) is still water. Generally, **physical properties** are things you can see, smell, taste, or feel.

Examples of Physical Properties

Physical properties include the phase of matter, its color and odor. For example, oxygen is a colorless, odorless gas. Chlorine is a greenish gas with a strong, sharp odor. The physical properties of oxygen gas are colorless and odorless while the physical properties of chlorine gas are green and stinky. Other physical properties include hardness, freezing and boiling points, temperature, density, the ability to dissolve in other substances, and the ability to conduct heat or electricity. Can you think of other physical properties?

Density

Density - (amount of mass in a given volume) is a physical property of matter. It is defined as a substance's mass per unit volume. It reflects how closely packed the particles of matter are. Density is calculated from the amount of mass in a given volume of matter, using the formula:

$$\text{Density } (D) = \frac{\text{Mass } (M)}{\text{Volume } (V)}$$

Problem: What is the density of a substance that has a mass of 20 g and a volume of 10 mL?

Solution: $D = \frac{20\ g}{10\ mL} = 2.0\ g/mL$

Problem: An object has a mass of 180 kg and a volume of 90 m^3. What is its density?

Solution: $D = \frac{180\ kg}{90\ m^3} = 2.0\ kg/m^3$

You Try It!

To better understand density, think about a bowling ball and a volleyball. The bowling ball feels heavy. It is solid all the way through. It contains a lot of tightly packed particles of matter. In contrast, the volleyball feels light. It is full of gasses. It contains fewer, more widely spaced particles of matter. Both balls have about the same volume, but the bowling ball has a much greater mass. Its matter is more dense.

Chemical Properties of Matter

Some properties of matter can be measured or observed only when matter undergoes a change to become an entirely different substance. These properties are called **chemical properties** - (properties that describe the ability of a substance to undergo a specific chemical change) they include **flammability -** (ability to ignite) and **reactivity -** (ability to participate in a chemical reaction).

FIGURE 1.2
Density is not the only physical property of matter. Here are some additional physical properties.

Flammability

Flammability is the ability of matter to ignite. Wood is flammable. When wood burns, it changes to ashes, carbon dioxide, water vapor, and other gases. After burning, it is no longer wood.

Reactivity

Reactivity is the ability of substances to undergo chemical reactions and release or absorb energy either by reacting with themselves or with other materials. For example, iron is highly reactive with oxygen. When it combines with oxygen, it forms the reddish powder called rust. Rust is not iron but an entirely different substance, iron oxide, that consists of both iron and oxygen.

Summary

- Matter is anything that has mass and volume. Mass is the amount of matter in a substance. Volume is the amount of space matter takes up.
- Matter has both physical and chemical properties. Physical properties can be measured or observed without matter changing to a different substance.
- Chemical properties of matter can be measured or observed only when matter undergoes a change to become an entirely different substance.

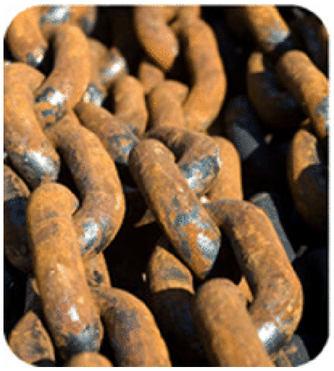


FIGURE 1.3
The iron in this steel chain has started to rust.

Think like a Chemist

Recall

1. What is matter?
2. Label each property as either Physical (P) or Chemical (C).

______Density

______Hardness

______Flammability

______Mass

______Volume

______Reactivity

______Odor

______Freezing point

Apply Concepts

3. Create a table listing two physical and two chemical properties of iron.

TABLE 1.1:

Physical	Chemical

4. Using your knowledge of salt dissolving in water, explain why the ability to dissolve is a physical property and not a chemical property?

Think Critically

5. Some kinds of matter are attracted to a magnet. Is this a physical or chemical property of matter? How do you know?

1.2 Is it possible to change your breath into food?

FIGURE 1.4
When glass breaks, its physical properties change. Instead of one solid sheet of glass, it now has holes and cracks.

Objectives

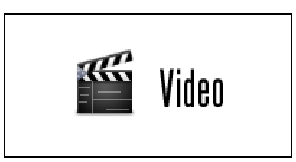
- Define and give examples of physical changes in matter.
- Define and give examples of chemical changes in matter.
- State five evidences that a chemical change has taken place.
- List two examples of a chemical change that requires atmospheric oxygen.

Introduction

You hit a baseball out of the park and head for first base. You're excited. The score is tied, and now your team has a chance of getting a winning home run. Then you hear a crash. Oh no! The baseball hit a window in a neighboring house. The glass has a big hole in it, surrounded by a web of cracks (see **Figure** 1.4). The glass has changed. It's been broken into jagged pieces. But the glass is still glass. Breaking the window is an example of a physical change in matter.

Physical Changes in Matter

A **physical change** - (change in one or more physical properties of matter without any change in chemical properties) does not change the identity of the original substance. Glass breaking is just one example of a **physical change**. Some other examples are shown in the graphic and in this video: http://bit.ly/MG5zBH



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In each example, matter may look different after the change occurs, but it's still the same substance with the same chemical properties. For example, smaller pieces of wood have the ability to burn just as larger logs do.

Because the type of matter remains the same with physical changes, the changes are often easy to undo. For example, braided hair can be unbraided. Melted chocolate can be put in a fridge to re-harden. Dissolving salt in water can precipitate out of solution.

FIGURE 1.5

In each of these changes, only the physical properties of matter change. The chemical properties remain the same.

Q: How do you think you could reverse salt dissolving in water?

Occasionally a physical change cannot be undone. An example would be grinding a piece of wood into sawdust. Such a change is irreversible because the sawdust cannot be reformed into the same piece of wood that it was before. Cutting the grass or pulverizing a rock are other examples of physical changes that cannot be reversed.

Chemical Changes in Matter

Communities often use fireworks to celebrate important occasions. Fireworks certainly create awesome sights and sounds! Do you know what causes the brilliant lights and loud booms of a fireworks display? The answer is chemical changes.

What is a Chemical Change?

A **chemical change** - (matter changes into an entirely new substance with different properties) is also called a chemical reaction. Many complex **chemical changes** occur to produce the explosions of fireworks.

An example of a simpler chemical change is the burning of methane. Methane is the main component of natural gas, which is burned in many home furnaces. During burning, methane combines with oxygen in the air to produce entirely different chemical substances, including the gases carbon dioxide and water vapor. You can watch some very colorful chemical changes occurring in the video at this URL: https://www.youtube.com/watch?v=BqeWpywDuiY

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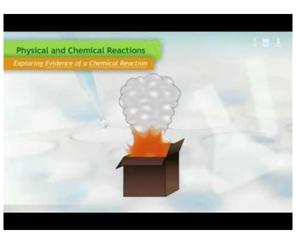
Identifying Chemical Changes

Most chemical changes are not as dramatic as exploding fireworks, so how can you tell whether a chemical change has occurred? There are usually clues. You just need to know what to look for. A chemical change has probably occurred if bubbles are released, there is a change of color, or an odor is produced. Other clues include the release of heat, light, or sound. Examples of chemical changes that produce these clues are shown in the graphic.

Q: How can you tell whether a chemical change has occurred?

Often, there are clues. Several are demonstrated in the video below. http://bit.ly/1fsJ6RS



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Physical Properties Change Due to Chemical Changes

When a chemical change takes place bonds are broken and atoms are rearranged creating new substances. The new substance will have new physical properties that are unique to that substance.

Chemical Reactions Involving Atmospheric Oxygen

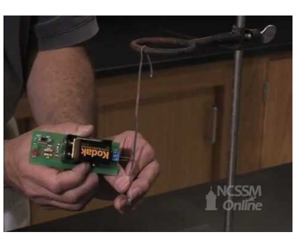
Don't try this at home! This performer isn't really eating fire, but he still puts on an impressive show. You know that fire is dangerous. It's hot, it can burn you, and it can easily get out of control. But do you know what fire is? Fire is the result of a chemical reaction. Whenever something burns, a type of reaction called a **combustion** reaction occurs.

What is a Combustion Reaction?

A **combustion** reaction occurs when a substance reacts quickly with oxygen (O_2). For example, in the **Figure** 1.6, charcoal is combining with oxygen. **Combustion** is commonly called burning, and the substance that burns is usually referred to as fuel. The products of a complete combustion reaction include carbon dioxide (CO_2) and water vapor (H_2O). This reaction typically gives off heat and light as well.

FIGURE 1.6
The burning of charcoal is a combustion reaction.

Another combustion reaction involves magnesium. Watch as it reacts with oxygen to form magnesium oxide as seen in this video: http://bit.ly/1cDVy1l



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Another type of reaction that requires atmospheric oxygen is known as an **oxidation reaction**. When exposed to oxygen in the air an object made of iron will eventually begin to **rust**.

FIGURE 1.7
Rust (iron oxide) forms on an unprotected iron surface.

As the rust forms on the surface of the iron, it flakes off to expose more iron, which will continue to rust. Rust (Fe_2O_3) is clearly a substance that is different from iron (Fe). Rusting is an example of a chemical change that requires atmospheric oxygen; this is known as corrosion. Corrosion is the gradual deterioration of materials, (usually metals), by chemical reactions within the environment.

Reversing Chemical Changes

Because chemical changes produce new substances, sometimes they cannot be easily undone. For example, you can't change a fried egg back to a raw egg. Some chemical changes can be reversed, but only by other chemical changes. For example, to undo the tarnish on copper pennies, you can place them in vinegar. The acid in the vinegar reacts with the tarnish. This is a chemical change that makes the pennies bright and shiny again. You can try this yourself at home to see how well it works or check out the video at this URL: http://bit.ly/1fuo7ie

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Summary

- Physical changes are changes in the physical properties of matter but not in the makeup of matter. An example of a physical change is glass breaking.
- Chemical changes are changes in the arrangement of the atoms in matter; they create a new substance. They are the result of a chemical reactions and cause a change in physical properties as well. Some chemical changes require oxygen to take place. Examples of these are rusting of metal or wood burning.
- A chemical change cannot be undone unless another chemical reaction takes place.

Think like a Chemist

1. How is a physical change in matter different from a chemical change?
2. List five signs that indicate a chemical change has occurred.

Apply Concepts

3. Butter melts when you heat it in a pan on the stove. Is this a chemical change or a physical change? How can you tell?
4. Eggs change when you heat them in a pan on the stove. Is this a chemical change or a physical change? How can you tell?

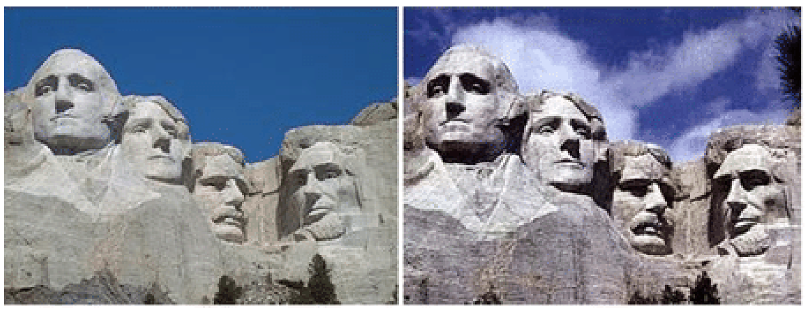
Online Interactive Activities

- Play with fire! This interactive explores the chemical reactions involved in combustion. http://tinyurl.com/UT8th1-2a
- Practice identifying physical and chemical changes. http://tinyurl.com/UT8th1-2b

1.3 Chemical and Physical Changes

Objectives

- Identify the kinds of energy given off or taken in when a substance undergoes a chemical or physical change.
- Relate the amount of energy added or taken away from a substance to the motion of molecules in the substance.
- Measure and graph the relationship between the states of water and changes in its temperature.
- Cite evidence showing that heat may be given off or taken in during a chemical change. Plan and conduct an experiment, and report the effect of adding or removing energy on the chemical and physical changes.



Introduction

Matter is always changing state. Look at the two pictures of Mount Rushmore in Figure below. The picture on the left was taken on a sunny summer morning. In this picture, the sky is perfectly clear. The picture on the right was taken just a few hours later. In this picture, there are clouds in the sky. The clouds consist of tiny droplets of liquid water.

Q: Where did the water come from?

How does the amount of energy determine the phase of matter?

These neat rows of cola bottles represent matter in three different phases—solid, liquid, and gas. The bottles and caps are solids, the cola is a liquid, and carbon dioxide dissolved in the cola is a gas. Solids, liquids, and gases such as these have different properties.

- Solids have a fixed shape and a fixed volume.
- Liquids also have a fixed volume but can change their shape.
- Gases have neither a fixed shape nor a fixed volume.

Q: What explains these differences in phases of matter? Hint: The answer has to do with energy.

Moving Matter

Energy is the ability to move matter or change matter in some other way. For example, your body uses chemical energy when you lift your arm or take a step. In both cases, energy is used to move matter—you. The energy of moving matter is called kinetic energy. The particles of matter are in constant motion therefore the particles have kinetic energy. The theory that all matter consists of constantly moving particles is called the kinetic theory of matter. You can learn more about the theory at this URL: http://bit.ly/1aNHL9K

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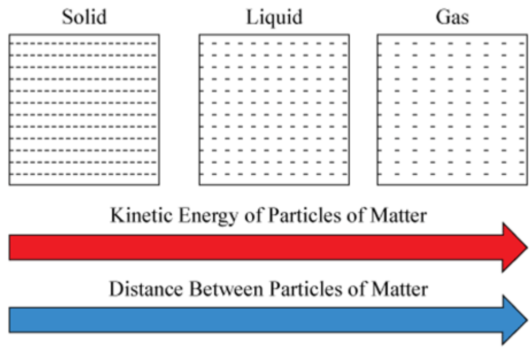
Kinetic Energy

Differences in kinetic energy explain why matter exists in different states. Particles of matter are attracted to each other, so they tend to pull together. The particles can move apart only if they have enough kinetic energy to overcome this force of attraction. It's like a tug of war between opposing sides, with the force of attraction between particles on one side and the kinetic energy of individual particles on the other side. The outcome of the "war" determines the phase of matter.

- Matter exists as a solid if particles do not have enough kinetic energy to overcome the force of attraction between them. The particles are packed closely together and held rigidly in place. All they can do is vibrate. This explains why solids have a fixed volume and a fixed shape.
- Matter exists as a liquid if particles have enough kinetic energy to partly overcome the force of attraction between them. The particles can slide past one another but not pull apart completely. This explains why liquids can change shape but have a fixed volume.
- Matter exists as a gas if particles have enough kinetic energy to completely overcome the force of attraction between them. The particles can pull apart and spread out. This explains why gases have neither a fixed volume nor a fixed shape.

Look at the figure below. It shows the relationship between kinetic energy and phase of matter. You can see an animated diagram at this URL: http://bit.ly/1eeA50U



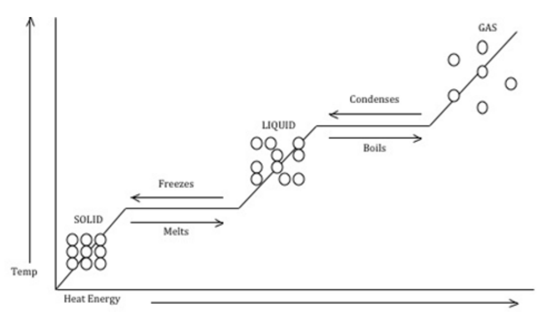
What are phase changes?

Phase changes are physical changes in matter. They are reversible changes that do not involve changes in the chemical makeup or chemical properties of matter. Common phase changes include **melting**, **freezing** and **evaporation**.

Energy, temperature and phase changes

Energy is always involved in changes of phase. Matter either loses or absorbs energy when it changes from one phase to another. For example, when matter changes from a liquid to a solid, it loses energy to its surroundings. The opposite happens when matter changes from a solid to a liquid. For a solid to change to a liquid, matter must absorb energy from its surroundings.

When energy is added to water, its temperature increases. . . .unless it is changing phase. Look at the graph that shows the relationship between temperature and phase of water as energy is added. Notice that when energy is added to solid water (ice) the temperature rises until the ice reaches its melting point. While the ice is melting the temperature stays the same. Once the ice has melted and the water is liquid then the temperature rises again until the liquid water boils. Once again, the temperature stays the same until the liquid water has evaporated and become water vapor (stream). When all the liquid water has changed phase and become a gas (water vapor) then the temperature rises again. The temperature does not change until the phase change is complete. The temperature does not change while a phase change is happening because the energy is involved in the forces of attraction between molecules rather than the kinetic energy of the molecules.



The amount of energy in matter can be measured with a thermometer. That is because a thermometer measures temperature, and **temperature** is a measure of the average kinetic energy of the particles of matter in a substance.

Changes between Liquids and Solids

Think about how you would make ice. First you would fill the tray with water, then you would place the tray in a freezer. The freezer has a very low temperature.

FIGURE 1.8
Water dripping from a gutter turned to ice as it fell toward the ground, forming icicles. Why did the liquid water change to a solid?

Freezing

The warmer water in the tray loses heat to the colder air in the freezer. The water cools until its particles no longer have enough energy to slide past each other causing a phase change. Instead, they remain in fixed positions, locked in place by the forces of attraction between them. The liquid water has changed to solid ice.

The process in which a liquid changes to a solid is called **freezing**. The temperature at which a liquid changes to a solid is its freezing point. The freezing point of water is 0°C (32°F). Other types of matter may have higher or lower freezing points. For example, the freezing point of iron is 1535°C. The freezing point of oxygen is -219°C.

Melting

If you took ice cubes out of a freezer and left them in a warm room, the ice would absorb energy from the warmer air around it. The energy would allow the particles of frozen water to overcome some of the forces of attraction holding them together. They would be able to slip out of the fixed positions they held as ice. In this way, the solid ice would turn to liquid water.

The process in which a solid changes to a liquid is called **melting**. Melting point is the temperature at which a solid changes to a liquid. For a given type of matter, the melting point is the same as the freezing point.

Q: What is the melting point of ice? What is the melting point of iron?

Changes between Liquids and Gases

If you fill a pot with cool water and place the pot on a hot stovetop, the water heats up. **Heat (thermal) energy** travels from the stovetop to the pot, and the water absorbs the energy from the pot.

If water gets hot enough, it starts to boil. Bubbles which contain water vapor form in boiling water. This happens as particles of liquid water gain enough energy to completely overcome the force of attraction between them and change to the gaseous state. The bubbles rise through the water and escape from the pot as steam.

The temperature at which a liquid boils is its boiling point. The boiling point of water at sea level is 100°C (212°F). Other types of matter may have higher or lower boiling points. For example, the boiling point of table salt is 1413°C. The boiling point of nitrogen is -196°C.

Evaporation

A liquid can change to a gas without boiling. This process is called **evaporation**. It occurs when particles at the exposed surface of a liquid absorb just enough energy to pull away from the liquid and escape into the air. This happens faster at warmer temperatures. Look at the puddle in the **Figure** 1.9. It formed in a pothole during a rain shower. The puddle will eventually evaporate. It will evaporate faster if the sun comes out and heats the water than when the sky remains cloudy.

FIGURE 1.9
Evaporation of water occurs even at relatively low temperatures. The water trapped in this pothole will evaporate sooner or later.

Summary

- Changes of state are physical changes. They occur when matter absorbs or loses energy.
- Processes in which matter changes between liquid and solid states are freezing and melting.

Think like a Chemist

1. How does the amount of energy determine the phase of matter?
2. Explain how the amount of energy a substance has changes when it boils and when it melts.
3. Explain why changing phase from a liquid to a gas is a physical change, not a chemical change.
4. Explain why the temperature does not change during a phase change.
5. Cliff opened the oven door to check on the cake he was baking. As hot, moist air rushed out of the oven, his eye glasses steamed up. Explain why.

Online Interactive Activity

- This interactive shows the relationship between energy and phases of matter. http://tinyurl.com/UT8th1-3

1.4 Chemical Reactions

Objectives

- Explain what happens during a chemical reaction.
- Identify the reactants and products in any chemical reaction.
- Demonstrate that mass is conserved in a chemical reaction.
- Cite examples of common significant chemical reactions.
- Identify variables that affect the rate of a chemical reaction.

Introduction

Does the term chemical reaction bring to mind an image like this one?

In the picture, a chemist is mixing chemicals in a lab. Many people think that chemical reactions only take place in labs. However, most chemical reactions do not. So, where do they occur? They happen in the world all around you. They even happen inside your own body. In fact, you are alive only because of the many chemical reactions that constantly take place inside your cells.

What is a Chemical Reaction?

A **chemical reaction** is a process in which some substances change into different substances. **Reactants** are the starting substances in a chemical reaction and **products** are the substances produced in a chemical reaction. Chemical reactions are represented by **chemical equations** in which reactants (on the left) are connected by an arrow to products (on the right).

$$\text{Reactants} \rightarrow \text{Products}$$

Using Chemical Symbols and Formulas

When scientists write chemical equations, they use chemical symbols and chemical formulas instead of names to represent reactants and products. Look at the chemical reaction illustrated in **Figure** 1.10. In this reaction, carbon reacts with oxygen to produce carbon dioxide. Carbon is represented by the chemical symbol C. The chemical symbol for oxygen is O, but pure oxygen exists as diatomic ("two-atom") molecules, represented by the chemical

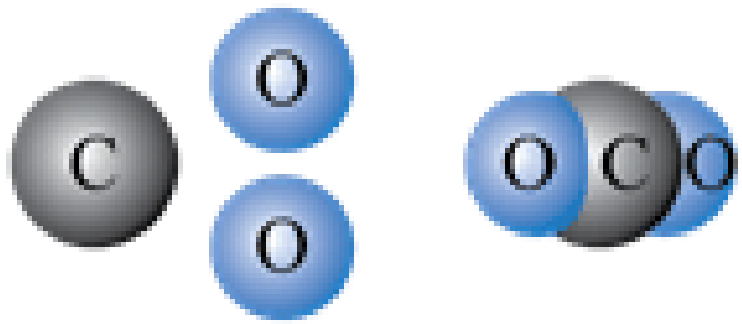


FIGURE 1.10
In this reaction, carbon reacts with oxygen to produce carbon dioxide.

formula O_2. A molecule of the compound carbon dioxide consists of one atom of carbon and two atoms of oxygen, so carbon dioxide is represented by the chemical formula CO_2.

Using this information we can write a chemical equation for this reaction. First we can see that C reacts with oxygen, these are our reactants. Second we are told that they produce carbon dioxide, this is our product. Therefore we can write the chemical equation for the above reaction as:

$$C + O_2 \rightarrow CO_2$$

Same Atoms, New Bonds

The reactants and products in a chemical reaction contain the same atoms, but they are rearranged during the reaction. As a result, the atoms are in different combinations in the products than they were in the reactants. This happens because chemical bonds break in the reactants and new chemical bonds form in the products.

Consider the chemical reaction in which water forms from oxygen and hydrogen gases.

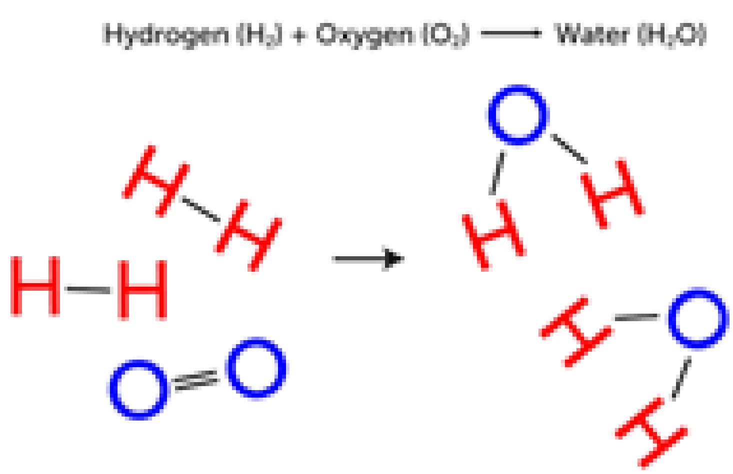


FIGURE 1.11
Breaking bonds in the reactants and making bonds to form products in a chemical reaction.

The figure represents this reaction. Bonds break in molecules of hydrogen and oxygen, and then new bonds form in molecules of water. In both reactants and products there are four hydrogen atoms and two oxygen atoms, but the atoms are combined differently in water.

Common Significant Reactions

Chemical reactions are happening all the time. Some reactions are so vital yet so common that they are hardly noticed. For instance when you ride in a car, eat food, or even breathe.

Combustion of Hydrocarbons

The fuel that burns in a combustion reaction contains compounds called hydrocarbons.

Hydrocarbons are compounds that contain only carbon (C) and hydrogen (H). Natural gas is a fuel that is commonly used in home furnaces and gas stoves. The main component of natural gas is the hydrocarbon called methane (CH_4). You can see a methane flame in **Figure** 1.12. The combustion of methane is represented by the equation:

$$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$$

FIGURE 1.12
The combustion of methane gas heats a pot on a stove.

Burning wood for a fire is also a combustion reaction. Oxygen is necessary for wood to burn. As the wood burns, the wood combines with the oxygen in the air to change to ash, carbon dioxide, water vapor and other gases. The gases float off into the air, leaving behind just the ashes.

Photosynthesis and Respiration

Most of the energy used by living things comes either directly or indirectly from the sun. That is because sunlight provides the energy for photosynthesis. **Photosynthesis** is the process that uses light energy from the sun, together with carbon dioxide and water, to make glucose and oxygen. The overall chemical equation for photosynthesis is:

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

Photosynthesis changes light energy to chemical energy. The chemical energy is stored in the bonds of glucose molecules. Glucose, in turn, is used for energy by the cells of almost all living things.

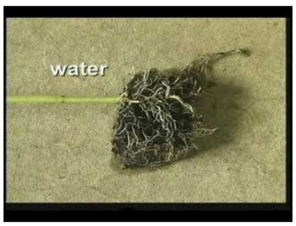
Photosynthetic organisms such as plants make their own glucose. Other organisms get glucose by consuming plants (or organisms that consume plants).

Cellular **respiration** is the process in which the cells of living things break down the organic compound glucose with oxygen to produce carbon dioxide and water. The overall chemical equation for cellular **respiration** is:

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

Cellular respiration occurs in the cells of all kinds of organisms, including those that make their own food (producers) as well as those that get their food by consuming other organisms (consumers).

You can learn more about photosynthesis and cellular respiration in the video at this URL: bit.ly/1cE0G5L



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Following the Law

Why must chemical equations have the same number and kind of atoms in the products that were present in the reactants? It's the law! Matter cannot be created or destroyed in chemical reactions. This is the **law of conservation of mass**. In every chemical reaction, the same mass of matter must end up in the products as started in the reactants.

Lavoisier and Conservation of Mass

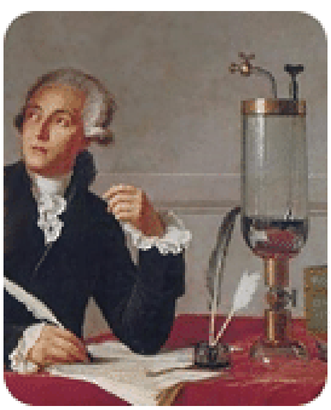


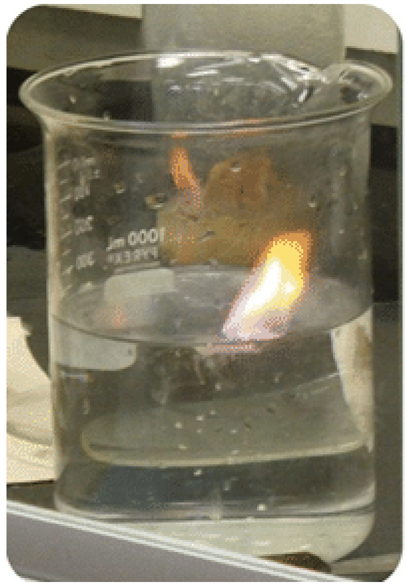
FIGURE 1.13

Antoine Lavoisier

How do scientists know that mass is always conserved in chemical reactions? Careful experiments in the 1700s by a French chemist named Antoine Lavoisier led to this conclusion. Lavoisier carefully measured the mass of reactants and products in many different chemical reactions. He carried out the reactions inside a sealed jar, like the one in the illustration.

In every case, the total mass of the jar and its contents was the same after the reaction as it was before the reaction took place. This showed that matter was neither created nor destroyed in the reactions. Another outcome of Lavoisier's research was the discovery of oxygen.

How Fast Does It Go?

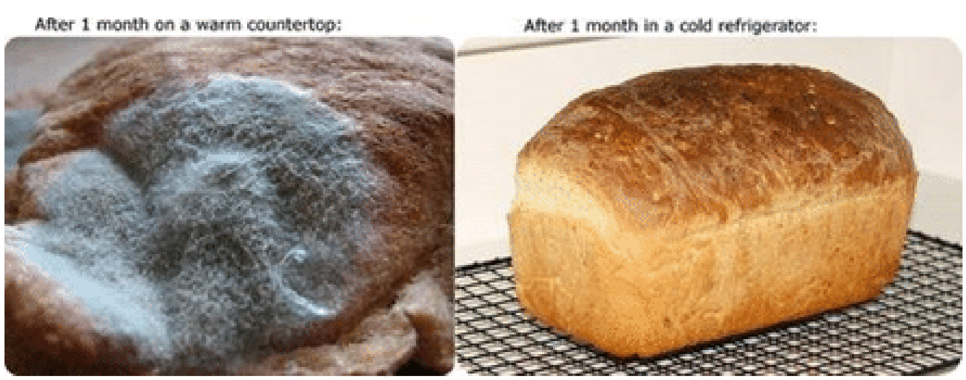


Potassium reacts violently with water. That's what is happening in the beaker pictured above. Why does potassium have such explosive reactions? It's because the reactions occur so quickly. The **rate of reaction** refers to the speed at which a chemical reaction takes place. Several factors affect the rate of a given chemical reaction. They include the:

- Temperature of reactants
- Concentration of reactants
- Surface area of reactants
- Presence of a catalyst

Increasing any of the factors generally increases the rate of reaction.

Temperature of Reactants



When the temperature of reactants is higher, the rate of the reaction is faster. At higher temperatures, particles of reactants have more energy, so they move faster. As a result, they are more likely to bump into one another and to collide with greater force. For example, food spoils because of chemical reactions, and these reactions occur faster at higher temperatures (see the bread in the figure). This is why we store foods in the refrigerator or freezer. The lower temperature slows the rate of spoilage.

Concentration of Reactants

Concentration is the number of particles of a substance in a given volume. When the concentration of reactants is higher, the reaction rate is faster. At higher concentrations, particles of reactants are crowded closer together, so they are more likely to collide and react. Did you ever see a sign like the one in the figure?

FIGURE 1.14
High concentrations of oxygen in oxygen tanks used by patients are very flammable.

You might see it where someone is using a tank of pure oxygen. Combustion, or burning, is a chemical reaction in which oxygen is a reactant. A greater concentration of oxygen in the air makes combustion more rapid if a fire starts burning.

Q: Why is it dangerous to use open flames in an area where oxygen is in use?

Surface Area of Reactants

When a solid substance is involved in a chemical reaction, only the matter at the surface of the solid is exposed to other reactants. If a solid has more surface area, more of it is exposed and able to react. Therefore, increasing the surface area of solid reactants increases the rate of reaction. Look at the hammer and nails pictured in the Figure 8. Both are made of iron and will rust when the iron combines with oxygen in the air. However, the nails have a greater surface area, so they will rust faster.

FIGURE 1.15
A rusting hammer, has a lower surface area that a pile of rusting nails.

Presence of a Catalyst

Some reactions need extra help to occur quickly. They need another substance called a catalyst. A catalyst is a substance that increases the rate of a chemical reaction. A catalyst isn't a reactant, so it isn't changed or used up in the reaction. Therefore, it can catalyze many other reactions.

Summary

- Physical changes are changes in the physical properties of matter but not in the makeup of matter. An example of a physical change is glass breaking.
- Chemical changes are changes in the makeup and chemical properties of matter. An example of a chemical change is wood burning.
- Matter cannot be created or destroyed even when it changes. This is the law of conservation of mass.
- How fast a chemical reaction occurs is called the reaction rate.
- Several factors affect the rate of a chemical reaction, including the temperature, concentration, and surface area of reactants, and the presence of a catalyst.

Think like a Chemist

1. Chemical changes always result in the identity of the original substances changing. Physical changes do not. Do the interactive lab at the following URL to see if you can identify the chemical changes: http://bit.ly/1emyJ2F
2. Look at the following reaction: $6\ CO_2 + 6\ H_2O + \text{Light Energy} \rightarrow C_6H_{12}O_6 + 6\ O_2$
    1. List the reactants.
    2. List the products.
    3. Identify this chemical reaction.
3. How are photosynthesis and respiration similar? How are they different?
4. List the four factors that influence the rate of a chemical reaction and explain how increasing each factor increases the rate of reaction.

Online Interactive Activities

- See that there must be the same number and kinds of atoms on both sides of a chemical reaction by balancing simple chemical equations. http://tinyurl.com/UT8th1-4a
- Play with reactants, products, and leftovers. http://tinyurl.com/UT8th1-4b

Chapter 2 Standard II: Energy

Chapter Outline

Standard 2: Students will understand that energy from sunlight is changed to chemical energy in plants, transfers between living organisms, and that changing the environment may alter the amount of energy provided to living organisms.

Objective 1: Compare ways that plants and animals obtain and use energy.

1. Recognize the importance of photosynthesis in using light energy as part of the chemical process that builds plant materials.
2. Explain how respiration in animals is a process that converts food energy into mechanical and heat energy.
3. Trace the path of energy from the sun to mechanical energy in an organism (e.g., sunlight - light energy to plants by photosynthesis to sugars - stored chemical energy to respiration in muscle cell - usable chemical energy to muscle contraction- mechanical energy).

Objective 2: Generalize the dependent relationships between organisms.

1. Categorize the relationships between organisms (i.e., producer/consumer, predator/prey, mutualism/parasitism/ decomposer) and provide examples of each.
2. Use models to trace the flow of energy in food chains and food webs.
3. Formulate and test a hypothesis on the effects of air, temperature, water, or light on plants (e.g., seed germination, growth rates, seasonal adaptations).
4. Research multiple ways that different scientists have investigated the same ecosystem.

Objective 3: Analyze human influence on the capacity of an environment to sustain living things.

1. Describe specific examples of how humans have changed the capacity of an environment to support specific life forms (e.g., people create wetlands and nesting boxes that increase the number and range of wood ducks, acid rain damages amphibian eggs and reduces population of frogs, clear cutting forests affects squirrel populations, suburban sprawl reduces mule deer winter range thus decreasing numbers of deer).
2. Distinguish between inference and evidence in a newspaper or magazine article relating to the effect of humans on the environment.
3. Infer the potential effects of humans on a specific food web.
4. Evaluate and present arguments for and against allowing a specific species of plant or animal to become extinct, and relate the argument to the flow of energy in an ecosystem.

2.1 How does the sun make you move?

FIGURE 2.1
The oxygen that we breathe is just a waste product of what reaction?

Objectives

- Describe the importance of photosynthesis.
- Explain the process of cellular respiration for plants and animals.
- Understand energy paths.

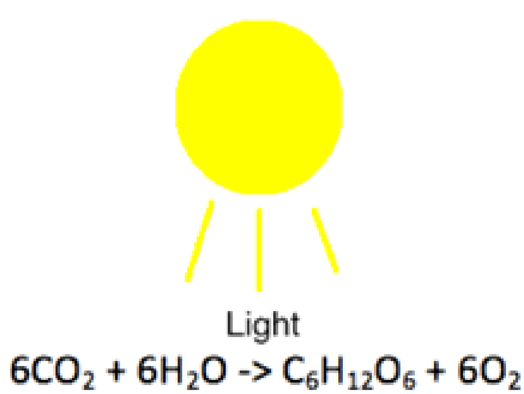
Introduction

Photosynthesis

Photosynthesis - (process that uses light energy from the sun, together with carbon dioxide and water, to make glucose and oxygen) is one of the most important processes that occur on the planet. It uses **solar energy -** (energy from the sun) together with carbon dioxide and water, to make **glucose - (sugar)** and oxygen. The primary role of photosynthesis is to make **glucose** which suggests that oxygen, which is released back into the atmosphere, is just a waste product.

Food from Light

Most of the energy used by living things comes either directly or indirectly from the sun. That's because sunlight provides the energy for photosynthesis. The process uses carbon dioxide and water and also produces oxygen. The overall chemical equation for photosynthesis is:



The overall chemical reaction for photosynthesis is 6 molecules of carbon dioxide (CO_2) and 6 molecules of water (H_2O), with the addition of **solar energy**. This produces 1 molecule of glucose ($C_6H_{12}O_6$) and 6 molecules of oxygen (O_2). Using chemical symbols, the equation is represented as follows:

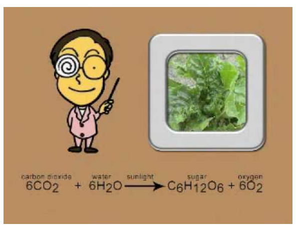
$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

Photosynthesis changes **solar energy** (energy from the sun) to **chemical energy** (energy stored in the bonds between atoms). The **chemical energy** is stored in the bonds of glucose molecules. Glucose, in turn, is used for energy by the cells of almost all living things.

Photosynthetic organisms such as plants make their own glucose. Other organisms get glucose by consuming plants (or organisms that consume plants).

For a song about photosynthesis, go to:

- http://bit.ly/1a7p6mW



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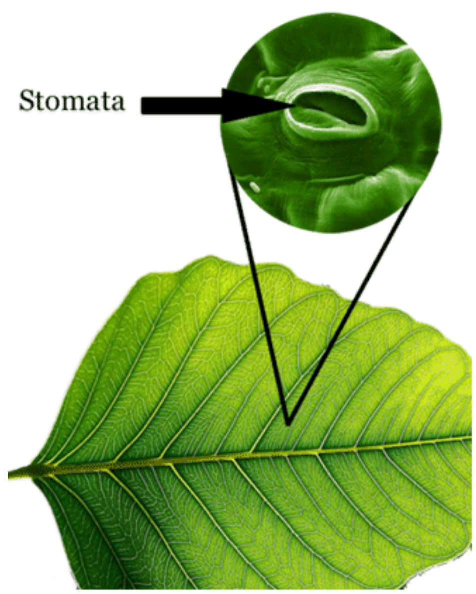
You can think of a single leaf as a photosynthesis factory. A factory has specialized machines to produce a product. It's also connected to a transportation system that supplies it with raw materials and carries away the finished product. In all these ways, a leaf resembles a factory. The enlarged section of a leaf in the figure below lets you look inside a leaf "factory".



The Reactants of Photosynthesis

Reactants (starting ingredients) of photosynthesis are carbon dioxide and water. Plants take in carbon dioxide from the air through the stomata, which are located under the leaves. Water, largely, enters the plant through the roots.

The Products of Photosynthesis

What is produced by the plant cell during photosynthesis? The **products** (results) of photosynthesis are glucose (sugar) and oxygen. This means they are made during photosynthesis. Glucose, the food of plants, can be used to store energy in the form of large carbohydrate molecules. Glucose is a simple sugar molecule, which can be combined with other glucose molecules to form large carbohydrates, such as starch and other plant materials.

Oxygen is a waste product of photosynthesis. It is released into the atmosphere through the stomata. As you know, animals need oxygen to live. Without photosynthetic organisms like plants, there would not be enough oxygen in the atmosphere for animals to survive.

Most **producers** (organisms that make their own food) use photosynthesis to make their food. The "food" the producers make is the sugar glucose. Producers make food for the rest of the ecosystem. Producers must first capture solar energy then convert the solar energy to chemical energy in the form of food. The chemical energy is passed on to the **consumers** (organisms that get their energy by eating other organisms) when the consumers eat the producers, and further still to the consumers that eat those consumers, and so on.

Recall that the only required ingredients needed for photosynthesis are sunlight, carbon dioxide (CO_2), and water (H_2O). From these simple inorganic ingredients, photosynthetic organisms produce the carbohydrate glucose ($C_6H_{12}O_6$), and other complex organic compounds. Essentially, these producers are changing the energy from the sunlight into a usable form of energy.

Cellular Respiration

Cellular respiration - (the process in which living things break down glucose with oxygen to produce carbon dioxide, water, and energy) occurs in the cells of all kinds of organisms, producers and consumers.

All organisms need a constant supply of energy to stay alive. They require energy for physical activities such as walking or jumping and for the reactions that happen in their cells. **Cellular respiration** is the process that happens in cells that provides the energy organisms need to stay alive.

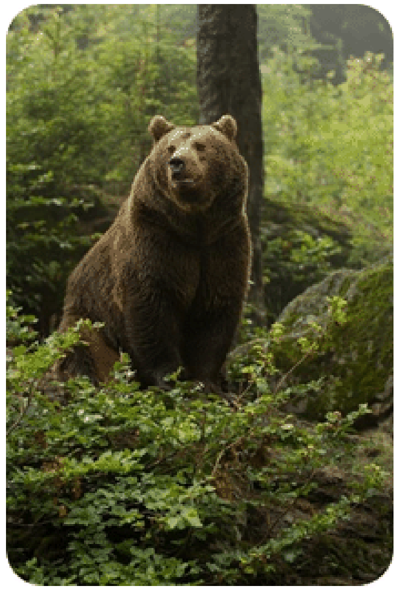
The overall chemical equation for **cellular respiration** is:

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

Notice that this formula is the *almost reverse* of photosynthesis; the products of photosynthesis are the reactants of cellular respiration and vice versa. Notice, however, that the forms of energy are different. Cellular respiration breaks down the chemical energy found in sugars and converts it to **mechanical** and **heat energy** used by the organism.

Consider the bear. . . . . .

Bears get the energy they need from their food. Brown bears eat a varied diet, from nuts and berries to fish and other animals. When bears eat a berry, they are obtaining energy that the plant originally captured from the sun. Even when the bear eats an animal, the energy in that animal ultimately came from eating a producer that captured the sun's energy.



Animals take in the chemical energy and convert it to **mechanical energy** (energy to move) and **heat energy**.

Summary

- Photosynthesis is the process that uses light energy from the sun, together with carbon dioxide and water, to make glucose and oxygen.
- Photosynthesis supplies energy to most of Earth's living organisms.
- Respiration is a process that converts the chemical energy in food into mechanical and heat energy.
- The formula for respiration is almost the reverse of that for photosynthesis.
- Plants convert light energy to chemical energy. This chemical energy is known as food. Other organisms use this food to provide them with the mechanical and heat energy required to sustain life.

Think like a Cellular Biologist

1. What process do plants use to capture and store energy?
2. What are the reactants and products of cellular respiration?
3. From the cell's point of view, why must you breathe and eat?
4. Trace the path of energy from sun to you.

Online Interactive Activities

- This interactive about photosynthesis includes leaf anatomy and has good information on the reactants and products of photosynthesis. http://tinyurl.com/UT8th2-1a
- This is a photosynthesis simulation. http://tinyurl.com/UT8th2-1b
- This is a multi-level photosynthesis and respiration game. http://tinyurl.com/UT8th2-1c

2.2 Relationships

Objectives

- Categorize relationships between organisms.
- Model a flow of energy.

Believe it or not, teenagers are not the only organisms that have relationships. All kinds of organisms have relationships, plants and animals included. The section that follows describes several relationships between organisms in living systems.

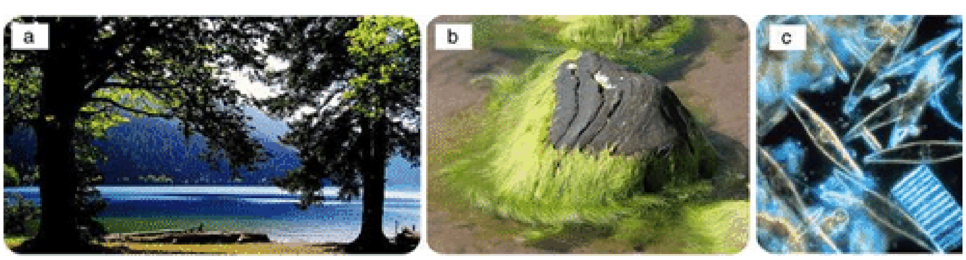
Producers and Consumers

The energy of the sun is first captured by **producers** (organisms that make their own food) through the process of photosynthesis. Remember, photosynthesis, as described in the last section, captures solar energy and converts it to chemical energy in the form of food.

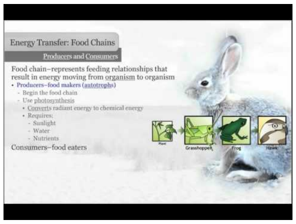
This food is stored energy for the rest of the ecosystem. The energy captured by producers is passed on to consumers. **Consumers** (cannot make their own food) must eat other organisms to obtain energy and nutrients.

The survival of every ecosystem is dependent on the **producers**. Without producers capturing the energy from the sun and turning it into glucose, an ecosystem could not exist. On land, plants are the dominant producers.

Phytoplankton, tiny photosynthetic organisms, are the most common producers in the oceans and lakes. Algae, which is the green layer you might see floating on a pond, are an example of phytoplankton.



For more information about producers and consumers, go to: http://bit.ly/1fuoc5x



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Decomposers

Recall that producers make their own food through photosynthesis. All animals are consumers, and they eat other organisms. Fungi and many protists and bacteria are also consumers. But, whereas animals eat other organisms, fungi, protists, and bacteria "consume" organisms through different methods.

What is breaking down this leaf?

FIGURE 2.2

Notice how this leaf is slowly being broken down. This process can be carried out by fungi and bacteria on the ground. Breaking down old leaves is an important process because it releases the nutrients from the dead leaves back into the soil for living plants to use.

Decomposers (organisms that obtain nutrients and energy by breaking down dead organisms and animal waste) are an important part of the ecosystem. Decomposers release nutrients, such as carbon and nitrogen, back into the environment. These nutrients are recycled back into the ecosystem so that the producers can use them. They are passed to other organisms when they are eaten or consumed.

The stability of an ecosystem depends on the actions of the decomposers. Examples of decomposers are mushrooms on a decaying log, bacteria in the soil, and the dung beetle. Imagine what would happen if there were no decomposers. Wastes and the remains of dead organisms would pile up and the nutrients within the waste and dead organisms would not be released back into the ecosystem. Producers would not have enough nutrients.

For more information about decomposers, see the following URL: http://bit.ly/1dT58ck

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Predator-Prey Relationships

Can insects hunt for food?

When you think of an animal hunting for its food, large animals such as lions may come to mind. But many tiny animals also hunt for their food. For example, the praying mantis eats grasshoppers. To eat the grasshopper, the praying mantis first has to catch the grasshopper, which is a form of hunting. And hunting is a what predators do to their prey. A predator/prey relationship is when a **predator** (hunter) hunts, kills, and eats the **prey** (victim).

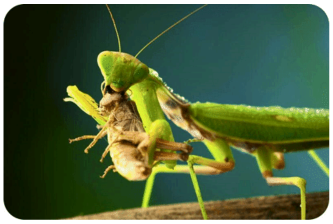
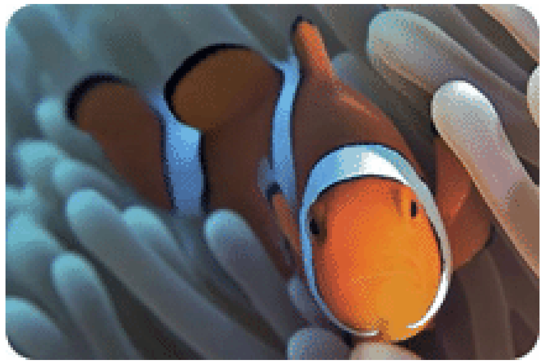


FIGURE 2.3
Predator-prey relationships are essential to maintaining the balance of organisms in an ecosystem.

For another example of an animal hunting, see the video at the following URL: http://shapeoflife.org/hunter

Mutualism

Mutualism describes a relationship between two different species in which both species are helped.



An example of **mutualism** is between herbivores (plant-eaters) and the bacteria that live in their intestines. The bacteria get a place to live. Meanwhile, the bacteria help the herbivore digest food. Both species benefit, so this is a mutualistic relationship.

The clownfish and the sea anemones also have a mutualistic relationship. The clownfish protects the anemone from anemone-eating fish, and the stinging tentacles of the anemone protect the clownfish from predators.

Commensalism

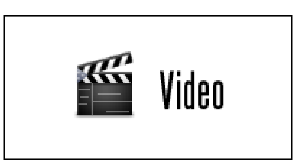
Commensalism is a relationship between two species in which one species is helped and the other species is unaffected, that is, it is not helped and it is not harmed.

Commensalisms may involve an organism using another for transportation or housing. For example, spiders build their webs on trees. The spider gets to live in the tree, but the tree is unaffected.

Parasitism

Parasitism is a relationship in which one species is helped and the other species is harmed. The hookworm is an example of parasitism. Hookworms are roundworms that affect the small intestine and lungs of another organism. They live inside of humans and cause them pain. Because parasites must live inside of a host in order to survive they usually do kill their hosts. Parasites are found in animals, plants, and fungi.

To find out more about each of these, see the video at this URL: http://bit.ly/1aNJhcb



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Energy Models

Energy must constantly flow through an ecosystem for the system to remain stable. What exactly does this mean? Essentially, energy flow describes how energy moves from the sun through producers to consumers in an ecosystem.

Food chains (diagrams that shows the **energy flow** through one organism to the next) demonstrate the eating patterns in an ecosystem. Energy flows from one organism to another. Arrows are used to show the direction of the flow of energy from one organism to another. The arrow points from the organism being eaten to the organism that eats it. Not all of the energy is passed forward to the next organism; most of the energy is lost as heat and mechanical energy.

For example, an arrow pointing from leaves to a grasshopper shows that energy flows from the leaves to the grasshopper. Next, a frog might prey on the grasshopper, a snake may eat the frog, and then a hawk might eat the snake. The **food chain** would be:

$$\text{leaves} \rightarrow \text{grasshopper} \rightarrow \text{frog} \rightarrow \text{snake} \rightarrow \text{hawk}$$

How do the grasshopper and the grass interact?

Grasshoppers don't just hop on the grass. They also eat the grass. Other organisms also the grass and some animals eat the grasshoppers. These interactions can be visualized by drawing a food web.

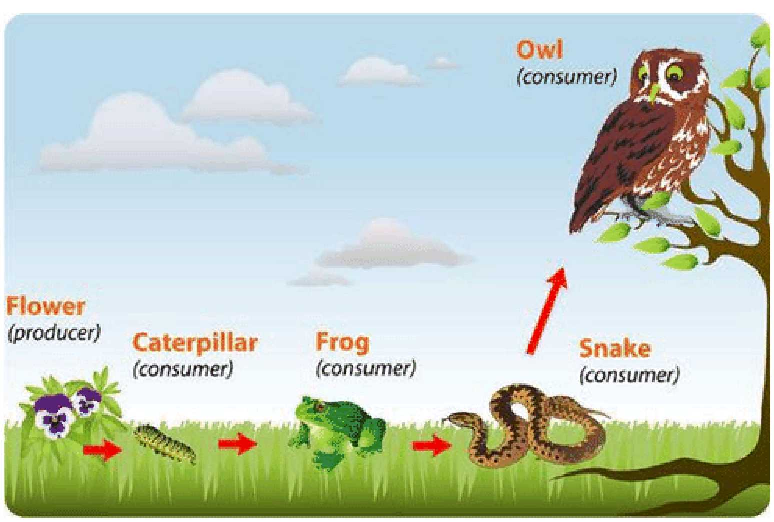


FIGURE 2.4
This food chain includes producers and consumers. How could you add decomposers to the food chain?

In an ocean ecosystem, one possible food chain might look like this:

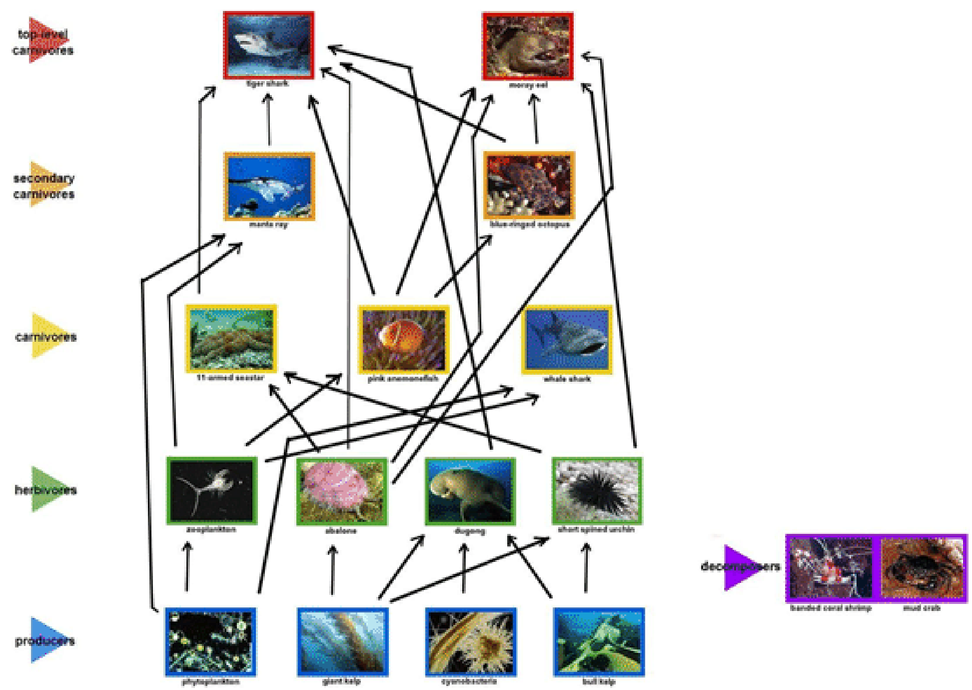
$$\text{phytoplankton} \rightarrow \text{krill} \rightarrow \text{fish} \rightarrow \text{shark}$$

The producers are always at the beginning of the food chain, bringing energy into the ecosystem. Through photosynthesis, the producers create their own food in the form of glucose, but also create the food for the consumers in the ecosystem.

When the consumers eat other organisms, they use the energy in those organisms. In this example, phytoplankton are eaten by krill, which are tiny, shrimp-like animals. The krill are eaten by fish, which are then eaten by sharks.

Q: Could decomposers be added to a food chain?

Each organism can eat and be eaten by many different types of organisms; so simple food chains are rare in nature.



Since feeding relationships are so complicated, we can combine food chains together to create a more accurate flow of energy within an ecosystem. A **food web** (diagram that shows many possible feeding relationships between organisms through multiple pathways in an ecosystem) is very complex. If you expand our original example of a food chain, you could add deer that eat clover and foxes that hunt chipmunks. A **food web** shows many more arrows, but still shows the flow of energy. A complete food web may show hundreds of different feeding relationships.

Practice

Use the resource below to answer the questions that follow.

- Decomposers: http://bit.ly/1a8CV6h

MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/179616

1. What is the role of decomposers in an ecosystem? What is the source of matter that is decomposed?
2. How do the actions of earthworms improve soil quality?
3. How does this impact the amount of biomass an ecosystem can support?

Summary

- **Consumers** must obtain their nutrients and energy by eating other organisms.
- **Producers** use light energy to convert matter into chemical energy that is then available for other organisms to consume.
- **Decomposers** break down animal remains and wastes to get energy.
- Predation happens when a **predator** organism hunts, kills, and eats another living organism or organisms, known as **prey**.
- **Mutualism** is a relationship between two species in which both species benefit.
- **Commensalism** is a relationship between two species in which one species is helped and the other species in unaffected.
- In a **parasitism**, the parasitic species benefits, while the host species is harmed.
- **Energy flow** is a term that describes how energy moves from the sun through producers to consumers in an ecosystem.
- A **food chain** is a simple diagram that shows feeding interactions in an ecosystem through a single pathway.
- A **food web** is a diagram that shows complex feeding interactions between many organisms in an ecosystem through multiple intersecting pathways.

Think like an Ecologist

1. How do producers gain energy from sunlight?
2. What are some examples of producers?
3. What is the role of decomposers in an ecosystem?
4. How would increasing the population of a coyote (predator) affect the population of both rabbits (prey) and grasses (producers)?
5. Is the benefit gained by each individual in a mutualistic relationship equal? Why or why not?
6. Refer to the food web of the Arctic Ocean, describe what would happen if the pink anemone fish were removed. Which organism are the most affected? Which are the least affected? Why?
7. Why are the fruit and vegetable sections called the produce aisle?
8. If bacteria tried to “friend” you one Facebook, why would you accept? Why would you block?

Online Interactive Activity

- Students manipulate a food web and see the results: http://tinyurl.com/UT8th2-2a

2.3 Are You A Parasite?

What's happening to this land?

This picture, taken in southern Mexico, shows land being cleared for agriculture. The forest has been cut down and burned to make room for a farm. In the process, homes to many plants and animals were destroyed. This is an example of habitat destruction.

Habitat Destruction

From a human point of view, a habitat is where you live, go to school, and go to have fun. Your habitat can be altered and you can easily adapt. Most people live in a few different places and go to a number of different schools throughout their life. But a plant or animal may not be able to adapt to a changed habitat. A *habitat* is the natural home or environment of an organism. Humans often destroy the habitats of other organisms. Habitat destruction can cause the extinction of species. *Extinction* is the complete disappearance of a species. Once a species is extinct, it can never recover. Some ways humans cause habitat destruction are by clearing land and by introducing non-native species of plants and animals.

Land Loss

Clearing land for agriculture and development is a major cause of habitat destruction. Within the past 100 years, the amount of total land used for agriculture has almost doubled. Land used for grazing cattle has more than doubled. Agriculture alone has cost the United States half of its wetlands and almost all of its tall grass prairies.

FIGURE 2.5
Big bluestem grasses as tall as humans were one of the species of the tall grass prairie, largely destroyed by agricultural use.

Native prairie ecosystems, with their thick fertile soils, deep-rooted grasses, diversity of colorful flowers, burrowing prairie dogs, and herds of bison and other animals, have virtually disappeared.

FIGURE 2.6
Wetlands, like the one seen in the photo, filter water and protect coastal lands from storms and floods.

Slash-and-Burn Agriculture

Other habitats that are being rapidly destroyed are forests, especially tropical rainforests. The largest cause of deforestation today is known as slash-and-burn agriculture (shown in the opening image). This means that when people want to turn a forest into a farm, they cut down all of the trees and then burn the remainder of the forest. Slash and burn agriculture technique is used by over 200 million people in tropical forests throughout the world.

As a consequence of slash-and-burn agriculture, nutrients are quickly lost from the soil. This often results in people abandoning the land within a few years. Then the top soil erodes and desertification can follow. *Desertification* turns forest into a desert, where it is difficult for plants to grow. Half of the Earth's mature tropical forests are gone. At current rates of deforestation, all tropical forests will be gone by the year 2090.

Non-native Species

One of the main causes of extinction is introduction of exotic species into an environment. These exotic and new species are also called *invasive species* or *non-native species*. These non-native species, being new to an area, may not have natural predators in the new habitat, which allows their populations to easily adapt and grow. Invasive species out-compete the native species for resources. They also can carry disease and disrupt food chains. Sometimes invasive species are so successful at living in a certain habitat that the native species go extinct.

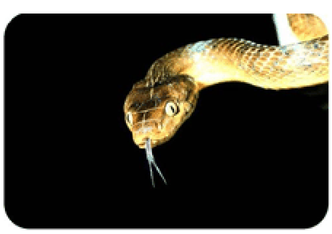


FIGURE 2.7
The brown snake is an exotic species that hitchhiked on an aircraft to the Pacific Islands, causing the extinction of many bird and mammal species which had evolved in the absence of predators.

Competition is when two or more species try to use the same resource. For example, wild horses, antelope, and cattle are in competition for water and grazing in southern UT. Non-native species compete with native species for food, water, and shelter. Often non-native species grow faster, reproduce more quickly, and/or do not have natural predators and are therefore able to out compete the native species. Sometimes this causes native species to become extinct.

The **capacity** of an environment is the number of organisms the environment can support. For example, an environment with few plants has a lower capacity to support animals than an environment with more plants. Habitat destruction lowers an environment's ability to sustain living things.

FIGURE 2.8
Zebra muscles, another invasive species, live on aquatic surfaces, both natural and man-made. In the photo, they have infested the walls of the Arthur V. Ormond Lock on the Arkansas River. They cause significant damage to American waterways, boats, and power plants.

Other causes of habitat destruction include poor fire management, overfishing, mining pollution, and storm damage. All of these can cause irreversible changes to a habitat and ecosystem.

FIGURE 2.9
Strip coal mining has destroyed the entire ecosystem.

Examples of Habitat Destruction

A habitat that is quickly being destroyed is the *wetland*. By the 1980s, over 80% of all wetlands in parts of the U.S. were destroyed. In Europe, many wetland species have gone extinct. For example, many *bogs* in Scotland have been lost because of human development.

Another example of species loss due to habitat destruction happened on Madagascar's central highland plateau. From 1970 to 2000, slash-and-burn agriculture destroyed about 10% of the country's total native plants. The area turned into a wasteland. Soil from erosion entered the waterways. Much of the river ecosystems of several large rivers were also destroyed. Several fish species are almost extinct. Also, some coral reef formations in the Indian Ocean are completely lost.

Evidence vs. Inference

Evidence is based on observation and/or measurement. It is what is actually seen, heard, touched, smelled, or tasted. **Inferences** are explanations and/or conclusions based on evidence. We create inferences to make sense of the evidence given to us.

FIGURE 2.10
Lions taking down Cape Buffalo.

Some of the evidence seen in the photo are: 4 lions, 1 wildebeest, brown plants, trees without leaves, etc. Several inferences could be made that would explain the observed evidence. Some of the inferences that could be made are: The lions are eating the wildebeest, the lions are members of the same pride, the lions are trying to wake the wildebeest up, etc.

The following example comes from: http://www.uen.org/core/science/sciber/sciber8/stand-2/humanimp.shtml

PRACTICE: Inference versus Evidence

Go to http://www.nationalgeographic.com/eye/impact.html . On the right side, under Human Impact, select ozone and pollution, deforestation and desertification or overpopulation. Read an article and list 5 evidences of human impact and 5 inferences.

The Effects of Humans on a Specific Food Web

A food web is all of the feeding relationships in an ecosystem. A food web is a complex and interconnected unit. This becomes clear to us when human actions have unexpected effects. An example of this is evident in the events on the Southeast Asian island of Borneo.

In 1955 the World Health Organization used the pesticide DDT to kill mosquitoes that carry the disease malaria. Malaria is a disease of red blood cells. Severe fever and sweats characterize it. The DDT killed the mosquitoes and relieved the malaria, but it caused an undesirable chain reaction on the island.

First, the island homes' thatched roofs started collapsing. What could this have to do with DDT? The DDT had not only killed the mosquitoes but also wasps that ate thatch-eating caterpillars. Without the wasps, the caterpillars multiplied and devoured the thatch roofs.

Second, the DDT was killing cockroaches as well as mosquitoes and wasps. Island lizards then ate the cockroaches. The pesticide in the cockroaches damaged the lizard's nervous system. The effect was that the lizard's movement and reflexes slowed. Because they moved so slowly, most of them were caught and eaten by house cats. After they ate the lizards the cats suffered the effects of the DDT and died in great numbers.

Without cats in the village rats from the forest moved in. The rat's fur carried fleas. The fleas were infected with the bacteria that cause the plague. Plague is a devastating disease that can cause many people to die. It is also known as the Black Plague, Mass mortality. Finally, officials were forced to parachute crates of healthy cats into Borneo to control the rat population and rid the island of plague.

The chain of events on Borneo occurred because the organisms on Borneo were connected to each other in a food web. When one part of the web was disturbed other parts were affected.

Analysis

1. How would you describe the effect that DDT had on the island of Borneo in 1955?
2. What would you advise the island residents to do differently if they have a similar problem in the future?
3. How could this story help us know how to deal with the world around us?
4. Should DDT be used anywhere on Earth? Explain why you made this decision.
5. What are some other methods that the residents of Borneo have used to solve its mosquito problem?
6. How were the animals in the story interconnected?
7. What could happen where you live that is similar to this story?

Summary

- Humans have changed the capacity of environments to support specific life forms in various ways.
- Habitat destruction, land loss, slash-and-burn agriculture, and invasive species are all examples of how humans have impacted the environment.
- Evidence is based on observation and/or measurement. Inferences are conclusions drawn based on given evidence.

Think like an Environmental Scientist

1. How have humans positively and negatively affected the environment?
2. How can being aware of environmental conditions/issues such as air quality, make you a better citizen?
3. Defend the mosquito! Why should we keep it?
4. Humans have cut down a vast section of rainforest in Borneo and Sumatra. This has changed the natural biodiversity of the area from hundreds of species of plants to one-palm oil trees. What affect do you think this has had on animals (especially large mammals such as orangutans) that live in that area?

Online Interactive Activity

- This interactive from the Global Footprint Network has you input your life style and shows how many Earths it takes if everyone on the globe lived your same lifestyle. http://tinyurl.com/UT8th2-3

2.4 References

1. . https://commons.wikimedia.org/wiki/File:Kelp_Forest_-_MBA_-_DSC06952.JPG .
2. . https://commons.wikimedia.org/wiki/File:Orange_Peel_Fungus_(4496685453).jpg .
3. . http://en.wikipedia.org/wiki/File:Polyporus_squamosus_Molter.jpg .
4. . https://commons.wikimedia.org/wiki/File:Lions_taking_down_cape_buffalo.jpg .

Chapter 3 Standard III: Earth

Chapter Outline

Standard 3: Students will understand the processes of rock and fossil formation.

Objective 1: Compare rocks and minerals and describe how they are related.

1. Recognize that most rocks are composed of minerals.
2. Observe and describe the minerals found in rocks (e.g., shape, color, luster, texture, hardness).
3. Categorize rock samples as sedimentary, metamorphic, or igneous.

Objective 2: Describe the nature of the changes that rocks undergo over long periods of time.

1. Diagram and explain the rock cycle.
2. Describe the role of energy in the processes that change rock materials over time.
3. Use a model to demonstrate how erosion changes the surface of Earth.
4. Relate gravity to changes in Earth's surface.
5. Identify the role of weathering of rocks in soil formation.
6. Describe and model the processes of fossil formation.

Objective 3: Describe how rock and fossil evidence is used to infer Earth's history.

1. Describe how the deposition of rock materials produces layering of sedimentary rocks over time.
2. Identify the assumptions scientists make to determine relative ages of rock layers.
3. Explain why some sedimentary rock layers may not always appear with youngest rock on top and older rocks below (i.e., folding, faulting).
4. Research how fossils show evidence of the changing surface of the Earth.
5. Propose why more recently deposited rock layers are more likely to contain fossils resembling existing species than older rock layers.

Objective 4: Compare rapid and gradual changes to Earth's surface.

1. Describe how energy from the Earth's interior causes changes to Earth's surface (i.e., earthquakes, volcanoes).
2. Describe how earthquakes and volcanoes transfer energy from Earth's interior to the surface (e.g., seismic waves transfer mechanical energy, flowing magma transfers heat and mechanical energy).
3. Model the process of energy buildup and release in earthquakes.
4. Investigate and report possible reasons why the best engineering or ecological practices are not always followed in making decisions about building roads, dams, and other structures.
5. Model how small changes over time add up to major changes to Earth's surface.

3.1 Rocks and Minerals

Objectives

- Describe the physical properties of minerals.
- Recognize that rocks are composed of minerals.
- Identify a rock as sedimentary, metamorphic, or igneous.

What is Geology?

Earth is a dynamic planet. Processes that change Earth's surface operated in the past much as they do today. Evidence of past surface and climatic changes are indicated in the rock and fossil records. Rocks are composed of minerals. Rocks and minerals cycle through processes that change their form.

Several processes contribute to changing Earth's surface. Earth's surface is changed by heat flowing from Earth's hot interior toward the cooler surface and by atmospheric processes. Earth's surface can change abruptly through volcanoes and earthquakes. Earth's surface can change gradually through mountain building, weathering, erosion, and deposition. Small changes that repeatedly occur over very long time periods can add up to major changes in Earth's surface. Geology is the study of all of this; the study of Earth's solid components and its changing surfaces.

Characteristics of Minerals

Are you a mineral?

There used to be a TV commercial that said "you are what you eat". If that's true - and to some extent it is - then you are a mineral. Nearly all of our food is salted, and salt is a mineral called halite? You also wear minerals, play with and on minerals, and admire the beauty of minerals. However, a mineral by definition cannot be organic (made of living material) so despite what you heard on TV, you aren't what you eat!

What is a Mineral?

Minerals are everywhere! Scientists have identified more than 4,000 minerals in Earth's crust, although the bulk of the planet is composed of just a few. A **mineral** is a naturally occurring, inorganic, solid, with a crystalline structure and specific chemical composition.

A **mineral** possesses the following characteristics:

- It must be naturally occurring.
- It must be inorganic (made of non-living material).
- It must be solid.
- It must be crystalline, meaning it has a repeating arrangement of atoms.
- It must have a specific chemical composition.

Naturally Occurring

Minerals are made by natural processes, meaning those that occur in or on Earth. This means that minerals cannot be manmade. Some natural processes that form minerals are evaporation and cooling molten rock. Evaporation forms minerals when mineral-rich, saturated water changes from a liquid to a gas leaving behind the minerals. Those who have visited the Great Salt Lake are familiar with the salt deposits all around it. These mineral deposits form when the water evaporates leaving behind solid salt crystals. When molten rock (**magma** or lava) cools the minerals form as they solidify into crystals. A diamond created deep in Earth's crust by cooling magma is a mineral, but a diamond made in a laboratory by humans is not. Although a laboratory made diamond may look like a diamond, it is technically not considered a mineral because it didn't occur by natural processes.

Inorganic

The easiest way to understand inorganic is to define the word organic because inorganic means "not organic". Organic substances are made by living creatures and include proteins, carbohydrates, and oils. Inorganic substances are not made from living creatures. Coal is made of plant and animal remains. Is it a mineral? Coal is a classified as a sedimentary rock, but is not a mineral, because minerals cannot be directly made from living organisms.

Solid

A solid is a substance that is rigid and holds its shape. It is not a liquid or gas and therefore not a fluid. Magma or lava will cool to form rocks and minerals; however, we do not consider magma or lava a mineral because it is in the liquid form.

Crystalline Structure

Minerals are "crystalline" structures. A crystal is a solid in which the atoms are arranged in a regular, repeating pattern. In the diagram the green and purple (light and dark) spheres represent sodium and chlorine. Notice that they are arranged in a regular, repeating pattern. In this case, they alternate in all directions.

Sodium ions (small spheres) bond with chloride ions (larger spheres) to make table salt (halite). All of the grains of salt that are in a salt shaker have this crystalline structure.

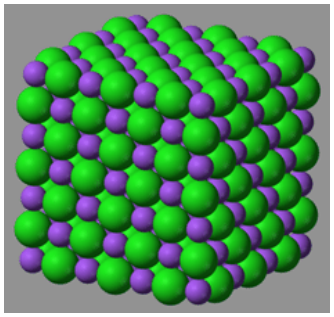
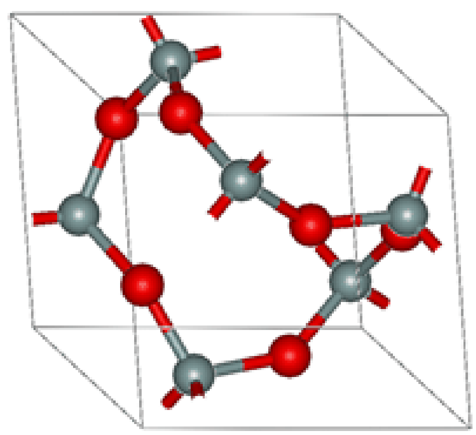


FIGURE 3.1

This is a diagram of the mineral halite also known as sodium chloride, NaCl, and salt.

Chemical Composition

Nearly all (98.5%) of Earth's crust is made up of only eight elements - oxygen, silicon, aluminum, iron, calcium, sodium, potassium, and magnesium - and these are the elements that make up most minerals.



All minerals have a specific chemical composition. The mineral silver is made up of only silver atoms and diamond is made only of carbon atoms, but most minerals are made up of a mixture of different chemical compounds. Each mineral has its own chemical formula. Table salt (also known as halite), pictured in the previous diagram, is NaCl (sodium chloride). It is always made of one atom sodium and one atom chlorine. Quartz is always made of two oxygen atoms bonded to a silicon atom represented by the chemical formula SiO_2.

So What Things Are Minerals?

The definition of a mineral is more restricted than you might think at first. For example, glass is made of sand, which is rich in the mineral quartz. But glass is not a mineral, because it is not crystalline. Instead, glass has a random assemblage of molecules. What about steel? Steel is made by mixing different metal minerals like iron, cobalt, chromium, vanadium, and molybdenum, but steel is not a mineral because it is made by humans and therefore is not naturally occurring. However, almost any rock you pick up is composed of minerals.

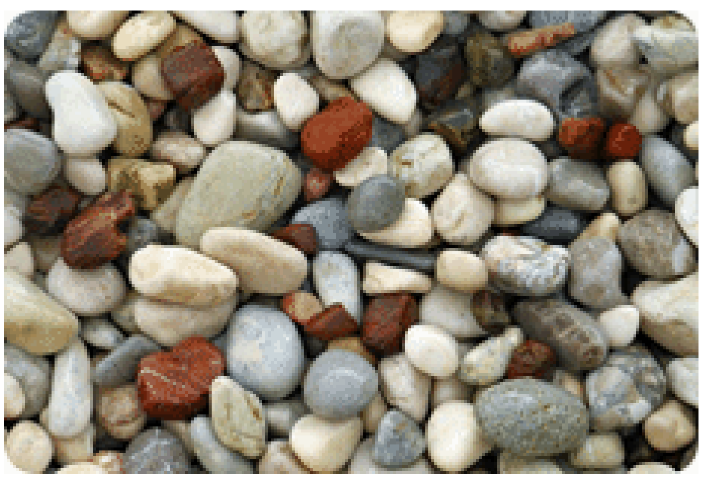
Physical Properties of minerals

As was mentioned before, scientists have identified more than 4,000 minerals in Earth's crust. Most minerals can be identified with little more than the naked eye and a few simple tests. We do this by examining the physical properties of the mineral in question, which include:

- Color: the color of the mineral.
- Streak: the color of the mineral's powder (this is often different from the color of the whole mineral).
- Luster: shininess.
- Density: mass per volume, typically reported in "specific gravity", which is the density relative to water.
- Breakage (cleavage or fracture) how a mineral breaks:
  - Cleavage: the mineral's tendency to break along planes of weakness.
  - Fracture: the irregular pattern in which a mineral breaks.
- Hardness: what minerals it can scratch and what minerals can scratch it.

Rock Composition

How many different rock types are in this photo?



A beach or river bed is a good place to see a lot of different **rock** types since the rocks there represent the entire drainage system. How could you tell how many different rock types were in the photo? What characteristics would you look for?

What are Rocks?

A **rock** is a naturally formed Earth material. Rocks are made of collections of mineral grains that are held together in a firm, solid mass.

The different colors and textures seen in this rock below are caused by the presence of different minerals.

How is a rock different from a mineral?

Rocks are made of minerals. The mineral grains in a rock may be so tiny that you can only see them with a microscope, or they may be as big as your fingernail or even your finger.

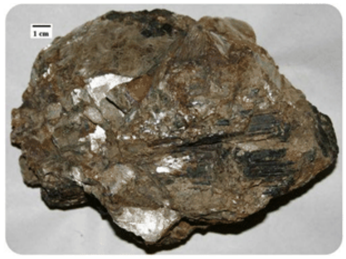
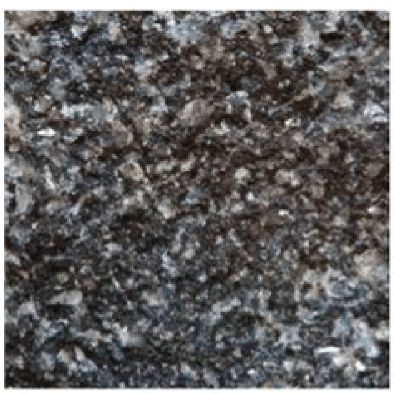
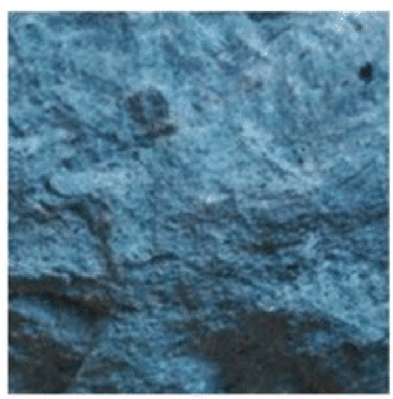


FIGURE 3.2
The photo shows pegmatite from South Dakota with crystals of lepidolite, tourmaline, and quartz (1 cm scale on the upper left).

Rocks are identified primarily by the minerals they contain and by their texture. Each type of rock has a distinctive set of minerals. A rock may be made of grains of only one mineral type, such as quartz to make the rock quartzite. More commonly, rocks are made of a mixture of different minerals. Texture is a description of the size, shape, and arrangement of mineral grains. Are the two samples in the figure the same rock type? Do they have the same minerals? The same texture?



Sample 1



Sample 2

TABLE 3.1: Rock Samples

Sample	Minerals	Texture	Formation	Rock type
Sample 1	plagioclase, hornblende, pyroxene	Crystals, visible to naked eye	Magma cooled slowly	Diorite
Sample 2	plagioclase, hornblende, pyroxene	One type of crystal visible, rest microscopic	Magma erupted and cooled quickly	Andesite

The table shows that the two rocks, Sample 1 and Sample 2, have the same chemical composition and contain mostly the same minerals but they do not have the same texture. Sample 1 has visible grains and Sample 2 has some visible grains in a fine matrix. The two different textures indicate different histories. Sample 1 is diorite, a rock that cooled slowly from magma (molten rock) underground. Sample 2 is andesite, a rock that cooled rapidly from very similar magma that erupted onto Earth's surface.

A few rocks are not made of minerals because the material they are made of does not fit the definition of a mineral. Coal, for example, is made of organic material, which is not a mineral. Can you think of other rocks that are not made of minerals? List your ideas below:

Rock Types

What type of rocks are there?

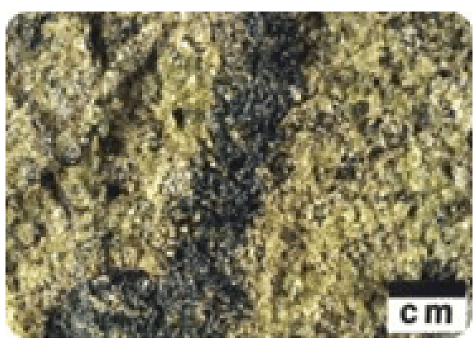
Rocks are classified into three major groups according to how they form. These three types will be described in more detail later in this chapter, but here is an introduction.

Igneous rocks form from the cooling and hardening of molten magma in many different environments. The chemical composition of the magma and the rate at which it cools determine what rock forms. **Igneous rocks** can cool slowly beneath the surface or rapidly at the surface. These rocks are identified by their composition and texture. More than 700 different types of igneous rocks are known.

Sedimentary rocks form by the compaction and cementing together of sediments, broken pieces of rock-like gravel, sand, silt, or clay. Those sediments can be formed from the **weathering** (the breaking down of rock) and **erosion** (the transportation of weathered sediment) of pre-existing rocks. **Sedimentary rocks** also include chemical precipitates, the solid materials left behind after a liquid evaporates.

Metamorphic rocks form when the minerals in an existing rock are changed by heat or pressure (without melting) below the surface of the Earth.

Igneous Rocks Characteristics



Igneous rocks can have one or more of the following identifiable characteristics:

- Large visible crystals
- Small crystals
- Glasslike
- Holes from air bubbles while cooling

Formation

Igneous rocks form when magma or lava cool and form crystals. **Magma** is melted rock found under Earth's crust and lava is melted rock on the surface of Earth's Crust. What an igneous rock looks like is determined by two things.

One is the composition of the minerals in the magma or lava. The other is how fast the magma or lava cools. The rate of cooling determines the size of the crystals and therefore the texture of the rock.

Sedimentary Rocks Characteristics

Sedimentary rocks can have one or more of the following identifiable characteristics:

- Appearance of sand, pebbles, rocks cemented together
- Layers (usually only noticed in large specimen)
- Appearance of fossils

Formation

Most sedimentary rocks form from **sediments**. The **sediments** must be packed together to form a rock. Sedimentary rocks also form as minerals precipitate from saline water.

Sediments are small fragments of rocks and minerals. Sediments are formed from rocks which have been broken down by **weathering**. **Weathering** is the breakdown of rock into smaller pieces such as pebbles, sand, silt and clay. Sedimentary rocks may include **fossils**. **Fossils** are materials left behind by once-living organisms. Fossils can be pieces of the organism, like bones. They can also be traces of the organism, like footprints.

FIGURE 3.3
Cobbles, pebbles and sands are the sediments that are seen on this beach.

Erosion is the process that transports sediments. Ice, water, wind, and gravity are agents of erosion. These agents move sediments from the place where they formed. The sediments are then deposited in a different location.

Sediments will eventually settle and be deposited. As wind slows the silt it carries will drop. Glaciers will melt and drop the rocks carried. Moving water is the most common example of erosion. For example rivers carry lots of sediment. Where the water slows, it dumps these sediments along its banks, into lakes and the ocean.

The rock layers at the Grand Canyon are horizontal. We know that layers at the bottom are older than layers at the top. Sediments are deposited in many different types of environments. Beaches and deserts collect large deposits of sand. Sediments also end up at the bottom of the ocean and in lakes, ponds, rivers, marshes, and swamps. Avalanches produce large piles of sediment. The environment where the sediments are deposited determines the type of sedimentary rock that forms.

FIGURE 3.4
When sediments settle out of water, they form horizontal layers. A layer of sediment is deposited. Then the next layer is deposited on top of that layer. So each layer in a sedimentary rock is younger than the layer under it.

Metamorphic Rocks Characteristics

Metamorphic rocks can have one or more of the following identifiable characteristics:

- Stripes in thin, parallel, wavy lines (foliation)
- Tiny crystals that line up in the same direction
- Very hard, usually can scratch metal

Formation

Metamorphic rocks start off as some kind of rock. The starting rock can be igneous, sedimentary, or even another metamorphic rock. Heat and/or pressure then change the rock into a metamorphic rock. Metamorphic rocks are changed by heat and pressure but they do NOT melt. The change can be physical, chemical, or both.

During metamorphism, a rock may change chemically. Atoms move in or out of a mineral. This creates a different mineral. The new minerals that form during metamorphism are more stable in the new environment. Extreme pressure may lead to physical changes. If pressure is exerted on the rock from one direction, the rock forms layers if it has flat, platey minerals which is an example of foliation. If pressure is exerted from all directions, or the rock does not have flat, platey minerals, then the rock usually does not show foliation.

Think like a Geologist

1. Describe two characteristics of minerals?
2. What is the difference between a rock and a mineral?
3. Which processes determine if a rock is igneous, metamorphic, or sedimentary?
4. A volcano would produce which type of rock?

Online Interactive Activities

- Interact with igneous rocks. http://tinyurl.com/UT8th3-1a
- Interact with metamorphic rocks. http://tinyurl.com/UT8th3-1b
- Interact with sedimentary rocks. http://tinyurl.com/UT8th3-1c

3.2 The Rock Cycle

Objective

- Diagram and explain the rock cycle.

Sedimentary

- Identify the role of weathering of rocks in soil formation.
- Use a model to demonstrate how erosion changes the surface of Earth.
- Describe how the deposition of rock materials produces layering of sedimentary rocks over time.

Igneous Formation

- Melt Cool

Metamorphic Formation

- Heat Pressure
- Describe the role of energy in the processes that change rock materials over time.
- Relate gravity to changes in Earth's surface.
- Describe and model the processes of fossil formation.

Does a rock ever change?

FIGURE 3.5
Is this what geologists mean by the rock cycle?

Okay, maybe not. The rock cycle shows how any type of rock can become any other type of rock. The three rock types are joined together by the processes that change one to another.

The Rock Cycle

You learned about the three rock types: igneous, sedimentary, and metamorphic. You also learned that all of these rocks can change. In fact, **any rock can change to become any other type of rock**. These changes usually happen very slowly. Some changes happen below Earth's surface. Some changes happen above ground. These changes are all part of the **rock cycle**. The **rock cycle** describes each of the main types of rocks, how they form, and how they change.

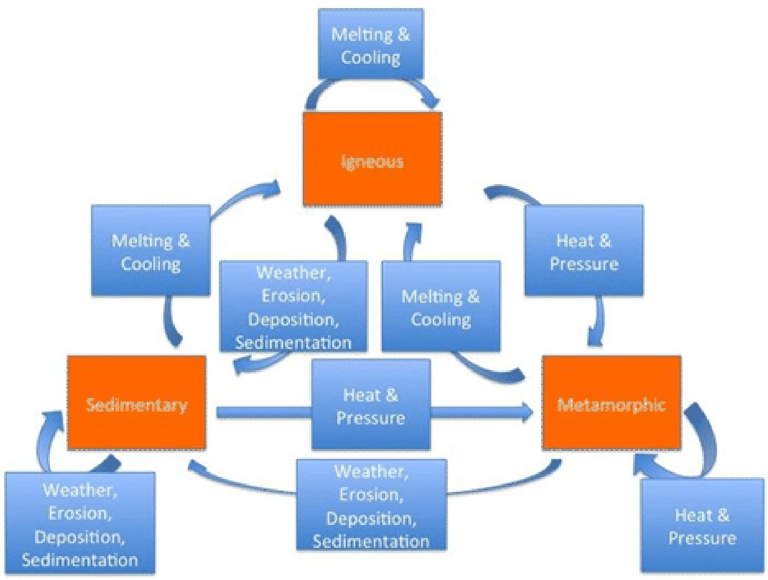


FIGURE 3.6
The figure shows how the three main rock types are related to each other. The arrows within the circle show how one type of rock may change to rock of another type. These are the processes that change one rock type to another rock type.

Processes of the Rock Cycle

There are three main processes that can change rock:

Cooling and crystallization. Deep within the Earth, temperatures can get hot enough to create magma. As magma cools, crystals grow, forming an igneous rock. The crystals grow larger if the magma cools slowly, as it does if it remains deep within the Earth. If the magma cools quickly, the crystals will be very small. When crystals form from magma it is called crystallization. Cooling and crystallization form **igneous rock**.

Weathering, erosion, sedimentation, compaction, cementation. Water, wind, ice, and even plants and animals all act to wear down rocks. Over time they can break larger rocks into sediments. Rocks break down by the process called **weathering**. Moving water, wind, and glaciers then carry these pieces from one place to another. This is called **erosion**. The sediments are eventually dropped, or deposited, somewhere. This process is called **sedimentation**. The sediments may then be **compacted and cemented** together. This forms a **sedimentary rock**. This whole process can take hundreds or thousands of years.

Metamorphism. This long word means "to change form". A rock undergoes metamorphism if it is exposed to extreme heat and pressure within the crust. With metamorphism, the rock does not melt all the way. The rock changes due to heat and pressure. A **metamorphic rock** may have a new mineral composition and/or texture.

The rock cycle really has no beginning or end. It just continues. The processes involved in the rock cycle take place over hundreds, thousands, or even millions of years. Even though for us rocks are solid and unchanging, they slowly change all the time.

How does energy affect rocks?

Processes

There are 4 main forces of energy that cause rocks to change over time:

- Heat (from Earth's Core)
- Gravity
- Water

- Wind

Heat

Earth's core has been estimated to reach temperatures near 5,430°C/9800°F. This intense heat fuels the movement of the mantle and therefore causes the plates of the crust to move. This heat is also important to the formation of both igneous and metamorphic rocks. Igneous rocks reach such intense heat levels that the rocks melt and eventually cool. Heat is also required to change rocks into metamorphic rocks however the heat isn't sufficient to melt them.

Gravity

Gravity is the force that keeps materials on Earth's surface; you are most familiar with this when you see objects fall. The force of gravity is an important force that causes rock materials to fall after weathering occurs and is the main force behind processes like weathering, erosion, and deposition. As rocks fall they are moving from one location to another (erosion) and when they hit the ground they break into smaller pieces (weather). Where they end after the fall (deposition) is where they will remain until another force acts upon them. Gravity is responsible for water flowing down slopes. This eventually leads into the growth and flow of rivers and rivers are a large contributor to weathering and erosion. Gravity is also crucial to create the tremendous pressure necessary to make a metamorphic rock.

Wind and Water

Wind and water are forces that cause weather, erosion, and deposition to occur. On a normal day wind can blow small dust particles and sand material for hundreds or thousands of miles. When the wind is strong the high speed of moving dust and sand can act as an eroding force when the particles hit against a larger rock surface. Water is the cause for most weathering and erosion in stream and river beds. The simple movement of water carrying rocks, sand, and dust materials can smooth rocks as small pieces are slowly broken off. One of the reasons beaches are covered by sand is that waves are constantly pounding against the shoreline. Another reason could be the particles that are being carried by the waves to the shore.

Where does soil come from?

How are these two soils different?

What color is the soil on the left? What color is the soil on the right? Notice that one is very dark and the other much lighter. Why do you think they differ so much in color? Which soil do you think is better for growing things? The color of the soil is determined by the minerals and amount of organic matter found in that soil.

Soil development takes a very long time. It may take hundreds or even thousands of years to form the fertile upper layer of soil. Soil scientists estimate that in the very best soil forming conditions, soil forms at a rate of about 1 mm/year. In poor conditions, it may take thousands of years!

Soil formation requires weathering. Where there is less weathering, soils are thinner. However, soluble minerals may be present. Where there is intense weathering, soils will probably be thicker but it is more likely that the minerals and nutrients will have been washed out.

Climate is the most important factor determining soil type. Climate includes both temperature and amount of precipitation. Given enough time, a climate will produce a particular type of soil. Two rocks of the same type will form a different soil type in a different climate.

Climates that have more rain weather minerals and rocks more. Rain allows chemical reactions especially in the top layers of the soil. More rain can dissolve more rock and can carry away more material. As material is carried away, new surfaces are exposed. This also increases the rate of weathering.

Climate with higher temperatures increase the rate of chemical reactions. This also increases soil formation. In warmer regions, plants and bacteria grow faster. Plants and animals weather material and produce soils. Arid regions have thinner soils.

Biological Activity

Biological activity produces the organic material in soil. Organic matter forms from the remains of plants and animals. It is an extremely important part of the soil. Organic matter coats the mineral grains. It binds them together into clumps that hold the soil together. This gives the soil its structure. Soils with high humus (or organic material) are better able to hold water. Soils rich with organic materials hold nutrients better and are more fertile. These soils are more easily farmed.

The color of soil indicates its fertility. Black or dark brown soils are rich in nitrogen and contain a high percentage of organic materials. Soils that are nitrogen poor and low in organic material might be gray, yellow, or red. (See photo.) Soil with low organic material is not good for growing plants. This is the answer to the question posed at the beginning of this section.

FIGURE 3.7

This sandy soil shows evidence of very little organic activity. Plants grow, but are far apart and short-lived. This means that little soil can form. The soil that's there has little organic content.

How do fossils form?

What Are Fossils?

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** 3.8).

Most people at the time did not believe that fossils were once part of living creatures. Authors in that day thought

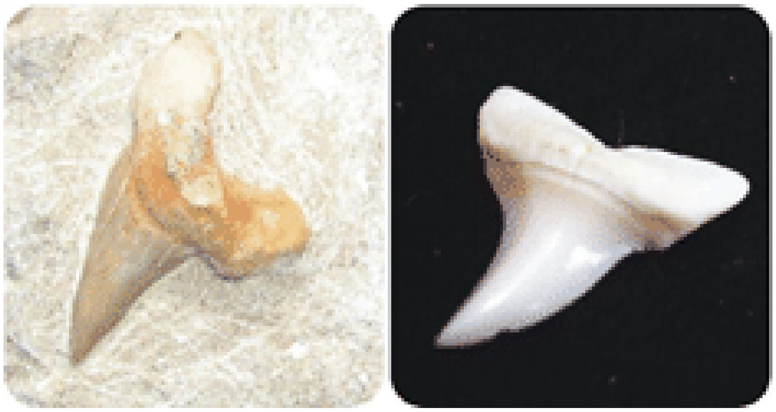


FIGURE 3.8
Fossil Shark Tooth (left) and Modern Shark Tooth (right).

that the fossils of marine animals found in tall mountains, miles from any ocean could be explained in one of two ways:

1. 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.)
2. 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 trace of an ancient organism. **Fossils** include hard body parts, left behind when the soft parts have decayed away, and trace fossils, such as burrows, tracks, or fossilized coprolites (feces). Fossils are most commonly found in sedimentary rocks because of the processes that make sedimentary rocks allow for the organism remains to rest long enough for fossilization to occur. Fossils cannot exist in igneous rocks because the intense heat that is required for rock material to melt would destroy the original structure of the organism's remains.

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 3.9
Hyenas eating a water buffalo. Will the water buffalo 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, if the bones remain on Earth's surface, the bones are scattered and fragmented into small pieces, eventually turning into dust. The remaining nutrients return to the soil. If kept in these conditions, this water buffalo will not be preserved as a fossil.

It is more likely that a marine organism will become a fossil but it is still more likely that it will not. 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.

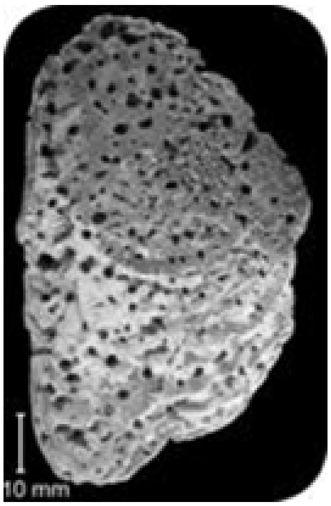


FIGURE 3.10

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 3.11

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** 3.12).

FIGURE 3.12
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 Skeletons can be covered by mud in lakes, swamps, or bogs.

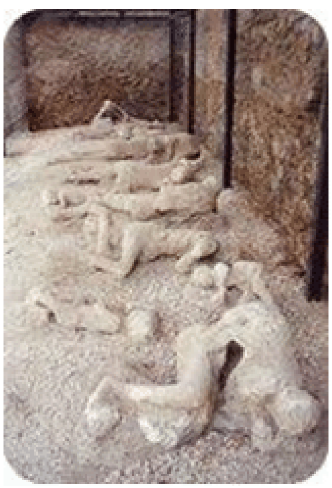


FIGURE 3.13
People buried by the extremely hot eruption of ash and gases at Mt. Vesuvius in 79 AD.

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.

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 and the 145 million-year-old Solnhofen Limestone in Germany.

FIGURE 3.14
Artists concept of animals surrounding the La Brea Tar Pits.

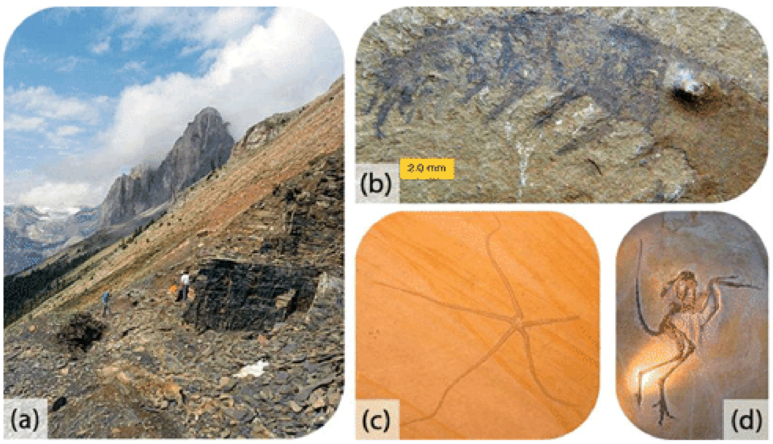


FIGURE 3.15
(a) The Burgess shale contains soft-bodied fossils. (b) Anomalocaris, meaning "abnormal shrimp" is now extinct. The image is of a fossil. (c) A brittle star from the Solnhofen Limestone. (d) The famous Archeopteryx fossil from the Solnhofen Limestone has distinct feathers and was one of the earliest birds.

Think like a Geologist

1. What's the rock cycle?
2. How does climate affect soil formation?
3. How do you tell where an igneous rock formed?
4. Explain why sedimentary rock would form after an igneous or metamorphic rock.

Online Interactive Activities

- This interactive teaches about the three types of rocks and how they form in the rock cycle. http://tinyurl.com/UT8th3-2a
- Students click on the different rock types and choose which direction they will take in the rock cycle. http://tinyurl.com/UT8th3-2b
- For an interactive animation of the rock cycle go to: http://tinyurl.com/UT8th3-2c
- Experience the rock layers of the Grand Canyon. http://tinyurl.com/UT8th3-2d

3.3 Describe how rock and fossil evidence is used to infer Earth's history?

Objectives

- Understand that deposition of weathered and eroded material creates layers of sedimentary rocks.
- Assume the relative age of rocks based on layer.
- Identify processes that lead to rock layer unconformities (i.e. folding, faulting).
- Describe how fossils show evidence of Earth's changing surface and organisms (e.g. Pangea, Continental drift).

Which rock layer is the oldest?

Scientists assume that the way things happen now is the same way things happened in the past. Earth processes have not changed much over time. Mountains grow and mountains slowly wear away, just as they did billions of years ago.

Historical geologists study the Earth's past. They use clues from rocks and fossils to figure out what happened in the past. Based how long it takes for Earth's processes to occur now, they compute how long it must have taken for past Earth events to occur. They have concluded that the Earth is about 4.6 billion years old.

Formation of Rock Layers

Rock layers form as different sediments are deposited by Earth's process. Sediments are deposited on beaches and deserts, at the bottom of oceans, and in lakes, ponds, rivers, marshes, and swamps. Landslides drop large piles of sediment. Glaciers leave large piles of sediments, too. All of these will eventually solidify to form layers of rock over time and it takes a long, LONG time.

Sedimentary Rock Rules

Sedimentary rocks follow certain rules.

1. Sedimentary rocks are formed with the oldest layers on the bottom and the youngest on top.

2. Sediments are deposited horizontally, so sedimentary rock layers are originally horizontal, as are some volcanic rocks, such as ash falls.
3. Sedimentary rock layers that are not horizontal are deformed.

Since sedimentary rocks follow these rules, they are useful for seeing the effects of stress on rocks. Sedimentary rocks that are not horizontal must have been deformed.

You can trace the deformation a rock has experienced by seeing how it differs from its original horizontal, oldest-on-bottom position. This deformation produces geologic structures such as folds, joints, and faults that are caused by stresses.

Geologic History

You're standing in the Grand Canyon and you see rocks like those in the image. Using the rules listed above, try to figure out the geologic history of the geologic column. The Grand Canyon is full mostly of sedimentary rocks, which are important for deciphering the geologic history of a region.

In the Grand Canyon, the rock layers are exposed like a layer cake. Each layer is made of sediments that were deposited in a particular environment - perhaps a lake bed, shallow offshore region, or a sand dune.

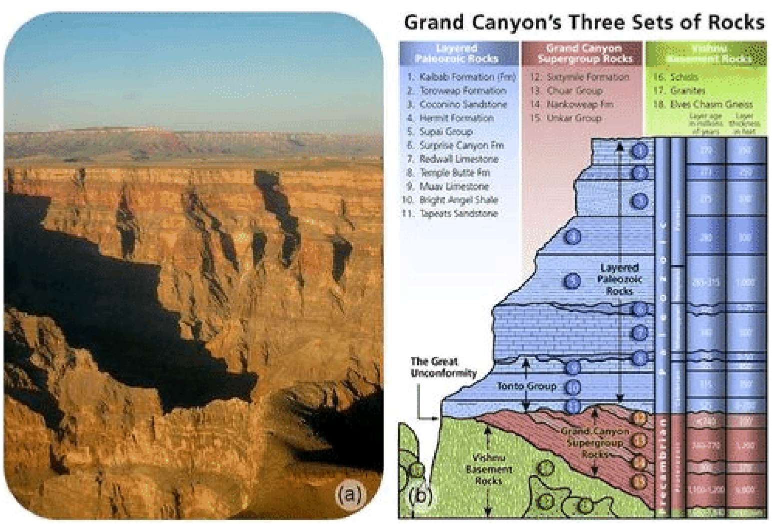


FIGURE 3.16

(a) The rocks of the Grand Canyon are like a layer cake. (b) A geologic column showing the rocks of the Grand Canyon. In this geologic column of the Grand Canyon, the sedimentary rocks of the first group, layers 1 through 11, are still horizontal. The second group of rocks, layers 12 - 15, have been tilted. The last group of rocks, layers 16 - 18 are not sedimentary. The oldest layers are on the bottom and youngest are on the top.

Matching Rock Layers

When rock layers are in the same place, it's easy to give them **relative ages**. **Relative age** is a way of comparing the age of different rocks based on age or the location of those other rocks, either younger or older. The relative ages of rocks are important for understanding Earth's history.

New rock layers are always deposited on top of existing rock layers. Therefore, deeper layers must be older than layers closer to the surface. The oldest layers are deposited first with the youngest layers on top. But, what if rock layers are far apart? What if they are on different continents? What evidence is used to match rock layers in different places?

FIGURE 3.17
Some rock layers extend over a very wide area. They may be found on more than one country or even on in more than one continent. These rock layers can be matched up by comparing similar rock features.

Widespread Rock Layers

A great example is the famous White Cliffs of Dover on the coast of southeastern England. These distinctive rocks are matched by similar white cliffs in France, Belgium, Holland, Germany, and Denmark. It is significant that this chalk layer goes across the English Channel. The rock is so soft that the Channel Tunnel connecting England and France was carved into it!

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** 3.18.

- **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.

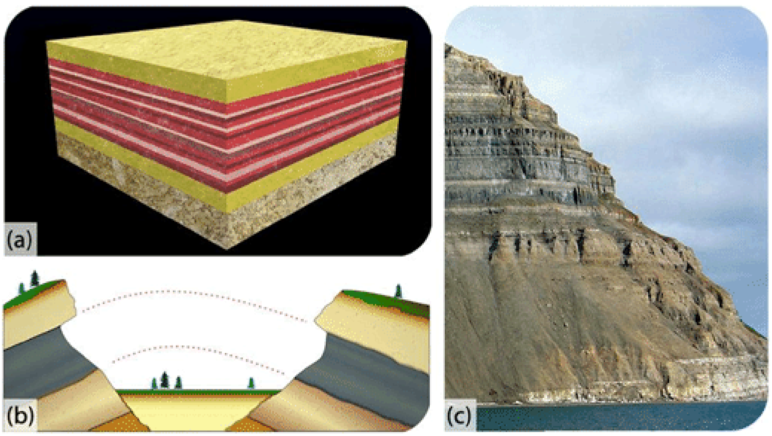


FIGURE 3.18
(a) Original horizontality - layers originally will deposit horizontal due to gravity. (b) Lateral continuity - layers continue to spread out sideways even if not seen or missing. (c) Superposition - youngest rock layers are on the surface, older layers as you go deeper.

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.

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.

- The youngest rock layers are at the top and the oldest are at the bottom, which is described by the law of superposition.

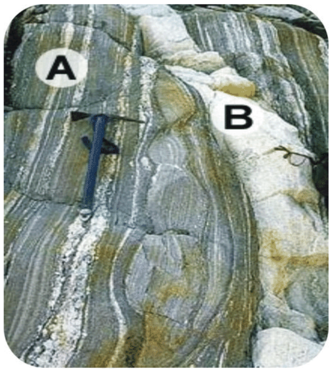


FIGURE 3.19

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.

- 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.

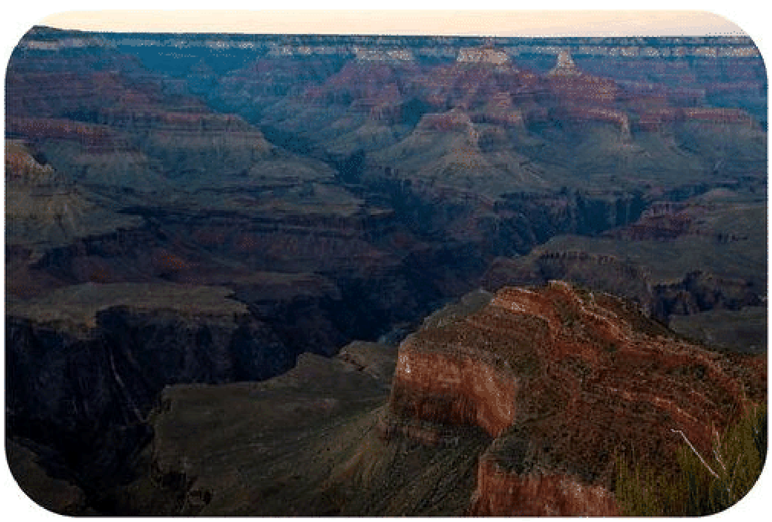


FIGURE 3.20

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.

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?

An interactive website on relative ages and geologic time is found here: http://tinyurl.com/dxvpyz .

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? Write it down and then check the following paragraphs.

The full sequence of events is:

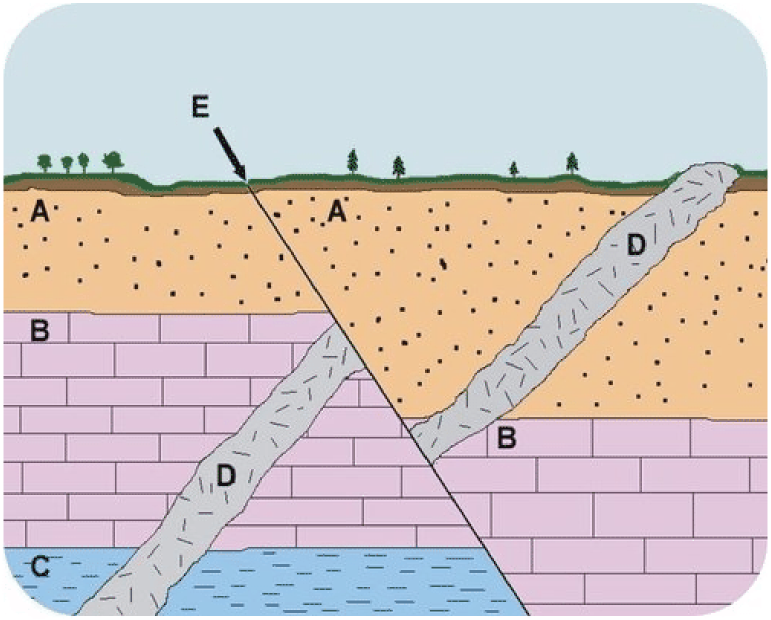


FIGURE 3.21
A geologic cross section: Sedimentary rocks (A-C), igneous intrusion (D), fault (E). The principle of cross-cutting relationships states that a fault or intrusion is younger than the rocks that it cuts through. The fault cuts through all three sedimentary rock layers (A, B, and C) and also 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.

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.

Unconformities

Geologists can learn a lot about Earth's history by studying sedimentary rock layers. Rock layers are not always discovered in correct order. In some places, there's a gap in time when no rock layers are present or rock layers are overturned and reversed. What processes would lead to unconformities in rock layers?

What is an unconformity?

A gap in the sequence of rock layers is called an unconformity. Index fossils are commonly used to match rock layers in different places. There are two common ways the unconformities can be creating. The first is a process called **folding** and the second is **faulting**.

Folding

If you were to make observations of rock layers all over the globe, you would often see that in many places the rock layers are not always horizontal. Movement of the crust create stresses that deform, tilt, and bend these layers. We call this folding.

Rocks deforming plastically under compressive stresses crumple into **folds**. They do not return to their original shape. If the rocks experience more stress, they may undergo more folding or even fracture.

FIGURE 3.22
Anticlines are formations that have folded rocks upward. Synclines are folds that point down.

FIGURE 3.23
Some folding can be fairly complicated. What do you see in the photo?

Faults

The word "fault" refers to a defect. There may be no greater defect than the scar of the San Andreas Fault across California. Rocks on either side of the fault are estimated to have originated in locations about 350 miles apart! We're still in the arid western United States, but now our searching for geological features is more dangerous!

If the blocks of rock on one or both sides of a fracture move, the fracture is called a **fault**. (See photo.) Stresses along faults cause rocks to break and move suddenly. When a fault moves suddenly, it is called an earthquake.

FIGURE 3.24
Faults are easy to recognize as they cut across bedded rocks.

How do you know there's a fault in this rock? Try to line up the same type of rock on either side of the lines that cut across them. One side moved relative to the other side, so you know the lines are a fault.

Usually the youngest rock layers are found on the surface of the Earth and layers become progressively older as you go deeper into the crust. However, sometimes we see older layers on top of younger layers. Faulting and folding are two processes that allow this to happen. Folded layers can bend over on top of younger layers, and faults can push older layers over top of younger layers.

Index Fossils

Two separate 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.

2. Existed for a relatively brief period of time so that the approximate age of the rock layer is immediately known.
3. Had a large abundance of organisms to increase the chances of fossilization.

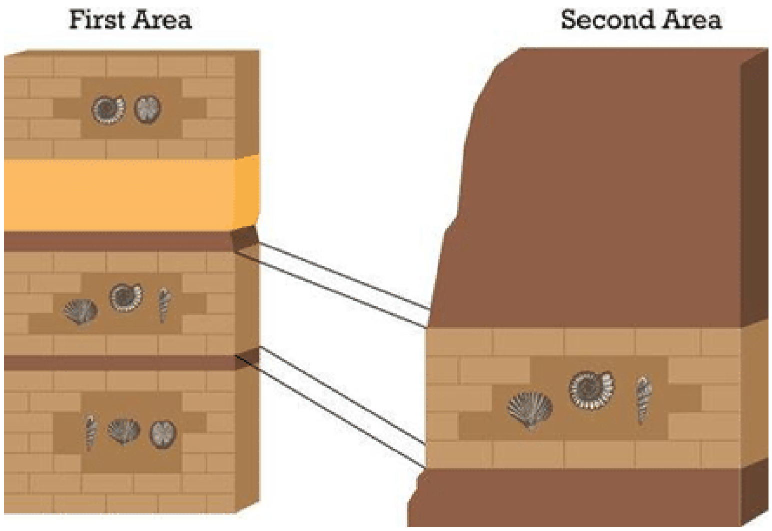


FIGURE 3.25
Many fossils may qualify as index fossils. Ammonites, trilobites, and graptolites are often used as index fossils.

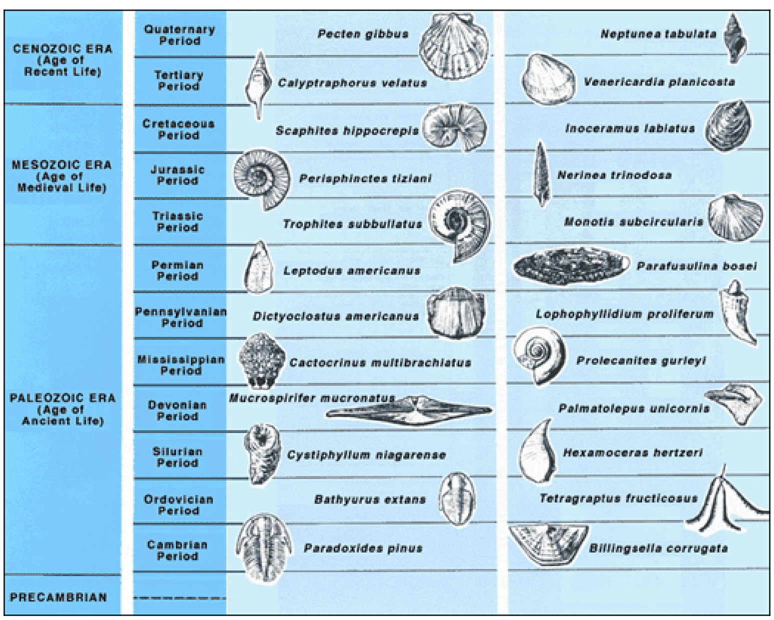


FIGURE 3.26
Several examples of index fossils are shown here. Mucrospirifer mucronatus is an index fossil that indicates that a rock was laid down from 416 to 359 million years ago.

Microfossils, which are fossils of microscopic organisms, are also useful index fossils. Fossils 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.

Evidence of Earth's Changing Surface

Since its formation the Earth's surface has changed dramatically. Fossils are one type of evidence used to determine how Earth's surface has changed. There are also several other lines of evidence that help scientist know that changes have occurred.

Clues from Fossils

Fossils are our best form of evidence about Earth's 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

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.

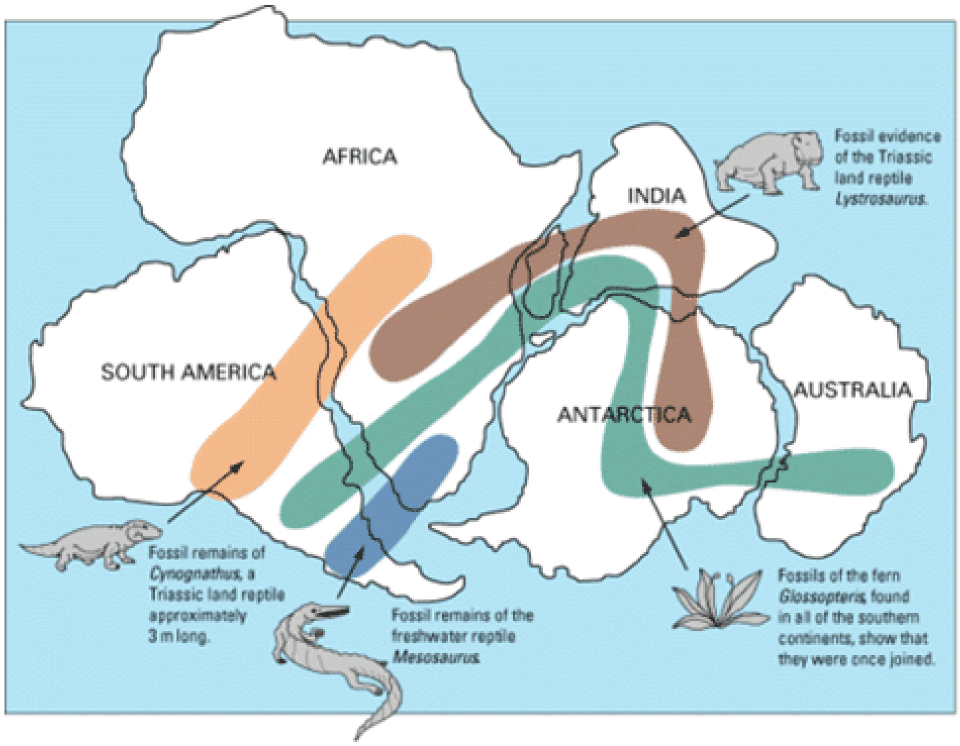
Geologic History

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.

On his voyage on the Beagle, Charles Darwin noticed many things besides just the Galapagos finches that made him famous. Another important observation that Darwin made 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.

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.



It is interesting to observe that as we study different ages of rock layers, we see different types of fossils. Fossils in younger, recent rock layers have fossils that tend to look more like today's species. Fossils in older rock layers tend to look very different from what we see alive on Earth today. Why is this the case?

Evolution is the study of how organisms change over time. This occurs naturally and is shown by fossils in the rock record. Over millions of years small changes add up to large changes in what the organisms looks like or how it behaved.

Think like a Geologist

1. Why are younger rocks normally above older rocks?
2. What could cause an older layer of rock to be above a younger layer?
3. How might a rock become bent?
4. What are some examples of rocks changing over time?

Online Interactive Activity

- In this simulation, students move rock layers and fossils to various heights and try to create a geologic rock column. http://tinyurl.com/UT8th3-3a

3.4 Compare rapid and gradual changes to Earth's surface

Objectives

- Describe how energy from the Earth's interior causes changes to Earth's surface (i.e., earthquakes, volcanoes) (start with layers and heat in core, mantle).
- Describe how earthquakes and volcanoes transfer energy from Earth's interior to the surface (e.g., seismic waves transfer mechanical energy, flowing magma transfers heat and mechanical energy).
- Identify the processes of energy buildup and release in earthquakes.
- Describe how small changes over time add up to major changes to Earth's surface.
- Analyze why people don't always follow scientists recommendations.

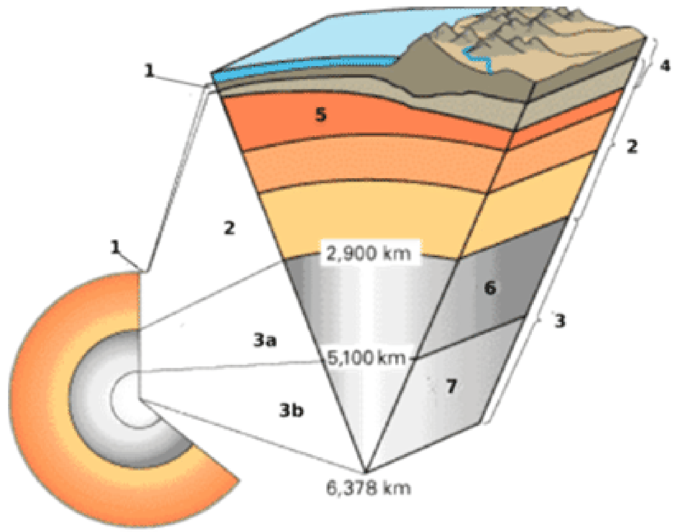
Energy in Earth's Interior

If someone told you to figure out what is inside Earth, what would you do? How could you figure out what is inside our planet? How do scientists figure it out?

Earth's Layers

What's below our feet? What's way below?

If we could cut Earth open, we'd see the inner core at the center, then the outer core, the mantle in the middle and the crust on the outside. If you are talking about plates, though, there's the brittle lithosphere riding on the plastic asthenosphere.



Layers of the Earth: The layers scientists recognize are pictured above.

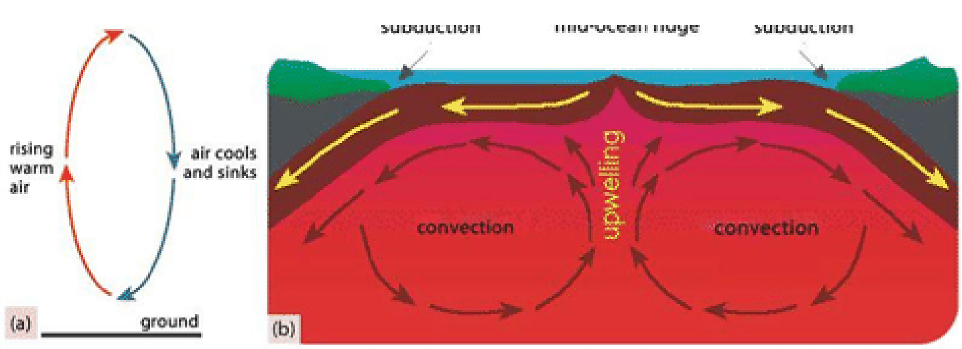
Core, mantle, and crust are divisions based on composition:

1. The crust is less than 1% of Earth by mass. The two types are oceanic crust and continental crust.
2. The mantle is hot, ultramafic rock. It represents about 68% of Earth's mass.
3. The core is mostly iron metal. The core makes up about 31% of the Earth.

Heat Flow In The Mantle

Scientists know that the mantle is extremely hot because of the heat flowing outward from it and because of its physical properties.

Convection in the mantle is the same as convection in a pot of water on a stove. Convection currents within Earth's mantle form as radioactive material in the mantle and crust generate heat, as well some residual heat left over from Earth's formation deep within the Earth. As the radioactive material heats up the mantle, particles move more rapidly, decreasing its density and causing the warmer mantle material to rise very slowly. The rising material begins the convection current. When the warm material reaches the surface, it spreads horizontally. The material over time cools because it is no longer near the source of radioactive material. It eventually becomes cool and dense enough to sink back down into the mantle. Near the bottom of the mantle, the material travels horizontally and is heated by the Earth's interior and radioactive material. It reaches the location where warm mantle material rises, and the mantle convection cell is complete.



In a convection cell, warm material rises and cool material sinks. In mantle convection, the heat source is the core.

Diagram of convection within Earth's mantle.

Melting Forms Volcanoes

When the mantle above a tectonic plate melts, volcanoes form above it. This can also happen in areas not located on plate boundaries where magma rises. This called a hot spot. As with convection currents, when magma melts it becomes less dense than the rock around it. The magma squeezes upward towards the surface forming a volcano. A volcano is a vent through which molten rock and gas escape from the interior of the earth.

Volcanoes allow energy from the Earth's interior to be transferred to the Earth's surface. This transfer of energy causes significant changes to the Earth's surface. Volcanoes are sources of ash flows, lava flows, and lahars. Events associated with volcanoes, such as ash falls and mudslides, also alter the Earth's surface.

Volcanoes transfer energy when the flowing magma carries heat and mechanical energy from the interior to the Earth's surface.

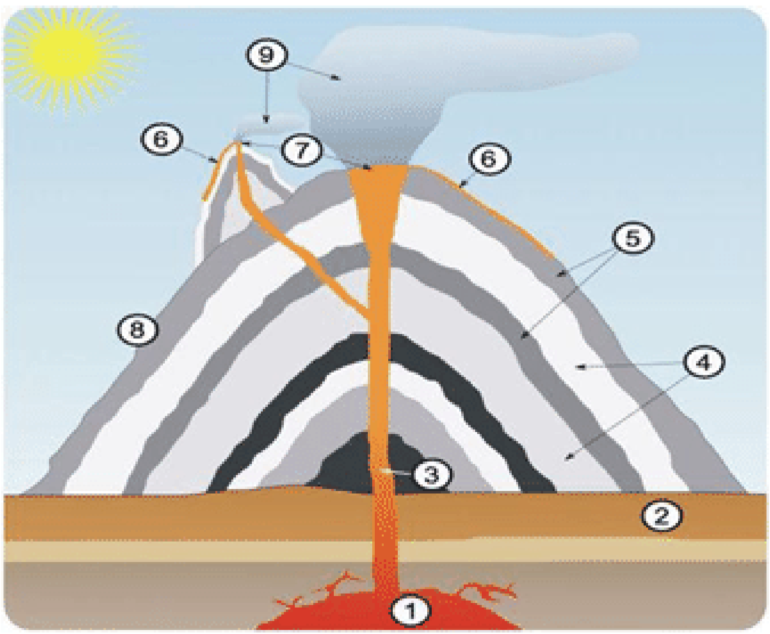


FIGURE 3.27
In the figure, magma rises from the magma chamber (1) rises up the pipe (3) and exits as lava from the vent (7).

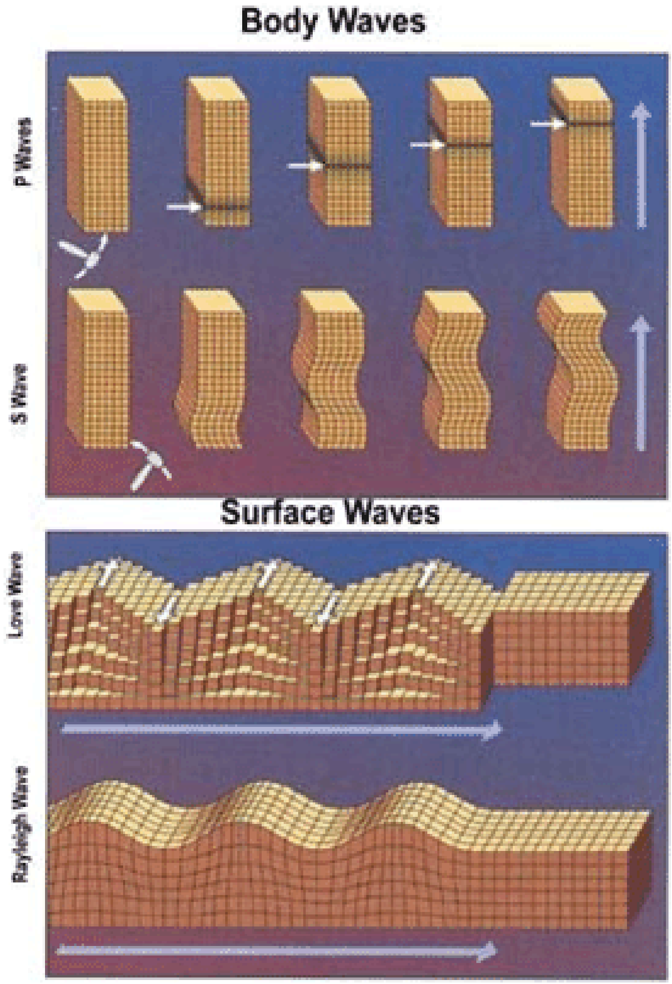
Earthquakes

An **earthquake** is the result of a sudden release of energy caused by a slippage or break in the Earth's crust. An earthquake occurs when stored potential energy in tectonic plates is released. Energy is stored over time until it reaches the rock's elastic limit, at which point the rock fractures and the energy is released as mechanical energy. The mechanical energy is seen in the form of seismic waves.

These seismic waves can cause many changes to the Earth's surface including faulting, cracks in the Earth's surface, and immense damage to manmade structures.

Seismic Waves

Geologists study earthquake waves to "see" Earth's interior. Waves of energy radiate out in all directions from an earthquake's focus-(where the slippage of the crust occurred). These waves are called seismic waves. Seismic waves go different speeds through different materials. Based on these observations geologist can determine the layers of the Earth.



There are three types of seismic waves:

- Primary waves
- Secondary waves
- Surface waves

Geologic Change and its Ramifications

Gradual changes due to continental drift, weathering, deposition, sedimentation, and uplift build upon each other over time to create great mountain ranges, valleys and other land features. For example if a tectonic plate only moves at a rate of one centimeter per year this may seem very little during one person's lifetime. However after a million years the tectonic plate will have moved 1000 kilometers or 621 miles. So in the geological time scale entire continents can move thousands of miles.

Likewise, over the course of thousands of years glaciers and rivers carve valleys and erosion and weathering reduce mountains to molehills. Small changes over time add up to major changes in the Earth's surface.

Geology and Building Decisions

People are not always wise when making decisions about building roads, dams, homes, and communities in geologically active areas. Though geologists, engineers, and ecologists have collected data about the changing nature of the Earth's surface, people continue to build in unwise places. There are many reasons for this. For example, people may build a home on a hill because they like the view or because they want to get away from the city, ignoring the fact that their home is on an active fault zone or on a slope that is prone to landslides.

There are many engineering advances that increase our ability to deal with Earth's changes. Current technologies allow buildings to withstand larger and larger earthquakes. Warning systems for tsunamis and earthquakes have been installed in major cities to allow people to protect themselves.

While it is possible to protect buildings from earthquakes it is not possible to make building earthquake proof. Structures can be built flexible or with rubber dampers to absorb seismic waves so they can withstand some earthquakes. Other more expensive building may have active processes for dampening or absorbing seismic waves. These buildings may have large pendulums or actuators to move the building.

Unfortunately in many cases recommendations from scientists and engineers are ignored. Some possible causes for this include ignorance of recommendations, lack of funding, or lack or resources. In some cases people will ignore warning systems.

FIGURE 3.28

While technologies exist to help prevent damage during natural disasters technology alone cannot keep people safe. Recommendations for evacuation and safety should be followed. Knowledge or earthquake safety should be used and passed on and building designers need to follow proper safety precautions as recommended by scientists and engineers.

Think like a Geologist

1. How does heat from the Earth's interior reach its surface?
2. What kinds of land features are created by volcanoes?
3. Are changes on the Earth's surface gradual or rapid (or both)? Explain.

Online Interactive Activities

- From the United States Geological Survey (USGS) this website lets students explore recent earthquakes (within the last 7 days) that have occurred around the globe. http://tinyurl.com/UT8th3-4a
- Students look at seismograph data and calculate the time interval between the two waves to triangulate the origin of the earthquake. http://tinyurl.com/UT8th3-4b
- Simulate engineering for earthquakes. http://tinyurl.com/UT8th3-4c
- Role play an engineer to prepare a city for an earthquake. http://tinyurl.com/d8nwm2

3.5 References

1. . https://en.wikipedia.org/wiki/File:Rockstrata3435.JPG .
2. . https://en.wikipedia.org/wiki/File:Pswaves.jpg .

CHAPTER 4 Standard IV: Motion

Chapter Outline

Standard 4: Students will understand the relationships among energy, force, and motion.

Objective 1: Investigate the transfer of energy through various materials.

1. Relate the energy of a wave to wavelength.
2. Compare the transfer of energy (i.e., sound, light, earthquake waves, heat) through various mediums.
3. Describe the spread of energy away from an energy-producing source.
4. Compare the transfer of heat by conduction, convection, and radiation and provide examples of each.
5. Demonstrate how white light can be separated into the visible color spectrum.

Objective 2: Examine the force exerted on objects by gravity.

1. Distinguish between mass and weight.
2. Cite examples of how Earth's gravitational force on an object depends upon the mass of the object.
3. Describe how Earth's gravitational force on an object depends upon the distance of the object from Earth.
4. Design and build structures to support a load.
5. Engineer (design and build) a machine that uses gravity to accomplish a task.

Objective 3: Investigate the application of forces that act on objects, and the resulting motion.

1. Calculate the mechanical advantage created by a lever.
2. Engineer a device that uses levers or inclined planes to create a mechanical advantage.
3. Engineer a device that uses friction to control the motion of an object.
4. Design and build a complex machine capable of doing a specified task.
5. Investigate the principles used to engineer changes in forces and motion.

Objective 4: Analyze various forms of energy and how living organisms sense and respond to energy.

1. Analyze the cyclic nature of potential and kinetic energy (e.g., a bouncing ball, a pendulum).
2. Trace the conversion of energy from one form of energy to another (e.g., light to chemical to mechanical).
3. Cite examples of how organisms sense various types of energy.
4. Investigate and report the response of various organisms to changes in energy (e.g., plant response to light, human response to motion, sound, light, insects' response to changes in light intensity).
5. Investigate and describe how engineers have developed devices to help us sense various types of energy (e.g., seismographs, eyeglasses, telescopes, hearing aids).

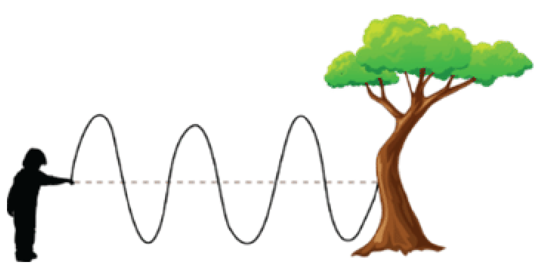
4.1 Does a Tsunami Carry Energy?

Objectives

- Relate the energy of a wave to wavelength.
- Describe the spread of energy away from an energy-producing source.
- White light can be separated into the visible color spectrum.

Tsunamis are unusually large ocean waves. You can see an example of a tsunami in the photo. Tsunamis can cause incredible destruction and loss of life. The tsunami in the figure below crashed into Thailand on December 26, 2004. Measuring the height of a tsunami (or any other wave) is one way of determining the amount of energy the wave is carrying.

A **wave**—disturbance that transfers energy through a medium or through space—is one way that energy can travel. **Energy** is the ability to do work; to cause change and/or move matter. **Waves** transfer energy through a **medium**-(the matter through which waves travel). The medium through which tsunamis travel is water. The medium through which the sound of the bell that dismisses you from class travels is air. In the diagram the rope is the medium that transfers the wave's energy from the boy to the tree.



Properties of Waves

Two ways to measure the amount of energy a wave carries are height and length. The height of a wave is its **amplitude**. **Wavelength** is the distance between two corresponding points on adjacent waves. Both wave amplitude and wavelength are illustrated in the following figure.

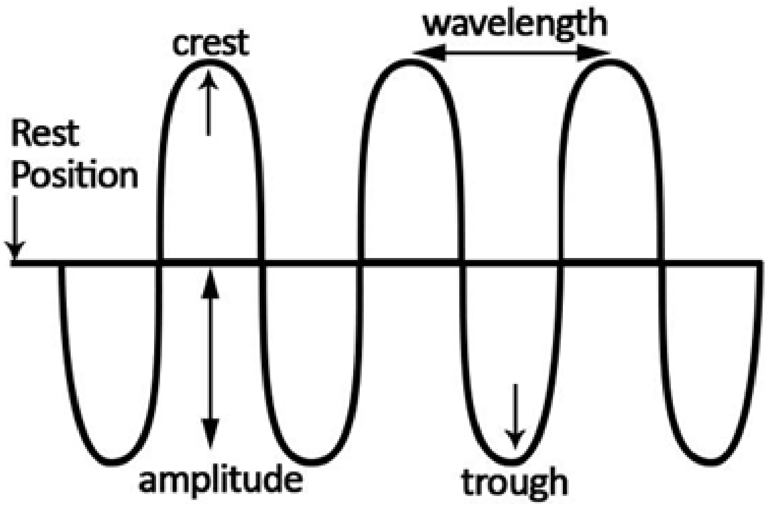


FIGURE 4.1
Wave amplitude and wavelength are two important measures of wave size.

Wave Amplitude

Amplitude - (height of wave from rest position) is the maximum distance the particles of a medium move from their resting position when a wave passes through. The **resting position** - (the point where wave is when there is not disturbance) is where the particles would be if there were no wave. The **crest** - (peak of wave) is the highest point the particles of a medium travel above the resting position and the **trough** - (valley of wave) is the lowest. Refer to the diagram above. The trough and crest are equal distances from the resting position. Wave amplitude is the distance between the resting position and the crest OR the resting position and the trough. The higher the crest (or the lower the trough), the greater the amplitude. The greater the amplitude, the greater the wave's energy.

What determines a wave's amplitude? It depends on the energy of the disturbance that causes the wave. 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, like those in the **Figure** 4.1. The ripples are low-amplitude waves. Now imagine throwing a big boulder into the pond. Very large waves will be generated by the disturbance. These waves are high-amplitude waves.

Wavelength

Another important measure of wave size (and its related energy) is **wavelength** - (the distance between two corresponding points on adjacent waves). **Wavelength** can be measured as the distance between two adjacent crests or two adjacent troughs. It is usually measured in meters (m). Wavelength is related to the energy of a wave. Short-wavelength waves have more energy than long-wavelength waves of the same amplitude. You can see examples of waves with shorter and longer wavelengths in the diagram. This youtube video also shows waves generated on a harp showing wavelength, amplitude, etc. (It also applies to other wave characteristics, longitudinal wave, sound generation etc.)

- https://www.youtube.com/watch?v=iGd7SdeaSXI

MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/179229

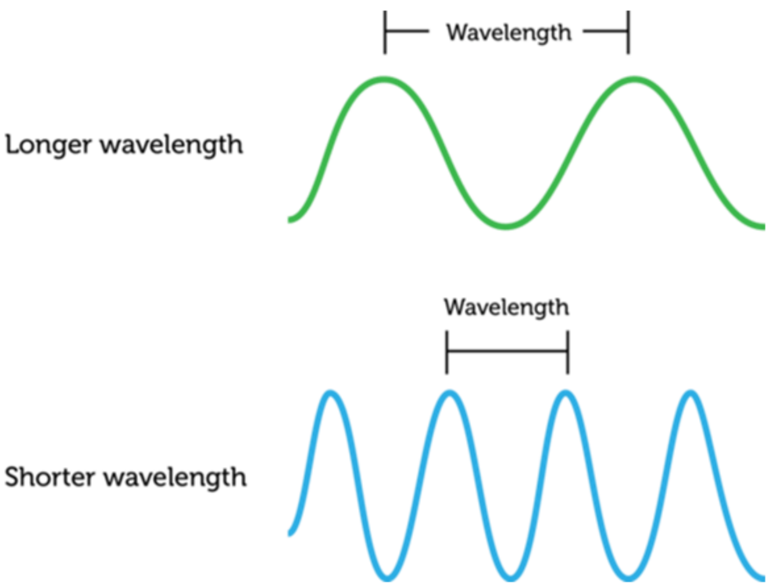


FIGURE 4.2

Both of these waves have the same amplitude, but they differ in wavelength.

Q: Which wave has more energy?

Wave Frequency

Imagine making waves in a rope. Tie one end of the rope to a doorknob (or another fixed point) and move the other end 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** - (the number of waves that pass a fixed point in a given amount of time) of the waves.

Wave **frequency** can be measured by counting the number of crests that pass a point in one second. The higher the number, the greater the frequency of the wave. The SI unit for wave frequency is the **Hertz (Hz)**. One Hertz equals one wave passing a fixed point in one second. The following figure shows high-frequency and low-frequency waves.

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.

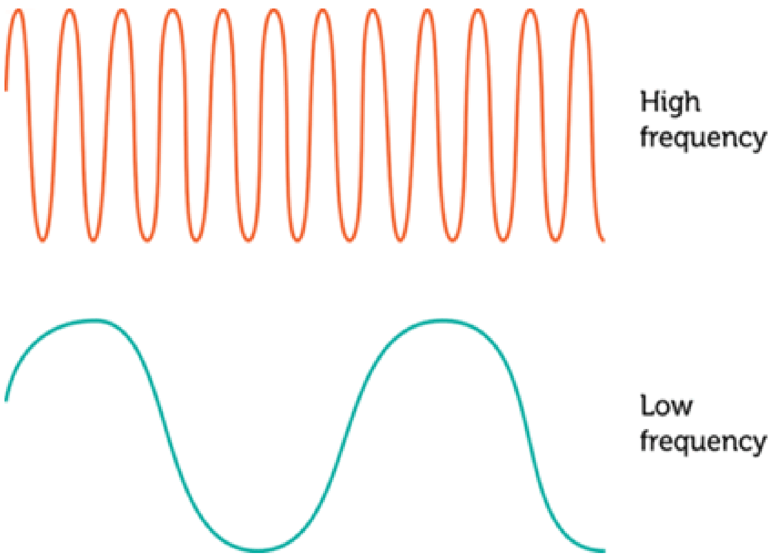
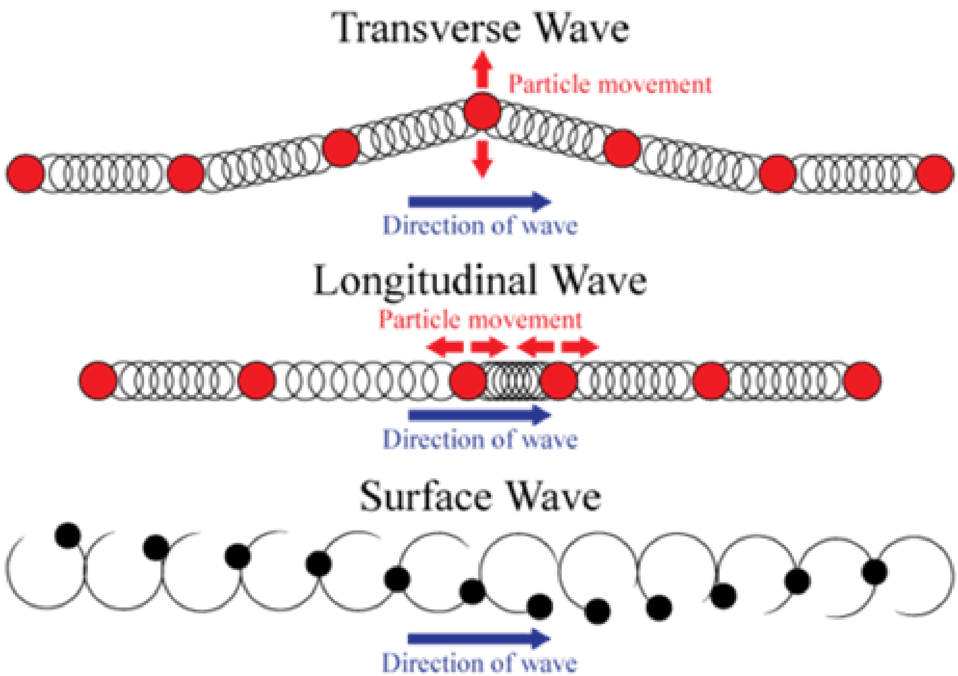


FIGURE 4.3
A transverse wave with a higher frequency has crests that are closer together.

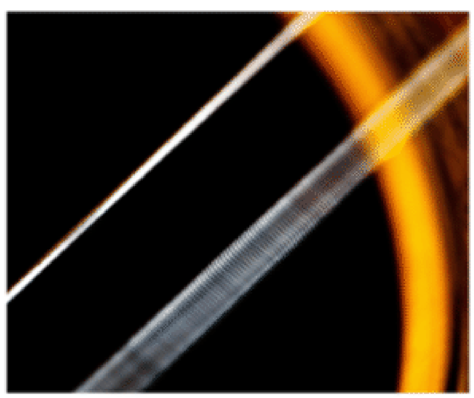
Three Types of Mechanical Waves

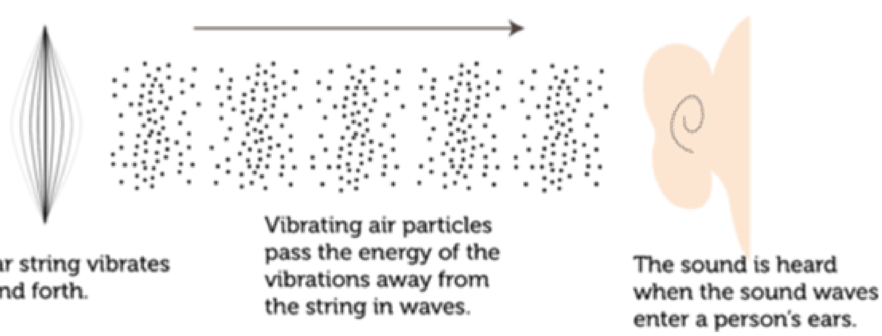
There are three types of mechanical waves: transverse, longitudinal, and surface waves. Examples of mechanical waves include: seismic waves, sound waves, and water waves. Mechanical waves differ in how particles of the medium move. You can see this in the Figure below and in the animation at the following URL: http://bit.ly/1fsUsFD

- In a **transverse wave**, particles of the medium vibrate up and down perpendicular to the direction of the wave. In a transverse wave, wave amplitude is the height of each crest above the resting position. The higher the crests are, the greater the amplitude.
- In a **longitudinal (compression) wave**, particles of the medium vibrate back and forth parallel to the direction of the wave. In a longitudinal wave, amplitude is a measure of how compressed particles of the medium become when the wave passes through. The closer together the particles are, the greater the amplitude.
- In a **surface wave**, particles of the medium vibrate both up and down and back and forth, so they end up moving in a circle.



Waves Move Energy Away from an Energy Producing Source





Plucking a guitar string makes it vibrate. The diagram 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 compress. The compressions travel through the air in all directions away from the guitar string as waves.

Seismic waves are the energy from earthquakes. Seismic waves move outward in all directions away from their source. Each type of seismic wave travels at different speeds in different materials. All seismic waves travel through rock, but not all travel through liquids or gases. (This is how the nature of the interior of the earth is determined.)

Why Does White Light Have Color?

Visible light is transferred by radiation. Visible light consists of a range of wavelengths. The wavelength determines the color that the light appears. As seen in the **Figure** 4.4, light with the longest wavelength appears red and light with the shortest wavelength appears violet. In between is the spectrum of the other colors of light.

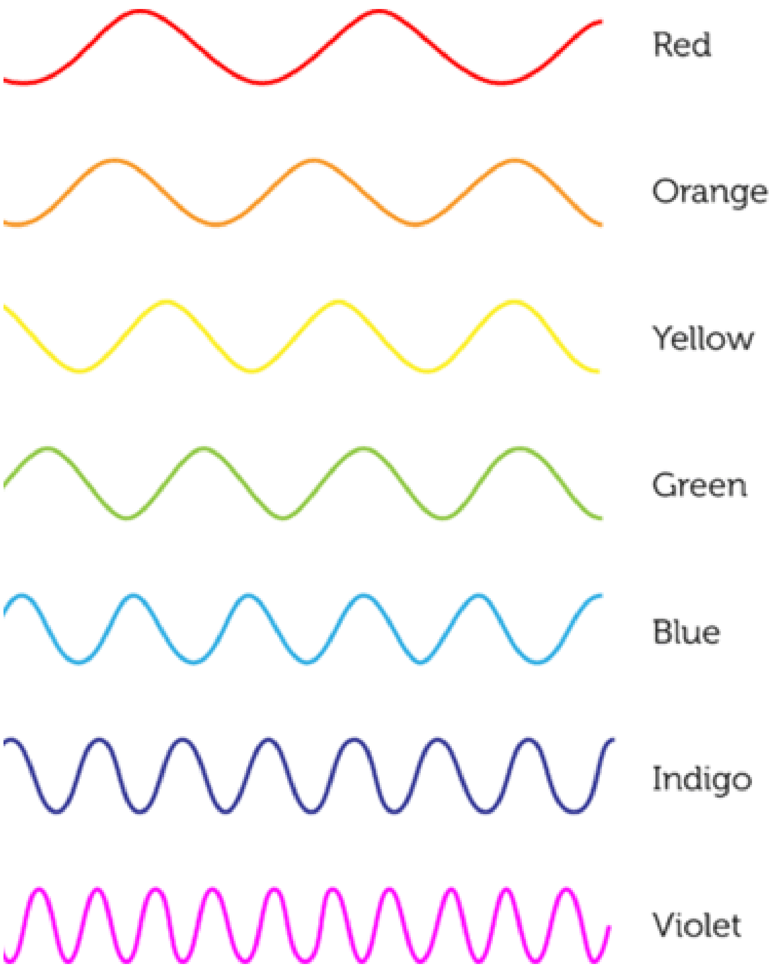


FIGURE 4.4
The color of light depends on its wavelength.

Separating Colors of Light

A prism, like the one in the **Figure** 4.5, can be used to separate white (visible) light into its different colors. A prism is a pyramid-shaped object made of transparent matter, usually clear glass. It transmits light but slows it down. When light passes from the air to the glass of the prism, the change in speed causes the light to bend. Different wavelengths of light bend at different angles. This causes the beam of light to separate into light of different wavelengths. What we see is a rainbow of colors.

Summary

- Wave amplitude is the maximum distance the particles of a medium move from their resting positions as a wave passes through.
- Wavelength is the distance between two corresponding points of adjacent waves. Waves with greater amplitudes or shorter wavelengths have more energy.

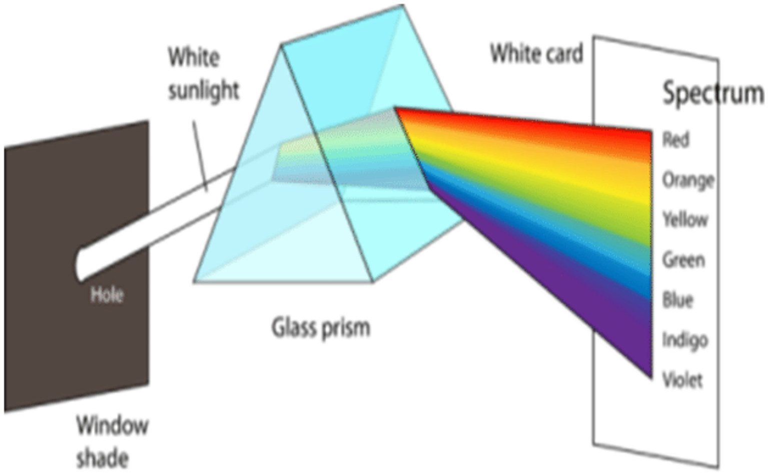


FIGURE 4.5
A prism separates visible light into its different wavelengths.

- Wave frequency is the number of waves that pass a fixed point in a given amount of time. Higher frequency waves have more energy.
- Most waves require a medium and travel faster through solids than liquids or gases. Light waves do not require a medium.
- Wave energy travels outward in all directions from the energy source.

Think like a Scientist

1. What is wave amplitude? How would this relate to what ocean waves a surfer likes?
2. Describe wavelength. Would wavelength have an impact on hearing loss?
3. Define wave frequency.
4. What is a medium?
5. Relate wave amplitude, wavelength, and wave frequency to wave energy.

4.2 Have you ever cooked over a campfire?

Objectives

- Compare the transfer of heat by conduction, convection, and radiation and provide examples of each.
- Compare the transfer of energy (i.e. sound, light, earthquake waves, heat) through various mediums.

Waves Transfer Energy through Various Mediums

The speed of waves depends on the medium through which they are traveling and on the type of energy. (Each type of energy will have a different speed in the same medium. Sound waves are mechanical waves and travel better through solids than through gases. The table gives the speed of sound in several different media. Generally, sound waves travel most quickly through solids, followed by liquids, and then by gases. Particles of matter are closest together in solids and farthest apart in gases. When particles are closer together, they can more quickly pass the energy of vibrations to nearby particles.

TABLE 4.1: Waves

Medium (20°C)	Speed of Sound Waves (m/s)
Dry Air	343
Water	1437
Wood	3850
Glass	4540
Aluminum	6320

Try This At Home

Tie two hangers together with a 20 m piece of string. Have two people each touch the hanger to their ears and move away from each other until the string is pulled taut. Now gently tap one of the hangers. What happens? Remove the hangers so they are not touching the ears and repeat the exercise. What happens? The person on the other end of the string will not hear the tap when the hangers are not touching the ears but will hear the tap when the hanger is touching the ear because sound travels better through a solid than a gas.

Most waves require a medium through which to travel. For example, sound cannot travel through the vacuum of space because there are no particles there to transmit the wave. Light waves are an exception. Light waves do not require a medium; they can travel through space. Light waves are electromagnetic waves and travel slower through more dense mediums. The table gives the speed of light in several different media.

TABLE 4.2:

Medium (20°C)	Speed of Light Waves (m/s)
Vacuum	3×10^8 (or 300000000)
Air	2.99×10^8
Water	2.26×10^8
Glass	2.0×10^8
Diamond	1.24×10^8

Q: What would happen to life on Earth if light could not travel through the vacuum of space?

How Does Heat Energy Transfer from Place to Place?

The girl in the figure is adding fuel to a campfire where soup is heating in a big metal pot. Thermal energy from the fire heats the water. Eventually, all the water in the pot will be boiling hot. The girl also feels warmth from the flames, even though she isn't touching them. Thermal energy is transferred from the fire in three ways:

- **Conduction** (transfer of heat through surfaces touching),
- **Convection** (transfer of heat through fluid such as water or air), and
- **Radiation** (transfer of heat through electromagnetic waves).

FIGURE 4.6
Thermal energy from the fire is transferred to the pot and water and to the girl tending the fire.

Conduction (Conduction, Convection and Radiation can apply to other energy types besides thermal energy.)

Conduction is the transfer of thermal energy between particles of matter that are touching. When energetic particles collide with nearby particles, they transfer some of their thermal energy from particle to particle. Like dominoes falling, thermal energy moves throughout a substance. In the cooking photo, conduction occurs between particles of the metal in the pot and between particles of the pot and the water. The ice and flat iron photos show additional examples of conduction.

Conduction is usually faster in liquids and certain solids than in gases. Metals are often excellent conductors. That's why the metal pot gets hot all over, even though it gains thermal energy from the fire only at the bottom of the pot. The metal heating element of the flat iron heats up almost instantly and quickly transfers energy to the strands of hair that it touches. Particles of gases are farther apart and have fewer collisions, so they are not good at transferring thermal energy.

Convection

Convection is the transfer of thermal energy by particles moving through a fluid. Particles transfer energy by moving from warmer to cooler areas. Consider the pot of boiling soup pictured. The energy is transferred through the soup

FIGURE 4.7
How is thermal energy transferred in each of these examples?

by convection. Particles of soup near the bottom of the pot get hot first. They have more energy so they spread out and become less dense. With lower density, these particles rise to the top of the pot. By the time they reach the top of the pot they have cooled off. They have less energy to move apart, so they become more dense. With greater density, the particles sink to the bottom of the pot and the cycle repeats. This loop of moving particles is called a convection current.

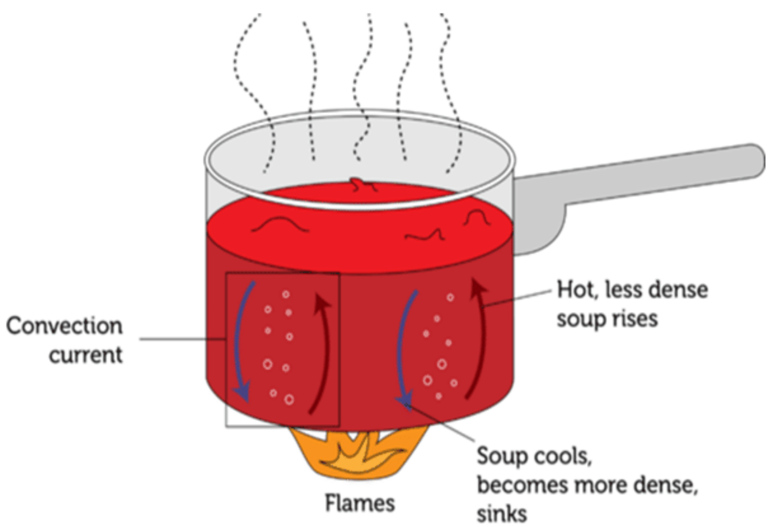


FIGURE 4.8
Convection currents carry thermal energy throughout the soup in the pot.

Convection currents move thermal energy through many fluids, including molten rock inside Earth, water in the oceans, and air in the atmosphere. In the atmosphere, convection currents create wind. You can see one way this happens in the **Figure** 4.9. Land heats up and cools off faster than water because it has lower specific heat. Therefore, land is warmer during the day and cooler at night than water. Air close to the surface gains or loses heat as well. Warm air rises because it is less dense, and when it does, cool air moves in to take its place. This creates a convection current that carries air from the warmer to the cooler area.

Radiation

Both conduction and convection transfer energy through a medium. **Radiation** is an example of transferring energy without a medium. **Radiation** is the transfer of electromagnetic waves that can travel through empty space. When the waves reach objects, they transfer energy to the objects, causing their atoms and molecules to vibrate which

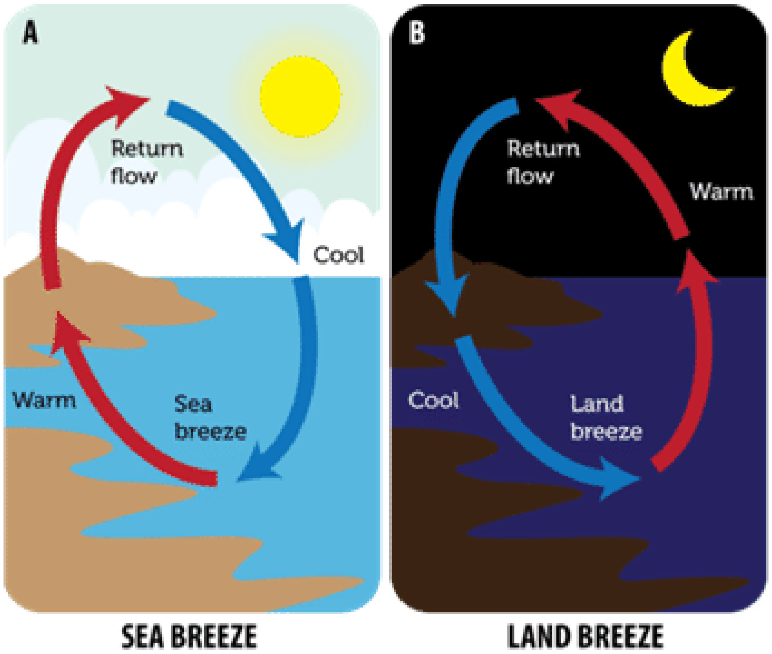


FIGURE 4.9
A sea breeze blows toward land during the day, and a land breeze blows toward water at night. Why does the wind change direction after the sun goes down?

warms the object. This is how the sun's energy reaches Earth and heats its surface (See **Figure** 4.10). Radiation is also how thermal energy from a campfire warms people nearby. You might be surprised to learn that all objects radiate thermal energy, including people. In fact, when a room is full of people, it may feel noticeably warmer because of all the thermal energy the people radiate!

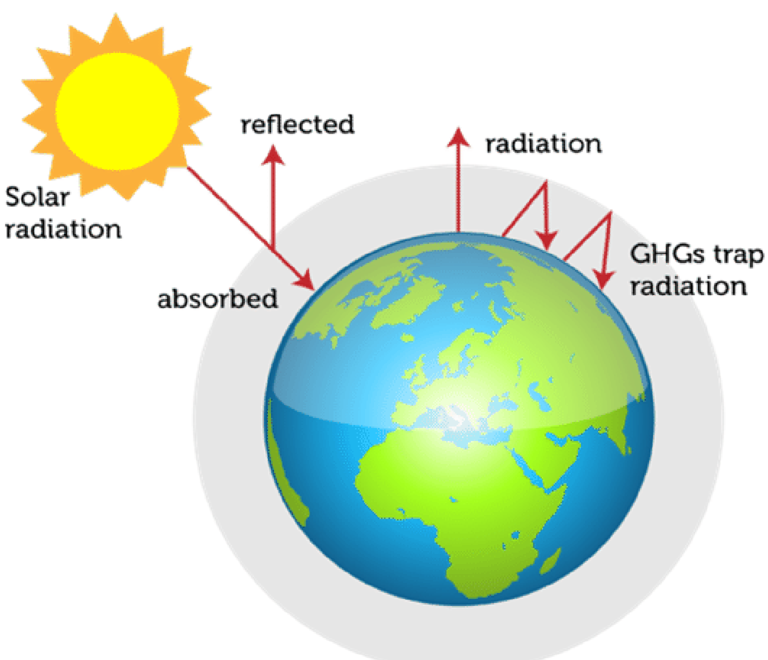


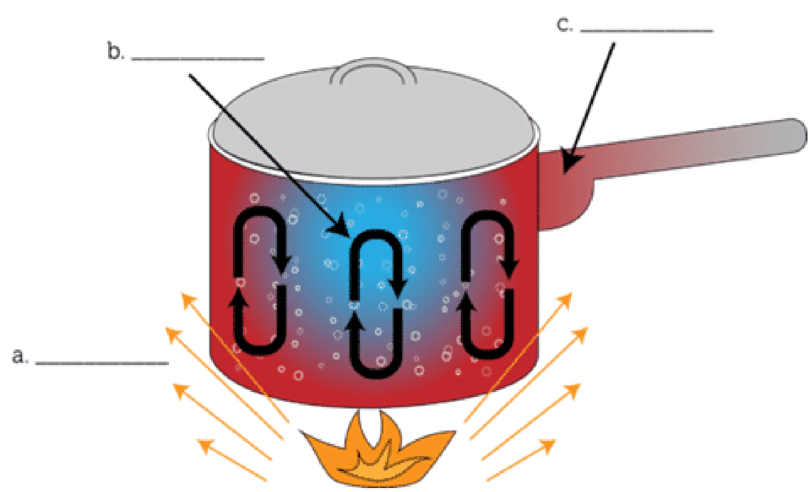
FIGURE 4.10
Earth is warmed by energy that radiates from the sun. Earth radiates some of the energy back into space. Greenhouse gases (GHGs) trap much of the re-radiated energy, causing an increase in the temperature of the atmosphere close to the surface (This is why the atmosphere is often described as a "blanket" around the earth). When the waves reach objects, they transfer thermal energy to the objects. This is how the sun's energy reaches and warms Earth.

Summary

- Conduction is the transfer of energy (including thermal) between particles of matter that are touching. Thermal conductors are materials that are good conductors of thermal energy. Thermal insulators are materials that are poor conductors of thermal energy. Both conductors and insulators have important uses.
- Convection is the transfer of thermal energy by particles moving through a fluid. The particles transfer energy by moving from warmer to cooler areas. They move in loops called convection currents.
- Radiation is the transfer of energy (including thermal) by waves that can travel through empty space.
- White light can be separated into the visible color spectrum; red, orange, yellow, green, blue, indigo, violet (Roy G Biv).

Think like a Scientist

1. Define conduction, convection, and radiation.
2. What is the relationship between wavelength and color in white light? How does the energy in the light wave relate to the color (and its related wavelength)?
3. Why does convection occur only in fluids?
4. Fill in each blank in the diagram below with the correct method of heat transfer.



5. Describe how conduction, convection, and radiation are used to heat a house?

Online Interactive Activity

- This interactive explores sources of man-made and natural radiation. http://tinyurl.com/UT8th4-1a

4.3 Mass and Weight: What is the Difference?

Everything you can see and touch is made of **matter**, including you! The only things that aren't matter are forms of energy, such as light and sound. In science, **matter** is defined as anything that has mass and volume. Mass and volume measure different aspects of matter.

Mass

Mass is a measure of the amount of matter in a substance or an object. The basic SI unit for **mass** is the kilogram (kg), but smaller masses may be measured in grams (g). To measure mass, you would use a balance. In the lab, mass may be measured with a triple beam balance or an electronic balance, but the old-fashioned balance in the scale pictured may give you a better idea of what mass is. If both sides of this balance were at the same level, it would mean that the fruit in the left pan has the same mass as the iron object in the right pan. In that case, the fruit would have a mass of 1 kg, the same as the iron. As you can see, however, the fruit is at a higher level than the iron. This means that the fruit has less mass than the iron.

Q: If the fruit were at a lower level than the iron object, what would be the mass of the fruit?

Weight

Weight is a measure of the force of gravity pulling on an object. It is measured with a scale, like the kitchen scale in the **Figure** 4.11. The scale detects how forcefully objects in the pan are being pulled downward by the force of gravity. The SI unit for weight is the newton (N). The common English unit is the pound (lb). With Earth's gravity, a mass of 1 kg has a weight of 9.8 N (2.2 lb). In general, the more matter an object contains, the more it weighs.

Mass vs. Weight

Mass is commonly confused with **weight**. The two are closely related, but they measure different things. Mass measures the amount of matter in an object; **weight** measures the force of gravity acting on an object. The force of gravity on an object depends on its mass but also on the strength of gravity. If the strength of gravity is held constant, then an object with a greater mass also has a greater weight.

FIGURE 4.11

This kitchen scale measures weight. How does weight differ from mass?

Q: With Earth's gravity, an object with a mass of 1 kg has a weight of 2.2 lb. How much does a 10 kg object weigh on Earth?

A: A 10 kg object weighs ten times as much as a 1 kg object: $10 \times 2.2\ lb = 22\ lb$

Problem Solving

Problem: At Earth's gravity, what is the weight in Newtons of an object with a mass of 10 kg?

Solution: At Earth's gravity, 1 kg has a weight of 9.8 N. Therefore, 10 kg has a weight of $(10 \times 9.8\ N) = 98\ N$.

You Try It!

Problem: If you have a mass of 50 kg on Earth, what is your weight in Newtons?

FIGURE 4.12

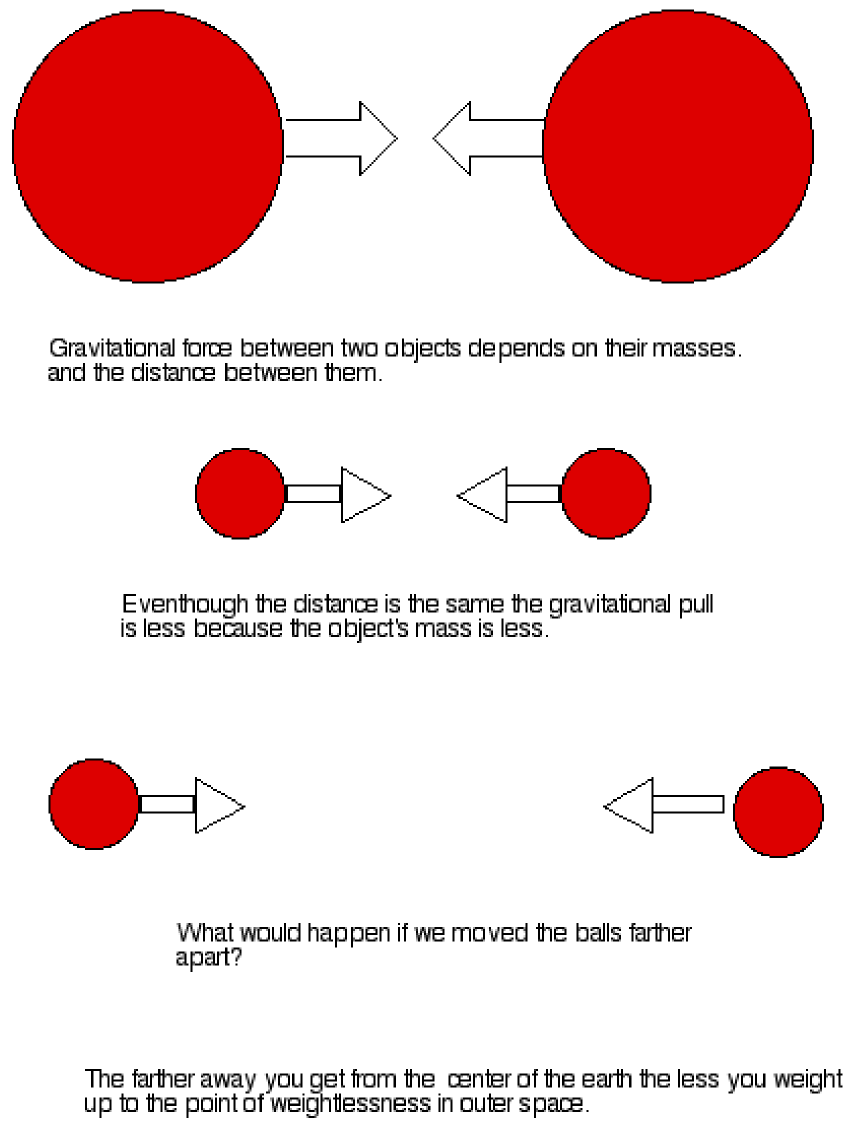
If the astronaut weighed 175 pounds on Earth, he would have weighed only 29 pounds on the moon. If his mass on Earth was 80 kg, what would his mass have been on the moon?

An object with more mass is pulled by gravity with greater force, so mass and weight are closely related. Even if the mass of an object stays the same, the weight of an object can change if the force of gravity changes. Look at the photo of astronaut Edwin E "Buzz". Aldrin Jr taken by fellow astronaut Neil Armstrong, the first human to walk on the moon. Aldrin weighed less on the moon than he did on Earth because the moon's gravity is weaker than Earth's. Aldrin's mass, on the other hand, did not change. He still contained the same amount of matter on the moon as he did on Earth.

Gravity

Gravity is the attraction between two masses. All objects that have mass also have a gravitational force. The larger the mass the more gravitational pull the object has. Even a tiny dust particle has gravity. Do you have gravity? Of course you do - but compared to Earth, your gravity does not affect many things around you. (This is why pencils don't "fall" toward you.) So now, which has more gravity, you or Earth?

Distance has an effect on gravity. Thinking about this, if you were an astronaut, and you went farther into space, why does your weight decrease? As your distance from Earth increases, the force of gravity between you and Earth decreases. When you are in space, gravity has less effect on your mass. Look closely at the diagram to help you understand this concept.



Structures that Support a Load

A load is anything that has mass. Cars, cats, and candy bars are examples of loads. Engineers design structures to support specific loads. Bridges are an example of structures that are designed to support loads.

The San Francisco Bay Bridge Construction

The San Francisco Bay Bridge did just that in the 1989 Loma Prieta earthquake! A section of the upper deck collapsed down onto the lower deck. Since then, engineers have been designing and building a new bridge that is more seismically safe: This link has information on the seismic upgrade of the Oakland Bay bridge.

FIGURE 4.13
Have you ever been worried while traveling over a bridge that might collapse?

- http://bit.ly/1ihRaGg

Can you design a seismically safe bridge?

Extension Investigation

Using the Bridge to Classroom's bridge simulator (http://bit.ly/1fFuRYN), build a model of your own that you think could withstand an earthquake.

1. Begin by looking at the various types of bridges (beam girder, steel arch, etc.). For each type of bridge, draw a sketch and describe its characteristics.
2. Decide which type of bridge you want for each segment of the bridge. Drag them into place.
3. For each of the safety features, draw a sketch and describe their characteristics.
4. Add safety features as necessary to your bridge.
5. Now, test your bridge! Select different fault lines and magnitudes. Record the results of your tests.
6. Go back and redesign to build a more seismically safe structure!
7. Now that you are familiar with the critical factors when designing a seismically safe structure and with the various bridge designs, create your own bridge! Using only toothpicks and glue, can you create a bridge that can withstand the most amount of shaking and support the most amount of weight?

Summary

- Mass is the measure of the amount of matter in an object.
- Weight is the measure of the pull of gravity on an object.
- Gravity is a universal attraction between objects that have mass.
- The amount of gravity an object has is related (directly) to its size, as size increases so does its amount of gravity and visa versa.
- The amount of gravity decreases as the distance between the objects increase and visa versa.

Think like a Scientist

1. What is the difference between weight and mass?

2. Explain why Jupiter has more gravity than Earth.
3. Explain why you would have the same mass on Jupiter but a different weight.

4.4 How Do Machines Make Work Easier?

Objectives

- Calculate the mechanical advantage created when using a lever.
- Describe how simple machines are used to create complex machines.
- Define friction and describe how it influences motion.

Simple Machines

Machines are devices that make work easier by changing the direction or strength of an applied **force - (a push or pull on an object)**. Complex machines are made of two or more simple machines. There are six basic simple machines: **lever, inclined plane, wheel and axle, pulley, wedges, and screws.**

Link to and interactive site on simple machines.

- http://cosi.org/downloads/activities/simplemachines/sm1.html

Lever

Did you ever use a hammer to pull a nail out of a board? If not, you can see how it's done in the photo. When you pull down on the handle of the hammer, the claw end pulls up on the nail. A hammer is an example of a lever. A lever is a simple machine consisting of a bar that rotates around a fixed point called the fulcrum. For a video introduction to levers using skateboards as examples, go to this link: http://bit.ly/1kn2BNR

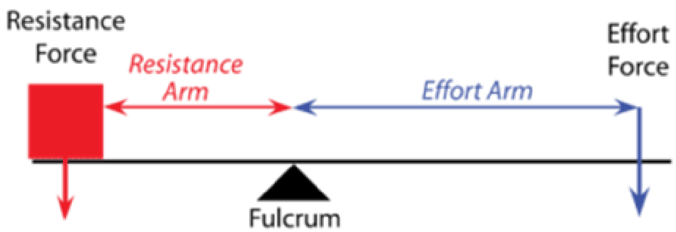
MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/179631

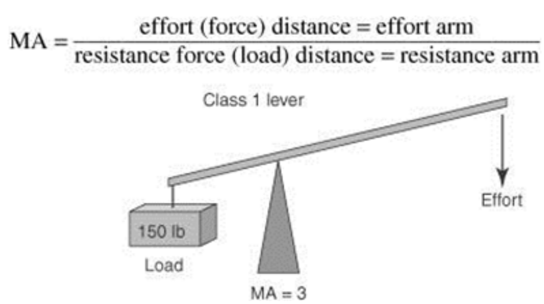
Using a hammer to remove a nail changes both the direction and strength of the applied force. Levers are an example of simple machines.

Levers have many components. The fulcrum is the pivot point of the lever. The load (or resistance) is whatever the lever is lifting. The resistance arm is the part of the lever that supports the load. The effort arm is the part of the lever where the force (the effort) is applied.



The longer the effort arm is, the easier it is to lift the load. In other words, the **mechanical advantage** of a lever is greater when the effort arm is longer. **Mechanical advantage** is the term used to describe how much the machine changes the effort required to lift or move a load. To calculate the **mechanical advantage of a lever**, simply divide the length of the effort arm by the length of the resistance arm.

$$\text{Mechanical Advantage } (ma) = \frac{(\text{Length of Effort Arm})}{(\text{Length of Resistance Arm})}$$



Inclined Planes

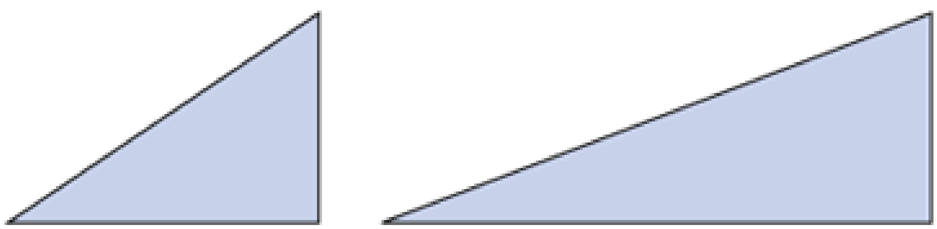
An inclined plane is a simple machine that consists of a sloping surface connecting a lower elevation to a higher elevation; in other words it is a ramp. An inclined plane is one of six types of simple machines, and it is one of the oldest and most basic. In fact, two other simple machines, the wedge and the screw, are variations of the inclined plane. A screw is an inclined plane wrapped around a post and a wedge is two inclined planes placed back to back. A screw-on lid is an example of a screw and an ax is an example of a wedge.

A ramp like the one in the figure is an example of an inclined plane. Inclined planes make it easier to move objects to a higher or lower elevation. The sloping surface of the inclined plane supports part of the weight of the object as it moves up the slope. The weight of the load is distributed over a longer distance therefore it takes less force to move the object uphill. This increases the mechanical advantage. The trade-off is that the object must be moved over a greater distance than if it were moved straight up to the higher elevation. You can see several other examples of inclined planes at this URL: http://bit.ly/1furJ3R

Q: Which inclined plane pictured has a greater mechanical advantage?

A: The inclined plane on the right has a more gradual slope, so it has a greater mechanical advantage. Less force is needed to move objects up the gentler slope, yet the objects attain the same elevation as they would if more force were used to push them up the steeper slope.

At the following URL, click on the inclined plane and go through the animation.



Q: Does the weaving back and forth of the road increase or decrease the mechanical advantage?

Wheel and Axle

Did you ever ride on a Ferris wheel, like the one pictured? If you did, then you know how thrilling the ride can be. A Ferris wheel is an example of a ***wheel* and *axle***. A **wheel and axle** is a simple machine that consists of two connected rings or cylinders, one inside the other, which both turn in the same direction around a single center point. The smaller, inner ring or cylinder is called the axle. The bigger, outer ring or cylinder is called the wheel. A car steering wheel is another example of a wheel and axle.

In a wheel and axle, force may be applied either to the wheel or to the axle. In both cases, the direction of the force does not change, but the force or distance is changed in a way to make the movement more useful.

When the input force is applied to the axle, as it is with a Ferris wheel, the wheel turns with less force. However, the wheel turns over a greater distance, so it turns faster than the axle. The speed of the wheel is one reason that the Ferris wheel ride is so exciting.

When the input force is applied to the wheel, as it is with a steering wheel, the axle turns over a shorter distance but with greater force. This allows you to turn the steering wheel with relatively little effort, while the axle of the steering wheel applies enough force to turn the car.

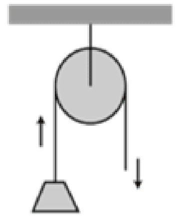
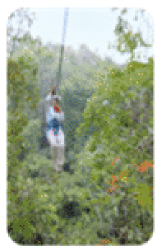
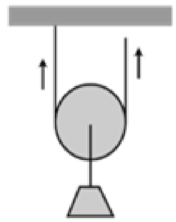
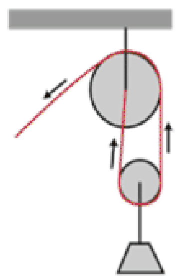
FIGURE 4.14
The highway in the picture switches back and forth as it climbs up the steep hillside. The much gentler slope of the road makes it easier for vehicles to reach the top of the mountain. The highway is an example of an inclined plane.

FIGURE 4.15
Both a Ferris wheel and a car steering wheel have an outer wheel and an inner axle.

Pulley

Another simple machine that uses a wheel is the pulley. A pulley is a simple machine that consists of a rope and grooved wheel. The rope fits into the groove in the wheel and pulling on the rope turns the wheel. The figure below shows two common uses of pulleys.

In both of these examples, pulling the rope turns the wheel of the pulley. Some pulleys are attached to a beam or other secure surface and remain fixed in place. Other pulleys are attached to the object being moved and are moveable themselves. Some pulley sets have multiple rope segments. Increasing the number of rope segments increased the total length of the rope being used. The more rope segments that are used to lift the load, the less force that is needed for the job and the greater the mechanical advantage.

Type of Pulley	Example	How it Works	No. of Rope Segments Pulling up	Ideal Mechanical Advantage	Change in Direction of Force?
Single fixed pulley	Flagpole pulley 		1	1	yes yes yes
Single movable pulley	Zip-line pulley 		2	2	no
Compound pulley (fixed & movable pulleys)	Crane pulley 		≥ 2	≥ 2	no

You can experiment with an interactive animation of compound pulleys with various numbers of pulleys at this link: http://bit.ly/1fiwDyJ **(requires Java, Google Chrome will not support it)**.

MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/179633

Complex Machines

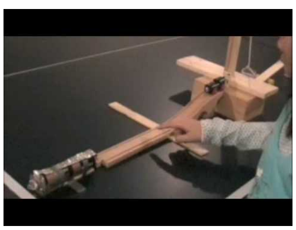
Did you ever look closely at the moving parts of a bicycle? Do you see any simple machines, such as pulleys, wheels and axles, levers, or screws? A bicycle consists of many simple machines combined together. It's an example of a **complex machine**.

Q: What simple machines can you identify in the bicycle parts pictured?

A **complex machine** is a machine that consists of more than one simple machine. Some complex machines consist of just two simple machines. You can read below about two examples—the wheelbarrow and corkscrew. Other

FIGURE 4.16
Single pulleys may be fixed or moveable. Compound pulleys consist of two or more pulleys.

complex machines, such as bicycles, consist of many simple machines. Big complex machines such as cars may consist of hundreds or even thousands of simple machines. You can see a student's complex machine invention that includes several simple machines at this URL: http://bit.ly/1eeC5WS



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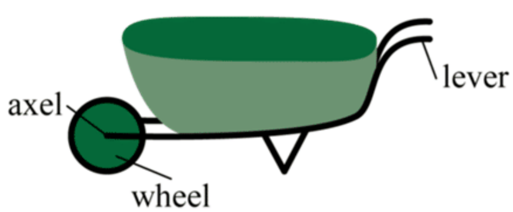
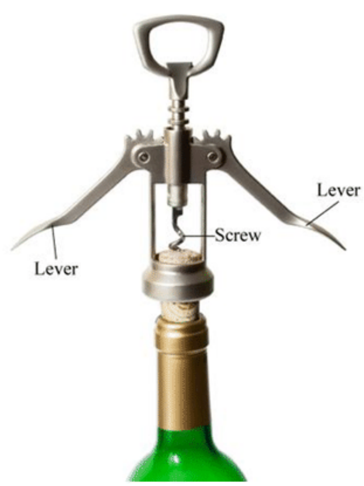
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/179633

Look at the wheelbarrow. It is used to carry heavy objects. It consists of two simple machines: a lever and a wheel and axle. Effort is applied to the lever by picking up the handles of the wheelbarrow. The lever, in turn, applies upward force to the load. The force is increased by the lever, making the load easier to lift. Effort is applied to the wheel of the wheelbarrow by pushing it over the ground. The rolling wheel turns the axle and increases the force, making it easier to push the load.





The corkscrew is also a complex machine. It is used to pierce a cork and pull it out of the neck of a bottle. It consists of a screw and two levers. Turning the handle on top twists the screw down into the center of the cork. Then, pushing down on the two levers causes the screw to pull upward, bringing the cork with it. The levers increase the force and change its direction.

Compared with simple machines, complex machines generally have lower efficiency but greater mechanical advantage.

Do the simple and complex machines quiz at the following URL. Be sure to check your answers

- http://bit.ly/1fFq8qg

Friction

Did you ever rub your hands together to warm them up? Why does this make your hands warmer? The answer is **friction**.

Friction is a force that opposes motion between two surfaces that are touching. Friction can work for or against us. For example, putting sand on an icy sidewalk increases friction so you are less likely to slip. On the other hand, too much friction between moving parts in a car engine can cause the parts to wear out.

FIGURE 4.17
Sometimes friction is useful. Sometimes it's not.

Friction occurs because no surface is perfectly smooth. Even surfaces that look smooth to the unaided eye appear rough or bumpy when viewed under a microscope. Look at the metal surfaces in the figure. The metal pipes are so smooth that they are shiny. However, when highly magnified, the surface of metal appears to be very bumpy. All those mountains and valleys catch and grab the mountains and valleys of any other surface that contacts the metal. This creates friction.

Rougher surfaces have more friction between them than smoother surfaces. That's why we put sand on icy sidewalks and roads. Increasing the area of surfaces that are touching also increases the friction between them. That's why you can't slide as far across ice with shoes as you can with skates. The greater surface area of shoes causes more friction and slows you down. Heavier objects also have more friction because they press together with greater force. Did you ever try to push boxes or furniture across the floor? It's harder to overcome friction between heavier objects and the floor than it is between lighter objects and the floor.

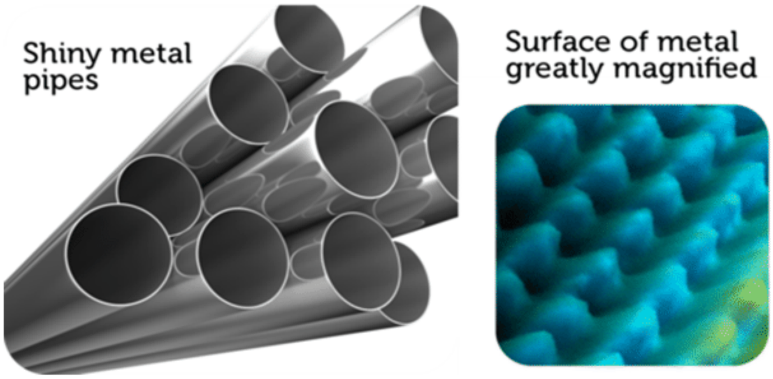


FIGURE 4.18
The surface of metal looks very smooth unless you look at it under a high-powered microscope.

FIGURE 4.19
The knife-like blades of speed skates minimize friction with the ice.

You know that friction produces heat. That's why rubbing your hands together makes them warmer (an energy conversion from mechanical to heat). But do you know why the rubbing produces heat? Friction causes the molecules on rubbing surfaces to move faster, so they have more heat energy. Heat from friction can be useful. It not only warms your hands. It also lets you light a match. On the other hand, heat from friction can be a problem inside a car engine. It can cause the car to overheat. To reduce friction, oil is added to the engine. Oil coats the surfaces of moving parts and makes them slippery so there is less friction.

FIGURE 4.20
When you rub the surface of a match head across the rough striking surface on the matchbox, the friction produces enough heat to ignite the match.

Summary

- A lever is a simple machine that consists of a bar that pivots on a fixed point called the fulcrum.
- An inclined plane is a simple machine that consists of a sloping surface connecting a lower elevation to a higher elevation. It is used to move objects more easily to the higher elevation.
- A wedge is a simple machine that consists of two inclined planes.
- A screw is a simple machine that consists of an inclined plane wrapped around a cylinder or cone.
- A wheel and axle is a simple machine that consists of two connected rings or cylinders, one inside the other, which both turn in the same direction around a single center point.
- A pulley is a simple machine that consists of a rope and grooved wheel.

- A complex machine is a machine that consists of more than one simple machine.
- Friction is a force that opposes motion between two surfaces that are touching. Friction is greater when objects have rougher surfaces, have more surface area that is touching, or are heavier so they press together with greater force.

Think like a Scientist

1. Describe an inclined plane.
2. Calculate the mechanical advantage of a lever with a 10 cm effort arm and a 2 cm resistance arm.
3. Give an example of a wheel and axle.
4. Identify three simple machines found in a car.
5. List three factors that affect friction.
6. A leaf rake is a type of lever. Where is the fulcrum and where are the input and output forces applied? Explain your answer.

Online Interactive Activities

- Students create use simple machines to create Rube Goldberg Devices. http://tinyurl.com/UT8th4-3a
- Students help Harry, a brown hairy creature, and Pic, a green pickle, use simple machines to build pyramids. http://tinyurl.com/UT8th4-3b
- Go to different rooms in a house and a shed and identify the simple machines in there. http://tinyurl.com/UT8th4-3c
- Connect simple machines to move a pink ball to the goal. http://tinyurl.com/UT8th4-3d
- Students manipulate masses on a first class lever. http://tinyurl.com/UT8th4-3e

Multimedia

MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/179634

- Construct a roller coaster from a limited assortment of pieces. http://tinyurl.com/UT8th4-3f

4.5 If a tree falls in a forest, and no one is around to hear it, does it make a sound?

What could these four photos possibly have in common? Can you guess what it is? All of them show things that have kinetic energy—energy of motion.

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.

Picture a diver standing at the end of the diving board, ready to dive. After she dives and is falling toward the water, she'll have kinetic energy, or the energy of moving matter. But even as she stands motionless high above the water, she has energy. Do you know why?

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. A sled at the top of a hill has potential energy. You can watch a cartoon introduction to gravitational potential energy by playing video at this URL: http://bit.ly/1iVljxX

The Cyclic Nature of Potential and Kinetic Energy

Mechanical energy commonly changes between kinetic and potential energy. Kinetic energy is the energy of moving objects. Potential energy is energy that is stored in objects, typically because of their position or shape. Kinetic energy can be used to change the position or shape of an object, giving it potential energy. Potential energy gives the object the potential to move. If it moves, the potential energy changes back to kinetic energy.

That's what happened to Sari. That's Sari coming down the water slide. When she was at the top of the slide, she had potential energy. Why? She had potential energy because she had the potential to slide into the pool. As she moved down the slide, her potential energy changed to kinetic energy. By the time she reached the pool, all the potential energy had changed to kinetic energy.

Q: How could Sari regain her potential energy?

A: Sari could climb up the steps to the top of the slide. It takes kinetic energy to climb the steps, and this energy would be stored in Sari as she climbed. By the time she got to the top of the slide, she would have the same amount of potential energy as before.

A pendulum is an excellent example of how an object can cycle between kinetic and potential energy. A roller coaster is another fun example of changes between kinetic and potential energy. Can you think of other fun examples of energy changing between kinetic and potential energy?

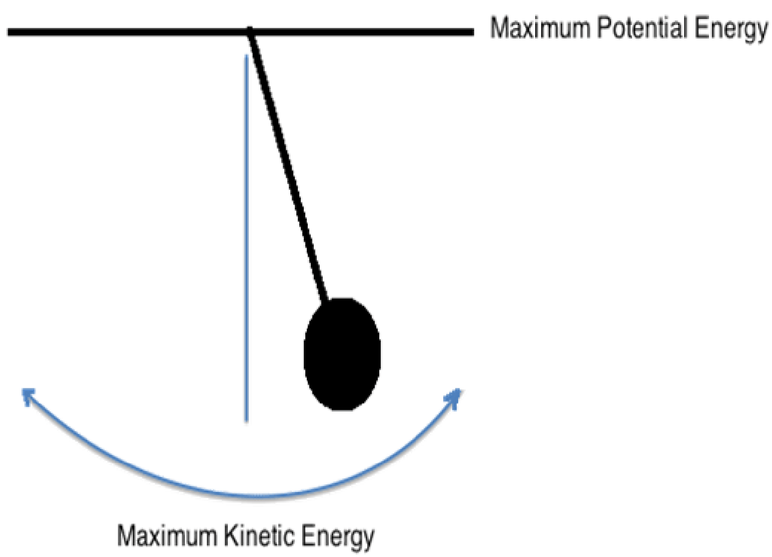


FIGURE 4.21
Playground equipment such as swings, slides, and trampolines also involve these changes.

Energy Conversions

There are many forms of energy. The most common forms are chemical-(energy stored in the bonds between atoms), heat (energy of the motion of atoms), electrical (energy of moving electrons), nuclear (energy stored in the nucleus of an atom), light (energy radiated in electromagnetic waves), and mechanical (energy of motion). Any of these forms of energy can be converted into any other form. For example, the electrical energy in wires is converted to light energy when a light switch is turned on. Often one form of energy is converted to two or more different forms. For example, the chemical energy found in wood is converted to light and heat energy when the wood is burned.

Can you trace the conversion of light energy from the sun to heat and mechanical energy in the body of an organism? The sun's light energy is converted to chemical energy by plants during photosynthesis. When an animal consumes a plant, the chemical energy in the plant is converted to heat and mechanical energy during respiration.

Energy is always conserved in energy conversions which means that energy is not created or destroyed. This is called the Law of Conservation of Energy.

Summary

- Kinetic energy is energy of motion and potential energy is energy of position or shape. Mechanical energy commonly changes back and forth between kinetic and potential energy.

- Different forms of energy—such as electric, chemical, light, nuclear, mechanical and heat energy—often change forms. Energy conversion is the process in which energy changes from one form to another. Energy is always conserved in energy conversions.

Think like a Scientist

1. What is the difference between kinetic and potential energy?
2. Which has the most potential energy, a rock on the top of a 1000 m mountain or the same rock on top of a 5000 m mountain? Explain your answer.
3. Define energy conversion.
4. Trace the energy conversion that occurs when a flashlight is turned on. (**Hint:** Flashlight batteries have chemical energy.)
5. Explain how energy changes back and forth between kinetic and potential energy when you jump on a trampoline. Include a sketch to help explain the energy conversions.

4.6 How Do Organisms Sense Energy?

The noise of a cheering crowd at a game can be deafening! Really. The light from the sun can be blinding. The heat from boiling oil can be incredibly painful. Energy, in its many forms, surrounds us.

Organisms have various ways to sense the energy that surrounds them. Plants sense light energy and respond by growing towards it. Snakes' pit organs sense heat energy from prey. Worms can sense vibrations in the Earth. Dogs' ears can sense sounds that human ears cannot hear. Our skin senses heat energy and our taste buds respond to chemical energy.

FIGURE 4.22
Engineers have developed devices to help us sense various forms of energy.

The telescope is an example of a device developed by engineers to help us sense light. Much of what has been learned about space since Galileo has been through a telescope. Although astronomers use very large telescopes, many of which pick up wavelengths of energy other than visible light, there is still much to be gained from looking at the planets and stars on a clear night.

Other examples of inventions that help us sense energy are:

- Seismographs sense the energy released during Earthquakes.

- Eyeglasses and contact lenses help people better focus the light energy that enters their eyes.
- Hearing aids amplify sound waves which helps many people hear.

Summary

- Organisms sense energy in many ways. Engineers have developed devices that help us sense various types of energy.

Think like a Scientist

1. Give three examples of how organisms sense energy.
2. Give three examples of devices developed by engineers help us sense energy.

4.7 References

1. . http://www.uen.org/core/science/sciber/sciber8/stand-4/gravity.shtml .

CONCEPT 5 Glossary - 8th Grade

Chapter 1

Atoms: are the smallest particles of an element that still have the element's properties. They are the building blocks of matter.

Chemical change: occurs whenever matter changes into an entirely different substance with different chemical properties. A chemical change is also called a chemical reaction.

Chemical energy: is energy that is stored in the bonds between atoms in a chemical substance.

Chemical equation: a symbolic representation of a chemical reaction with the reactants on the left side and the products on the right side of the equation.

Chemical property: describes the ability of a substance to undergo a specific chemical change.

Chemical reaction: a process in which some substances change into different substances.

Combustion: a chemical change, especially oxidation, accompanied by the production of heat and light; the act of burning.

Condensation: the process in which water vapor—or another gas—changes to a liquid when energy is removed.

Corrosion: is the gradual deterioration of materials, (usually metals), by chemical reactions within the environment.

Density: is a physical property of matter. It is defined as a substance's mass per unit volume.

Deposition: is the process in which a gas changes directly to a solid without going through the liquid state.

Element: the simplest form of matter that has a unique set of properties.

Energy: ability to do work; the ability to move matter or change matter in some other way.

Evaporation: is the process in which a liquid changes to a gas without becoming hot enough to boil.

Flammability: is the ability of matter to burn.

Freezing: is the process in which water or any other liquid changes to a solid.

Law of Conservation of Mass: in a given chemical reaction, the mass of the products is equal to the mass of the reactants.

Mass: is the amount of matter in a substance or object.

Matter: is anything that has mass and volume.

Melting: occurs when a solid absorbs enough energy to change phase and become a liquid.

Molecules: are two or more atoms bonded together to create a new substance with unique properties.

Photosynthesis: is the process that uses light energy from the sun, together with carbon dioxide and water, to make glucose and oxygen.

Physical change: a change in one or more physical properties of matter without any change in chemical properties.

Physical property: properties of matter that can be measured or observed without matter changing to an entirely different substance. Physical properties are typically things you can detect with your senses.

Products: the substances produced in a chemical reaction.

Rate of reaction: refers to the speed at which a chemical reaction takes place.

Reactants: the starting substances in a chemical reaction.

Reactivity: is the ability of substances to undergo chemical reactions and release energy either by reacting with themselves or with other materials.

Respiration: is the process in which the cells of living things break down the organic compound glucose with oxygen to produce carbon dioxide and water.

Sublimation: occurs when a solid absorbs enough energy to change directly to a gas without going through the liquid phase.

Temperature: is a measure of the average kinetic energy of the particles of matter in a substance.

Volume: is the amount of space that a substance or an object takes up.

Chapter 2

Capacity: the number of organisms an ecosystem can support.

Cellular respiration: is the process in which the cells of living things break down the organic compound glucose with oxygen to produce carbon dioxide, water and energy.

Chemical energy: that is energy is stored in the connections between chemical bonds between atoms in a chemical substance.

Commensalism: relationship in which one species benefits while the other species is not affected.

Competition: two or more species trying to use the same resource(s).

Consumer: organism that must eat or consume other organisms to obtain energy and nutrients.

Decomposer: organism that obtains nutrients and energy by breaking down dead organisms and animal wastes.

Desertification: when a land region becomes more arid, losing its bodies of water as well as vegetation and wildlife.

Ecosystem: a community of living organisms and their interaction with non-living components within an environment.

Environment: the living and non-living factors interacting in a particular area.

Evidence: data collected by observation and/or measurement.

Extinction: when there are no living members of a species left on Earth.

Food chain: diagram that shows feeding interactions in an ecosystem through a single pathway.

Food web: diagram that shows feeding interactions between many organisms in an ecosystem through multiple intersecting pathways.

Glucose: simple sugar molecule with the chemical formula $C_6H_{12}O_6$.

Habitat: the physical area where a species lives.

Inference: an explanation of evidence that is based on knowledge and experience.

Invasive-species: a species introduced into a habitat where they do not naturally occur.

Mechanical energy: is the energy to move-the energy of motion.

Mutualism: relationship in which both species benefit.

Parasitism: relationship in which one species benefits while the other species is harmed.

Photosynthesis: is the process that uses light energy from the sun, together with carbon dioxide and water, to make glucose and oxygen.

Predator: consumer that hunts and kills another consumer.

Prey: species that is hunted and killed by another species.

Producer: organism that can absorb the energy of the sun and convert it into food through the process of photosynthesis; i.e., plants and algae.

Solar energy: energy that comes from the Sun.

Wetland: an area that is saturated with water or covered by water for at least one season of the year.

Chapter 3

Breakage: how a mineral breaks, for example cleavage or fracture.

Color: the color of a mineral observed by the human eye.

Continental Drift: the theory that tectonic plates have slowly moved.

Cooling: process responsible for turning lava into igneous rock.

Crystal: solid in which all the atoms are arranged in a regular, repeating pattern.

Crystallization: the process of becoming a crystal.

Density: amount of mass in a given volume of matter; calculated as mass divided by volume.

Deposition: a process where sediment is added to land masses.

Earthquake: vibrations released due to movement of the Earth's tectonic plates.

Erosion: the movement of sediments by water, air, gravity.

Fault: a fracture in Earth's surface.

Fossils: the remains or traces of living organisms formed mostly of the hard parts of organism.

Geology: the study of rocks, minerals, and their history.

Hardness: minerals ability to resist scratching.

Igneous: rock that forms when magma cools.

Index fossil: is a fossil used to identify a geological time period.

Luster: describes the way a mineral reflects light.

Magma: plastic like rock found deep in the Earth's interior.

Metamorphic: rock that forms when another rock is changed by heat and/or pressure.

Metamorphism: changes in rock due to intense pressure and heat (does not melt).

Minerals: naturally occurring inorganic, crystalline solid with a characteristic chemical composition.

Paleontology: the study of fossils and organic remains found in rock material.

Relative Age: determining the age or rocks in comparison to other rocks.

Rock: a collection of minerals but may be made of materials that are not minerals.

Rock cycle: never ending cycle in which one rock type turns into another.

Sediment: small particle of soil or rock deposited by wind or water.

Sedimentary: rock that forms from sediments that are compacted and/or cemented together, or from the precipitation of material from a liquid.

Sedimentation: the deposition of sediment from a fluid forming layers.

Streak: color of powder left by rubbing a mineral on a hard surface.

Volcano: an opening in earth surface; or vent, from which lava and gases escape.

Weathering: is the process that changes solid rock into sediments.

Chapter 4

Amplitude: the maximum distance the particles of a medium move from their resting position when a wave passes through.

Complex machines: a machine that utilizes two or more simple machines. (inclined plane, wedge, screw, lever, wheel and axle).

Conduction: is the transfer of thermal energy between particles of matter that are touching.

Convection: the transfer of thermal energy by particles moving through a fluid.

Crest: the highest point on a wave.

Energy: the ability to do work or cause a change.

Force: a push or a pull on an object.

Frequency: the number of waves that pass a fixed point in a given amount of time.

Friction: a force that opposes motion. The force that one surface exerts on another when the two rub against each other.

Gravity: the invisible force that pulls objects toward each other.

Hertz: a measure of a frequency of a wave. One hertz is equal to one wave per second.

Inclined Plane: a simple machine.

Kinetic energy: energy of movement or motion.

Lever: a simple machine consisting of a bar that rotates around a fixed point.

Machine: a device that makes work easier.

Medium: the substance through which a wave travels.

Potential energy: energy that is stored and held in readiness.

Radiation: is the transfer of energy by waves that can travel through empty space.

Screw: a simple machine that consists of an inclined plane wrapped around a central cylinder.

Simple Machine: a machine made of one or possibly two parts that makes work easier.

Trough: the lowest point on a wave.

Wave: a disturbance that transfers energy from place to place.

Wavelength: the distance between two corresponding points on adjacent waves.

Wedge: simple machine that consists of two inclined planes, giving it a thin end and thick end.

Wheel and axle: a simple machine that consists of two connected rings or cylinders, one inside the other which turn in the same direction around a single center point. The inner ring or cylinder is called the axle, and the outer one is called the wheel.