
INTEGRATED SCIENCE

# CREDITS

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We also thank the amazing Utah science teachers whose collaborative efforts made the book possible. Thank you for your commitment to science education and Utah students!

Cover photo by Corrine Beaumont, PhD

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**IT'S YOUR LEARNING, IT'S YOUR BOOK. ENJOY.**

This space on the edge of each page is your space for drawing, taking notes and making the book your own.

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b) 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).
c) Investigate and report on the chemical and physical properties of a particular substance.

Objective 2: Observe and evaluate evidence of chemical and physical change. (P. 19)

a) Identify observable evidence of a physical change (e.g., change in shape, size, phase).
b) Identify observable evidence of a chemical change (e.g., color change, heat or light given off, change in odor, gas given off).
c) Observe and describe chemical reactions involving atmospheric oxygen (e.g., rust, fire, respiration, photosynthesis).
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d) Research multiple ways that different scientists have investigated the same ecosystem.

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a) 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).
b) Distinguish between inference and evidence in a newspaper or magazine article relating to the effect of humans on the environment.
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e) Engineer (design and build) a machine that uses gravity to accomplish a task.

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c) Engineer a device that uses friction to control the motion of an object.
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b) Trace the conversion of energy from one form of energy to another (e.g., light to chemical to mechanical).
c) Cite examples of how organisms sense various types of energy.
d) 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).
e) Investigate and describe how engineers have developed devices to help us sense various types of energy (e.g., seismographs, eyeglasses, telescopes, hearing aids).

# CHAPTER 1

# MATTER

# WHAT DO YOU AND A TINY SPECK OF DUST IN OUTER SPACE HAVE IN COMMON?

THINK YOU KNOW THE ANSWER?
READ CHAPTER ONE: "MATTER" TO FIND OUT.

# LET'S BEGIN!

## MATTER

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

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

## LESSON OBJECTIVES

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


## VOCABULARY

- chemical property
- density
- flammability
- mass
- matter
- physical property
- reactivity
- volume

## Introduction:
# What Is Matter?

Both you and a speck of dust consist of atoms of matter. So does the ground beneath your feet. In fact, everything you can see and touch is made of matter. The only things that aren't matter are forms of energy, such as light 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 and volume.*

### Mass

***Mass*** is the amount of matter in a substance or object. Mass is commonly measured with a balance. A simple mechanical balance is shown in Figure below. It allows an object to be matched with other objects of known mass. SI units for mass are the kilogram, but for smaller masses grams are often used instead.

This balance shows one way of measuring mass. When both sides of the balance are at the same level, it means that objects in the two pans have the same mass.

The amount of space matter takes up is its volume. How the volume of matter is measured depends on its state.

***The volume of liquids*** is measured with measuring containers. In the kitchen, liquid volume is usually measured with measuring cups or spoons. In the lab, liquid volume is measured with containers such as graduated cylinders. Units in the metric system for liquid volume include liters (L) and milliliters (mL).

***The volume of gases*** depends on the volume of their container. That's because gases expand to fill whatever space is available to them. For example, as you drink water from a bottle, air rushes in to take the place of the water. An "empty" liter bottle actually holds a liter of air. How could you find the volume of air in an "empty" room?

***The volume of regularly shaped solids*** can be calculated from their dimensions. For example, the volume of a rectangular solid is the product of its length, width, and height ($l \times w \times h$). For solids that have irregular shapes, the displacement method is used to measure volume. You can see how it works in Figure below and in the video below. The SI unit for solid volumes is cubic meters ($m^3$). However, cubic centimeters ($cm^3$) are often used for smaller volume measurements.

**http://www.youtube.com/watch?v=q9L52maq_vA**

### Physical Properties of Matter

Matter has many properties. Some are physical properties. Physical properties of matter are properties that can be measured or observed. 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 if it freezes and changes to ice, it is still water. Generally, physical properties are things you can see, hear, smell, or feel with your senses.

### Examples of Physical Properties

Physical properties include the state of matter and its color and odor. For example, oxygen is a colorless, odorless gas. Chlorine is a greenish gas with a strong, sharp odor. Other physical properties include hardness, freezing and boiling points, the ability to dissolve in other substances, and the ability to conduct heat or electricity. These properties are demonstrated in Figure 1. Can you think of other physical properties?


Figure 1. These are just a few of the physical properties of matter.

## Density

Density is an important physical property of matter. 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 Solving

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

*Solution:*
You Try It!

$$D = 20 \text{ g}/10 \text{ mL} = 2.0 \text{ g/mL}$$

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

To better understand density, think about a bowling ball and 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 air. 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 denser.

### 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. They include flammability and reactivity.

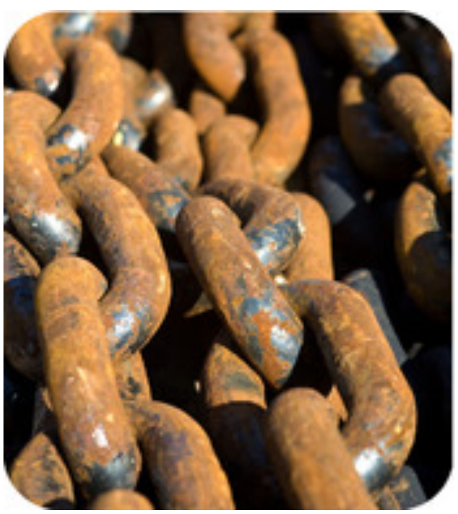
### Flammability

Flammability is the ability of matter to burn. Wood is flammable; iron is not. 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 matter to combine chemically with other substances. For example, iron is highly reactive with oxygen. When it combines with oxygen, it forms the reddish powder called rust (see Figure below). Rust is not iron but an entirely different substance that consists of both iron and oxygen.

The iron in this steel chain has started to rust.



# LESSON 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.

# LESSON REVIEW QUESTIONS

Recall

1. Define matter.

2. Identify two physical properties and two chemical properties of matter.

Apply Concepts

3. Create a table comparing and contrasting physical properties of tap water and table salt.

4. Apply the concept of density to explain why oil floats on water.

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?

# STANDARD 1, OBJECTIVE 2: OBSERVE AND EVALUATE EVIDENCE OF CHEMICAL AND PHYSICAL CHANGE

### Lesson 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). 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.

FIGURE 1: When glass breaks, its physical properties change. Instead of one solid sheet of glass, it now has holes and cracks.

### Physical Changes in Matter

A physical change in matter is a change in one or more of matter's physical properties but the identity of the matter does not. Glass breaking is just one example of a physical change. Some other examples are shown in Figure below and in the video (see link below). 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.

### Vocabulary

- chemical change
- physical change
- combustion
- corrosion

Cutting a log into smaller pieces changes its size and shape, but it's still wood.

Braiding hair changes how the strands are arranged but not their other properties.

Crushing a metal can changes its shape. But the crushed can is still made of metal and has the same properties, such as the ability to conduct heat.

Crisp squares of chocolate melt into a shapeless puddle in the heat. The puddle tastes yummy because it's still chocolate.

Wind-blown sand has worn away this rock to create an arch, but the rock's composition has not changed. The bits of rock worn away by the wind still contain the same minerals as they did when they were part of the large rock.

FIGURE 2: In each of these changes, only the physical properties of matter change. The chemical properties remain the same.

http://www.youtube.com/watch?v=Cne9ncSaN5c

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 again. Melted chocolate can be put in a fridge to re-harden. Dissolving salt in water is also a physical change. How do you think you could undo it?

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 reconstituted into the same piece of wood that it was before. Cutting the grass or pulverizing a rock would be other 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 occurs whenever matter changes into an entirely different substance with different chemical properties. A chemical change 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:
**http://www.youtube.com/watch?v=BqeWpywDuiY**

### 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 loud sounds. Examples of chemical changes that produce these clues are shown in the Figure 3.

How can you tell whether a chemical change has occurred? Often, there are clues. Several are demonstrated in the video below.
**http://www.youtube.com/watch?v=gs0j1EZJ1Uc**

Fireworks produce heat, light, and loud sounds. These are all signs of chemical change. You can learn how fireworks produce these signs of chemical change at this URL:
**http://www.scifun.org/chemweek/fireworks/fireworks.htm**


FIGURE 3: Evidence that a chemical change has taken place.

### 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 (O2). For example, in the Figure 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 (CO2) and water vapor (H2O). The reaction typically gives off heat and light as well.

FIGURE 6: The burning of charcoal is a combustion reaction.

Another combustion reaction involves magnesium. Watch as it reacts with oxygen to form magnesium oxide.

**http://www.youtube.com/watch?v=EZ3JT2nWfMA**

Another type of reaction that requires atmospheric oxygen is known as an oxidation reaction.  When exposed to air, an object made of iron will eventually begin to rust (**Figure** 7).

FIGURE 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 is clearly a substance that is different from iron. Rusting is an example of a chemical change that requires atmospheric oxygen known as corrosion.  This type of reaction happens to several different types of metals including the pennies.

### Reversing Chemical Changes

Because chemical changes produce new substances, they often cannot be 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.

## Lesson 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 leaves changing color in the fall.
- 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.

## Lesson Review Questions

1. What is a physical change in matter?
2. What happens during a chemical change in matter?
3. List five evidences of a chemical change.

## Apply Concepts

4. When a plant grows, its mass increases over time. Does this mean that new matter is created? Why or why not?
5. 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?

## Think Critically

6. Compare and contrast physical and chemical changes in matter. Give an example of each type of change.
7. Points to Consider
8. Some physical changes in matter are changes of state.
9. What are the states of matter?
10. What might cause matter to change state?

*Opening image courtesy of Don Eigler, IBM Almaden Research Center http://www.nisenet.org/scientific-images/quantum_corral_side_view. This image is for non-profit educational use only.*

# Standard 1, 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.

## Lesson 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. Where did the water come from? It was there all along in the form of invisible water vapor.

## Vocabulary

- condensation
- deposition
- evaporation
- freezing
- melting
- sublimation
- temperature
- vaporization

Both of these pictures of Mount Rushmore were taken on the same day just a few hours apart. Where did the clouds come from in the picture on the right? Photos from http://www.flickr.com/photos/jamiedfw/445506874/ and http://www.flickr.com/photos/uhuru1701/2247554641/

# ENERGY AND STATES OF MATTER

These neat rows of cola bottles represent matter can in three different states—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. It gives cola its fizz. 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. What explains these differences in states of matter? The answer has to do with energy.

### Moving Matter

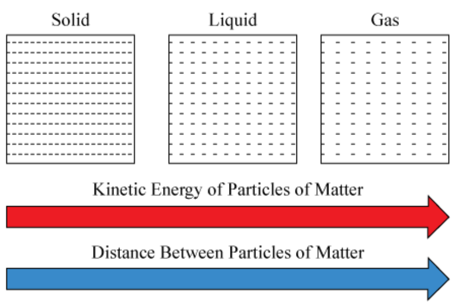
Energy is the ability to cause changes in matter. For example, your body uses chemical energy when you lift your arm or take a step. In both cases, energy is used to move matter—you. Any matter that is moving has energy just because it's moving. The energy of moving matter is called kinetic energy. Scientists think that the particles of all matter are in constant motion. In other words, the particles of matter 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://www.youtube.com/watch?v=Agk7_D4-deY.**

### 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 state of matter.

- If particles do not have enough kinetic energy to overcome the force of attraction between them, matter exists as a solid. 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.
- If particles have enough kinetic energy to partly overcome the force of attraction between them, matter exists as a liquid. The particles can slide past one another but not pull apart completely. This explains why liquids can change shape but have a fixed volume.
- If particles have enough kinetic energy to completely overcome the force of attraction between them, matter exists as a gas. 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 sums up visually the relationship between kinetic energy and state of matter. You can see an animated diagram at this URL: **http://www.tutorvista.com/content/physics/physics-i/heat/kinetic-molecular-theory.php**

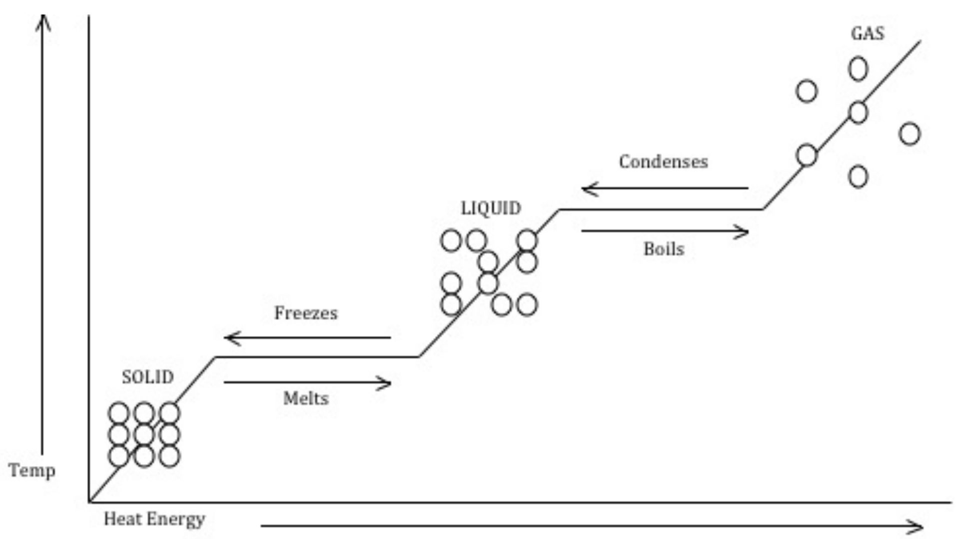



## What Are Changes of State?

Changes of state are physical changes in matter. They are reversible changes that do not involve changes in matter's chemical makeup or chemical properties. Common changes of state include melting, freezing, sublimation, deposition, condensation, and vaporization. These changes are shown in **Figure** below. Each is described in detail below.

## Energy, Temperature, and Changes of State

Energy is always involved in changes of state. Matter either loses or absorbs energy when it changes from one state to another. For example, when matter changes from a liquid to a solid, it loses energy. 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. The amount of energy in matter can be measured with a thermometer. That's because a thermometer measures temperature, and **temperature** is the average kinetic energy of the particles of matter. You can learn more about energy, temperature, and changes of state at this URL: **http://hogan.chem.lsu.edu/matter/chap26/animate3/an26_035.mov.**




Which process changes a solid to a gas? Which process changes a gas to a solid?
Image courtesy of Ricky Scott

### Changes Between Liquids and Solids

Think about how you would make ice cubes in a tray. First you would fill the tray with water from a tap. Then you would place the tray in the freezer compartment of a refrigerator. The freezer is very cold. What happens next?

### 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. Instead, they remain in fixed positions, locked in place by the forces of attraction between them. The liquid water has changed to solid ice. Another example of liquid water changing to solid ice is pictured in Figure below.

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?

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. The 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. What is the melting point of ice? What is the melting point of iron, pictured in Figure below?

Molten (melted) iron is poured into a mold at a foundry. It takes extremely high temperatures to change iron from a solid to the liquid shown here. That's because iron has a very high melting point.

## Changes Between Liquids and Gases

If you fill a pot with cool tap water and place the pot on a hot stovetop, the water heats up. Heat energy travels from the stovetop to the pot, and the water absorbs the energy from the pot. What happens to the water next?

### Vaporization

If water gets hot enough, it starts to boil. Bubbles of 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 process in which a liquid boils and changes to a gas is called vaporization. The temperature at which a liquid boils is its boiling point. The boiling point of water 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 also 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 Figure below. 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 if the sky remains cloudy.

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

### Condensation

If you take a hot shower in a closed bathroom, the mirror is likely to "fog" up. The "fog" consists of tiny droplets of water that form on the cool surface of the mirror. Why does this happen? Some of the hot water from the shower evaporates, so the air in the bathroom contains a lot of water vapor. When the water vapor contacts cooler surfaces, such as the mirror, it cools and loses energy. The cooler water particles no longer have enough energy to overcome the forces of attraction between them. They come together and form droplets of liquid water.

The process in which a gas changes to a liquid is called condensation. Other examples of condensation are shown in Figure below. A gas condenses when it is cooled below its boiling point. At what temperature does water vapor condense?

Water vapor condenses to form liquid water in each of the examples pictured here.

Water vapor in the air condenses on cool blades of grass, forming dewdrops.

A cold drink "sweats" on a warm day when water vapor in the warm air condenses on the cold glass.

Clouds form when water vapor in the air condenses on dust particles in the atmosphere.

## Changes Between Solids and Gases

Solids that change to gases generally first pass through the liquid state. However, sometimes solids change directly to gases and skip the liquid state. The reverse can also occur. Sometimes gases change directly to solids.

## Sublimation

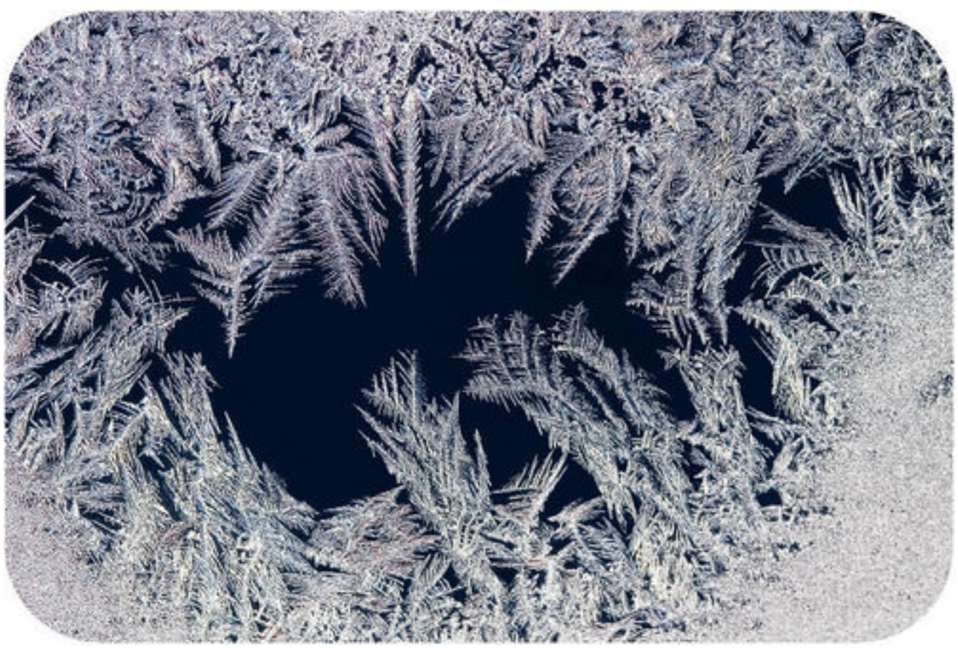
The process in which a solid changes directly to a gas is called sublimation. It occurs when the particles of a solid absorb enough energy to completely overcome the force of attraction between them. Dry ice (solid carbon dioxide, CO2) is an example of a solid that undergoes sublimation. Figure right shows chunks of dry ice in water changing directly to carbon dioxide gas. Sometimes snow undergoes sublimation as well. This is most likely to occur on sunny winter days when the air is very dry. What gas does snow become?


Solid carbon dioxide changes directly to the gaseous state.

### Deposition

The opposite of sublimation is deposition. This is the process in which a gas changes directly to a solid without going through the liquid state. It occurs when gas particles become very cold. For example, when water vapor in the air contacts a very cold windowpane, the water vapor may change to tiny ice crystals on the glass. The ice crystals are called frost. You can see an example in Figure below.

Frost is solid water that forms when water vapor undergoes deposition.



# LESSON 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.
- Processes in which matter changes between liquid and gaseous states are vaporization, evaporation, and condensation.
- Processes in which matter changes between solid and gaseous states are sublimation and deposition.

# LESSON REVIEW QUESTIONS

Recall

6. Identify the processes involved in changes of state between liquids and solids.
7. Define vaporization and evaporation. State how the two processes differ.
8. What is sublimation? Give an example.
9. Define deposition. When does it occur?

Apply Concepts

10. Cliff opened the oven door to check on the cake he was baking. As hot, moist air rushed out of the oven, his eyeglasses steamed up. Explain why.

Think Critically

11. Explain the role of energy in changes of state.
12. Form a hypothesis to explain why the melting points of different solids vary.

Points to Consider

In this chapter, you read that atoms and molecules of the same kind of matter have forces of attraction between them. Atoms consist of even smaller particles. These particles are held together by certain forces as well.

13. What are the particles that make up atoms?
14. What forces might hold them together?

Activity and simulation to support this section:

http://phet.colorado.edu/en/simulation/states-of-matter
http://concord.org/activities/melting-ice

# STANDARD 1, OBJECTIVE 4: IDENTIFY THE OBSERVABLE FEATURES OF CHEMICAL REACTIONS.

### Lesson 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 chemical reactions take place in labs. However, most chemical reactions do not. 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. Substances that start a chemical reaction are called reactants. Substances that are produced in the reaction are called products. Chemical reactions are represented by chemical equations in which reactants (on the left) are connected by an arrow to products (on the right).

### Reactants → 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 below. 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 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 $CO_2$.

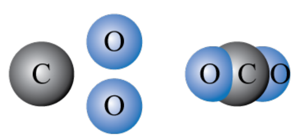



FIGURE 1: In this reaction, carbon reacts with oxygen to produce carbon dioxide.

### Vocabulary

- chemical equation
- products
- reactants
- law of conservation of mass
- reaction rate

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:

$C + O2 \rightarrow CO2$

### 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.

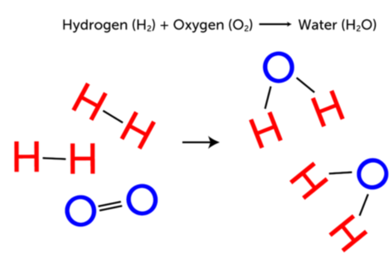



FIGURE 2: Breaking bonds in the reactants and making bonds to form products in a chemical reaction.

Figure 2 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 breath.

### 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). The charcoal pictured above consists of hydrocarbons. So do fossil fuels such as natural gas. 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 (CH4). You can see a methane flame in the Figure. The combustion of methane is represented by the equation:

$CH4 + 2O2 \rightarrow CO2 + 2H2O$

FIGURE 3: 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 the wood in Figure 4 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.

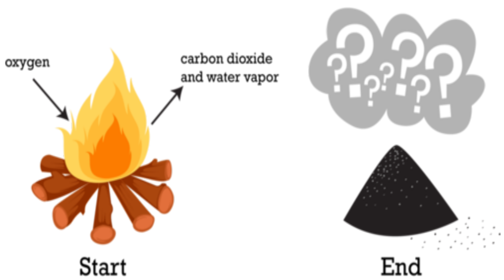



FIGURE 4: Burning is a chemical process. Is mass destroyed when wood burns?

### 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. This is the process in which plants and certain other organisms synthesize glucose ($C_6H_{12}O_6$). The process uses carbon dioxide and water and also produces oxygen. The overall chemical equation for photosynthesis is:

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

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). For a fantastic rap about photosynthesis, go to this URL:
**http://www.youtube.com/watch?v=Wi60tQa8jfE**

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:

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

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).

### Energy Changes in Cellular Respiration

The reactions of cellular respiration are catabolic reactions. In catabolic reactions, bonds are broken in larger molecules and energy is released. In cellular respiration, bonds are broken in glucose, and this releases the chemical energy that was stored in the glucose bonds. Some of this energy is converted to heat. The rest of the energy is used to form many small molecules of a compound called adenosine triphosphate, or ATP. ATP molecules contain just the right amount of stored chemical energy to power biochemical reactions inside cells.

You can learn more about photosynthesis and cellular respiration in the video at this URL:
**http://www.youtube.com/watch?v=JyMfKP1D7OE**

### Following the Law

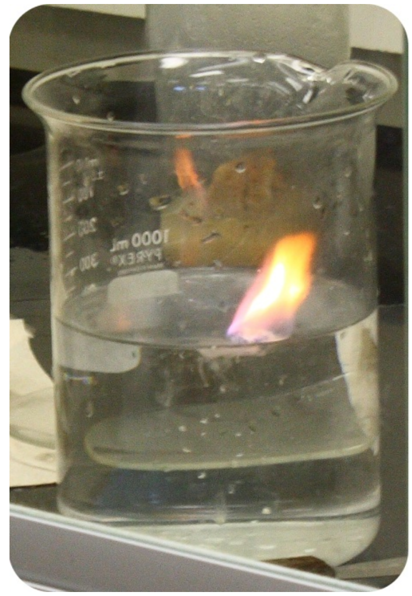
Why must chemical equations have the same number and kind of atoms in the products that were present in the reactants? It's the law! Matter cannot be created or destroyed in chemical reactions. This is the law of conservation of mass. In every chemical reaction, the same mass of matter must end up in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

### Lavoisier and Conservation of Mass

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 below. 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. You can learn more about Lavoisier and his important research at: **http://www.youtube.com/watch?v=x9iZq3Zxb08**

Antoine Lavoisier.

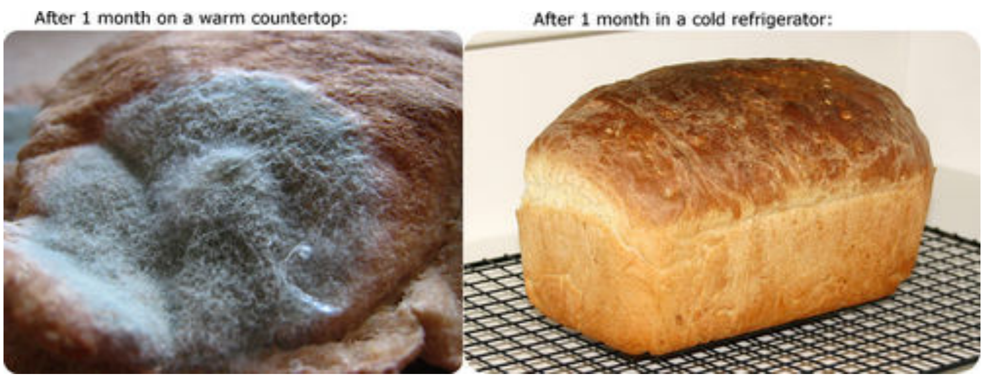
### How Fast Does It Go?



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. How fast a chemical reaction occurs is called the reaction rate. 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.

At the following URL, you can see animations showing how these factors affect the rate of chemical reactions. **http://www.kentchemistry.com/links/Kinetics/FactorsAffecting.htm**




### 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 on the left in the Figure 5). This is why we store foods in the refrigerator or freezer (like the bread on the right above in the Figure 6). 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 7? You might see it where someone is using a tank of pure oxygen for a breathing problem. 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: It is dangerous to smoke or use open flames when oxygen is in use. Can you explain why?**

**A: Because of the higher-than-normal concentration of oxygen, the flame of a match, lighter, or cigarette could spread quickly to other materials or even cause an explosion.**


FIGURE 7: High concentrations of oxygen in oxygen tanks used by patients are very flammable.

### 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 reaction rate. 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 8: 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.

# CHAPTER 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.

# REVIEW QUESTIONS

Practice

Chemical changes always result in the. Physical changes do not. Do the interactive lab at the following URL to see if you can identify the chemical changes.

http://vital.cs.ohiou.edu/steamwebsite/downloads/ChangeLab.swf

Watch the video about reaction rate at the following URL, and then answer the questions below.
http://www.youtube.com/watch?feature=endscreen&NR=1&v=F-Cu_AoWOK4

1. What is collision theory?
2. How does collision theory relate to factors that affect reaction rate?

Review

3. What happens in any chemical change?
4. List three signs that a chemical change has occurred.
5. Give an example of a chemical change. Explain why you think it is a chemical change.
6. Why can chemical changes often not be reversed?
7. Define reaction rate.
8. List factors that influence the rate of a chemical reaction.
9. Choose one of the factors you listed in your answer to question 2, and explain how it affects reaction Points to Consider
10. The physical and chemical properties of substances can be used to identify them. That's because different kinds of matter have different properties.
11. What property could you use to tell the difference between iron and aluminum?
12. How could you tell whether a liquid is honey or vinegar?

# ENERGY

# CHAPTER 2

# THE OXYGEN THAT YOU BREATHE IS THE WASTE PRODUCT OF WHAT REACTION?

THINK YOU KNOW THE ANSWER?
READ CHAPTER TWO: "ENERGY" TO FIND OUT.

# LET'S MOVE

## ENERGY

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.

Standard 2, Objective 1:
Compare ways that plants and animals obtain and use energy.

## LESSON OBJECTIVES

1. Describe the importance of photosynthesis.
2. Explain the process of respiration for plants and animals.
3. Understand energy paths.

## VOCABULARY

- photosynthesis
- respiration
- solar energy
- chemical energy
- mechanical energy

Figure 2. The oxygen that we breathe—is just a waste product of what reaction?

### INTRODUCTION:
# PHOTOSYNTHESIS

Photosynthesis is the process that uses light energy from the sun, together with carbon dioxide and water, to make glucose and oxygen. The primary role of photosynthesis is to make glucose (sugar), suggesting 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. This is the process in which plants and certain other organisms makes glucose ($C_6H_{12}O_6$). The process uses carbon dioxide and water and also produces oxygen. The overall chemical equation for photosynthesis is:

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

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:

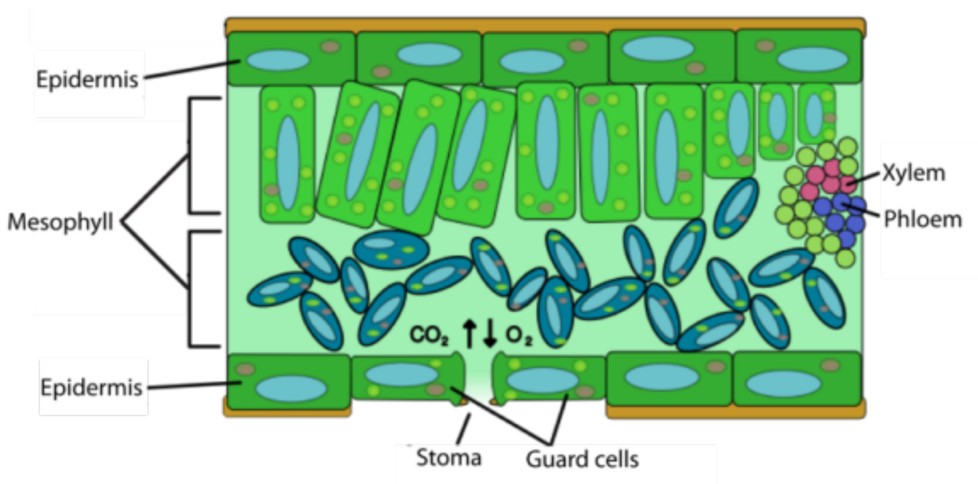
$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

Photosynthesis changes 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).

For a rap about photosynthesis, go to:
**http://www.youtube.com/watch?v=Wi60tQa8jfE**

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 cross section of a leaf in Figure below lets you look inside a leaf "factory."



### The Reactants

The starting ingredients of photosynthesis are carbon dioxide and oxygen.  For photosynthesis then, the reactants 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

What is produced by the plant cell during photosynthesis? The products of photosynthesis are glucose and oxygen. This means they are produced at the end of 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. 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.

The glucose that has been made as part of the process of photosynthesis is a chemical process.  Plants take the glucose (that they have made in photosynthesis) as the starting material and make other plant structures through further chemical processes. These would be used to make the leaves, stems, roots, seeds, and flowers. Many producers make their own food through the process of photosynthesis. The "food" the producers make is the sugar, glucose. Producers make food for the rest of the ecosystem. As energy is not recycled, energy must consistently be captured by producers. This energy is then passed on to the organisms that eat the producers, and then to the organisms that eat those organisms, 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.

### Energy Conversion

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).

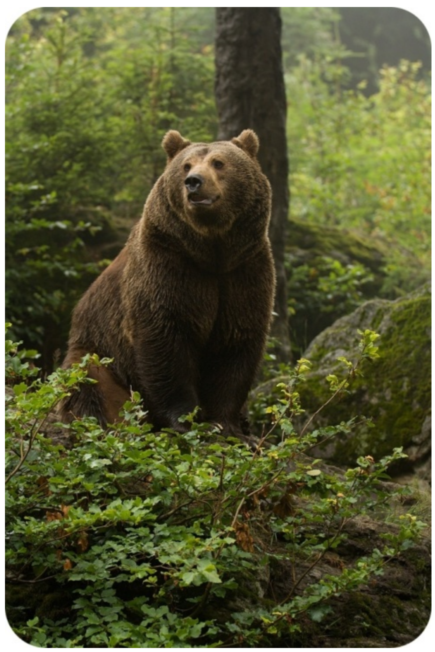
Energy is the ability to do work. In organisms, this work can be physical work, like walking or jumping, or it can be the work used to carry out the chemical processes in their cells. Every biochemical reaction that occurs in an organism's cells needs energy. All organisms need a constant supply of energy to stay alive. 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:

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

Notice that this formula is the *reverse* of photosynthesis.

### Where does all the bear’s energy come from?

Bears get their energy 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 and heat energy.

What is the goal of cellular respiration?

# CIRCLE OF LIFE

## ENERGY

Standard 2, Objective 2:
Generalize the dependent relationships between organisms.

## LESSON OBJECTIVES

1. Categorize relationships between organisms.
2. Model a flow of energy.

## VOCABULARY

- Food chain
- Food Web
- Producers
- Consumer
- Decomposers
- Predators
- Prey
- Herbivores
- Omnivores
- Carnivores
- Mutualism
- Parasitism
- Commensalism

http://commons.wikimedia.org/wiki/File:Kelp_Forest_-_MBA_-_DSC06952.JPG

## PRODUCERS

The energy of the sun is first captured by ***producers***, organisms that can make their own food. Many producers make their own food through the process of ***photosynthesis***. The "food" the producers make is the sugar, ***glucose***. Producers make food for the rest of the ecosystem. As energy is not recycled, energy must consistently be captured by producers. This energy is then passed on to the organisms that eat the producers, and then to the organisms that eat those organisms, and so on.

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.

Many organisms are not producers and cannot make their own food. So how do these organisms obtain their energy? They must get their energy from other organisms. They must eat other organisms, or obtain their energy from these organisms some other way. The organisms that obtain their energy from other organisms are called *consumers.*

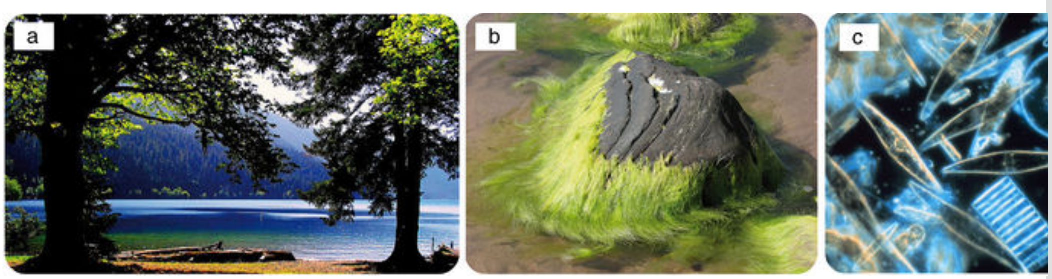
The consumers can be placed into different groups, depending on what they consume.

*Herbivores* are animals that eat producers to get energy. For example, rabbits and deer are herbivores that eat plants. The caterpillar pictured below (Figure below) is an herbivore. Animals that eat phytoplankton in aquatic environments are also herbivores.

*Carnivores* feed on animals, either herbivores or other carnivores. Snakes that eat mice are carnivores. Hawks that eat snakes are also carnivores (Figure below).

*Omnivores* eat both producers and consumers. Most people are omnivores, since they eat fruits, vegetables, and grains from plants, and also meat and dairy products from animals. Dogs, bears, and raccoons are also omnivores.

There are also bacteria that use chemical processes to produce food. They get their energy from sources other than the sun, but they are still called producers. This process is known as ***chemosynthesis***, and is common in ecosystems without sunlight, such as certain marine ecosystems.




Producers include plants (a), algae (b), and diatoms (c).

## SUMMARY

With just a few exceptions, all life on Earth depends on the sun's energy for survival.

Producers make food for the rest of the ecosystem through the process of photosynthesis, where the energy of the sun is used to convert carbon dioxide and water into glucose.

### Practice

Use the resource below to answer the questions that follow.

View the producers and consumers video at:
**http://www.youtube.com/watch?v=P0a97kS_3SA (1:59)**

1. Can producers function without sunlight?

3. Why or why not? Explain your answer fully.

4. What are some examples of producers?

5. What are different types of consumers?

# CONSUMERS AND DECOMPOSERS

### What is breaking down this leaf?

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.

*Decomposers* (Figure 3) get nutrients and energy by breaking down dead organisms and animal wastes. Through this process, 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 include mushrooms on a decaying log. Bacteria in the soil are also decomposers. 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.

Figure 3. 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 since it releases the nutrients in the dead leaves back into the soil for living plants to use.

Examples of decomposers are fungi (a) and flesh-eating bacteria (b).

http://en.wikipedia.org/wiki/File:Polyporus_squamosus_Molter.jpg

http://upload.wikimedia.org/wikipedia/commons/6/6a/Necrotizing_fasciitis_left_leg.JPEG

# SUMMARY

Consumers must obtain their nutrients and energy by eating other organisms. Decomposers break down animal remains and wastes to get energy.

Decomposers are essential for the stability and survival of an ecosystem.

## Practice

Use the resource below to answer the questions that follow.

**Decomposers at http://www.youtube.com/watch?v=Z6V0a_7N1Mw (3:19)**

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

# 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, this praying mantis is eating a grasshopper. To eat the grasshopper, the praying mantis first had to catch the grasshopper, which is a form of hunting.

*Predation* is another mechanism in which species interact with each other. Predation is when a predator organism feeds on another living organism or organisms, known as prey. It does this by keeping the prey from surviving, reproducing, or both. *Predator-prey relationships* are essential to maintaining the balance of organisms in an ecosystem.

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, this praying mantis is eating a grasshopper. To eat the grasshopper, the praying mantis first had to catch the grasshopper, which is a form of hunting.

# SUMMARY

Predation happens when a predator organism feeds on another living organism or organisms, known as prey.

### Practice

Use the resources below to answer the questions that follow.

Dragonfly Larva Hunts Newt at Shape of Life:

**http://shapeoflife.org/video/behavior/arthropods-dragonfly-larva-hunts-newt (2:06)**

1. Notice the dragonfly larva's movements. How deliberate do its movements appear to be? Given that this is a young individual, what sort of behavior do you think this represents, innate or learned? Explain your reasoning.

2. What predation-related attributes or adaptations do you see in the newt and the dragonfly larva?

3. What sort of predation occurs between the dragonfly larva and the newt? What sort of predation occurs between the dragonfly larva?

# SYMBIOSIS

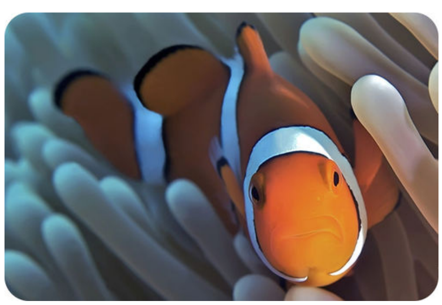
Symbiosis describes a close and long-term relationship between different species. At least one species will benefit in a symbiotic relationship. There are three types of symbiotic relationships: mutualism, communalism, and parasitism.

Mutualism is a symbiotic relationship in which both species benefit.

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

Parasitism is a symbiotic relationship in which the parasitic species benefits while the host species is harmed.

An example of a mutualistic relationship 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.



Are these little fish about to become lunch?

Actually, this big fish is not opening his mouth to munch on these little fish. He is opening his mouth to get his teeth cleaned! These small fish eat dead skin and parasites from his body. Both types of fish benefit from this relationship.

Commensal relationships 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.

An example of a parasite is a hookworm. Hookworms are roundworms that affect the small intestine and lungs of a host organism. They live inside of humans and cause them pain. However, the hookworms must live inside of a host in order to survive. Parasites may even kill the host they live on. Parasites are found in animals, plants, and fungi. Hookworms are common in the moist tropic and subtropic regions. There is very little risk of getting a parasite in industrialized nations.

# SUMMARY

Symbiosis describes a close and long-term interaction between different species.
In a mutualism, both species benefit; in a commensalism, one species benefits while the other is not affected.

In a parasitism, the parasitic species benefits, while the host species is harmed.

### Practice

Use the resource below to answer the questions that follow.

Symbiosis: Mutualism, Commensalsim and Parasitism at:
**http://www.youtube.com/watch?v=zSmL2F1t81Q (5:17)**

1. What defines a symbiotic relationship?
2. Is the benefit gained by each individual in a mutualistic relationship equal? Why or why not?
3. What could a mutualistic relationship, in which one organism receives little benefit, also be called?
4. Given that the distinction between symbiotic relationships is defined by perceived benefit for an organism, how easy do you think it is to misdefine these relationships? Do you think it is easier to define these relationships for some organisms than for other? Why or why not?
5. What are the two explanations for where a clownfish's protective mucus comes from? Design an experiment to determine which one of these possibilities is more likely. Can you think of a third explanation?

# ENERGY MODELS

Energy must constantly flow through an ecosystem for the system to remain stable. What exactly does this mean? Essentially, it means that organisms must eat other organisms. ***Food chains*** (Figure below) show the eating patterns in an ecosystem. Food energy flows from one organism to another. Arrows are used to show the flow of energy from one organism to another. The arrow points from the organism being eaten to the organism that eats it. For example, an arrow from leaves to a grasshopper shows that energy flows from leaf to grasshopper. Energy and nutrients are moving 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:

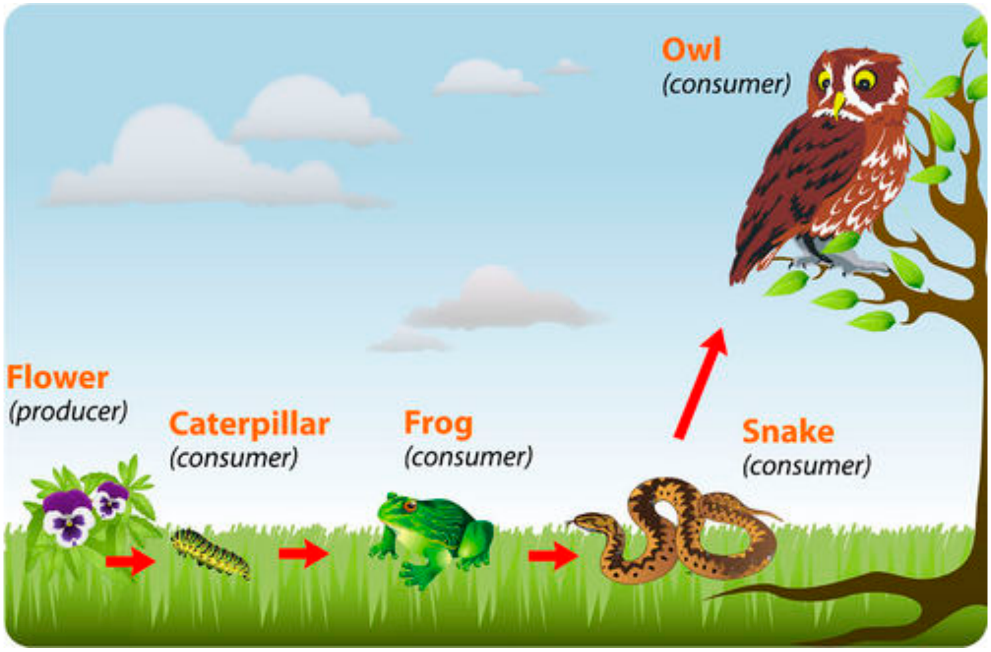
leaves → grasshopper → frog → snake → hawk

A food chain cannot continue to go on and on. For example the food chain could not be:

leaves → caterpillar → spider → frog → lizard → fox → 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 eat the grass, and some animals even eat the grasshopper. These interactions can be visualized by drawing a food web.



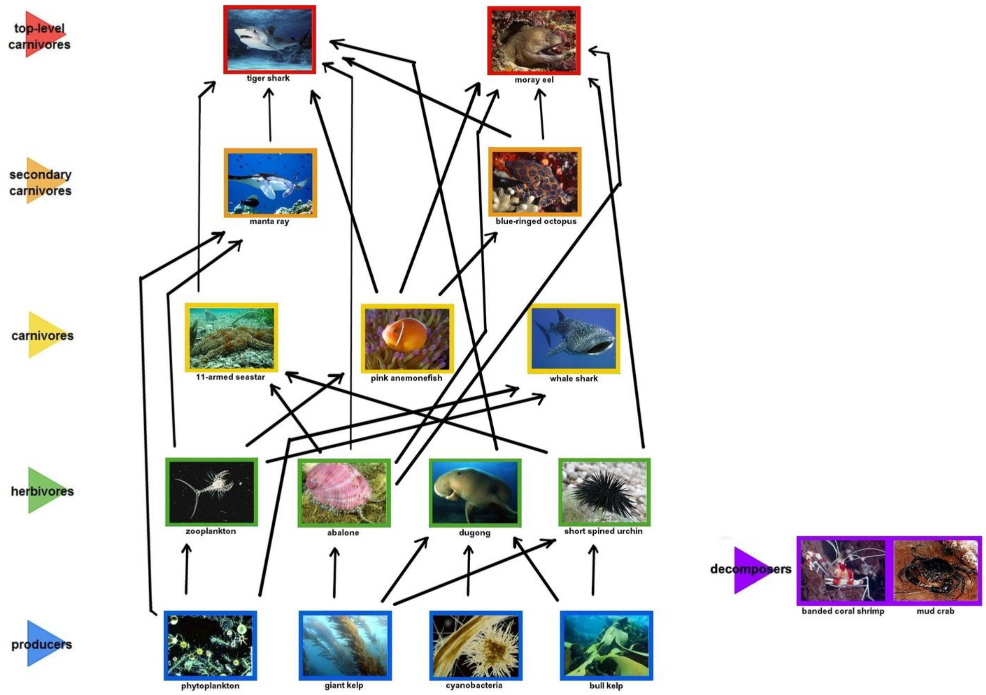

This food chain includes producers and consumers. How could you add decomposers to the food chain?

In an ocean ecosystem, one possible food chain might look like this: phytoplankton → krill → fish → 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 other organisms in the ecosystem. The herbivores come next, then the carnivores. When these consumers eat other organisms, they use the glucose in those organisms for energy. 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. 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. There are also many different species of fish and sharks. So a food chain cannot end with a shark; it must end with a distinct species of shark. A food chain does not contain the general category of "fish," it will contain specific species of fish. In ecosystems, there are many food chains.

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* (Figure below) shows the feeding relationships between many organisms in an ecosystem. 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.

Food web in the Arctic Ocean.




http://great-barrier-reef-biome.wikispaces.com/Reef+Food+Web

# SUMMARY

A food chain is a diagram that shows feeding interactions in an ecosystem through a single pathway.

A food web is a diagram that shows feeding interactions between many organisms in an ecosystem through multiple intersecting pathways.

**Practice**

Use the resource below to answer the questions that follow.

Decomposers at:
**http://www.youtube.com/watch?v=Z6V0a_7N1Mw (3:19)**

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

# Standard 2, Objective 3: Analyze human influence on the capacity of an environment to sustain living things

### 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 (Figure below) and almost all of its tallgrass prairies (Figure below). 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 below).

Figure 4. Wetlands such as this one in Cape May, New Jersey, filter water and protect coastal lands from storms and floods.

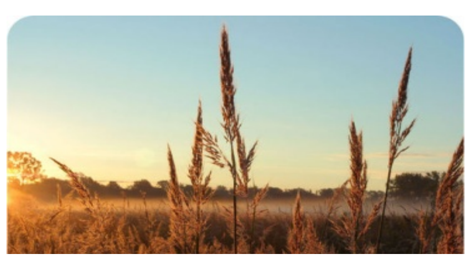


Figure 5. Big bluestem grasses as tall as a human were one of the species of the tall grass prairie, largely destroyed by agricultural use.

Figure 6. Herds of bison also made up part of the tall grass prairie community.

## Slash-and-Burn Agriculture

Other habitats that are being rapidly destroyed are forests, especially tropical rainforests. The largest cause of deforestation today is Í (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. This 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 can also be 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. Sometimes invasive species are so successful at living in a certain habitat that the native species go extinct (Figure below).

Recently, cargo ships have transported zebra mussels, spiny waterfleas, and ruffe (a freshwater fish) into the Great Lakes (*Figure below*). These invasive species are better at hunting for food. They have caused some of the native species to go extinct.

Invasive species can disrupt food chains, carry disease, prey on native species directly, and out-compete native species for limited resources, like food. All of these effects can lead to extinction of the native species.

Figure 8. An exotic species, the brown tree snake, hitchhiked on an aircraft to the Pacific Islands, causing the extinctions of many bird and mammal species which had evolved in the absence of predators.

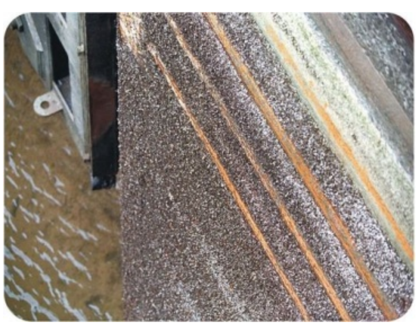


Figure 7. These zebra mussels, an invasive species, live on most man-made and natural surfaces. Here they have infested the walls of the Arthur V. Ormond Lock on the Arkansas River. They have caused significant damage to American waterways, locks, and power plants.

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

Figure 9. Strip coal mining, pictured here, 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

Evidences are the facts that are gathered. It represents things as they really are. Inference is what we do to make sense of the evidences given to us.

Some of the evidences in the above photo are: 4 lions, 1 wildebeast, brown plants, trees without leaves, etc. Some inferences that could be made but are not equally probable are: The lions are playing around the wildebeast, the lions are trying to wake the wildebeast up, etc.

Figure 10. http://en.wikipedia.org/wiki/File:Lions_taking_down_cape_buffalo.jpg

*Analyze Human Influence on the Capacity of an environment to sustain Living Things From UEN Sciber-Text: http://www.uen.org/core/science/sciber/sciber8/stand-2/humanimp.shtml*

### 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 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?**

# PRACTICE: INFERENCE VERSUS EVIDENCE

*The following box content is from: http://www.uen.org/core/science/sciber/sciber8/stand-2/humanimp.shtml*

## Humans are Altering Earth's Environment

By John Newsworthy

WASHINGTON — Today, climatologists raised the public's awareness of the greenhouse effect by saying that we depend on the greenhouse effect to keep our world temperatures at normal levels. The greenhouse effect is explained as Earth's atmosphere trapping heat energy from moving out of the atmosphere. This keeps Earth's surface warm.

Climatologists demonstrated this using a plant greenhouse to model the process. Our atmosphere acts like a plant greenhouse. Light comes into the greenhouse, but much of the resulting heat is trapped. Without the greenhouse effect the temperature of planet Earth would be much colder.

Some scientists fear that the greenhouse effect could cause temperatures to rise too high as certain gases in the environment increase. One reason that this happens is that we are burning more and more fossil fuels, like gasoline. Carbon dioxide is the main atmospheric gas that has scientists worried. Carbon dioxide is released as fossil fuels are burned.

During this century, the amount of carbon dioxide in Earth's atmosphere has increased by 20%. Our industrial society has also increased the release of methane and nitrous oxide. These are also greenhouse gases. If these gases continue to increase at their current rate, the planet could warm by 5 degrees Celsius over the next twenty years.

An increase in the greenhouse effect results in a process called global warming. Global warming could cause severe damage to Earth's environment. The effects of global warming include ice melting in polar climates, hotter days and loss of crops and plants. Disease could thrive in a warmer environment. Human death rates may increase due to disease. People may be forced to move to different climates. Animals may not be able to survive. Some animals require a certain temperature for eggs to hatch or water temperatures that are more moderate to ensure their survival.

Most scientists agree that we should try to reduce greenhouse gases. Doing this could minimize the problems of global warming. Reducing carbon dioxide from cars and factories and conserving energy would help. We should conduct more research to provide scientists and citizens better answers.

Analysis:

1. What statements in the article are inferences only?
2. List five examples of inferences in the article.
3. Which statements in the article are supported by evidence?
4. List five statements in the article that are backed by evidence.

*The following content is from http://www.biol.andrews.edu/everglades/ecosystems/human_impact/human_impact.html*

## Man and His Environment

Every year millions of people flock to the sandy beaches of Florida in hopes of surf, sun and fun. The things that one can do at the beach are almost unlimited: picnicking, touring the ocean on a motor boat, fishing, snorkeling, or just playing games on the beach. Amidst all the fun it is hard to think about the effects this has on the environment. Even the simplest picnic is problematic to the ecosystem; there is almost always litter left behind, either accidentally or purposely. With a high gust of wind a sandwich bag could fall into the water and pose a threat to wildlife. Eighty percent of all marine pollution comes from human activities on land. According to Scholastic Update, five major sources of ocean pollution are: runoff from land 44%, air pollution 33%, shipping 12%, dumping wastes 10%, and offshore oil production 1%.

A prime example of this would be human impact on the loggerhead sea turtle which may mistake a sandwich bag for a jellyfish, one of their primary sources of food, and try to eat it. Upon ingestion, however, the turtle may choke and die. The mere presence of all the people found on the beach provides another problem for the turtle. In reproduction the sea turtle lays it's eggs deep in the sand of the beach, however with all the millions of people walking on the beach, a nest of eggs is likely to be destroyed either by a person walking by or an umbrella pole placed into the sand. Another threat to the sea turtle is the bright lights from lamp poles and buildings. When the new turtles hatch at night they mistake the bright lights for the moon and head away from the water towards the city. In this case death is inevitable; in order for the sea turtles to survive they must make it to the water before the gulls can have them for a meal.

In 1968 Congress passed the National Flood Insurance Program which helps people pay for damages caused by wind and water. This allowed more people to move closer to the coast and take up residence rather than just visiting for a few weeks out of the year. Due to the massive influx of people wanting beach front property, miles of beach are being destroyed and billions of dollars are spent to rebuild the homes that are destroyed every year due to hurricanes and floods. The Clean Water Act and Marine Protection, Research, and Sanctuaries Act were passed in 1972, regulating the discharge and dumping of wastes into marine waters, putting limits on certain kinds of pollutants, and set standards for sewage treatment. The clean water act of 1969 led to the improvement in 60% of American rivers lakes and coastlines.

In undisturbed conditions Southern Florida would mostly be wetlands but because of the demand for land most of the wetlands have been drained with the use of canals and other areas filled in with dirt. The use of canals alters the ecosystem in so many ways. An apparent one is the prevention of water that overflows from Lake Okeechobe southward into the Florida Bay and the Gulf of Mexico; the water is redirected towards the cities for use by those who live there. Construction of canals began in 1882 with the Caloosahatchee Canal which altered the the water levels in the Everglades by ten feet. There are four main canals in Southern Florida; Miami, Northnew River, Hillsborough, and West Palm Beach. The entire southern rim of Lake Okeechobee was diked making the canals the only way for water to travel. All the canals are fitted with gates to control the flow of water out of Lake Okeechobee. The lack of water in the Everglades causes many species of animals to find other habitats to live and breed and in some cases the lack of wetlands can cause extinction. Today there are several water conservation areas (WCAs) with huge pump stations that move water into or out of the WCAs, bringing water back to the Everglades during times of drought.

While in Florida many people try to explore another aspect of the world--life under water. Whether you are swimming, snorkeling, or for the more adventurous SCUBA diving, there are plenty of opportunities to see how vast man's effect has been on the environment as a whole. If one were to snorkel at John PenneKamp Coral Reef State Park one would find in several places old lobster traps, ship wrecks, and lots of wood planks. There are several sites off the coast of Florida where one can find sunken ships. Some of these ships are there as a result of accidents but a large portion of these ships are placed there to help build coral reefs. In parks like John Penne Kamp one would be informed that the coral reefs you are about to visit are protected and it is illegal to touch or stand on the coral. There is very good reason for this; the coral is made up of tiny organisms called polyps which are very sensitive to the oils on human skin and when touched the polyps in that area die. Due to these oils, the polyps' defense mechanisms take effect and produce a large amount of mucus which attracts hordes of other bacteria that normally do not live on the mucus. These other bacteria engulf the mucus and polyps and eats everything. However the effect does not stop there. It also reduces the reproduction capabilities of the surrounding polyps making recolonization difficult.

Every year thousands of people pay money to be taken through different parts of Florida by way of boat tours. Many of these tours are a threat to the ecosystems and the wild life. For instance, air boats are designed to cut across the marshes; this causes the sawgrass to die and thus changes the course of water flow that would normally be determined by alligator activities. Under natural conditions alligators would swim from their nest to other locations in search of food during which they would wear down the grass, creating paths that will control where the water goes and how fast the water travels. Many tourists want to see the aquatic animal life and so take boat tours such as the glass bottom boat tours which can pose a small threat to the ecosystem. If one were to look carefully at the back end of one of these boats while it is docked one would notice oil leaking out of the engine, which is highly toxic to any organism that ingests it. The most environmentally friendly type of boat tour is via canoe. There is no motor involved, so the canoe can only go as fast as your arms can take you. Without the motor there are no propellers so manatee and other aquatic life are less likely to get injured.

Propellers on motor boats are a big threat to manatee. Manatee can not hear low frequency noises and move at a very slow pace. Because of this, manatee can not hear the boats coming ahead of time nor can they move fast enough to get out of the way. Many manatee die from propellers hitting them but others survive with huge gashes on their backs. Manatees are endangered and there have been many efforts to save the manatees; organizations such as Walt Disney World are working to track manatee migration and have made a device that would alert boaters that a manatee was in the area. This device would be attached around the tail of the manatee by a rubber loop (this in no way was permanently attached to the manatee), coming off the loop is a rather long cable which is attached to it a long plastic buoy like object. The purpose of this device was to float above the manatee and as the manatee came closer to the surface of the water the buoy would pop up before the manatee surfaced for air and would warn boaters to avoid that area. Also when the buoy surfaced it had a tracking device in it that would send signals to a satellite which would then be transmitted back to a computer. Unfortunately this device was not taken seriously by boaters and a new device is in the works. This new device is a whistle on the propellers of the boat, it has a high enough frequency that a manatee should hear it and is currently being tested in Florida.

The environment is a very fragile system and man has the biggest effect on it. There is a saying that states the Earth is something we are borrowing from our children. This is very true, for what we do with the environment today effects the environment tomorrow. There are those that think we as a whole are doing nothing wrong to the environment and that the pollution and the extinction of animals is all a cycle of life and everything is balanced. This however can clearly be seen as an untruth for there were unspoiled places on this earth at many different points in time but this all changed when man thought that he could make it better for himself.

## Questions:

1. Explain the human environmental impact on the loggerhead turtle (give 3 examples)

2. Explain man's impact on coral reefs. What have we done to try to fix it?

3. Explain how man has affected manatees.
4. Draw a flow-chart of all of the events of the island of Borneo that negatively affected organisms.

# GLOSSARY

**commensalism**: Symbiotic relationship in which one species benefits while the other species is not affected.

**consumer**: Organism that must eat or consume other organisms to obtain energy and nutrients.

**mutualism**: Symbiotic relationship in which both species benefit.

**parasitism**: Symbiotic relationship in which one species benefits while the other species is harmed.

**symbiosis**: Close and long-term interaction between different species.

**predator-prey relationship**: Interaction between two organisms of unlike species; one organism acts as predator that captures and feeds on the other organism, which serves as the prey.

**prey**: Species that is consumed 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.

**symbiosis**: Close and long-term interaction between different species.

**carnivore**: Organism that feeds on other animals.

**consumer**: Organism that must consume other organisms to obtain food for energy.

**decomposer**: Organism that obtains nutrients and energy by breaking down dead organisms and animal wastes.

**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.

**chemosynthesis**: Process of using the energy in chemical compounds to make food; characteristic of producers in ecosystems without sunlight.

**energy**: Ability to do work.

**glucose**: Simple sugar molecule with the chemical formula C6H12O6.

**photosynthesis**: Process by which specific organisms (including all plants) use the sun's energy to make their own food from carbon dioxide and water; process that converts the energy of the sun, or solar energy, into carbohydrates, a type of chemical energy.

**phytoplankton**: Tiny photosynthetic organisms that are producers in aquatic ecosystems. predator-prey relationship: Interaction between two organisms of unlike species; one organism acts as predator that captures and feeds on the other organism, which serves as the prey.

**producer**: Organism that produces food (glucose) for itself and other organisms.

**herbivores** are animals that eat producers to get energy.

**carnivores** feed on animals, either herbivores or other carnivores.

**omnivores** eat both producers and consumers.

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

**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.

**chemical energy** that is stored in the connections between atoms in a chemical substance

**mechanical energy** – the energy of motion

# CHAPTER 3

# EARTH

# IS A MINERAL ALIVE OR NOT?

THINK YOU KNOW THE ANSWER?
READ CHAPTER THREE: "EARTH" TO FIND OUT.

# DIG IN!

## EARTH

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

Standard 3, Objective 1:
Compare rocks and minerals and describe how they are related.

## LESSON OBJECTIVES

1. Define the physical characteristics of a mineral
2. Describe the physical properties of minerals
3. Recognize that rocks are composed of minerals
4. Identify a rock as sedimentary, metamorphic, or igneous.

## VOCABULARY

- Mineral
- Magma
- Crystal
- Color
- Streak
- Luster
- Density
- Breakage
- Hardness
- Texture
- Igneous
- Metamorphic

### Introduction: 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.
*(Utah State Core Curriculum - 8th Grade Standard 3 Science Benchmark)*

# Section 1.1: 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 what is salt but the mineral halite?

You also wear minerals, play with and on minerals, and admire the beauty of minerals. However, a mineral by definition cannot be organic, 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.
- ✓ 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. Be careful about buying a laboratory-made "diamond" for jewelry. It may look pretty, but it's not a diamond and is not technically a mineral.

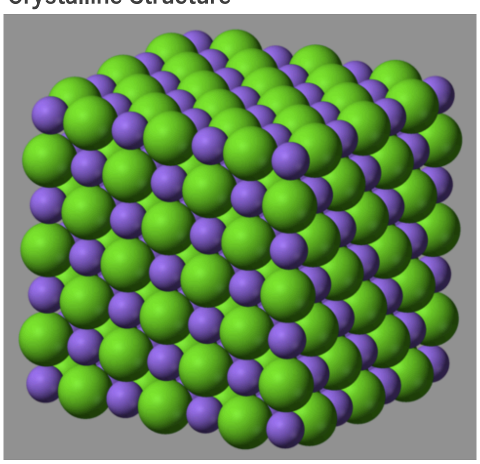
### Inorganic

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.

### Crystalline Structure



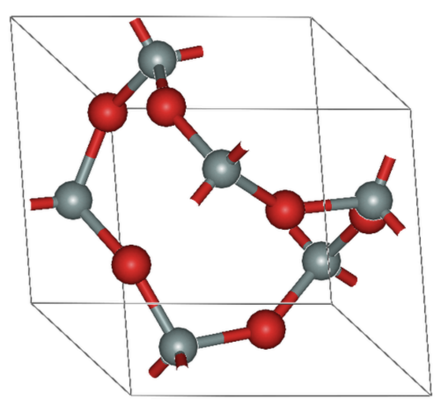
Minerals are "crystalline" structures. A crystal is a solid in which the atoms are arranged in a regular, repeating pattern. Notice that in Figure (8G-1.1b Crystaline structure.jpg) the green and purple spheres, representing sodium and chlorine, form a repeating pattern. In this case, they alternate in all directions.

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

### 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 Figure (8G-1.1b Crystaline structure.jpg), is NaCl (sodium chloride). Quartz is always made of two oxygen atoms (red) bonded to a silicon atom (grey), represented by the chemical formula SiO2 (Figure 8G-1.1c Quartz).



### 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.

# Section 1.2: Physical Properties of Minerals

### What Properties are used to Identify 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: how a mineral breaks
- ✓ Cleavage: the mineral's tendency to break along planes of weakness.
- ✓ Fracture: the pattern in which a mineral breaks.
- ✓ Hardness: what minerals it can scratch and what minerals can scratch it.

# Section 1.3: 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?

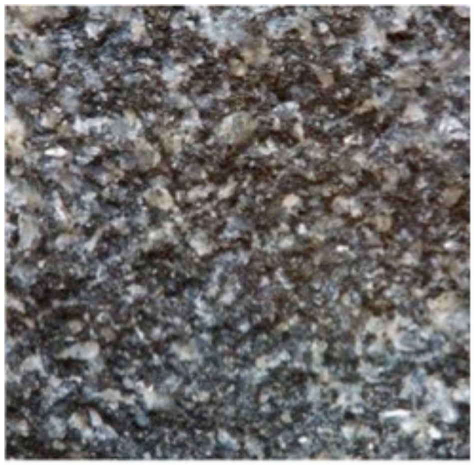
A rock is a naturally formed, non-living Earth material. Rocks are made of collections of mineral grains that are held together in a firm, solid mass (Figure below).

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 below).


As seen above, a pegmatite from South Dakota with crystals of lepidolite, tourmaline, and quartz (1 cm scale on the upper left).



Sample 1

Sample 2

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 all one mineral type, such as quartzite. Much 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 above the same rock type? Do they have the same minerals? The same texture?

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 |

As seen in Table above, these two rocks have the same chemical composition and contain mostly the same minerals, but they do not have the same texture. Sample 1 has visible mineral grains, but Sample 2 has some visible grains in a fine matrix. The two different textures indicate different histories. Sample 1 is a diorite, a rock that cooled slowly from magma (molten rock) underground. Sample 2 is an andesite, a rock that cooled rapidly from a 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?

# Section 1.4: Rock Types

### The Three Rock Types

Rocks are classified into three major groups according to how they form. These three types will be described in more detail in other lessons in this concept, 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 and erosion of preexisting 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 below the surface.

A simple explanation of the three rock types and how to identify them can be seen in this video:
**http://www.youtube.com/watch?v=tQUe9C4ONEE.**

This video discusses how to identify igneous rocks:
**http://www.youtube.com/watch?v=QOXtLjE3siE.**

This video discusses how to identify a metamorphic rocks:
**http://www.youtube.com/watch?v=qs9x_bTCiew.**

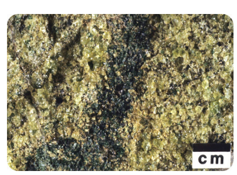
### Igneous Rocks Characteristics

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

- ✓ Large visible 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. Sedimentary rock formation is described in the next lesson.

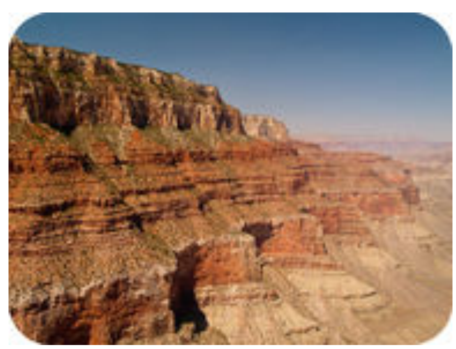
Sediments are small fragments of rocks and minerals. Pebbles, sand, silt, and clay are examples of sediments. Sedimentary rocks may include fossils. Fossils are materials left behind by once-living organisms. Fossils can be pieces of the organism, like bones. They can also be traces of the organism, like footprints.

### Transport
Sediments are transported by water, wind, ice, or gravity. These agents move them from the place where they formed. The sediments are then deposited in a location.

### Deposition
Sediments will eventually settle out of water (Figure below). For example, rivers carry lots of sediment. Where the water slows, it dumps these sediments along its banks, into lakes and the ocean.

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

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 (Figure below).



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.

### Metamorphic Rocks Characteristics

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

- ✓ **Stripes in thin, parallel, wavy lines**
- ✓ **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. The change can be physical, chemical, or both.

During metamorphism, a rock may change chemically. Ions 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. This is foliation. If pressure is exerted from all directions, the rock usually does not show foliation.

## VOCABULARY

- Cooling
- Crystallization
- Deposition
- Erosion
- Heat
- Metamorphism
- Sedimentation

# STANDARD 3, OBJECTIVE 2: DESCRIBE THE NATURE OF THE CHANGES THAT ROCKS UNDERGO OVER LONG PERIODS OF TIME

## OBJECTIVES

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.

# Section 2.1: Rock Cycle

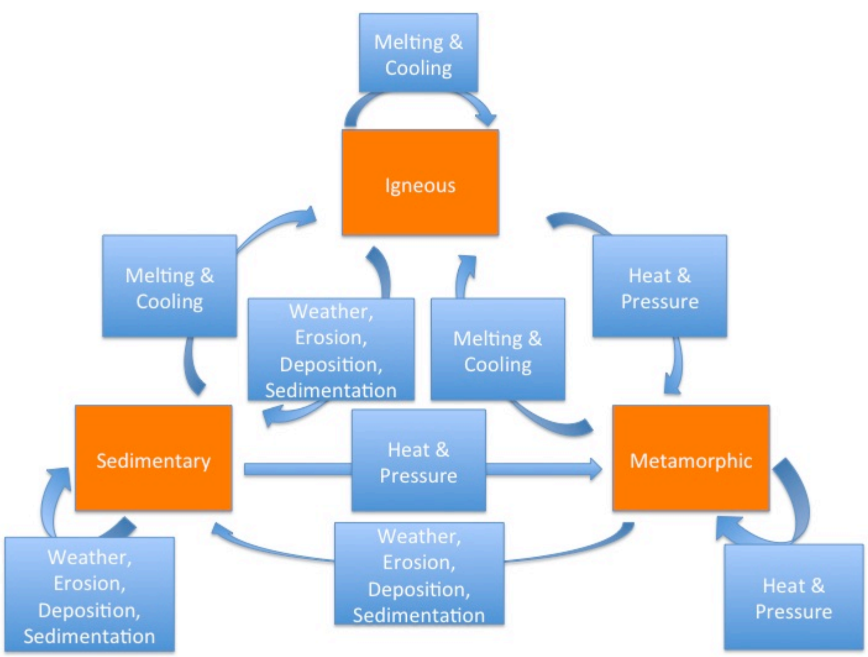
Is this what geologists mean by the rock cycle?

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.

The figure below shows how the three main rock types are related to each other (Figure below). 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.

Weathering and erosion. 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.

An interactive rock cycle diagram can be found here:

http://www.classzone.com/books/earth_science/terc/content/investigations/es0602/es0602page02.cfm?chapter_no=investigation

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.

## SECTION 2.2: ROLE OF ENERGY IN ROCK

### 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 can 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 object 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 is where they will remain until another force acts upon them (deposition). In order to reach the tremendous pressure necessary to make a metamorphic rock gravity is crucial create this needed pressure.

### Wind and Water

Wind and Water are forces that cause weather, erosion, and deposition to occur. Wind, on a normal day can blow small dust particles and sand material for hundreds or thousands of miles (erosion). 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. Waves constant pounding against a shoreline is one reason why beaches are covered in sand. The other could be because of the particles that are being carried by the waves to the shore.

## SECTION 2.3: SOIL FORMATION

### How are these two soils different?

What color is the soil on the left? What color is the soil on the right? Why do you think they differ so much in color? Which soil do you think is better for growing things? See below to find out!

### Soil Formation

How well soil forms and what type of soil forms depends on several different factors, which are described below.
An animation of how weathering makes soil is found here:
**http://courses.soil.ncsu.edu/resources/soil_classification_genesis/mineral_weathering/mineral_weathering.swf.**

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 1mm/year. In poor conditions, it may take thousands of years!

### Weathering

Soil formation requires weathering. Where there is less weathering, soils are thinner. However, soluble minerals may be present. Where there is intense weathering, soils may be thick. Minerals and nutrients would have been washed out.

### Climate

Climate is the most important factor determining soil type. Given enough time, a climate will produce a particular type of soil. The original rock type does not matter. Two rocks of the same type will form a different soil type in each different climate. This is true because most rocks on Earth are made of the same eight elements. When the rock breaks down to become soil, the soil is the same.
The same climate factors that lead to high weathering also produce more soil.
More rain weathers minerals and rocks more. Rain allows chemical reactions especially in the top layers of the soil. More rain can dissolve more rock. More rain can carry away more material. As material is carried away, new surfaces are exposed. This also increases the rate of weathering.

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. In tropical regions, where temperature and precipitation are consistently high, thick soils form. Arid regions have thin soils. Soil type also influences the type of vegetation that can grow in the region. We can identify climate types by the types of plants that grow there.

### Slope

Weathered material washes off steep slopes and so does not stay in place to form soil. Soil forms where land areas are flat or gently undulating.

### Time

Soils thicken as the amount of time available for weathering increases. The longer the amount of time that soil remains in a particular area, the thicker it will be.

### 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 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 Figure below). Soil with low organic material is not good for growing plants.

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.

An animation of how different types of weathering affect different minerals in soil:

**http://courses.soil.ncsu.edu/resources/soil_classification_genesis/mineral_weathering/elemental_change.swf.**

# SECTION 2.4: FOSSIL FORMATION

### 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 below).

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

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

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 traces of an ancient organism. Fossils include body fossils, left behind when the soft parts have decayed away, and trace fossils, such as burrows, tracks, or fossilized coprolites (feces) as seen above. Fossils are only 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 an organisms remains. Fossils also couldn't exist in metamorphic rock because the heat and pressure would not allow the organisms remains to remain in the original visible shape.

### Fossilization is Rare

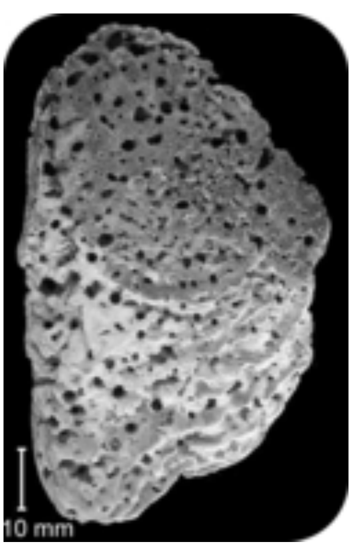
Becoming a fossil isn't easy. Only a tiny percentage of the organisms that have ever lived become fossils.

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 opposite).

Hyenas eating a water buffalo. Will the water buffalo in this photo become a fossil?

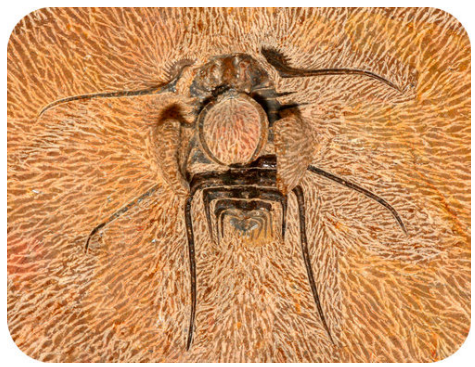
Most of its body is eaten by hyenas and other scavengers and the remaining flesh is devoured by insects and bacteria. Only bones are left behind. As the years go by if the bones remain on Earth's surface, the bones are scattered and fragmented into small pieces, eventually turning into dust. The remaining nutrients return to the soil. If kept in these conditions, this water buffalo will not be preserved as a fossil.

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




Fossil shell that has been attacked by a boring sponge.

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



A rare insect fossil.

### Conditions that Create Fossils

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

### Hard Parts

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

### Quick Burial

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

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

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

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

### Unusual Circumstances

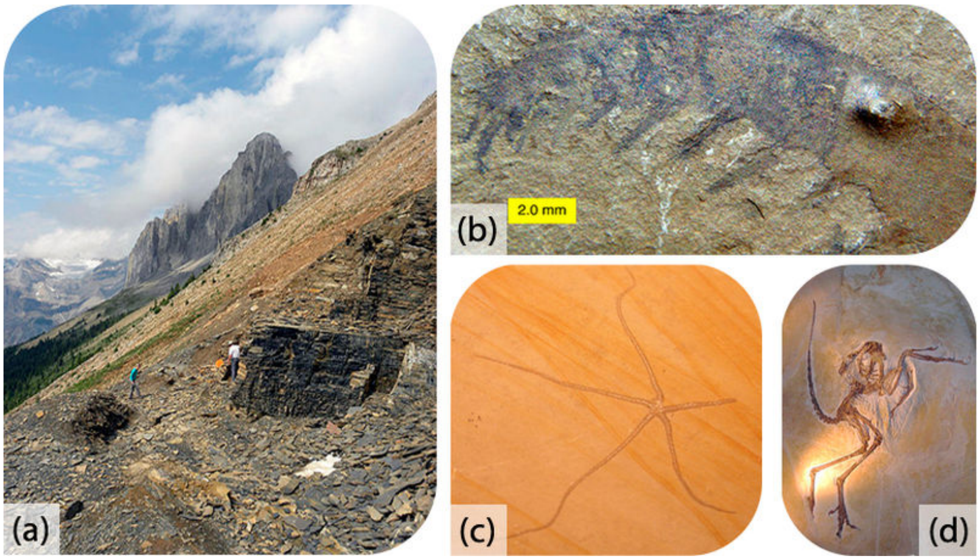
Unusual circumstances may lead to the preservation of a variety of fossils, as at the La Brea Tar Pits in Los Angeles, California. Although the animals trapped in the La Brea Tar Pits probably suffered a slow, miserable death, their bones were preserved perfectly by the sticky tar. (Figure below).

Artists concept of animals surrounding the La Brea Tar Pits.

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

### Exceptional Preservation

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




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

# VOCABULARY

- Relative age
- Index fossil
- Fault
- Continental drift

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

Objectives
- 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)

# SECTION 3.1 RELATIVE AGE OF ROCKS

### Introduction
Scientists argue 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 the order of events. They think about how long it took for those events to happen.

### Seashells at 20,000 feet!
On his voyage on the Beagle, Charles Darwin noticed many things besides just the Galapagos finches that made him famous. Another important discovery that Darwin made was he found shell beds high in the Andes Mountains. How did they get there? He determined that they must mean that mountains rise slowly above the ocean, an idea that was being championed at the time by Charles Lyell. If this is the case, Darwin reasoned, the mountains and Earth must be extremely old.

### 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.

### 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?

### Widespread Rock Layers



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.

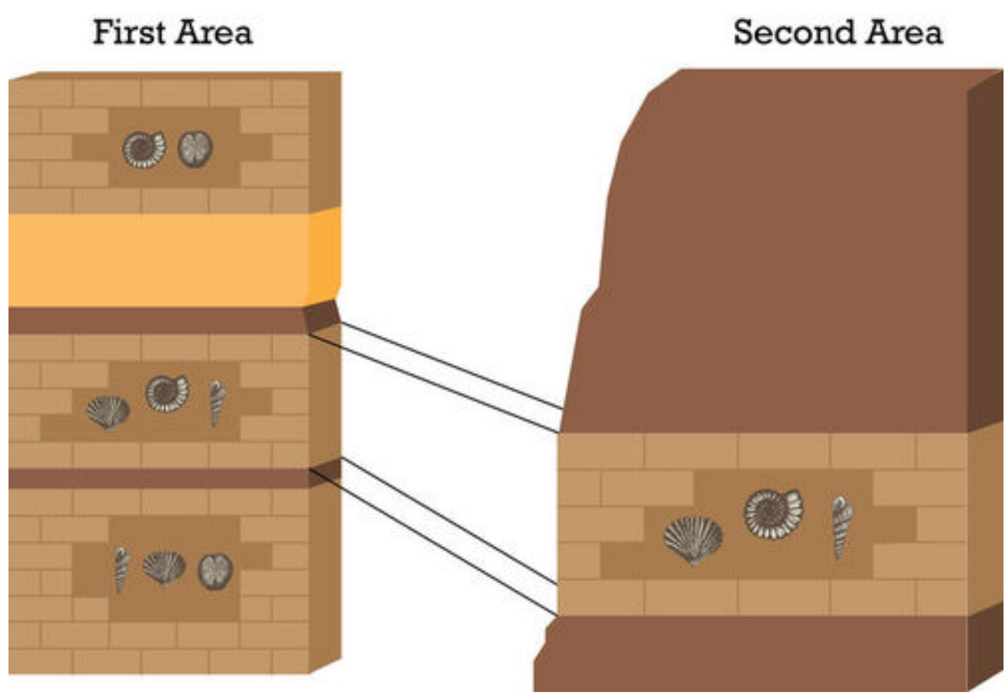
A great example is the famous White Cliffs of Dover on the coast of southeastern England. These distinctive rocks are matched by similar white cliffs in France, Belgium, Holland, Germany, and Denmark (see Figure below). It is important that this chalk layer goes across the English Channel. The rock is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

# SECTION 3.2 UNCONFORMITIES IN ROCK LAYERS

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?

### Unconformities

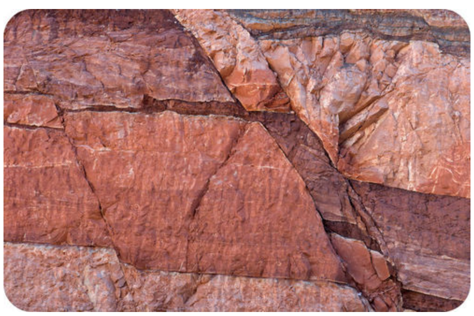
A gap in the sequence of rock layers is called an unconformity. Index fossils are commonly used to match rock layers in different places. You can see how this works in the Figure opposite. If two rock layers have the same index fossils, then they're probably are about the same age.



There are two common ways the unconformities can be creating. The first is a process called faulting and the second is folding.

### Faulting

The fracture in the figure below is called a fault. Sudden motions along faults cause rocks to break and move. The energy released is an earthquake. A rock under enough stress will fracture. Movement along a fault can cause shifts in rock layers, these shifts will change the location of different aged rocks from the normal order of young on top and old on the bottom.



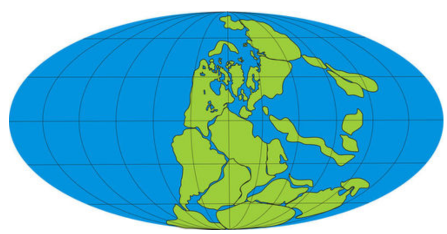
### Folding

Not only will rocks fracture and break along faults but if rocks are exposed to the correct heat and pressure they will fold. 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.

Section 3.3 Fossils and organisms show evidence of Earth's changing surface
Since its creation the Earth's surface has changed dramatically.  Through the processes of continental drift tectonic plates have slowly shifted. Several evidence sources exist to help scientist explain how these changes occur. In the previous section we discussed how rock layers can be matched up.  There are also numerous plant and animal fossils that indicate that continents have drifted.

### Continental Drift

Alfred Wegener was an early 20th century German meteorologist. Wegener believed that the continents were once all joined together. He named the supercontinent Pangaea, meaning "all earth." Wegener suggested that Pangaea broke up long ago. Since then, the continents have been moving to their current positions. He called his hypothesis continental drift.



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

### Evidence for Continental Drift

Wegener and his supporters collected a great deal of evidence for the continental drift hypothesis. Wegener found that this evidence was best explained if the continents had at one time been joined together.

### Rocks And Geologic Structures

Wegener found rocks of the same type and age on both sides of the Atlantic Ocean. He thought that the rocks formed side by side. These rocks then drifted apart on separate continents.

Wegener also matched up mountain ranges across the Atlantic Ocean. The Appalachian Mountains were just like mountain ranges in eastern Greenland, Ireland, Great Britain, and Norway. Wegener concluded that they formed as a single mountain range. The Appalachian Mountains are the remnants of a large mountain range that was created when North America rammed into Eurasia about 250 million years ago prior to Pangea. This mountain range broke apart as the continents split up. The mountain range separated as the continents drifted.

### Fossil Plants And Animals

Wegener also found evidence for continental drift from fossils (Figure below). The same type of plant and animal fossils are found on continents that are now widely separated. These organisms would not have been able to travel across the oceans.

Fossils of the seed fern Glossopteris are found across all of the southern continents. These seeds are too heavy to be carried across the ocean by wind. Mesosaurus fossils are found in South America and South Africa. Mesosaurus an aquatic reptile could swim, but only in fresh water. Cynognathus and Lystrosaurus were reptiles that lived on land. Both of these animals were unable to swim at all. Their fossils have been found across South America, Africa, India and Antarctica.

Wegener thought that all of these organisms lived side by side. The lands later moved apart so that the fossils are separated.

Wegener used fossil evidence to support his continental drift hypothesis. The fossils of these organisms are found on lands that are now far apart. Wegener suggested that when the organisms were alive, the lands were joined and the organisms were living side-by-side.

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. If an index fossil was found in two layers at different heights that would indicate that the Earth had shifted. Thus the index fossil would be found in two different layers.

### Geologic History

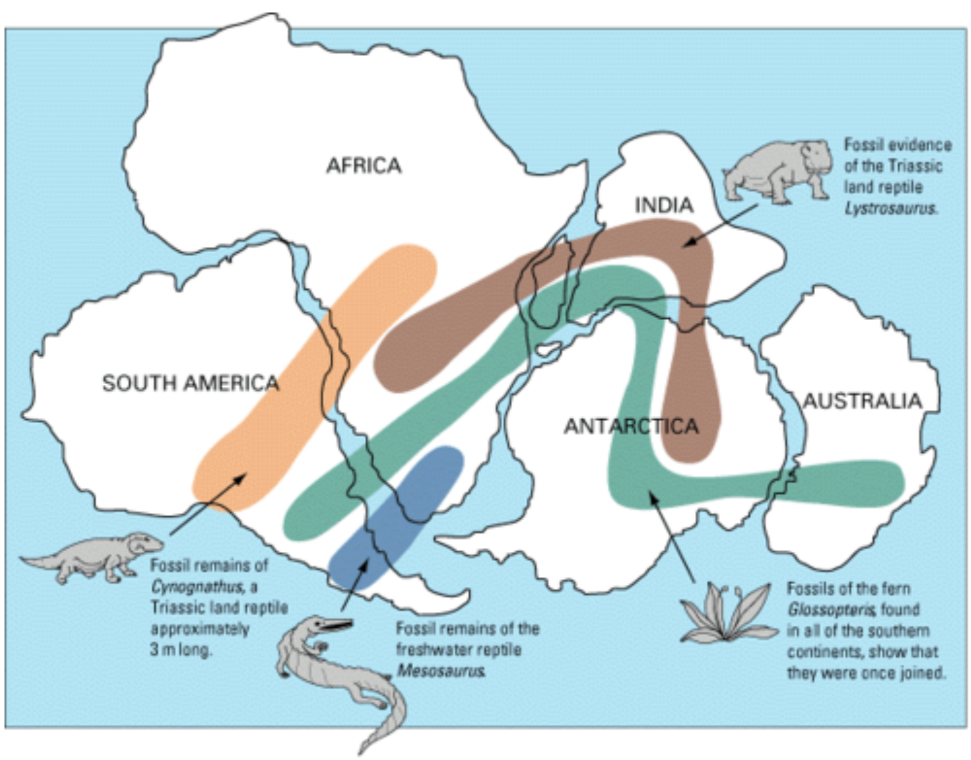
The presence of marine organisms in a rock indicates that the region where the rock was deposited was once marine. Sometimes fossils of marine organisms are found on tall mountains indicating that rocks that formed on the seabed were uplifted.

### Climate

By knowing something about the climate a type of organism lives in now, geologists can use fossils to decipher the climate at the time the fossil was deposited. For example, coal beds form in tropical environments but ancient coal beds are found in Antarctica. Geologists know that at that time the climate on the Antarctic continent was much warmer.

### History of Life on Earth

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



## VOCABULARY

- Earthquake
- Volcano

**Standard 3, Objective 4:** Compare rapid and gradual changes to Earth's surface

## OBJECTIVES

1. 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)
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. Identify the processes of energy buildup and release in earthquakes
4. Describe how small changes over time add up to major changes to Earth's surface
5. Analyze why people don't always follow scientists recommendations

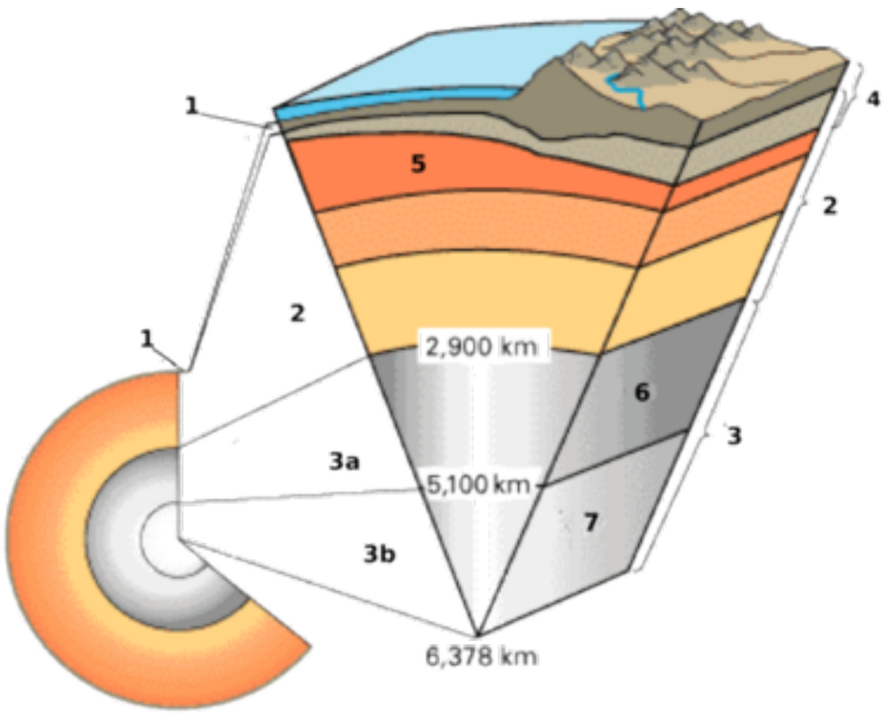
# 4.1 ENERGY IN EARTH'S INTERIOR

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 (Figure 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

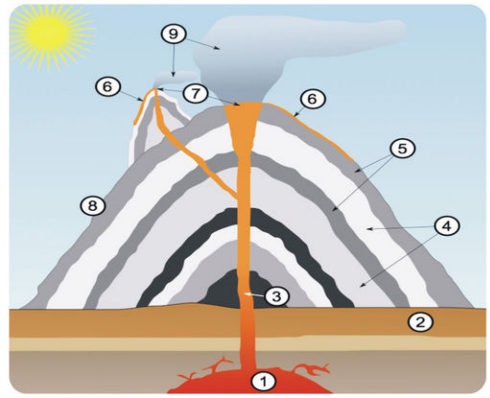
Scientists know that the mantle is extremely hot because of the heat flowing outward from it and because of its physical properties.

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 material near the core heats up. As the core heats the bottom layer of mantle material, particles move more rapidly, decreasing its density and causing the magma to rise. The rising material begins the convection current. When the warm material reaches the surface, it spreads horizontally. The material cools because it is no longer near the core. It eventually becomes cool and dense enough to sink back down into the mantle. At the bottom of the mantle, the material travels horizontally and is heated by the core. It reaches the location where warm mantle material rises, and the mantle convection cell is complete (Figure next page).

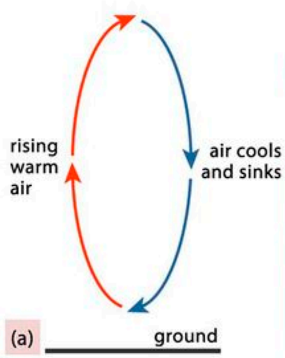
## Melting Forms Volcanoes

Mantle melting can come about three ways: when the temperature rises, if the pressure lowers, and if water is added. The temperature of the subducting plate increases as it sinks into the hot mantle. Sediments lying on top of the subducting plate contain water. As the sediments subduct, the water rises into the overlying mantle material. This lowers the melting temperature of the mantle.

When the mantle above a tectonic plate melts, volcanoes form above it. As with convection current 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 a magma chamber.




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




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

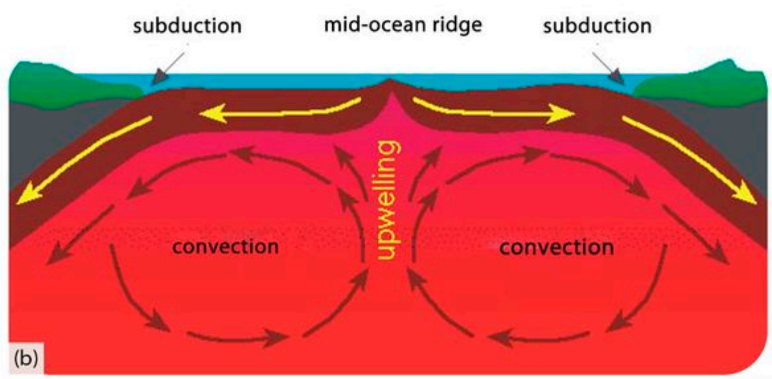



*Diagram of convection within Earth's mantle.*

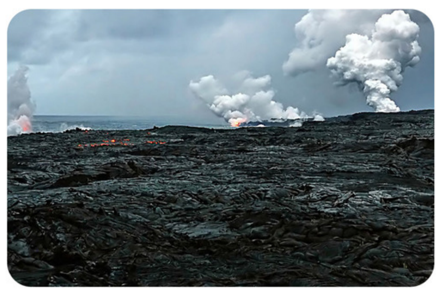
# VOLCANIC LAND FEATURES

### Domes

Lava flows often make mounds right in the middle of craters at the top of volcanoes, as seen in the Figure right.

### Lava Plateaus

A lava plateau forms when large amounts of fluid lava flow over an extensive area (Figure right). When the lava solidifies, it creates a large, flat surface of igneous rock. Earthquakes



### Land

Lava creates new land as it solidifies on the coast or emerges from beneath the water (Figure right). Over time the eruptions can create whole islands. The Hawaiian Islands are formed from shield volcano eruptions that have grown over the last 5 million years.

# SECTION 4.2 EARTHQUAKES

An earthquake is the result of a sudden release of energy in the Earth's crust that creates seismic waves.
http://en.wikipedia.org/wiki/Earthquake

These seismic waves can cause many changes to the Earth's surface. An earthquake occurs due to stored elastic potential energy in tectonic plates that have become stuck. Energy is stored over time until it reaches the rocks elastic limit, at which point the rock fractures release the energy as mechanical energy. The mechanical energy is seen in the form of seismic waves.

### Plate Boundaries

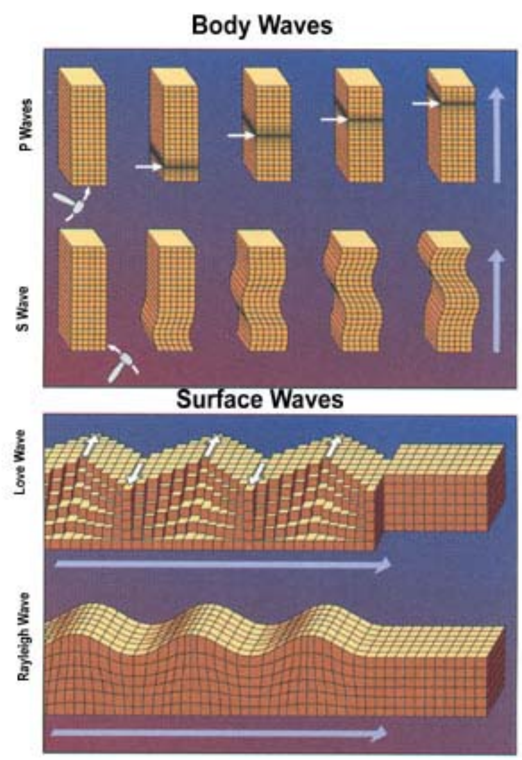
Plate boundaries are the edges where two tectonic plates meet. How can two plates move relative to each other? Most geologic activities, including volcanoes, earthquakes, and mountain building, take place at plate boundaries. The features found at these plate boundaries are the mid-ocean ridges, trenches, and large transform faults (Figure above).
Divergent plate boundaries: the two plates move away from each other.
Convergent plate boundaries: the two plates move towards each other.
Transform plate boundaries: the two plates slip past each other.

### Seismic Waves

Geologists study earthquake waves to "see" Earth's interior. Waves of energy radiate out from an earthquake's focus. These waves are called seismic waves (Figure below). 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





http://en.wikipedia.org/wiki/File:Pswaves.jpg

# 4.3 GRADUAL CHANGE

Gradual change due to continental drift, earthquakes, and volcanoes can 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 persons life time. 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.

### What are the consequences of plate tectonics?

Giant plates of lithosphere moving around on a sphere has consequences. Big consequences. Most earthquakes and volcanic eruptions are due to plate interactions. Mountains originate where plates interact. If Earth's crust never moved, there would be a lot fewer natural disasters!

### 4.4 Scientific recommendations

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. And yet each year people succumb to natural disasters due to a lack of understanding of warning signals or indifference to those alarms.

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 engineer go 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. People will try to surf a large Tsunami or take pictures of one and get caught in the waves and some people may not be aware of proper earthquake safety.

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.

# GLOSSARY

**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.

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

**Fault**: a fracture in Earth's surface.

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

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

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

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

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

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

**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.

**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.

**igneous**: rock that forms when magma cools.

**sedimentation**: the deposition of sediment from a fluid forming layers.

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

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

**Hardness**: minerals ability to resist scratching.

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

**Luster**: describes the way a mineral reflects light.

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

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

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

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

# CHAPTER 4

# MOTION

# DO YOU KNOW THE DIFFERENCE BETWEEN A WAVE AND AMPLITUDE?

THINK YOU KNOW THE ANSWER?
READ CHAPTER FOUR: "MOTION" TO FIND OUT.

# GET MOVING!

## MATTER

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

Standard 4, Objective 1:
Investigate the transfer of energy through various materials.

## LESSON OBJECTIVES

1. Define wave amplitude and wavelength.
2. Understand that movement involves one form of energy being transformed into another form.

## VOCABULARY

- Amplitude
- Compression
- Crest
- Frequency
- Longitudinal wave
- Rarefaction
- Transverse wave
- Trough
- wavelength

# INTRODUCTION

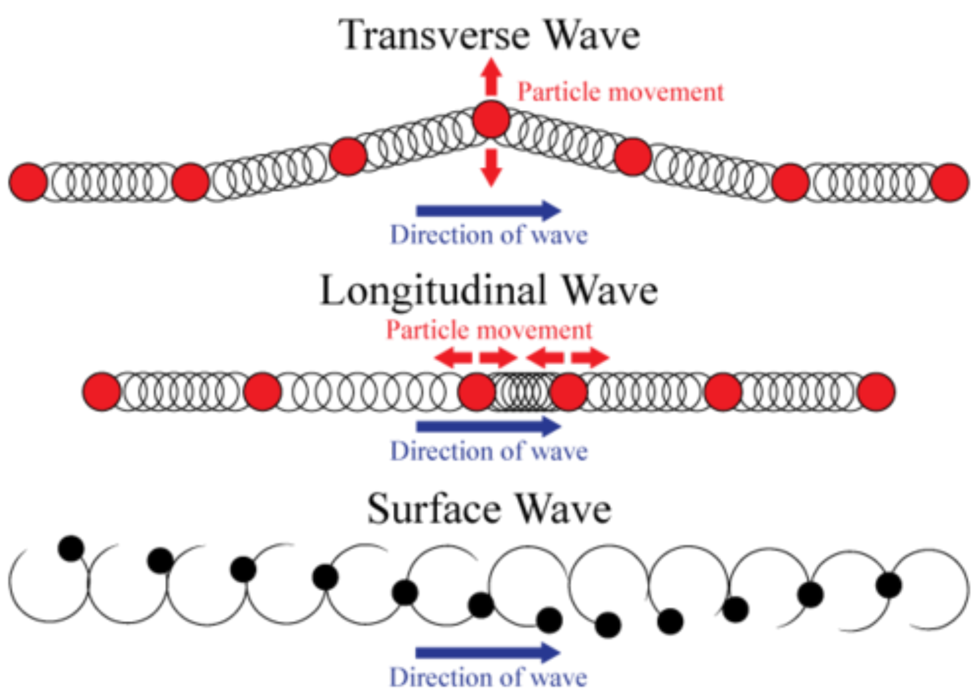
Tsunamis, or the waves caused by earthquakes, are unusually large ocean waves. You can see an example of a tsunami in Figure below. Because tsunamis are so big, they can cause incredible destruction and loss of life. The tsunami in the figure crashed into Thailand, sending people close to shore running for their lives. The height of a tsunami or other wave is just one way of measuring its size or energy. You'll learn about this and other ways of measuring waves in this lesson.

This tsunami occurred in Thailand on December 26, 2004.

There are three types of mechanical waves: transverse, longitudinal, and surface waves. They 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://www.acs.psu.edu/drussell/Demos/waves/wavemotion.html**

- In a transverse wave, particles of the medium vibrate up and down perpendicular to the direction of the wave.
- In a longitudinal wave, particles of the medium vibrate back and forth parallel to the direction of the wave.
- 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.



### Wave Amplitude and Wavelength

The height of a wave is its amplitude. Another measure of wave size is wavelength. Both wave amplitude and wavelength are described in detail below. Figure below shows these wave measures for both transverse and longitudinal waves. You can also simulate waves with different amplitudes and wavelengths by doing the interactive animation at this URL:

**http://sci-culture.com/advancedpoll/GCSE/sine%20wave%20simulator.html.**

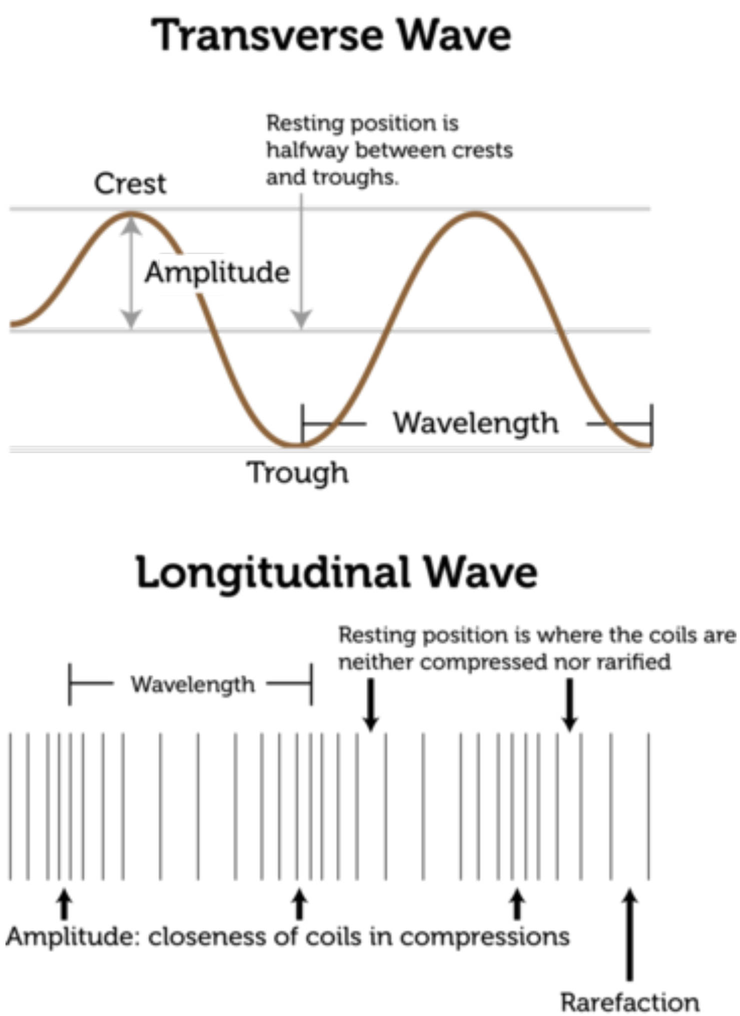



Figure 11. Wave amplitude and wavelength are two important measures of wave size.

## Wave Amplitude

***Wave amplitude*** is the maximum distance the particles of a medium move from their resting position when a wave passes through. The resting position is where the particles would be in the absence of a wave.

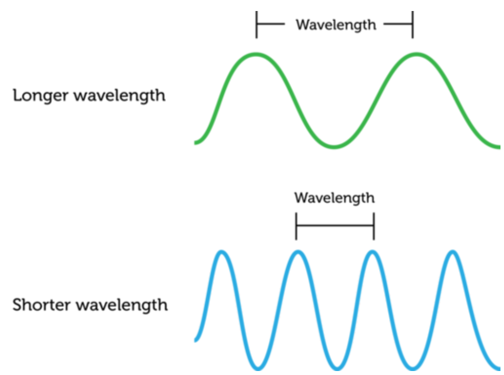
In a ***transverse wave***, wave amplitude is the height of each crest above the resting position. The higher the crests are, the greater the amplitude.

In a ***longitudinal 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.

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 Figure above. 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 is wavelength. Wavelength is the distance between two corresponding points on adjacent waves. Wavelength can be measured as the distance between two adjacent crests of a transverse wave or two adjacent compressions of a longitudinal wave. It is usually measured in meters. 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 Figure below.



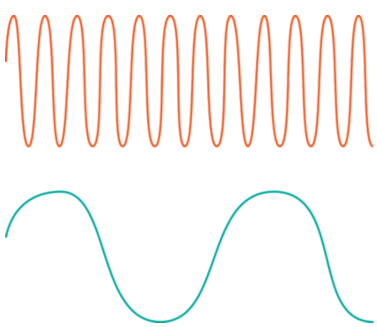

Both of these waves have the same amplitude, but they differ in wavelength. Which wave has more energy?

## Frequency

Imagine making transverse waves in a rope, like the waves in **Figure** above. You tie one end of the rope to a doorknob or other 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 of the waves.

### Wave Frequency

The number of waves that pass a fixed point in a given amount of time is **wave frequency**. Wave frequency can be measured by counting the number of crests or compressions that pass the point in 1 second or other time period. The higher the number is, the greater is the frequency of the wave. The SI unit for wave frequency is the **hertz (Hz)**, where 1 hertz equals 1 wave passing a fixed point in 1 second. **Figure** below shows high-frequency and low-frequency transverse waves. You can simulate transverse waves with different frequencies at this URL: **http://zonalandeducation.com/mstm/physics/waves/partsOfAWave/waveParts.htm.**




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

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.

There is no pot of gold at the end of this rainbow, but it's pretty special nonetheless. Rainbows don't form very often, and they usually don't last very long. Maybe because they are relatively rare or because they often signal the end of a rainstorm, some people think rainbows are a sign of good luck. You may have noticed that rainbows form when the sun starts to come out while raindrops are still falling. What do the sun and raindrops have to do with rainbows? In this chapter, you'll find out.

The speed of most waves depends on the medium through which they are traveling. Generally, waves travel fastest through solids and slowest through gases. That's because particles are closest together in solids and farthest apart in gases. When particles are farther apart, it takes longer for the energy of the disturbance to pass from particle to particle.

# LESSON 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.

Wave frequency is the number of waves that pass a fixed point in a given amount of time. Higher frequency waves have more energy.

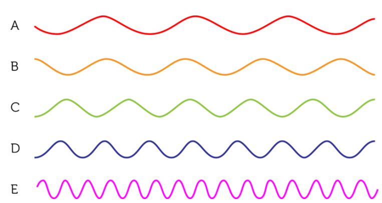
### Lesson Review Questions

1. How is wave amplitude measured in a transverse wave?
2. Describe the wavelength of a longitudinal wave.
3. Define wave frequency.

### Apply Concepts

4. All of the waves in the sketch below have the same amplitude and speed. Which wave has the longest wavelength? Which has the highest frequency? Which has the greatest energy?

### Think Critically




5. Relate wave amplitude, wavelength, and wave frequency to wave energy.
6. Waves A and B have the same speed, but wave A has a shorter wavelength. Which wave has the higher frequency? Explain how you know.

The speed of most waves depends on the medium through which they are traveling. Generally, waves travel fastest through solids and slowest through gases. That's because particles are closest together in solids and farthest apart in gases. When particles are farther apart, it takes longer for the energy of the disturbance to pass from particle to particle.

### Points to Consider

You read in this lesson that waves travel at different speeds in different media.

- When a wave enters a new medium, it may speed up or slow down. What other properties of the wave do you think might change when it enters a new medium?
- What if a wave reaches a type of matter it cannot pass through? Does it just stop moving? If not, where does it go?
- Light may pass through matter. This is called transmission of light. As light is transmitted, it may be scattered by particles of matter and spread out in all directions. This is called scattering of light.
- Light may be absorbed by matter. This is called absorption of light. When light is absorbed, it doesn't reflect from or pass through matter. Instead, its energy is transferred to particles of matter, which may increase the temperature of matter.

# ENERGY TRANSFER

## LESSON OBJECTIVES

- Waves transfer heat/thermal energy through various mediums.
- Compare the transfer of heat by conduction, convection, and radiation and provide examples of each.

## VOCABULARY

- conduction
- convection
- radiation
- thermal insulator
- thermal conductor

# INTRODUCTION

Did you ever cook over a campfire? The girl in **Figure** below 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, convection, and radiation.***

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

## Conduction

*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 **Figure** above, conduction occurs between particles of the metal in the pot and between particles of the pot and the water. **Figure** below shows additional examples of conduction. For a deeper understanding of this method of heat transfer, watch the animation "Conduction" at this URL: **http://www.sciencehelpdesk.com/unit/science2/3.**


Figure 12. How is thermal energy transferred in each of these examples?

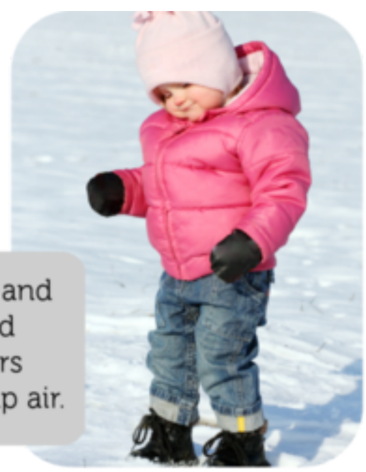
### Thermal Conductors

*Conduction* is usually faster in liquids and certain solids than in gases. Materials that are good conductors of thermal energy are called *thermal conductors*. Metals are excellent thermal conductors. They have freely moving electrons that can transfer energy quickly and easily. That's why the metal pot in Figure above soon gets hot all over, even though it gains thermal energy from the fire only at the bottom of the pot. In Figure above, the metal heating element of the curling iron heats up almost instantly and quickly transfers energy to the strands of hair that it touches.

### Thermal Insulators

Particles of gases are farther apart and have fewer collisions, so they are not good at transferring thermal energy. Materials that are poor thermal conductors are called *thermal insulators.* **Figure** below shows several examples. Fluffy yellow insulation inside the walls of a home is full of air. The air prevents the transfer of thermal energy into the house on hot days and out of the house on cold days. A puffy down jacket keeps you warm in the winter for the same reason. Its feather filling holds trapped air that prevents energy transfer from your warm body to the cold air outside. Solids like plastic and wood are also good **thermal insulators**. That's why pot handles and cooking utensils are often made of these materials.

Thermal insulators have many practical uses. Can you think of others?

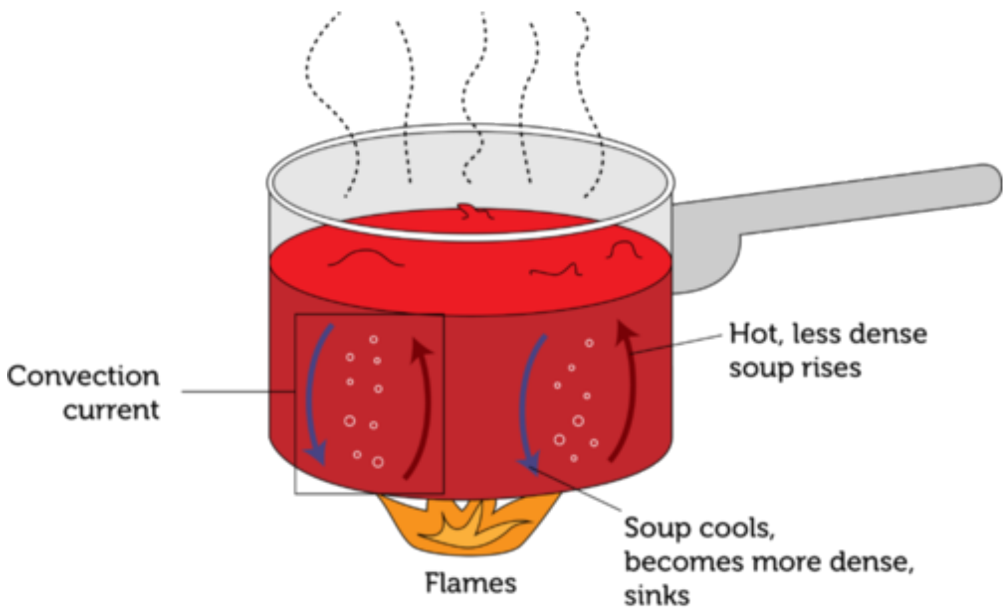


Fluffy insulation and feathers are good thermal insulators because they trap air.

Wood and plastic are good thermal insulators. That's why the spoon and pot handle stay cool enough to touch.

### Convection

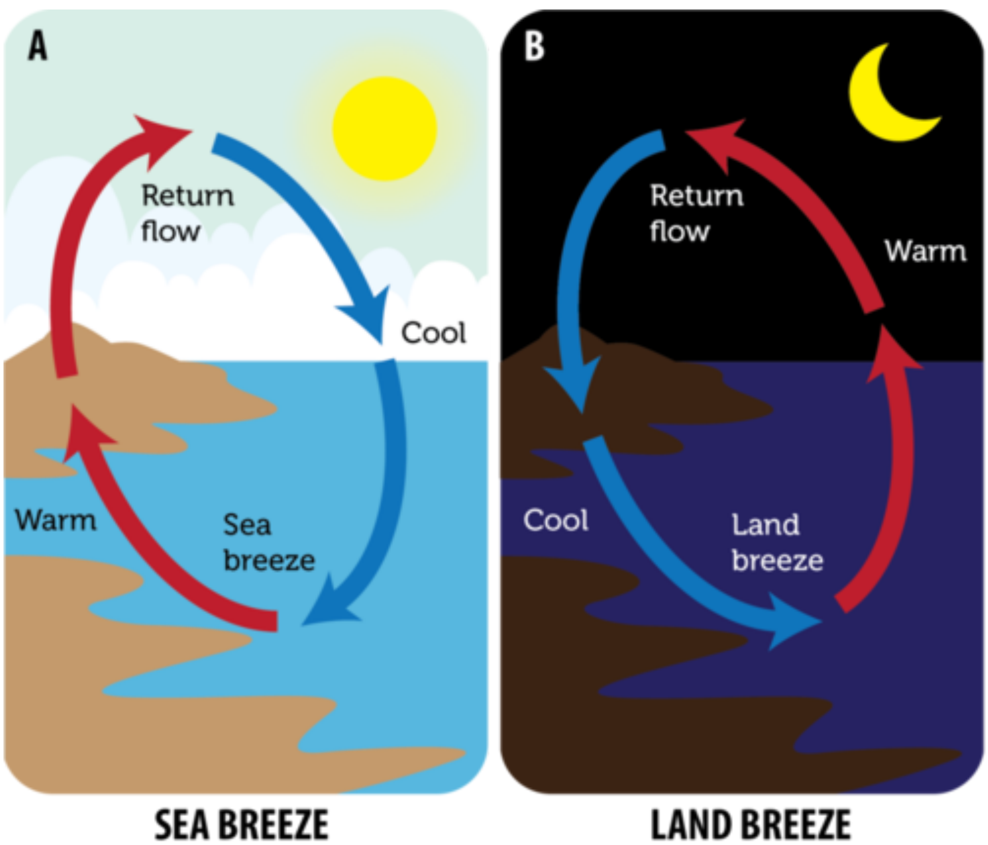
*Convection* is the transfer of thermal energy by particles moving through a fluid. Particles transfer energy by moving from warmer to cooler areas. That's how energy is transferred in the soup in **Figure** above. Particles of soup near the bottom of the pot get hot first. They have more energy so they spread out and become less dense. With lower density, these particles rise to the top of the pot (see **Figure** below). By the time they reach the top of the pot they have cooled off. They have less energy to move apart, so they become denser. 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.




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 **Figure** below. 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. You can learn more about convection currents by watching "Convection" at this URL: http://www.sciencehelpdesk.com/unit/science2/3

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?

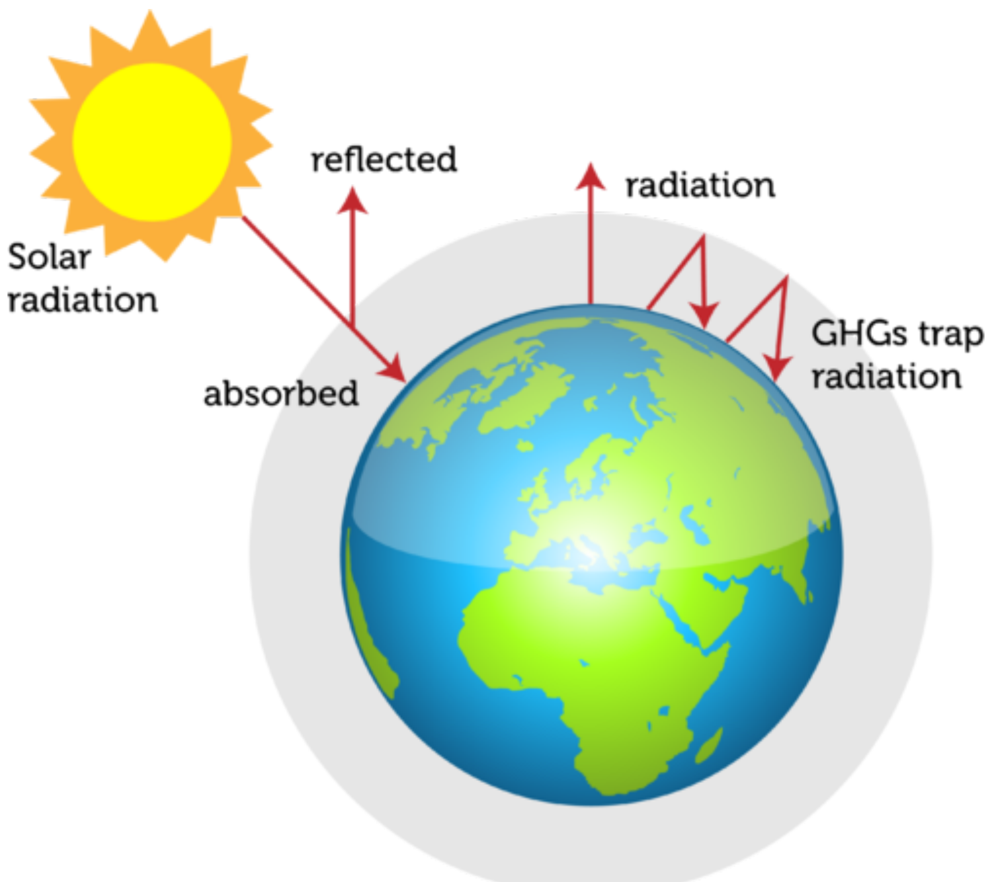


### Radiation

Both conduction and convection transfer energy through matter. Radiation is the only way of transferring energy that doesn't require matter. Radiation is the transfer of energy by waves that can travel through empty space. When the waves reach objects, they transfer energy to the objects, causing them to warm up. This is how the sun's energy reaches Earth and heats its surface (see **Figure** below). 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! To learn more about thermal radiation, watch "Radiation" at the URL below.

**http://www.sciencehelpdesk.com/unit/science2/3**

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. When the waves reach objects, they transfer thermal energy to the objects. This is how the sun's energy reaches and warms Earth



### How Energy Changes Form

Besides electrical, chemical, and thermal energy, some other forms of energy include mechanical and sound energy. Any of these forms of energy can change into any other form. Often, one form of energy changes into two or more different forms. For example, the popcorn machine below changes electrical energy to thermal energy. The thermal energy, in turn, changes to both mechanical energy and sound energy. You can read the **Figure** below how these changes happen. You can see other examples of energy changing form at this URL: **http://fi.edu/guide/hughes/energychangeex.html**

### Kinetic-Potential Energy Changes

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 does, the potential energy changes back to kinetic energy.

A tsunami is formed when an under ocean earthquake suddenly releases it's potential energy moving the sea floor, which is an example of mechanical energy. The sea floor moving causes the water to move and form an ocean wave, which is an example of a transverse wave. For more detail, see: **http://www.howitworksdaily.com/environment/how-a-tsunami-works/**

**Q:** Can you think of other fun examples of energy changing between kinetic and potential energy?

**A:** Playground equipment such as swings, slides, and trampolines involve these changes.


*Energy Conversions in a Popcorn Machine*

*1. The popcorn machine changes electrical energy to thermal energy, which heats the popcorn.*

*2. The heat causes the popcorn to pop. You can see that the popping corn has mechanical energy (energy of movement). It overflows the pot and falls into the pile of popcorn at the bottom of the machine.*

*3. The popping corn also has sound energy. That's why it makes popping sounds.*

# SUMMARY

Energy conversion is the process in which energy changes from one form or type to another. Energy is always conserved in energy conversions.

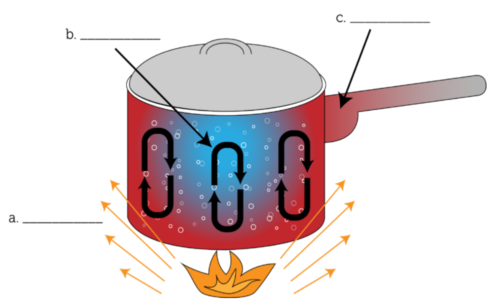
Different forms of energy—such as electrical, chemical, and thermal energy—often change to other forms of energy.

### Lesson Review Questions

1. Define conduction.
2. What is convection?
3. Define the radiation of thermal energy.

### Apply Concepts

Fill in each blank in the diagram below with the correct method of heat transfer.




How could you insulate an ice cube to keep it from melting? What material(s) would you use?

# LESSON SUMMARY

Conduction is the transfer of thermal energy 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 thermal energy by waves that can travel through empty space.

### Think Critically

Why does convection occur only in fluids? George says that insulation keeps out the cold. Explain why this statement is incorrect. What should George have said?

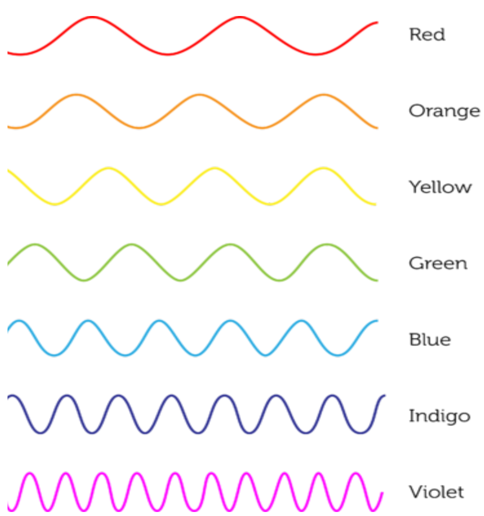
### Points to Consider

Thermal energy is very useful. For example, we use thermal energy to keep our homes warm and our motor vehicles moving.

7. How does thermal energy heat a house? What devices and systems are involved?
8. How does thermal energy run a car?
9. How does burning gas in the engine cause the wheels to turn?

# COLORS OF LIGHT

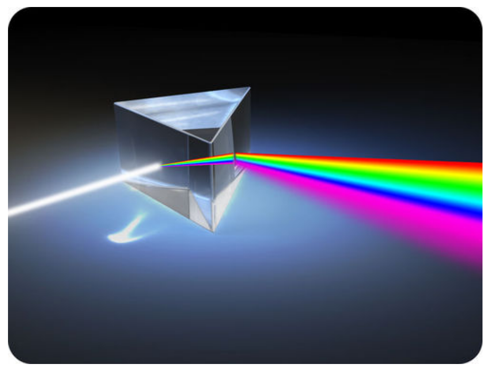
Visible light consists of a range of wavelengths. The wavelength of visible light determines the color that the light appears. As you can see in **Figure** below, light with the longest wavelength appears red, and light with the shortest wavelength appears violet. In between is a continuum of all the other colors of light. Only a few colors of light are represented in the figure.




The color of light depends on its wavelength.

### Separating Colors of Light

A prism, like the one in **Figure** below, can be used to separate 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. Look back at the rainbow that opened this chapter. Do you see all the different colors of light, from red at the top to violet at the bottom? Individual raindrops act as tiny prisms. They separate sunlight into its different wavelengths and create a rainbow.



A prism separates visible light into its different wavelengths.

# Standard 4, Objective 2: Examine the force exerted on objects by gravity.

**Matter** is all the "stuff" that exists in the universe. 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 **Figure** below 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, that is, the fruit's mass is less than 1 kg.

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

**A:** The mass of the fruit would be greater than 1 kg.


Mass is commonly confused with weight. The two are closely related, but they measure different things. Whereas 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 (as it is all over Earth), then an object with a greater mass also has a greater weight.

**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:**

$10 \times 2.2 \text{ lb} = 22 \text{ lb}$

## Mass versus Weight

In general, the more matter an object contains, the more it weighs. However, weight is not the same thing as mass. Weight is a measure of the force of gravity pulling on an object. It is measured with a scale, like the kitchen scale in Figure below. 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).


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

### 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 × 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?**

An object with more mass is pulled by gravity with greater force, so mass and weight are closely related. However, the weight of an object can change if the force of gravity changes, even while the mass of the object remains constant. Look at the photo of astronaut Edwin E.Aldrin Jr taken by fellow astronaut Neil Armstrong, the first human to walk on the moon, in Figure below. An astronaut weighed less on the moon than he did on Earth because the moon's gravity is weaker than Earth's. The astronaut'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.

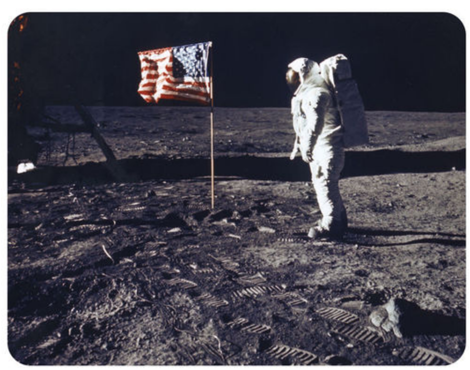


Figure 13. If the astronaut weighed 175 pounds on Earth, he would have weighed only 29 pounds on the moon. If his mass on Earth was 80 kg, what would his mass have been on the moon?

*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. So now, which has more gravity, you or Earth?

As you may have discovered in the activity, distance can have an affect on gravity. Thinking about this, if you were a astronaut, and you go farther into space, why do you become weightless? Well, as your distance from Earth increases, the force of gravity between you and Earth decreases. So when you're in space, gravity has less effect on your mass. Look closely at the following diagram to help you understand this concept.

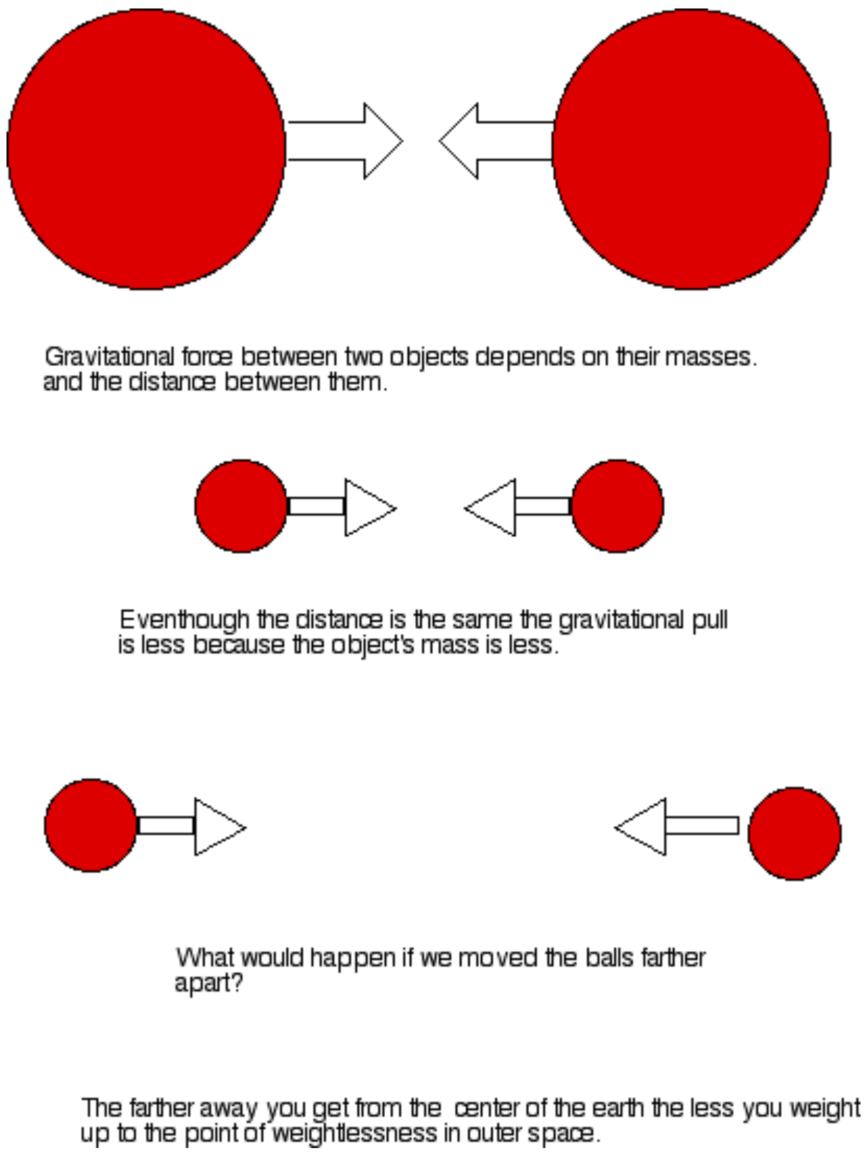



Figure 14. http://www.uen.org/core/science/sciber/sciber8/stand-4/gravity.shtml

The San Francisco Bay Bridge Construction

http://earthquake.usgs.gov

**Have you ever been worried while traveling over a bridge that it might collapse?**

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: http://www.dannyforster.com/tv/build-it-bigger/san-fran-oakland-bay-bridge Can you design a seismically safe bridge?

### Extension Investigation

1. Using the Bridge to Classroom's bridge simulator (http://eduweb.com/portfolio/bridgetoclassroom/engineeringfor.html), build a model of your own that you think could withstand an earthquake.

a) 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.

b) Decide which type of bridge you want for each segment of the bridge. Drag them into place.

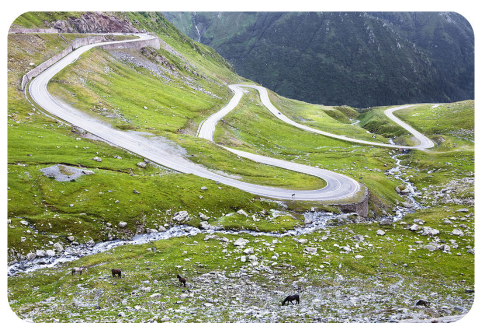
c) For each of the safety features, draw a sketch and describe their characteristics.

d) Add safety features as necessary to your bridge.

e) Now, test your bridge! Select different fault lines and magnitudes. Record the results of your tests.

f) Go back and redesign to build a more seismically safe structure!

2. 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? http://www.worsleyschool.net/science/files/bridge/bridge2.html



The highway above 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.

# ENERGY TRANSFER

Standard 4, Objective 3: Investigate the application of forces that act on objects, and the resulting motion.

## VOCABULARY

- Inclined plane
- Lever
- Pulley
- Screw
- Wedge
- Wheel and axle

## LESSON OBJECTIVES

1. Movement involves one form of energy being transformed into another form.
2. Energy has the potential to exert a force over a distance.
3. Calculate the mechanical advantage created when using a lever.

# 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 Figure below. 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://www.youtube.com/watch?v=72ZNEactb-k(1:35).**

Using a hammer to remove a nail changes both the direction and strength of the applied force. Where is the fulcrum of the hammer when it is used in this way?
A lever may or may not increase the force applied, and it may or may not change the direction of the force. It all depends on the location of the input and output forces relative to the fulcrum. In this regard, there are three basic types of levers, called first-class, second-class, and third-class levers. **Figure** below describes the three classes.

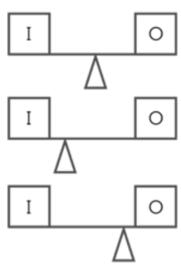
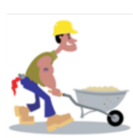
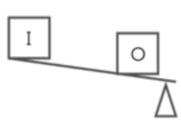
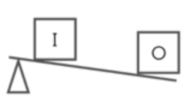
| Class of Lever | Example | Location of Input & Output Forces & Fulcrum | Ideal Mechanical Advantage | Change in Direction of Force? |
|---|---|---|---|---|
| First class | Seesaw  |   | IMA = 1<br>IMA < 1<br>IMA > 1 | yes<br>yes<br>yes |
| Second class | Wheelbarrow  |   | IMA > 1 | no |
| Third class | Hockey stick  |   | IMA < 1 | no |

Figure 15. Which class of lever would you use to carry a heavy load, sweep a floor, or pry open a can of paint?

### Comparing Classes and Mechanical Advantage of Levers

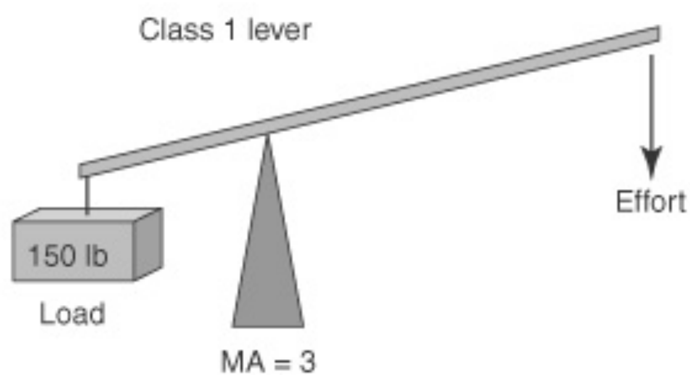
All three classes of levers make work easier, but they do so in different ways.

- **When the input and output forces are on opposite sides of the fulcrum, the lever changes the direction of the applied force. This occurs only with a first-class lever.**
- **When both the input and output forces are on the same side of the fulcrum, the direction of the applied force does not change. This occurs with both second- and third-class levers.**
- **When the input force is applied farther from the fulcrum, the input distance is greater than the output distance, so the ideal mechanical advantage is greater than 1. This always occurs with second-class levers and may occur with first-class levers.**
- **When the input force is applied closer to the fulcrum, the input distance is less than the output distance, so the ideal mechanical advantage is less than 1. This always occurs with third-class levers and may occur with first-class levers.**
- **When both forces are the same distance from the fulcrum, the input distance equals the output distance, so the ideal mechanical advantage equals 1. This occurs only with first class-levers.**

### Advantage of Third-Class Levers

You may be wondering why you would use a third-class lever when it doesn't change the direction or strength of the applied force. The advantage of a third-class lever is that the output force is applied over a greater distance than the input force. This means that the output end of the lever must move faster than the input end. Why would this be useful when you are moving a hockey stick or baseball bat, both of which are third-class levers?

$$\text{MA} = \frac{\text{effort (force) distance} = \text{effort arm}}{\text{resistance force (load) distance} = \text{resistance arm}}$$



# INCLINED PLANES

### What Is an Inclined Plane?

An *inclined plane* is a simple machine that consists of a sloping surface connecting a lower elevation to a higher elevation. 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.

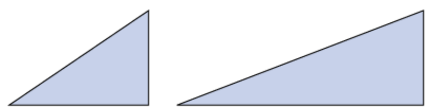
A ramp like the one in the Figure below is another example of an inclined plane. Inclined planes make it easier to move objects to a higher elevation. The sloping surface of the inclined plane supports part of the weight of the object as it moves up the slope. As a result, it takes less force to move the object uphill. 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://www.mikids.com/SMachinesInclinedPlanes.htm**

### Mechanical Advantage of an Inclined Plane

The mechanical advantage of a simple machine is the factor by which it multiplies the force applied to the machine. It is the ratio of output force (the force put out by the machined) to input force (the force put into the machine). For an inclined plane, less force is put into moving an object up the slope than if the object were lifted straight up, so the mechanical advantage is greater than 1. The more gradual the slope of the inclined plane, the less input force is needed and the greater the mechanical advantage.

Q: Which inclined plane pictured in the Figure below 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.

## SUMMARY

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.

Less force is needed to move an object uphill with an inclined plane, but the force must be applied over a greater distance. The mechanical advantage of an inclined plane is always greater than 1, because the machine puts out more force than the user puts into it.

### Vocabulary

inclined plane: Simple machine consisting of a sloping surface that connects lower and higher elevations.

### Practice

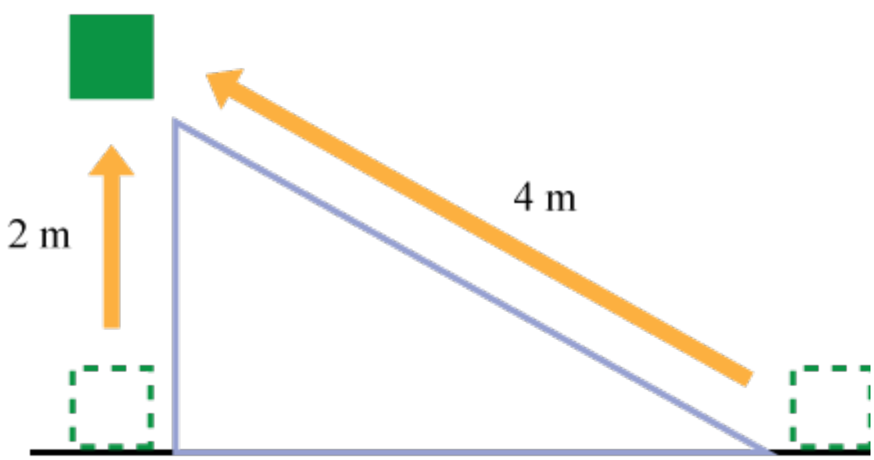
At the following URL, click on the inclined plane and go through the animation. Then answer the questions below.

**http://dev.cosi.org/files/Flash/simpMach/sm1.html**

In the animation, how is the mechanical advantage of an inclined plane calculated? Use this method to find the mechanical advantage of the inclined plane in the Figure below.

### Review

1. What is an inclined plane?
2. How does an inclined plane make work easier? How does it change the force that is applied to the inclined plane?
3. Why is the mechanical advantage of an inclined plane greater than 1?
4. What is an example of an inclined plane that wasn't mentioned in the article?



# WHEEL AND AXLE

Did you ever ride on a Ferris wheel, like the one pictured in Figure below? 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. The car steering wheel in Figure below 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 is either increased or applied over a greater distance.

When the input force is applied to the axle, as it is with a Ferris wheel, the wheel turns with less force, so the ideal mechanical advantage is less than 1. 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, so the ideal mechanical advantage is greater than 1. 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.

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

Where is the force applied in each wheel and axle pictured here? Is it applied to the axle or to the wheel?

# 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. Figure below shows two common uses of pulleys.

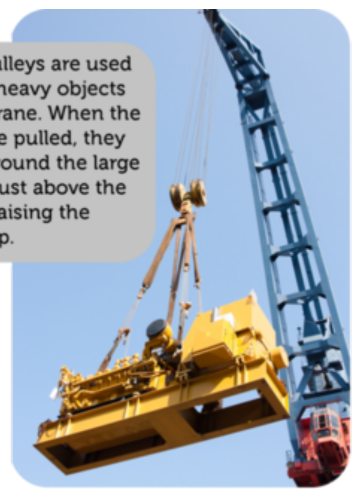
In both of these examples, pulling the rope turns the wheel of the pulley.
Some pulleys are attached to a beam or other secure surface and remain fixed in place. They are called fixed pulleys. Other pulleys are attached to the object being moved and are moveable themselves. They are called moveable pulleys. Sometimes, fixed and moveable pulleys are used together. They make up a compound pulley. The three types of pulleys are compared in Figure below. In all three types, the ideal mechanical advantage is equal to the number of rope segments pulling up on the object. The more rope segments that are helping to do the lifting work, the less force that is needed for the job. You can experiment with an interactive animation of compound pulleys with various numbers of pulleys at this link: http://www.walter-fendt.de/ph14e/pulleysystem.htm.

In a *single fixed* pulley, only one rope segment lifts the object, so the ideal mechanical advantage is 1. This type of pulley doesn't increase the force, but it does change the direction of the force. This allows you to use your weight to pull on one end of the rope and more easily raise the object attached to the other end.

In a *single moveable* pulley, two rope segments lift the object, so the ideal mechanical advantage is 2. This type of pulley doesn't change the direction of the force, but it does increase the force.

In a *compound* pulley, two or more rope segments lift the object, so the ideal mechanical advantage is equal to or greater than 2. This type of pulley may or may not change the direction of the force, depending on the number and arrangement of pulleys. When several pulleys are combined, the increase in force may be very great. To learn more about the mechanical advantage of different types of pulleys, watch the video at this link: **http://video.google.com/videoplay?docid=8517358537561483069#.**

Small pulleys are used to help control the shape of the sail on a boat. When you pull the cord, it rotates around the small wheel below the boom to move the boom downward.



Large pulleys are used to raise heavy objects with a crane. When the cords are pulled, they rotate around the large wheels just above the object, raising the object up.

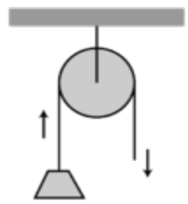
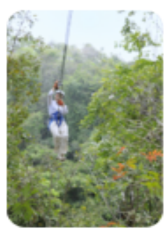
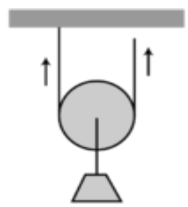
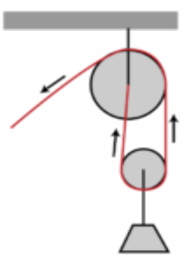
| Type of Pulley | Example | How it Works | No. of Rope Segments Pulling up | Ideal Mechanical Advantage | Change in Direction of Force? |
|---|---|---|---|---|---|
| Single fixed pulley | Flagpole pulley  |  | 1 | 1 | yes<br>yes<br>yes |
| Single movable pulley | Zip-line pulley  |  | 2 | 2 | no |
|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

Figure 16. Single pulleys may be fixed or moveable. Compound pulleys consist of two or more pulleys.

# LESSON SUMMARY

An inclined plane is a simple machine consisting of a sloping surface that connects lower and higher elevations. The ideal mechanical advantage of an inclined plane is always greater than 1.

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. The ideal mechanical advantage of wedges and screws is always greater than 1.

A lever is a simple machine that consists of a bar that rotates around a fixed point called the fulcrum. There are three classes of levers. Depending on its class, a lever may have an ideal mechanical advantage that is less than, equal to, or greater than 1. First-class levers also change the direction of the input force.

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. When force is applied to the inner axle, the ideal mechanical advantage is less than 1. When force is applied to the outer wheel, the ideal mechanical advantage is greater than 1.

A pulley is a simple machine that consists of a rope and grooved wheel. Single pulleys may be fixed or moveable. Single and moveable pulleys may be combined in a compound pulley. The ideal mechanical advantage of a pulley or compound pulley is always equal to or greater than 1. Fixed pulleys and some compound pulleys also change the direction of the input force.

# LESSON REVIEW QUESTIONS

Recall

1. What is an inclined plane?
2. Give an example of a wedge. What work does it do?
3. How does force change when it is applied to the axle of a wheel and axle?
4. What determines the ideal mechanical advantage of a pulley?

Apply Concepts

5. A leaf rake is a type of lever. Where is the fulcrum and where are the input and output forces applied? Which class of lever is a rake? Explain your answer.

Think Critically

6. Explain why inclined planes, wedges, and screws always have an ideal mechanical advantage greater than 1.
7. Compare and contrast the three classes of levers.

Try It Out!

8. Use a pry-bar or crow-bar as a hammer to pound two nails into a block of wood. Next, remove one nail using the curly end of the crow-bar. Finally, remove the second nail using the flat end of the crow-bar. You have just used all three classes of lever in one tool: the crow-bar!

### Points to Consider

In this lesson, you read that a compound pulley consists of two or more single pulleys. Many other machines also consist of two or more simple machines.

- **Can you think of additional examples of machines that consist of more than one simple machine? Which simple machines do they contain?**
- **How might combining simple machines into a more complex machine affect efficiency and mechanical advantage?**

# COMPLEX MACHINES

Did you ever look closely at the moving parts of a bicycle? You can see some of them in the opening image. Do you see any simple machines, such as pulleys, wheels and axles, levers, or screws? A bicycle consists of many simple machines. It's an example of a complex machine.

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

A: Find out if you are right at the following URL. Click on the parts of the bicycle in the animation to find the simple machines.

**http://library.thinkquest.org/CR0210120/Compound%20machine.html**

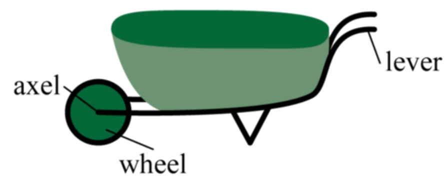
### What Is a Complex Machine?

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 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://www.youtube.com/watch?v=e4LUaAwuh_U&NR=1**

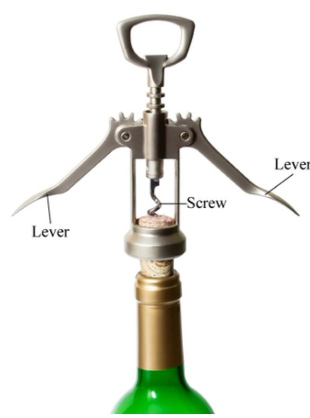
### Wheelbarrow

Look at the wheelbarrow in the Figure below. 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.




### Corkscrew

The corkscrew in the Figure below 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.




Efficiency of Complex Machines

Friction is a force that opposes motion between any surfaces that are touching. All machines have moving parts and friction, so they have to use some of the work that is applied to them to overcome friction. This makes all machines less than 100 percent efficient. Because complex machines have more moving parts than simple machines, they generally have more friction to overcome. As a result, complex machines tend to have lower efficiency than simple machines. When a complex machine consists of many simple machines, friction can become a serious problem, and it may produce a lot of heat. Lubricants such as oil or grease may be used to coat the moving parts of a machine so they slide over each other more easily. This is how friction is reduced in a car engine.

# SUMMARY

A complex machine is a machine that consists of more than one simple machine.

Complex machines such as a wheelbarrow or corkscrew consist of just two simple machines. Big complex machines such as cars consist of hundreds or thousands of simple machines.

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

### Practice

Do the simple and complex machines quiz at the following URL. Be sure to check your answers.
**http://www.quia.com/pop/36483.html?AP_rand=58166172**

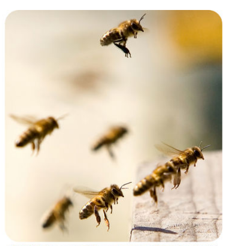
### Review

1. **What is a complex machine?**
2. **What simple machines are found in a wheelbarrow? How do they make it easier to carry heavy objects?**
3. **A pair of scissors is an example of a complex machine. Label the simple machines in the pair of scissors in the Figure below.**

4. **Why do complex machines tend to have lower efficiency but greater mechanical advantage than simple machines?**

# STANDARD 4, OBJECTIVE 4: ANALYZE VARIOUS FORMS OF ENERGY AND HOW LIVING ORGANISMS SENSE AND RESPOND TO ENERGY.

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




## Defining Kinetic Energy

*Kinetic energy* is the energy of moving matter. Anything that is moving has kinetic energy—from atoms in matter to stars in outer space. Things with kinetic energy can do work. For example, the spinning saw blade in the photo above is doing the work of cutting through a piece of metal. You can see a cartoon introduction to kinetic energy and how it is related to work at this URL: **http://www.youtube.com/watch?v=zhX01toLjZs**

This diver is 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?

## Stored Energy

The diver has energy because of her position high above the pool. The type of energy she has is called potential energy. *Potential energy* is energy that is stored in a person or object. Often, the person or object has potential energy because of its position or shape.

Q: What is it about the diver's position that gives her potential energy?

A: Because the diver is high above the water, she has the potential to fall toward Earth because of gravity. This gives her potential energy.

## Gravitational Potential Energy

Potential energy due to the position of an object above Earth's surface is called gravitational potential energy. Like the diver on the diving board, anything that is raised up above Earth's surface has the potential to fall because of gravity. You can see other examples of people with gravitational potential energy in the Figure below and below. You can also watch a cartoon introduction to gravitational potential energy by playing video #10 at this URL: **http://www.animatedscience.co.uk/flv/**

Sari and Daniel are spending a stormy Saturday afternoon with cartons of hot popcorn and a spellbinding 3-D movie. They are obviously too focused on the movie to wonder where all the energy comes from to power their weekend entertainment. They'll give it some thought halfway through the movie when the storm causes the power to go out!

### Kinetic-Potential Energy Changes

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 does, the potential energy changes back to kinetic energy.

That's what happened to Sari. After she and Daniel left the theater, the storm cleared and they went to the pool. That's Sari in the Figure below c oming down the water slide. When she was at the top of the slide, she had potential energy. Why? She had the potential to slide into the pool because of the pull of gravity. 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 roller coaster is another fun example of changes between kinetic and potential energy. Watch the roller coaster animation at the URL below to see the energy changes. Notice how the roller coaster's total energy (kinetic energy + potential energy) does not change.

Q: Can you think of other fun examples of energy changing between kinetic and potential energy?

A: Playground equipment such as swings, slides, and trampolines involve these changes.

# SUMMARY

Energy conversion is the process in which energy changes from one form or type to another. Energy is always conserved in energy conversions.

Different forms of energy—such as electrical, chemical, and thermal energy—often change to other forms of energy.

Mechanical energy commonly changes back and forth between kinetic and potential energy.

### Practice

You can check your understanding of how energy changes form by doing the quizzes at these URLs:

**http://www.think-energy.co.uk/ThinkEnergy/11-14/activities/EnergyTrans2.aspx**

**http://www.poweringourfuture.com/students/energy/2.html**

### Review

1. Define energy conversion.
2. Relate energy conversion to the law of conservation of energy.
3. Describe an original example of energy changing from one form to two other forms.
4. 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.

# FRICTION

Lesson Objectives

- Describe friction and how it opposes motion.
- Identify types of friction.

## Introduction

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

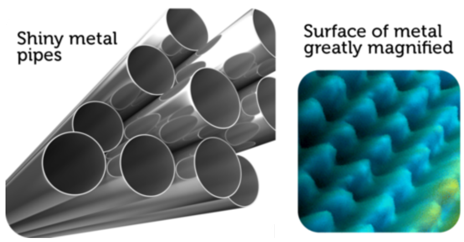
## What Is Friction?

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. Other examples of friction are illustrated in Figure below. You can see an animation showing how friction opposes motion at this URL: **http://www.darvill.clara.net/enforcemot/friction.htm.** For a musical introduction to friction from Bill Nye the Science Guy, go to this URL: **http://www.youtube.com/watch?v=a5SOCxYft20&feature=related (1:33).**

Sometimes friction is useful. Sometimes it's not.

### Why Friction Occurs

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 Figure below. 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.




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

### Factors that Affect 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 (see Figure below). 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.

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

### Friction Produces Heat

You know that friction produces heat. That's why rubbing your hands together makes them warmer. 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 (see Figure below). 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.

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.

### Types of Friction

There are different ways you could move heavy boxes. You could pick them up and carry them. You could slide them across the floor. Or you could put them on a dolly like the one in Figure below and roll them across the floor. This example illustrates three types of friction: static friction, sliding friction, and rolling friction. Another type of friction is fluid friction. All four types of friction are described below. In each type, friction works opposite the direction of the force applied to a move an object. You can see a video demonstration of the different types of friction at this URL: **http://www.youtube.com/watch?v=0bXpYbIzkR0&feature=related (1:07).**

A dolly with wheels lets you easily roll boxes across the floor.

### Static Friction

Static friction acts on objects when they are resting on a surface. For example, if you are walking on a sidewalk, there is static friction between your shoes and the concrete each time you put down your foot (see Figure below). Without this static friction, your feet would slip out from under you, making it difficult to walk. Static friction also allows you to sit in a chair without sliding to the floor. Can you think of other examples of static friction?

Static friction between shoes and the sidewalk makes it possible to walk without slipping.

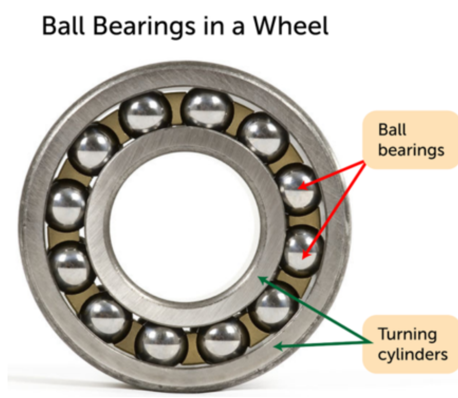
### Sliding Friction

Sliding friction is friction that acts on objects when they are sliding over a surface. Sliding friction is weaker than static friction. That's why it's easier to slide a piece of furniture over the floor after you start it moving than it is to get it moving in the first place. Sliding friction can be useful. For example, you use sliding friction when you write with a pencil and when you put on your bike's brakes.

### Rolling Friction

Rolling friction is friction that acts on objects when they are rolling over a surface. Rolling friction is much weaker than sliding friction or static friction. This explains why it is much easier to move boxes on a wheeled dolly than by carrying or sliding them. It also explains why most forms of ground transportation use wheels, including cars, 4-wheelers, bicycles, roller skates, and skateboards.

Ball bearings are another use of rolling friction (see **Figure** below). They allow parts of a wheel or other machine to roll rather than slide over one another.




The ball bearings in this wheel reduce friction between the inner and outer cylinders when they turn.

### Fluid Friction

Fluid friction is friction that acts on objects that are moving through a fluid. A ***fluid*** is a substance that can flow and take the shape of its container. Fluids include liquids and gases. If you've ever tried to push your open hand through the water in a tub or pool, then you've experienced fluid friction between your hand and the water. When a skydiver is falling toward Earth with a parachute, fluid friction between the parachute and the air slows the descent (see **Figure** below). Fluid pressure with the air is called air resistance. The faster or larger a moving object is, the greater is the fluid friction resisting its motion. The very large surface area of a parachute, for example, has greater air resistance than a skydiver's body.

Fluid friction of the parachute with the air slows this skydiver as he falls.

## LESSON SUMMARY

Friction is a force that opposes motion between two surfaces that are touching. Friction occurs because no surface is perfectly smooth. 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.

Types of friction include static friction, sliding friction, rolling friction, and fluid friction. Fluid friction with air is called air resistance.

Lesson Review Questions

Recall

1. What is friction?
2. List factors that affect friction.
3. How does friction produce heat?

Apply Concepts

4. Identify two forms of friction that oppose the motion of a moving car.

Think Critically

5. Explain why friction occurs.
6. Compare and contrast the four types of friction described in this lesson.

# Sensing Sound Energy

The noise of a cheering crowd at a game can be deafening! Really.

### The Ear and Hearing

The ear is a complex organ that senses sound energy so we can hear. Hearing is the ability to sense sound energy and perceive sound. All of the structures of the ear that are involved in hearing must work well for a person to have normal hearing. Damage to any of the structures, through illness or injury, may cause hearing loss. Total hearing loss is called deafness. To learn more about hearing loss, watch the animations at these URLs:

**http://www.youtube.com/watch?v=lioNIbtFxSY&NR=1**

**http://www.youtube.com/watch?NR=1&v=YpIptQSEEjY**

### Telescopes

WWGD? What would Galileo do (if he could see the things we can see through a telescope)?

If you think oceans are inhospitable, try space! Humans have been to our Moon and many have orbited Earth in spacecraft, even staying for months at a time in a space station. 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. If you haven't ever looked at the night sky through a telescope you should try to soon!

# GLOSSARY

**Amplitude**: The maximum distance from the resting point of a wave.

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

**Compression**: The part of a longitudinal wave where the particles are closer together.

**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 Types**: Kinetic, Potential, Chemical, Thermal, Nuclear, Electrical, and Gravitational.

**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.

**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

**Longitudinal wave**: particles of the medium vibrate back and forth parallel to the direction of the wave

**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

Rarefaction The part of a longitudinal wave where the particles are farthest apart.

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.

**Surface Wave**: particles of the medium vibrate both up and down and back and forth, so they end up moving in a circle.

**Transverse wave**: particles of the medium vibrate up and down perpendicular to the direction of the wave.

**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.

THIS BOOK BELONGS TO: