# Ms. Rogers' Super Awesome 8th Grade Science EOG Review Booklet

Use it. Study it. Pass the EOG!

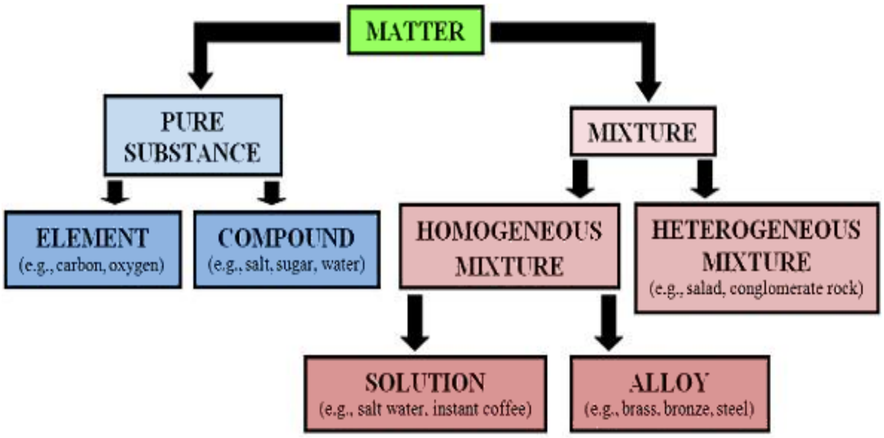
This is a summary of everything we've covered this year in 8th grade science. Yup, you heard me, EVERYTHING. So sit back, relax, and get to studying! Good Luck!!!

**Name**______________________________________________________
**Block**__________________

# Classification of Matter

*Everything that has mass and volume is made of* ***matter****.*

Atoms are the building blocks of matter. They cannot be broken down into smaller pieces using chemical reactions or physical change. Various groups of atoms compose all known matter. Matter can be classified into two major categories: pure substances and mixtures.




**Pure Substances**
A pure substance is a type of homogeneous matter that is made up of only one kind of material. All the particles (i.e., atoms or molecules) in a pure substance are exactly the same, and the same properties are exhibited throughout the substance. There are two main types of pure substances: elements and compounds.

- **Elements**—Elements are the simplest pure substance, because they are made up of only one type of atom. For example, the element carbon is only made up of carbon atoms, and the element zinc is only made up of zinc atoms. The simplest unit of an element that still has the properties of that element is the atom. However, the atoms of some elements are naturally found bound to other atoms of the same element in two-atom units called *diatomic molecules*.
  Today, there are over 100 known elements. These elements are represented by chemical symbols (e.g., C represents carbon and Zn represents zinc) and are listed in order of their atomic numbers on the periodic table.
- **Compounds**—Compounds are pure substances that are made up of more than one type of element, chemically combined in a fixed ratio. Depending on the type of compound, its simplest unit may be a molecule or a repeating crystal pattern. Although the properties of a compound differ from the properties of the elements that compose it, the molecules of a compound exhibit the same properties as one another. Also, since the elements within a compound are chemically combined, they can only be separated by chemical changes, such as the change caused by electrolysis.
  Compounds have a definite chemical composition that can be identified using a chemical formula. Water ($H_2O$), salt (sodium chloride, NaCl), and sugar (glucose, $C_6H_{12}O_6$) are all examples of compounds.

**Mixtures**
Mixtures are made up of two or more substances that are not chemically combined. Because they are not chemically combined, the substances retain their own individual properties of matter, even though they are mixed together. Furthermore, mixtures can be separated by physical means, such as filtration or distillation.

- **Homogeneous Mixtures**—A homogeneous mixture is uniform. That is, it has the same properties throughout. *Solutions* and *alloys* are two types of homogeneous mixtures. In a solution, one substance is dissolved into another substance (e.g., salt water, instant coffee). The substance being dissolved is called the *solute*, and the substance doing the dissolving is called the *solvent*. In solutions and alloys, the solute is evenly distributed in the solvent. In *aqueous* solutions, water is the solvent. A solution of a solid in a liquid can generally be separated through the process of vaporization. An alloy is a *solid solution* in which one metal is dissolved into another (e.g., the alloy brass is made of copper and zinc).
- **Heterogeneous Mixtures**—A heterogeneous mixture does not have the same properties throughout. In fact, the substances in a mixture often keep their own separate identities and individual properties. For example, a tossed salad is a heterogeneous mixture, and its properties are not the same throughout. Instead, each part of the salad (e.g., lettuce, tomato, croutons, etc.) keeps its own individual identity and properties.

  Some heterogeneous mixtures are ***suspensions***—fluids which contain insoluble solid particles that eventually settle out. A mixture of fine sand and water is a suspension. The pictures below illustrate how, after being mixed with water, sand particles settle to the bottom of the container.

  Some mixtures can be difficult to classify. For example, ***colloids*** may be classified as a heterogeneous or a homogeneous mixture, depending on the context. In a colloid, solid particles are dispersed in a liquid. While the particles are not dissolved, they may be dispersed well enough that they will not settle out over time as would a suspension. Milk is an example of a colloid. Unlike the components of solutions, the components of a colloid can be separated from one another using a filter if the pores of the filter are sufficiently small.

Mixtures can occur between all phases of matter.

# The Periodic Table

> *The **Periodic Table** is a chart displaying information about the elements. Elements are arranged in the table in a specific pattern that helps to predict their properties and to show their similarities and differences.*

The periodic table was developed by **Dmitri Mendeleev** in 1869. It provides a powerful tool for studying the elements and how they combine. There are over 100 known elements, so it is necessary to use a systematic method to organize them. The periodic table indicates each element's atomic symbol, atomic number, and average atomic mass (also called atomic weight).
The placement of an element on the periodic table gives clues about the element's chemical and physical properties, including its melting point, density, hardness, and thermal and electrical conductivities.

**Periods**
The periodic table is so named because it is organized into "periods." A **period** is defined *as an interval required for a cycle to repeat itself*. In the periodic table, the periods are the horizontal rows that extend from left to right. These periods consist of as few as two elements and as many as thirty-two elements.Both the atomic number and the atomic mass of the elements increase moving across the table from left to right and down the table from top to bottom.

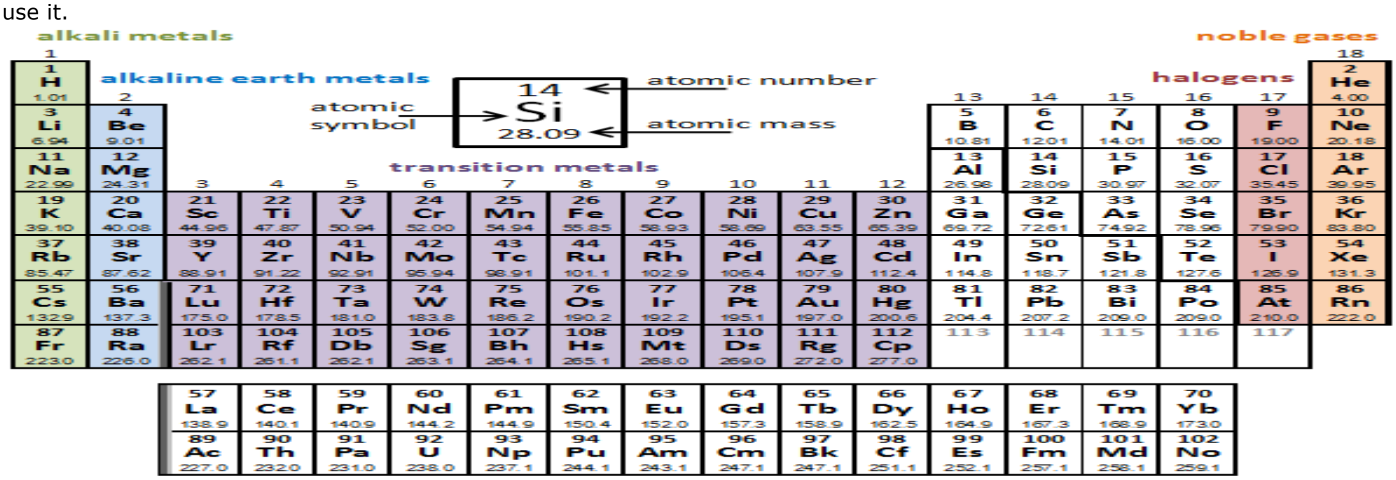
**Groups and Families**
The division of elements into vertical **groups** by column creates **families** of elements. Elements in the same group all have similar chemical properties. For example, lithium (Li), which is in group 1, can easily combine with chlorine (Cl), which is in group 17, and form lithium chloride (LiCl). Since sodium (Na) is also in group 1, it has similar chemical properties to lithium, and it can also combine easily with chlorine and form sodium chloride (NaCl).
Some individual groups (or families) in the periodic table also have special names. The properties of these groups are described below:

- **Group 1: Alkali metals**– All of the elements in group 1 of the periodic table (except hydrogen) are alkali metals. They are soft metallic solids with low melting points and they are the most reactive metals.
- **Group 2: Alkaline earth metals**– All of the elements in group 2 of the periodic table are alkaline earth metals. They are hard metallic solids and have higher melting points than alkali metals. Though they are also highly reactive, they are less reactive than alkali metals.
- **Group 17: Halogens**– All of the elements in group 17 are halogens. They have low boiling points and low melting points.
- **Group 18: Noble gases**– All of the elements in group 18 are noble gases. They tend to be stable and unreactive. In general, noble gases do not react or combine with any element.
- **Groups 3-12: Transition metals**– Elements located in groups 3-12 on the periodic table are known as transition elements. These elements tend to be hard metallic solids, and have high heat and electrical conductivities.

**Metals, Nonmetals & Metalloids**
The elements in the periodic table can be subdivided into metals, nonmetals, and metalloids. The stair step line that begins between boron, B, and aluminum, Al, and moves down and right to polonium, Po, and astatine, At, is the dividing line between metals and nonmetals.
This division is shown by the different colors in the periodic table below.

- **Metals** are the elements to the left of the stair step. Metals are typically dense solids with a shiny luster. They tend to form positive ions and are capable of conducting electricity. Metals most often form ionic bonds with nonmetals and metallic bonds with metals.
- **Nonmetals** are elements to the right of the stair step plus hydrogen. They tend to have low densities, a dull luster, low melting points, and do not conduct electricity. They are often brittle. Nonmetals tend to form ionic bonds with metals and covalent bonds with other nonmetals.
- **Metalloids** are the elements along the stair step that have some of the properties of both metals and nonmetals. The metalloid elements are B, Si, Ge, As, Sb, and Te. Some of these elements, such as Si and Ge, are semiconductors. Exceptions to the stair step rule include Al, Po, and At, though, Po and At, have also been classified as metalloids by some scientists.

The periodic table is very carefully organized. A wealth of information can be found in the periodic table if one understands how to use it.



# Chemical and Physical Properties

*Each substance has its own unique combination of **physical** and **chemical properties**, and substances can be identified based on these properties.*

**Physical properties** are characteristics of an element or compound that can be observed without changing the identity of the substance. They are the properties that the substance already has. ***Color, density, mass, and solubility are all physical properties.*** Some physical properties change depending on the amount of the substance present. These properties are called *extrinsic properties*. Mass and volume are examples of extrinsic properties.Other physical properties are not dependent on how much of the substance is present. These are called *intrinsic* properties. Boiling point and density are two examples of intrinsic properties. Whether you have a cup of water or an entire pot filled with water, the water in both will boil at 100 °C (at sea level). The water in both containers will also have the same density of about 1.0 g/mL (at 25 °C). ***Intrinsic properties are useful when identifying an unknown substance.*** During a physical change, substances are not altered chemically. They simply change from one state of matter to another, or they separate or combine without breaking or making bonds. Changes of state are physical changes. Making and separating mixtures are also physical changes. Mixtures can be separated using the differences in physical properties of each substance.

**Mass** is the amount of matter in an object. Mass is different from weight.

**Weight** is a *force* due to the pull of gravity on an object. The mass of an object stays constant in all situations. Weight, however, is influenced by the strength of the gravitational pull. Therefore, weight changes depending on the forces of gravity at that location. For example, the same object will weigh more on the Earth than it does on the Moon because the gravitational pull of the Earth is greater than the gravitational pull of the Moon. It's mass, though, will be the same on Earth as it is on the Moon because the amount of matter does not change.

**Volume** is the amount of space occupied by a substance; size.

**Density** is how much mass a material has per unit of volume. Denser materials have more matter in a given space than less dense materials. Density is found by dividing the mass of an object by its volume.

**Appearance** is how something looks. The property of appearance might include color, luster, shape, and the degree to which an object is transparent or opaque.

**Odor** is the smell that a substance gives off. For example, vinegar has a pungent odor.

**Texture** is how a substance feels to the touch. For example, sand has a grainy texture, while talc has a soft, fine texture.

The **boiling point** is the temperature at which a liquid changes to a gas. For water, it is 100 °C or 212 °F.

The **melting/freezing point** is the temperature at which a liquid changes from a solid to a liquid. For water, it is 0 °C or 32 °F.

**Solubility** refers to the ability of a substance to dissolve in a solvent such as water or the amount of a substance that can dissolve in a certain amount of water. The solubility of salt is about 36 grams per 100 mL of water.

**Polarity** refers to the distribution of electrical charge within a molecule of a substance. A water molecule is *polar* because its oxygen has a partial negative charge, while its hydrogens have partial positive charges. Polar solvents dissolve polar solutes, and nonpolar solvents dissolve nonpolar solutes.

**Viscosity** refers to how easily a liquid is able to flow.

**Conductivity** refers to the ability of a substance to transmit energy. Usually this refers to its ability to conduct electricity, but it may also refer to its ability to conduct heat. Metals and solutions that contain ions, such as HCl in water, can usually conduct electricity.

**Compressibility** refers to the ability of a given mass of a substance to decrease in volume in response to the application of an outside force.

**Magnetism** refers to the ability of a substance to respond to a magnetic field. Metals such as iron, nickel, and cobalt are ***magnetic*** because they can be attracted by magnetic fields.

**Chemical properties** are the characteristic ways in which an element or compound chemically behaves. They describe how substances react under certain conditions and with other substances. Chemical properties primarily depend on the types of atoms and bonds that are in a substance. During a **chemical change**, a **chemical reaction** takes place. Atoms are rearranged by making and/or breaking bonds to form new substances with different properties. Chemical properties and changes can be used to identify a substance, but these methods always change the substance into a new compound.

**Reactivity**describes whether a substance reacts easily with other substances. For example, most metals will react with acids.

An **unreactive** substance does not react easily with most other substances. The noble gases are the least reactive elements, and water is an example of an unreactive compound.

The **ability to react with acids or bases** describes whether or not a substance reacts chemically with an acid or a base.

**Flammability** describes the ability of a substance to ignite or burn.

**Combustibility** describes the ability of a substance to react rapidly with oxygen and release energy in the form of heat and/or light.

The **ability to oxidize** or the **ability to rust** refers to the tendency of some metals to rust or corrode by reacting with oxygen in the air.

The **ability to tarnish** refers to the tendency of some metals to react easily with certain gases in the air. This causes discoloration at the surface of the metal.

# Physical & Chemical Changes

*Matter can undergo physical and chemical changes. When a* ***physical change*** *occurs, a substance changes without altering its composition. When a* ***chemical change*** *occurs, a substance has chemically reacted to form one or more different substances.*

**Physical Changes**
When a **physical change** occurs, a substance changes its appearance but not its identity or chemical composition. For example, paper appears different after it has been shredded. However, the substance is still paper.

Some examples of physical changes include:

- liquid freezing into solid
- shredding a piece of paper
- pounding a metal, such as aluminum, into thin sheets
- breaking glass
- filtering a solid from a liquid
- a solid expanding as it is heated

A change in state is a physical change. When water is boiled it becomes vapor. The water changes from a liquid to a gas. However, the water is still water, so it is a physical change. When solid gold is melted, it changes state as it becomes a liquid. However, the gold has not changed its identity, (it is still gold), so this is also a physical change.Changes in state are physical changes. Water can change from a solid to a liquid, but it is still water.

A **chemical change** occurs when a substance changes its identity because its particles have been rearranged. The new substance that is formed has its own new properties.
For example, when zinc metal is placed in a hydrochloric acid solution, it reacts with the acid. The zinc atoms combine with chlorine atoms from the acid, and it becomes zinc chloride and hydrogen gas. All chemical changes involve chemical reactions. Chemical reactions can be written in the form of a chemical equation. The reaction of zinc (Zn) with hydrochloric acid (HCl) is represented by the following chemical equation: $Zn + 2HCl \rightarrow ZnCl_2 + H_2$. The properties of a product created during a chemical reaction are not necessarily the same as those of any of the reactants that make them up. In the reaction above, zinc is a solid that does not dissolve in water. The zinc chloride produced during the reaction, however, does dissolve in water.

The following are examples of important chemical changes.

- silver metal reacting with sulfur to form sulfur sulfide, or tarnish
- burning hydrogen gas in air
- heating a compound until it breaks down or decomposes
- the oxidation of metals in air, or rusting
- the reaction of an acid and a base

In each of these cases a chemical reaction has taken place, and the way that the atoms are arranged in the substance has changed. The same types of atoms are present, but they have separated or combined in new ways to form different substances with different properties.

**Evidence of a Chemical Reaction**
The following are examples of the most common signs that a chemical reaction has occurred.

- **Change in Temperature**: Reactions may either produce heat or absorb heat. If two room temperature liquids are mixed and the mixture gets hotter or colder, then a chemical change is probably taking place. Putting a substance in the refrigerator is not a chemical change.
- **Color Change**: If two substances are mixed and their color changes, then a chemical reaction may be taking place. This type of color change does not include color blending. Mixing red and blue paint to make purple is a physical change, not a chemical one.
- **Making a New Solid or Gas**: Another sign of a chemical change is the production of a solid precipitate or the development of a gas. A precipitate is a solid that forms from mixing two liquids. The production of a gas can be seen as bubbles. Freezing or boiling a substance, however, are physical changes.

In every case, a chemical change has occurred if the identity (molecular structure) of a substance has changed. If there has been a change in appearance, but not in identity, then only physical changes have occurred.

# Mixture Separation

*A mixture is made up of two or more substances that are not chemically combined.*
*Mixtures can be separated by physical means, so mixture separation is a physical change.*

Differences in physical properties such as density, particle size, molecular polarity, solubility, and boiling and freezing points permit physical separation of the components in a mixture. Some of the techniques that can be used to separate mixtures are discussed below.

**Filtration**If a mixture is composed of a liquid and an insoluble solid, the mixture can be separated by filtration. During filtration, the mixture is poured through a filter. The solid is trapped by the filter, but the liquid goes through the tiny pores in the filter and can be collected in a container beneath.

**Evaporation**If a mixture contains a soluble solid dissolved in a liquid, the two mixture components can be separated by evaporating the liquid off. As the solvent evaporates, the solid solute remains behind as a *residue*. Heat may or may not be used to accelerate evaporation. If large, pure crystals are desired, evaporation should be allowed to take place over as long a period as possible. However, if crystal size is irrelevant and purity is not a concern, the liquid can be boiled off rapidly. In the image below, an aqueous solution of sodium chloride (salt) was boiled until only a solid salt residue remained in the heating vessel.

**Sifting**Sifting, also called *screening* or *sieving*, is a method of filtering solids from one another based on particle size. For example, sifting could be used to remove small pebbles and shells from sand. A sieve or sifter like the one shown above is often used in kitchens to remove lumps from flour.

# Conservation of Matter

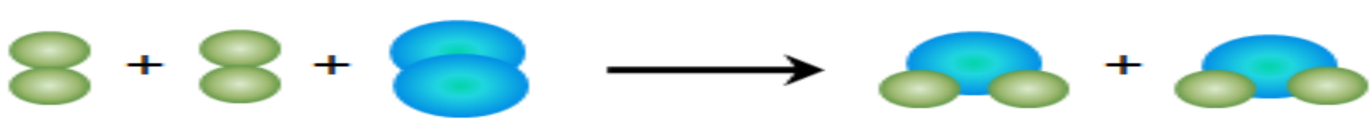
*When a substance goes through a chemical or physical change, the total mass of the substance or substances stays the same.*
*This is because matter can neither be created nor destroyed by physical or chemical changes. It can only change forms.*

According to **the law of conservation of matter**, matter is neither created nor destroyed. The mass of a substance will remain constant whether it is whole, separated into pieces, or in a different state. If a substance undergoes a chemical change, the masses of the products will equal the masses of the original reactants.

**Matter Conservation in Physical Changes**
If 50 grams of pure ice melts into liquid water, the form of the water changes into a liquid, but the amount of matter is the same. The liquid water will have a mass of 50 grams.If the 50 grams of liquid were allowed to boil in a pan until there was nothing left in the pan, the mass of the steam created would also be 50 grams.Or, if a pencil is broken into pieces, the total mass of the pieces should equal the mass of the original pencil. Also, if an object is made out of smaller pieces, the mass of the object is equal to all the masses of the smaller pieces put together.

**Matter Conservation in Chemical Reactions**
During a chemical change, atoms are rearranged to produce one or more new substances. These kinds of changes can also be called *chemical reactions*. Mass and energy are conserved in these reactions. For example, if charcoal is burned in air, the charcoal reacts with oxygen to form new chemical compounds. If the masses of all the products of the reaction (ashes, soot, gases) are added together, however, this mass will be equal to the original mass of the charcoal plus the oxygen it reacts with. Mass is not created or lost, it just changes into different substances.

**Chemical equations** can demonstrate how matter is conserved in a reaction because the number of *reactant* atoms always equals the number of *product* atoms. Chemical equations have the following general format: reactants $\rightarrow$ products
Reactants are the starting substances in the reaction. Products are the substances that the starting substances are transformed into; they are the substances that are produced following the reaction. The equation below shows the reaction of hydrogen gas and oxygen gas to form water. $2H_2 + O_2 \rightarrow 2H_2O$
In the above reaction, two molecules of hydrogen gas react with one molecule of oxygen gas to produce two molecules of water. In this case, the reactants are hydrogen gas and oxygen gas, and the product is water. The arrow always points toward the products.The *coefficients*, or the numbers in front of each substance, indicate how many molecules of that substance are present. The *subscripts*, or the small numbers that follow particular elements, indicate how many atoms of that element are present in a substance.So, in the above example, the two in front of the $H_2$ indicates that there are two molecules of hydrogen gas. The two that follows the H indicates that there are two atoms of hydrogen in each hydrogen molecule. If no number appears in front of a substance, assume that only one molecule of that substance is present. So, in the above example, the lack of a coefficient indicates that there is only one molecule of oxygen gas. The two that follows the O indicates that there are two atoms of oxygen in the oxygen molecule. The picture below shows the same reaction using models of the atoms in the reaction.



Although the atoms rearrange, there are four hydrogen atoms and two oxygen atoms on each side of the equation. This shows that atoms were not created or destroyed, only rearranged. That is, matter is conserved in the chemical reaction.

**Open and Closed Systems**Closed systems should be used when studying chemical reactions. When a chemical reaction takes place in a closed system, such as a closed container, all of the substances involved in the change are retained, and their masses can be measured to show that mass has been conserved. In an open system, such as an open container, some of the substances involved in the change may escape, and it would be impossible to measure the mass of those products.Flasks and beakers are open systems. If a chemical reaction that produces a gas-phase product takes place in these, the gas will be lost to the atmosphere. The mass of the substances left in the container will not equal the mass of the reactants. The two masses will differ by the mass of the gas given off.Some physical changes must also be observed in a closed system in order to observe conservation of mass. For example, the mass of a sample of water after it changed from a liquid to a gas could not be measured if the water was heated in an open container from which water vapor could escape into the atmosphere.

## Energy Resources

*Humans depend on electrical energy in order to perform a large percentage of their everyday tasks. There are different sources that can be used to generate this energy, each of which has environmental consequences. Some types of environmental impacts are longer-lasting than others.*

**Nonrenewable Energy Sources**
Any resource that is used at a faster rate than it can be replaced is called a *nonrenewable resource*. Most of the energy that is currently used comes from non-renewable sources. Fossil fuels and nuclear energy are both considered to be nonrenewable resources, and if they continue to be used at the current rate, these resources will eventually run out.

***Fossil Fuels-*** The most common method for obtaining energy is through the burning of fossil fuels, such as coal, oil, and natural gas. These fuels can be converted to other forms of energy in many ways, including the production of electricity through coal-burning power plants.Fossil fuels are abundant and cheap, and coal-burning power plants are currently the most effective way for generating widespread electricity where and when it is needed. However, coal-fired power plants cause large amounts of pollution and can affect the Earth's natural greenhouse effect.Power plants burn coal in order to produce electricity. While coal is plentiful and cheap, it produces a significant amount of air pollution. Measures are being taken to reduce the amount of pollution released by coal burning, but it is impossible to completely eliminate it.

***Nuclear Energy-***Nuclear energy is produced by splitting atoms of certain elements, such as uranium. The energy released by this process is then used to heat water to produce steam. Nuclear power plants generate electricity by capturing the energy of the rising steam, which turns the turbines that run generators.The main environmental drawback to using nuclear energy is that it produces radioactive waste, which is harmful to organisms and may remain harmful for thousands of years. Also, nuclear energy is a nonrenewable energy resource because it relies on materials that are limited in supply. However, many scientists believe nuclear energy could remain viable for more than 1,000 years at current usage rates.

**Renewable Energy Sources**
Some resources are replaced more quickly, or about as quickly as we can use them. These resources are called **renewable**. One drawback to the usage of many renewable energy sources is that technology and infrastructure for efficiently storing and transferring energy generated from these sources is not yet in place.

***Hydroelectric Energy-***Hydroelectric energy is sometimes considered an inexhaustible resource, which means humans cannot deplete supplies no matter how much of it we use. However, hydroelectricity can also be classified as renewable.Dams have been constructed to control rivers all over the world. The held-back water contains potential energy, which is converted to kinetic energy as it is then released through tunnels.Hydroelectric dams were designed to convert the kinetic energy of falling water into electrical energy. As the water flows across the dam, it spins a turbine. And the turbine runs a generator that produces the electrical current.Hydroelectric energy is much cleaner than fossil fuels, but the construction of dams is extremely disruptive to natural ecosystems, especially where it prevents fish and other aquatic animals from moving up or down a river. Hydroelectric energy can also be harnessed from the motion of tidal waters, but such examples are not as common as those that use river dams.

***Solar Energy-*** Solar energy is in inexhaustible resource. Human use of the solar energy has no effect on the supply of energy produced by the Sun.Solar power has far fewer environmental consequences than fossil fuels. On-site solar heating systems (the type that produce energy very close to where the energy is needed) are generally composed of a fluid system to move the heat from the collector to its point of usage, and a reservoir to stock the heat for future use.The negative effects of using solar energy are minor and are primarily related to the manufacturing and disposing of the solar panels which convert solar energy into electrical energy. Cost is the main reason that the technology is not more widespread. Solar energy is very expensive to harness in useful quantities. One other negative effect of using solar-generated electricity is that the large collections of panels needed to create a solar power station can significantly impact local ecosystems.Solar energy is also not as reliable as energy derived from fossil fuels, because weather is inconsistent, and the amount of sunlight available on any given day may not be sufficient to produce the needed amount of energy from solar panels. In addition, some latitudes and geographic locations may be more suitable for solar power than others. While California and Colorado might be excellent places for solar power plants, Wisconsin and Michigan might not be. But as the technology continues to improve, solar energy costs decrease, and more solar panels are being implemented.Solar energy can be harnessed using solar panels. While this process results in far less pollution or waste than burning fossil fuels, it is currently very expensive and therefore not yet used widely across the world.

***Wind Energy-*** Wind energy is an inexhaustible resource that comes from the movement of air heated by the Sun. As with solar energy, wind energy has very few negative environmental consequences, and these are mostly related to the manufacture and disposal of wind turbines. Wind turbines also pose hazards for birds and bats, and some communities may not embrace the establishment of wind farms because some people find the appearance of the large turbines off-putting.Unlike the technologies related to solar energy, wind technologies are relatively inexpensive. In terms of electricity prices, wind energy is able to compete with fossil-fuel generated electricity, but there are limitations to wind as well.Wind turbines are used to convert blowing wind energy into electricity. This process offers a much cleaner alternative to burning fossil fuels, but not every location is suitable for wind power. And wind power is unreliable, since the wind does not blow in consistent patterns.The inconsistency of wind patterns is one of the challenges facing the expansion of wind power. It is not always easy to predict when and where the wind will be blowing. And there is not enough wind in many locations to generate electricity. It is estimated that the U.S. has enough wind to supply about 20% of its current electricity demand, if wind energy is used to its full potential.

***Biomass Energy-***Biomass energy is perhaps the oldest form of energy used by humans. Biomass is simply plant or animal material, such as wood, manure, grass, and hay. The difference between biomass and fossil fuels is that biomass is from living or recently living organisms, while fossil fuels come from long-dead organisms. Consequently, biomass is considered renewable as long as it is used at the same rate (or slower) than it is replaced.Biomass resources are used throughout the world, and in many portions of the world, biomass is the primary source of energy. Biomass is traditionally burned for heating and cooking, but it can also be used to generate electricity.Burning biomass releases many pollutants into the air. A cleaner way to use biomass is to let it decompose and capture the gases it releases, called biogas. Decomposition produces methane, the main ingredient in natural gas, which can be burned relatively cleanly for fuel. Biomass-generated electricity can be relatively inexpensive, but most available materials are already used for other purposes in the U.S., such as in construction, agriculture, and food production. Biomass resources are considered renewable because new biomass can be grown quickly.

## Fossil Fuels

*Fossil fuels are energy resources that are created by natural processes including the decomposition of dead organisms. The most common fossil fuels are petroleum, coal, and natural gas.*

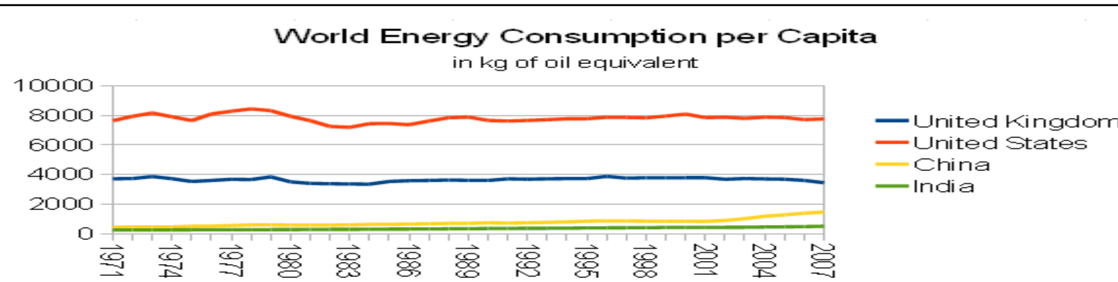
**Fossil Fuel Formation**
There are a number of very useful resources that can be found at or near Earth's surface. Sometimes, these resources are right at the surface and are easy to collect. At other times, these resources are located underground, and mines must be built in order to acquire them. Some of these resources are known as *fossil fuels*.Millions of years ago, large areas of jungle, forest, swamp, and wetlands left behind huge amounts of dead plant and animal material. This material decomposed through a number of different processes over the next several million years and was exposed to great temperatures and pressures in the Earth. The result is that, today, this material has been transformed into fossil fuels such as coal, which forms from plant matter, and oil and natural gas, which form from all kinds of dead organisms.Just like the animals living today, animals that lived millions of years ago got their energy by eating plants or by eating animals that had eaten plants. All of these plants got their energy from the Sun. Since fossil fuels were made from decomposing plant and animal materials, the energy contained in fossil fuels originally came from the Sun, as well.

**Uses of Fossil Fuels**
Fossil fuels are very useful for a number of reasons. One of these reasons is that they can be burned for energy. Coal, petroleum, and natural gas are each used to generate electricity. Coal is also sometimes used in steam engines to power trains. Large amounts of coal are mined out of the ground and burned in power plants to generate electricity. This image shows coal that is about to be shipped to a power plant for this purpose.Natural gas is sometimes burned in furnaces that heat homes and other types of buildings. Petroleum or oil, of course, is used to make gasoline, which powers cars, trucks, and other automobiles.
People also use fossil fuels for purposes other than just the production of energy.

**Fossil Fuels Are Nonrenewable**
Fossil fuels are known as nonrenewable resources, because there is a limited supply of them on Earth. At the rate that humans use them, these fuels will run out some day. It will take many millions of years for more fossil fuels to form, if they ever do.

## Resource Use & Conservation

*Many natural resources, such as coal and oil, are nonrenewable. Nonrenewable resources are depleted faster than they can be replenished. Since many countries use these resources as their primary source of energy, it is important to try to conserve them and manage their usage, so that these resources will be still be available for future generations.*



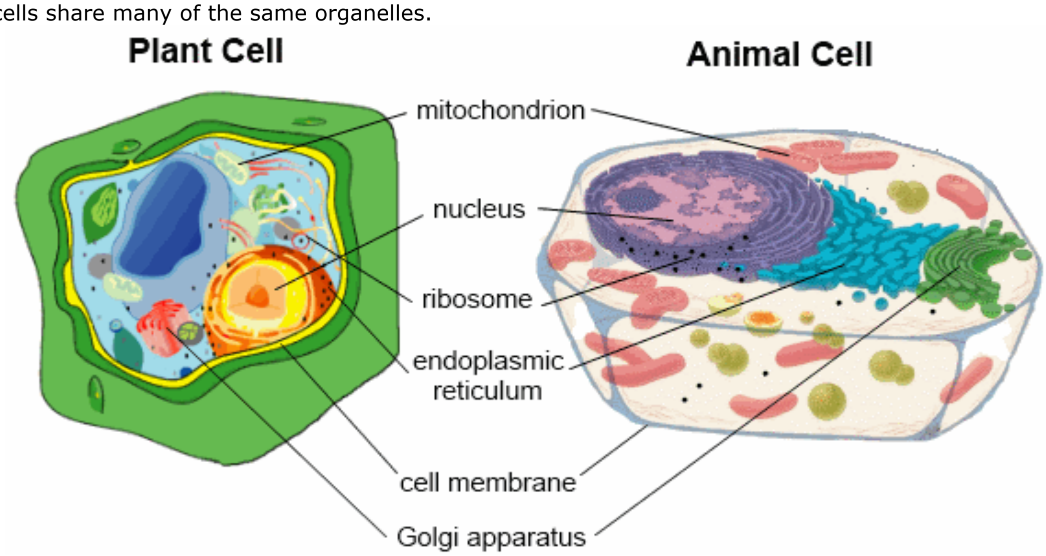
# Food, Cellular Energy & Life Processes

*All living organisms on Earth are made up of one or more microscopic structures called cells.*
*All organisms and their cells need food. Food is the fuel that organisms use for energy and for the building materials that they can use for growth and repair.*

**Cells Perform Life Functions**
Cells perform the functions that are necessary for life. They have a variety of parts, and each part has a different set of functions. Cells may be part of a multi-celled organism, or they may be single-celled organisms. Single-celled, or unicellular, organisms may live alone or as part of a colony. For single-celled organisms, each cell by itself can get food and air by taking it in from the environment directly. Many single-celled organisms can move themselves through their environments. Single-celled organisms include protozoa, bacteria, and some kinds of fungi.Multi-celled, or multicellular, organisms may have many different kinds of *specialized* cells. Each kind of cell has organelles and special shapes or features that help the cell to carry out its function. Cells from multi-celled organisms cannot survive on their own. The cells must work together in order to get food and air and to help the organism grow, reproduce, and repair itself. Cells of multicellular organisms must grow and divide in order for the organism to grow. This is because the size of individual cells does not change significantly. The body of a multicellular organism can also repair itself by using cell division to make more cells.

**All Organisms Need Food**
Food is a source of chemical energy that organisms use to perform life functions such as breathing, moving, eating, growing, and reproducing. Food is also made of many different kinds of molecules that organisms use to build their muscles and other tissues. The sugars produced by plants during photosynthesis are used by the plants for energy. Plants also combine these sugars with water and other nutrients taken in through the plant roots to make building materials for growth. The sugars plants produce are also a good source of food for many other organisms.

**Cellular Structures & Food Energy**
Cells consist of smaller pieces, called **organelles**. Organelles are like the "organs" of a cell; they are groups of complex molecules that perform specific life functions. The number and type of organelles present in a cell depends on the specific functions of that cell. Plant and animal cells share many of the same organelles.




The mitochondria found in both plant and animal cells are the organelles that release the energy from sugar molecules. The cell membrane, or plasma membrane, of a cell allows the cell to take in nutrients (or food molecules) while keeping out things that the cell does not need. Plant cells that contain chloroplasts can also make their own food by using energy from the Sun. If the plant does not have an immediate need for all the food it makes, it can use storage organs, such as tubers, to store the food for later use. *Plant cells have chloroplasts, a cell wall, and a large central vacuole that are not found in animal cells.*

**Digestion**
Organisms that eat plants or other animals must first break down their food into its smallest parts before they can use the energy in the food. Animals use acids and digestive enzymes to chemically break down the food that they eat.After the food is broken down into elements and compounds, they can be absorbed into the blood and carried to the cells in the organism. Cells can use the materials in food to do necessary processes, including growing, releasing energy, making molecules, reproducing, keeping the body warm, and changing shape. The extra materials that are not used by the body are excreted as waste.Animals have digestive systems that break food down into molecules that are carried to cells by a circulation system.

**Cellular Respiration**
Digestion breaks down many foods, such as starches, into sugars. Cells use a chemical reaction called *oxidation* to break down the sugars even more. Oxidation is the combination of oxygen with other molecules. This process releases the energy stored in the sugar and makes it useful. This process is called **cellular respiration**. Both plants and animals use the process of cellular respiration to release energy from sugars. Other products of cellular respiration include carbon dioxide gas and water.

# Microbes

*A **microbe** is a very small organism that cannot be seen without the aid of a microscope. Because microbes are very small, they are measured in very small units such as the micrometer, which is $^{1}/_{1,000,000}$ of a meter, or a nanometer, which is $^{1}/_{1,000,000,000}$ of a meter.*

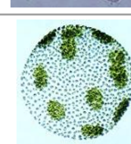
**Types of microbes include viruses, bacteria, parasites, protozoa, and small fungi**. Microbes can be found living as self sufficient life forms, living in a symbiotic partnership with other organisms in which they both contribute to each other's survival, or living as parasites that grow, feed, and live on or in another organism to whose survival they contribute nothing. Microbes can serve an important role in the degradation and decomposition of organic materials. They can also cause disease, acting as **contagions** spread through contact, or as noncontagious infectious agents. Some microbes, mostly viruses, are also **mutagens** that cause genetic changes in humans or animals. Diseases caused by viruses include influenza and the common cold. Bacterial infections include tetanus and anthrax. The different categories of microbial diseases require different treatments. For example, while antibiotics can be effective in the treatment of a bacterial infection, they will not treat a viral infection like the flu.

| Microbe | Shapes | Size | Structure | Living cells? | Examples of diseases caused by this microbe | Treatments for infections by this microbe |
|---|---|---|---|---|---|---|
| **Virus *(pl. viruses)*** | Helical, Polyhedral, multi-sided | 5 to 300 nanometers (nm) | Simple structure containing DNA or RNA—carried in a shell called the viral coat; no cytoplasm or organelles | Has living and nonliving features | Influenza (flu), Rhinovirus (common cold) | antiviral, viral vaccines |
| **Bacterium *(pl. bacteria)*** | Spheres, rods, spirals | 1-10 micrometers (µm) | Single celled structure with a cell wall and organelles, but no nuclei (prokaryotic) | Yes | Tetanus, Anthrax | antibiotics, antibacterial, bacterial vaccines, antimicrobials |
| **Protozoan *(pl. protozoa)*** | Ciliates, amoebae, flagellates | 11-150 micrometers (µm) | Single celled structure with organelles and nuclei (eukaryotic); some protozoa have specialized structures for movement | Yes | Malaria, Toxoplasmosis | antimicrobials, antibiotics |
| **Fungus *(pl. fungi)*** | Numerous, cells called hyphae | 20 micrometers (µm) to very large | Multicellular structure with a cell wall and organelles, including a nucleus (eukaryotic), but no chloroplasts | Yes | Athlete's foot, Ringworm, Aspergillus | antifungal, antimicrobials antibiotics |

# Protists

***Protists** are microscopic organisms containing a nucleus or nuclei that hold their genetic material, and accordingly are categorized as eukaryotic.*

**Most protists are one-celled organisms that exist as single, self-supporting cells**. Protists may display either plant-like characteristics, animal-like characteristics, or a combination of both. For example, some protists have chlorophyll and make their own food through photosynthesis like plants, while other protists are more animal-like and must consume their food. Protists can be categorized based on the way in which they move around. Protists may travel using a long, single flagellum, false-foot-like pseudopodia, or many hair-like cilia.

| Organism | Structure | Obtains food | Movement | Picture |
|---|---|---|---|---|
| **Euglena** | single, self-supporting cell | photosynthetic and consumer | whip-like structures called flagella |  |
| **Amoeba** | single, self-supporting cell | consumer: surrounds, engulfs, and ingests its food with pseudopodia | "false feet" called pseudopodia |  |
| **Paramecium** | single, self-supporting cell | consumer: draws food into a mouth-like opening lined with cilia | numerous short, hair-like cilia |  |
| **Volvox** | spherical colonies | photosynthetic: uses green chloroplasts to trap sunlight for use in producing energy | numerous short, hair-like cilia |  |

# Spread of Microbial Diseases

*There are many different types of diseases that could strike in any given population and wreak havoc on overall health. It is important for a community to know the normal disease rates so that an epidemic can be recognized. Rapid realization that an epidemic is occurring can help the community to respond quickly and effectively. It is also important to know which diseases are most likely to break out. This can help members of the community to plan possible treatments and quarantine practices for the most likely situations. Knowing how different diseases spread and how to treat different diseases may also be important for quickly handling an outbreak once it occurs.*

**Epidemics**
An epidemic is an outbreak of a disease that affects an unusually large number of individuals within a population, community, or region compared to recent memory. It does not affect individuals worldwide**.**

**Pandemic**
A pandemic is an epidemic of infectious disease that has spread over an entire continent, multiple continents, or even worldwide. A secondary difference is that an epidemic disease is not necessarily contagious (for example, obesity), while a pandemic disease is always contagious.

**Disease Vectors**
A disease vector is any organism that can spread infectious disease to another organism through bites, scratches, body fluids, or other contact. Rats, ticks, and mosquitoes are examples of vectors. Sometimes, a vector is not harmed or killed by the disease it carries. These vectors are especially dangerous because they are able to spread the disease to many other organisms. For example, the western blacklegged tick is a vector that carries Lyme disease. However, the bacterium that causes Lyme does not harm the tick that carries it.

**Disease Prevention**
**Aseptic** techniques, such as washing hands, sterilizing equipment, and using disinfectants to clean homes, have reduced the spread of many diseases and led to safer medical practices. Better sanitation and safer processing of food and water have improved the length and quality of human lives. Medicines, such as antibiotics, have been developed to fight bacterial infections like strep throat. Vaccinations using weak or inactive strains of viruses strengthen the body's immune system against many serious infections, like measles.

# Microorganisms & Industry

*Microorganisms, such as **bacteria** and **yeasts**, are often used in the making of foods. Other microorganisms are useful for environmental remediation or medical purposes.*

Microbes are often discussed as agents of disease, but the majority of microbes are harmless. Bacteria can be found almost everywhere, even in places that many other organisms could not survive. People have found ways of using microbes to help in many situations. Single-celled organisms are used in food production, to alter the environment, and in medical treatments.

**Microbes and Food**
Different microbes may be helpful or harmful. Helpful bacteria do not cause illness and may be used to produce new types of food because they change the flavor, texture, and/or color of the food in a way that many people like. The change in flavor does not come from the microbes themselves, but rather from the lactic acid and other chemicals that they produce.

- **Dairy**—Before civilization actually discovered the presence of microorganisms, people were using bacteria to prepare foods such as yogurt and cheese. The earliest accounts of yogurt making go back over 4,000 years. In addition to bacteria, certain cheeses use molds to alter the flavor. Molds are a kind of fungus. Brie, Camembert, and blue cheeses all include types of molds which give them their distinctive flavors, smells, and appearances.
- **Pickling**—Pickling uses the byproducts of helpful bacteria to preserve vegetables from damage by harmful bacteria. Pickling involves sealing food in a salt water solution for weeks or months. At first, some bacteria will keep growing and producing lactic acid. The lactic acid makes the food taste sour. Eventually there is too much acid for the bacteria and other kinds of microbes to survive, so the pickled food is protected from spoilage. Then the food can be stored in its sealed container for a long time.
- **Yeasts**—The carbon dioxide given off by the microbe **yeast** is what gives bread its light and airy texture. The yeast consumes sugars and produces carbon dioxide gas. The type of yeast can also change the flavor of the bread. For bread dough to rise, it needs to be kept warm and moist. Yeast and many other types of microbes grow best in these conditions.

As discussed above, many types of microbes can be beneficial in the preparation of food. However, other types of microbes can cause food to spoil or can make people ill. Freezing, dehydrating, and irradiating food are all ways to prevent the growth of harmful bacteria. Freezing preserves food by making it too cold for bacteria to reproduce quickly. Freezing may also kill bacterial cells if the water in the cells forms ice crystals. Dehydrating prevents microbial growth because microbes need moist environments in order to thrive. Irradiation with gamma rays can kill microbes already in or on food and therefore enable the food to stay fresh longer.

**Microbes and the Environment**
Though the bacteria that cause food spoilage compete with us for food, many species of bacteria feed on things that we cannot. These microbes are *decomposers*. They feed on the remains and waste products of organisms. By doing so, they break down unwanted organic materials into simpler substances that the ecosystem recycles.

- **Water Treatment**—All organisms produce waste, and humans have designed systems to control the disposal of their waste products. It is a model of the same mechanism that occurs in nature. All of the contents that are flushed down toilets either go to a self-contained septic system in the home or to a local facility that treats the sewage. Both work similarly; septic systems are simply smaller scale versions of water treatment facilities. Part of the treatment process includes *anaerobic* bacteria. Anaerobes are organisms that live in low or no oxygen environments. The bacteria feed on waste products, and break them down into simpler substances.
- **Bioremediation**—Bioremediation refers to the use of organisms or biological agents to return the environment to a more natural state after a disaster. One example of this is the use of oil-eating bacteria after the Gulf Oil Spill in 2010. Bacteria that feed on petrochemicals, or oil products, are found in different environments. They are beneficial because the bacteria can break down harmful substances into simpler, less toxic substances.

**Microbes and Medicine**
Bacteria have many uses in medicine, including drug production and cancer therapies.

- **Drug Manufacturing**—The genetic information of bacteria can be easily manipulated in a laboratory, and because they reproduce so rapidly, bacteria are useful tools. Most medicines are forms of substances originally obtained from other organisms. By studying genetics, researchers have been able to alter the DNA of bacteria to produce certain drugs. *E. coli*, for example, can be genetically engineered to produce insulin. After the insulin is made, it is isolated and refined for diabetic patients.
- **Cancer Research**—Medical researchers constantly look for ways of improving the delivery system of chemotherapy drugs for cancer patients. Chemotherapy works by killing cancer cells, but because the substances used are so toxic, they will also kill healthy cells they encounter. In addition, the drug is usually given intravenously, which means the drug travels via the blood. Often, the inner portions of tumors are not supplied well with blood. Therefore, the drugs do not reach parts of the tumor.

  Researchers have found a way to alter the bacteria so that they can take an inactive form of the chemotherapy drug and alter it to make it toxic. Only in the presence of the bacteria will the drug activate the toxic activities of the chemotherapy drugs. This prevents much of the contact between the harmful substances and healthy cells, and targets the cancer cells.

## Genetics & Biotechnology

***Biotechnology** applies biological scientific knowledge to create products and processes for human use.*

The **Human Genome Project** was a thirteen year long research effort that included scientists from several countries around the world. The main goal of the Human Genome Project was to sequence all the base pairs that compose human DNA.
While working on this project, scientists discovered that there are approximately 20,000 to 25,000 genes in the human genome. When scientists completed the Human Genome Project in 2003, the scientists produced a **gene map** which showed the relative location of each known gene on every human chromosome. The gene map also showed the DNA sequences of all the human genes. The Human Genome Project plays a vital role in the advancement of biotechnology, because modern biotechnological processes, such as genetic engineering, require scientists to know exactly where particular genes are located.Humans possess 23 pairs of chromosomes. One pair is sex-determining, and the other twenty-two pairs are autosomal (i.e., not sex-determining). The diagram shown above lists all of the traits that are known to be mapped to chromosome 21. Chromosome 21 is one of the smallest chromosomes, since it only contains about 46 million base pairs. Some of the larger chromosomes are made up of more than 200 million base pairs.

**Genetic Modification**
Applications of the Human Genome Project involve genetic engineering. Genetic engineering, or **genetic modification**, is the process of manipulating genes for practical purposes. Genetic modification often involves the use of *recombinant DNA*, which is DNA made from two or more different organisms. Using this technology, different enzymes can be used to cut, copy, and move segments of DNA. Characteristics produced by the segments of DNA can then be expressed when these segments are inserted into new organisms, such as bacteria. The diagram below shows the process of recombinant DNA technology.

**Gene Therapy**
Gene therapy is a process through which specific gene sequences are inserted into an individual's cells to replace a defective or mutant allele. Scientists have found that the most efficient and effective way to accomplish this goal is to use viruses to insert gene sequences into cells.Scientists hope that gene therapy can eventually be used to cure genetic disorders. To date, however, gene therapy has only had limited success because the host organism's immune system often rejects the new genetic material.

**Cloning**
Identical copies of genes and organisms may be produced through **cloning**. *Gene cloning* is the process through which a segment of DNA is copied. Gene cloning is commonly performed in science research labs, so scientists can produce enough material to study.***Reproductive cloning***is the process through which an identical copy of an organism is produced from an adult body (somatic) cell.Reproductive cloning is difficult to perform. In fact, more than 90% of clones do not develop into adult organisms, and the organisms that do develop often have poor health and die early.Clones of a number of animals, including sheep, mice, monkeys, and pigs, have been created. To date, however, human clones have not been created, and in most places, it is considered unethical to even attempt to create a human clone.

# Medicine and Health Care Technology

*Advancements in health care technologies have greatly improved the quality of human life. Examples include technologies that aid in visual diagnosis, such as microscopes and imaging technology. Other examples include medications, radiation treatment, and the use of artificial organs.*

**Microscopes**
Microscopes produce magnified images of very small things. A **light microscope** shows objects as they appear in visible light and is an excellent tool for getting a closer look at cells. For example, doctors typically diagnose cancer by examining the cells of human tissue under a light microscope.

An **electron microscope** shows small features by shooting a beam of electrons at them and analyzing how the electrons scatter after impact. The resulting images provide a more detailed view of objects than does a light microscope. For example, scientists can better study the individual structures of a cell using an electron microscope.

**Imaging Technology**
There are many different technologies that doctors can use to create internal images of the human body.

**Computed tomography (CT)** is an X-ray imaging technique that creates cross-sectional views of the human body. These images can be viewed by doctors individually or can be put together to make 3-D images. The different amount of X-ray radiation absorbed and reflected by different tissues causes them to appear in different light and dark shades in the images.
Also, abnormal areas of tissue will often appear lighter or darker than the rest of the tissue. This allows doctors to study internal body parts for signs of injury or disease. For example, CT scans allow doctors to view images deep within the human brain to check for tumors.

**Magnetic resonance imaging** (MRI) is an imaging technique that uses the response of the human body's atoms to radio waves and a strong magnetic field. The setup of an MRI machine is similar to a CT scanner—humans are placed on a table that slides through a window of radio waves and strong magnetism. Atoms in human tissue, especially hydrogen atoms in water molecules, are slightly magnetic.Atoms in different tissues line up differently within the machine's magnetic field. These differing alignments cause different responses to the machine's radio waves, and these differing responses to radio waves show up as different light and dark areas in MRI images (see image below). MRI is used for similar purposes as CT and is particularly useful at showing contrasts among different soft tissues.

**Ultrasound** is a technology that uses sound waves to create internal images of the human body. These images, called *sonograms*, are commonly used to monitor the health of a developing fetus during a woman's pregnancy. They are also used to analyze organs in adults and children.

**Medications** are natural or man-made substances used on or in the human body to treat diseases and other health problems. Thousands of medications have been developed to treat a wide range of conditions. Medications typically have several benefits as well as risks. For this reason, the use of medications is regulated by the government, and many medications should be used only if recommended by a doctor.A common example of a medication is aspirin. Aspirin was originally developed to relieve common body pains. However, unexpected additional benefits of aspirin, as well as risks, were later discovered. Most notable among the additional benefits is that aspirin can help to prevent heart disease in older people. On the other hand, aspirin can cause Reye's Syndrome in younger people and can be harmful to older people if used incorrectly.

**Radiation treatments** use of high energy radiation beams to destroy or damage cancer cells. Historically, healthy cells near cancer cells were also harmed during radiation treatment. Recent technological advances have introduced narrower radiation beams, however, which have reduced the impact on healthy tissue. In using radiation treatment against cancer, doctors use the minimum amount of radiation needed to treat their patients, as higher doses of radiation can increase further risk of cancer. Generally, the benefits of radiation treatment outweigh the risks.

**Artificial organs** are man-made devices implanted in humans to perform the function of organs that have failed. Typically, artificial organs, such as an artificial heart, are implanted temporarily until a suitable human heart can be transplanted from a donor. In this way, artificial organs help to extend the lives of humans.

# Personal Health

*Life style choices, environmental factors, and genetics can interfere with the efficient operation of the systems of the body.*

Commonly regarded factors that affect human health include diet, sleep, and exercise. However, genetic predispositions, environmental exposures, and lifestyle choices contribute to a person's overall health. Some specific examples of these factors include:*having good hygiene practices, choosing healthy foods, exercising regularly, making informed, intelligent decisions regarding drugs or medicines, following label instructions when handling chemicals or other harmful substances and being aware of genetic predisposition to disease.*

# Earth's History

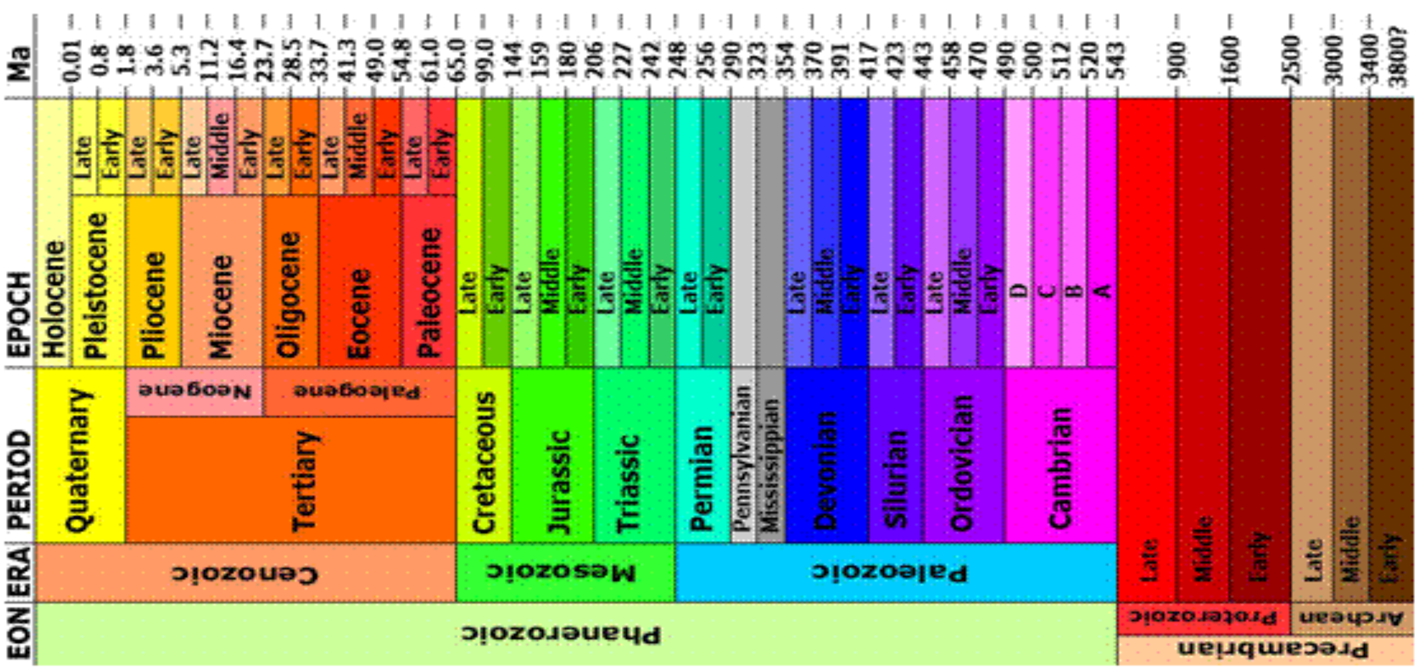
*The age of Earth is calculated to be approximately 4.6 billion years old. Scientists can learn about the history of the Earth by studying rocks and fossils.*

**Uniformitarianism**
The Earth has *evolved*, or changed, over time. Uniformitarianism is a geological principle stating that processes shaping the Earth today operate the same way and at the same rates as they did in the past. Another way to state uniformitarianism is that the present is the key to the past.For example, geologists assume that volcanoes erupted in Earth's ancient past much the same way they do today. This assumption is supported by the fact that lava flows and volcanic ash layers from Earth's past share many similarities with those forming today. Similar connections exist in the rock record for many other geological processes occurring today, such as plate tectonics, rock metamorphosis, and erosion.  Most of the changes that the Earth has undergone have been caused by natural processes. Humans have existed only a very short time relative to the Earth's 4.5-billion year history.

## Geologic Time Scale

Scientists learn about Earth's history by studying the rock and fossil record. Based on this record, scientists have learned how Earth and its atmosphere have changed over time, and they have divided Earth's history into distinct intervals of time on the **geologic time scale**. The geologic time scale, which is shown below, arranges time intervals from oldest (bottom) to most recent (top). The age units to the right are given as "Ma," which is a unit equal to 1 million years. Although the geologic time scale begins with the formation of the Earth around 4.54 billion (4540 Ma) years ago, 3.8 billion (3800 Ma) years ago is the approximate time that Earth's crust had become widespread and plate tectonics likely had begun.  The geologic time scale uses a hierarchy of time intervals. The broadest intervals of time (eons) are on the left side of the scale. As you move to the right, time intervals are divided into more specific intervals—eons are divided into **eras**, eras are divided into **periods**, and periods are divided into **epochs**.

A common way to organize geologic time is to break it down into four main intervals. The first interval is **Precambrian** time, which accounts for all of Earth's history before the Paleozoic era. After Precambrian time, Earth's history is divided into three eras, beginning with the **Paleozoic era**, then the **Mesozoic era**, and finally the **Cenozoic era**.
Each of the three eras can be divided into periods. The first period of the Paleozoic era is the **Cambrian period**. The most recent period of the Cenozoic era, which is still going on today, is the **Quaternary period**.
Each period can then be divided into epochs. The most recent epoch of the Quaternary period, which is still going on today, is the **Holocene epoch**.




**Ice Core Data**
Ice core data is gathered by climate scientists to compare the composition of the atmosphere today to its composition in the past. When snow or ice falls on certain regions on Earth, such as on Greenland, much of it does not melt. It is instead preserved for many thousands of years in layers of ice, with each layer representing one year. Such snow contains information about the atmosphere that it formed in. For example, from the ice cores, scientists can learn the concentrations of different gases in the atmosphere at different times in Earth's history.

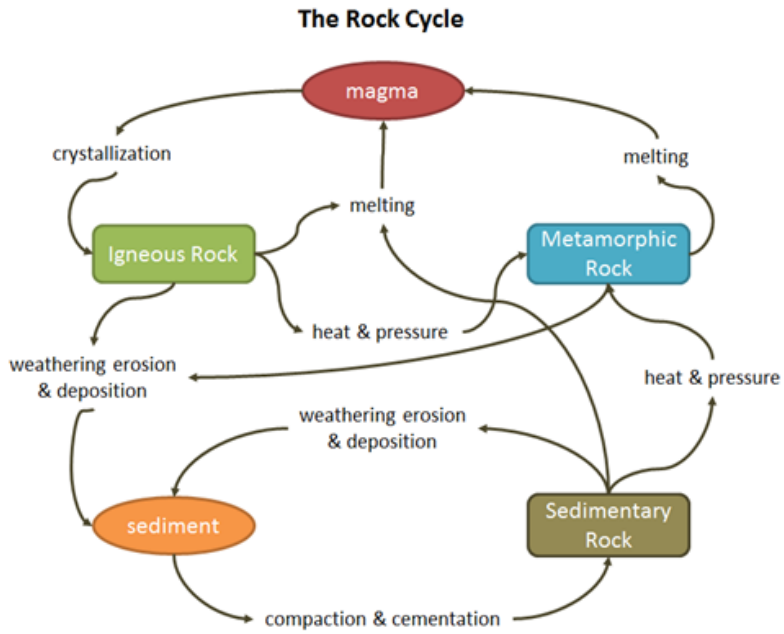
# The Rock Cycle

*There are three major classifications of rock, based on the method of their formation: **igneous rock**, **metamorphic rock** and **sedimentary rock**. The rock cycle is the series of processes by which rocks are transformed from one type to another and continually renewed.*

The origin of all rock can be ultimately traced back to the solidification of molten magma. Magma is a hot liquid made of melted minerals and compounds commonly found in rocks.

The rock cycle is a model that describes how rocks are created, changed, and destroyed. There are three major types of rock: igneous rock, metamorphic rock, and sedimentary rock. During the rock cycle, each type of rock may be changed into another type.

The rock cycle also includes several different processes. **Crystallization** is the process by which magma cools and forms solid rock. **Heat and pressure** often change one type of rock into another. **Weathering, erosion, and deposition** are the processes that break rock down into sediment at the Earth's surface. Wind, rain, running water, and ice commonly take part is these processes. **Compaction and cementation**—also known as **lithification**—is the process of loose sediments being formed into sedimentary rocks. And **melting**, of course, is the process that transforms solid rock back into liquid magma.
The rock cycle is a process that takes hundreds of millions of years. But since it has operated continuously during Earth's history, new rock at the Earth's surface is constantly replacing old rock.




**Igneous Rock**
Igneous rock forms when magma and lava cool and make mineral crystals. Igneous rock is typically hard and is often glossy or shiny. Examples of igneous rock include granite, basalt, pumice, and obsidian. There are two basic types of igneous rock, which are classified by how they form: intrusive and extrusive.

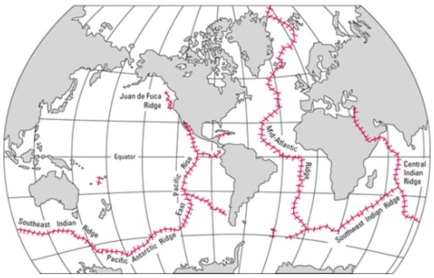
- *Intrusive* igneous rock forms underground, within the Earth's crust or mantle, where magma cools slowly. Because it cools slowly, intrusive igneous rock typically has *large mineral crystals*.
- *Extrusive* igneous rock forms above ground, as lava and other materials that erupt from volcanoes cool quickly. Because they cool quickly, extrusive igneous rocks have *small mineral crystals*.

**Sedimentary Rock**
Weathering is the breakdown of rock by agents such as wind and water. Erosion is the transporting of the broken rock material, or sediments, to a new location, where it is deposited. Sediments may also contain plant and animal matter. As more sediment is deposited, it stacks up in layers. Eventually, the upper layers put pressure on the lower layers. This causes sediments to pack closer together in a process called compaction. Through the process of cementation, minerals from groundwater form between sediment grains, connecting the grains together to form rock. The rocks formed from deposition, compaction, and cementation of sediment are sedimentary rocks. Sedimentary rocks often occur in distinct layers and sometimes contain fossils. Sedimentary rocks that are well-cemented hold together well, while poorly cemented rocks tend to crumble more easily. Some common sedimentary rock types include sandstone, siltstone, and shale. Sedimentary rocks that form mainly from chemical processes include limestone and dolomite. Evaporites, such as rock salt, are sedimentary rocks that form when minerals are left behind by evaporating water.

**Metamorphic Rock**
Metamorphosis means "transformation" or "change." The third major classification of rock is appropriately named *metamorphic* rock. Tectonic forces can push all types of rocks deeper into the Earth. These rocks are then subjected to extreme heat and pressure. If the rocks do not become hot enough to melt, these conditions can causes the crystal structure and texture of the rocks to change, forming a new kind of rock. **Metamorphic rocks** are rocks that form from other rocks under extreme heat and pressure. Some rocks have certain mineral grains that become flattened and line up in parallel planes or that separate into light and dark compositional bands when exposed to heat and pressure. These scenarios result in foliated metamorphic rocks, such as slate, phyllite, schist, and gneiss. Metamorphic rocks without these planes or bands are nonfoliated. Marble is a nonfoliated metamorphic rock that forms from the sedimentary rock limestone. Quartzite is a metamorphic rock that forms from quartz sandstone.

# Plate Tectonics

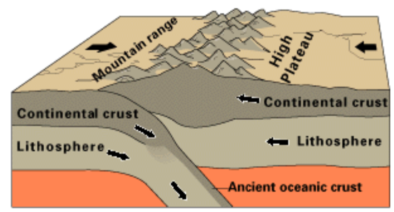
*The theory of **plate tectonics** says that the Earth's outer layer is divided into a dozen or more brittle, rocky plates. These plates are always in motion because they are floating on the Earth's flowing upper mantle. When the plates move, the continents and ocean floor above them move as well.*

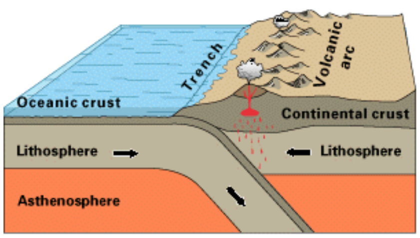



Scientific evidence suggests that all seven of the continents on Earth today used to be connected in a single land mass called **Pangaea**. Lithospheric plate motion caused Pangaea to break up and the individual continents to change shape and move away from their placements within Pangaea. The map below shows the approximate locations of the continents on Earth's surface 250 million years ago.***Evidence** for the existence of Pangaea includes the following facts:* 1. Fossils of similar life forms have been found on different continents. 2. The coastlines of some of today's continents have matching shapes. 3. Some of the different continents that exist today have similar types of rocks.

The scientific theory that explains the movements of the continents is called **plate tectonics**. The word "plate" is used to describe large, brittle blocks of the Earth's surface which appear to move upon the Earth's mantle as large pieces. The word "tectonics" comes from the Greek word that means "to build."At the places where two plates meet, constructive (building) or destructive (tearing down) processes may take place. Some of those processes are discussed below.

**Mountain Formation**
Plates move very slowly, at a rate of one or two centimeters per year. Over hundreds of millions of years, plates sometimes collide. When continents meet head-on, the crust tends to buckle and be pushed upward or sideways. This process, sometimes called "mountain building," is how some **mountain ranges** are formed.Some mountain ranges were formed so long ago that they have become eroded down to low hills. Other mountain ranges, such as the Himalayas and the Alps, are still slowly growing during the present day.

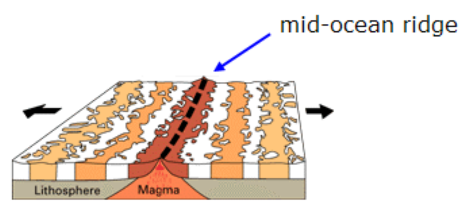


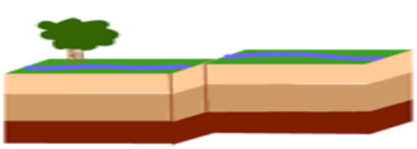
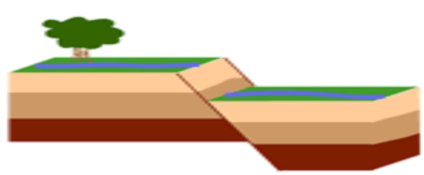
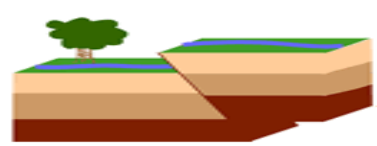

**Volcano Formation**
In some places, the crust on the ocean floor sinks back into the Earth's mantle. As the crust sinks, it melts, and hot melted rock rises up, squeezing through widening cracks. Magma escapes to the surface and creates **volcanoes**. A volcano is an opening in the Earth's crust from which lava, steam, and/or ashes erupt or flow. When a volcano erupts, the lava flows down and hardens to form new land. This new land may take the form of a volcanic mountain, a plateau, an island, or an archipelago. An archipelago is a chain of islands. Volcanoes are usually found in the ocean or along the coast. Volcanic eruptions can cause rapid destruction of habitats and changes to a landscape. They can also benefit the surrounding area. Volcanic ash and dust are rich with minerals. These minerals seep into the soil, making it more fertile and allowing new vegetation to grow back quickly. Another benefit is that many precious metals and gemstones can be found in cooled lava.

**Sea-Floor Spreading**
Plate tectonics is a relatively new scientific concept, combining the earlier theories of continental drift and **sea-floor spreading**. Sea-floor spreading is the movement of the Earth's crust away from the mid-ocean ridges.

During the process of sea-floor spreading, hot rock rises up from the mantle and spreads out on the surface to form the ocean floor. As the ocean floor spreads, it pushes the plates around, which in turn move the continents to new locations. The map below shows the locations of the Earth's mid-ocean ridges, which are the sites of sea-floor spreading.




**Earthquakes**
Sometimes, plates do not hit head on, but rub past each other instead. Since they do not have smooth edges, the rubbing is jerky and uneven. Pressure builds up and is then suddenly released. The result is an **earthquake**.An earthquake is the sudden moving and shaking of a part of the Earth's crust. Earthquakes occur along **fault lines**, which are cracks in the Earth's crust where lithospheric plates move past one another due to tectonic forces. There are different types of faults, and rocks may move along each of these in a different way. Examples of some different types of faults are shown in the pictures below.

Earthquakes can change the surface of the Earth very quickly as rocks on both sides of a fault line suddenly move.

# Geologic Dating

*The age of Earth is calculated to be approximately 4.6 billion years old. Scientists can learn about the history of the Earth by studying rocks and fossils.*

Rocks provide clues about what was happening on Earth when they formed. Geologists study rocks in order to figure out the Earth's history. A very important part of this process is figuring out the age of different rocks. This enables geologists to determine the order of events in Earth's history and how the Earth has changed over time. There are two broad types of geologic dating—**relative dating** and **absolute dating**.

**Relative dating** is a method in which the age of an object or event is determined relative to some other object or event. For example, a geologist may determine that one rock layer is older than another rock layer based on their positions in a sequence of rock layers. Three of the main principles of relative dating are discussed in the bulleted list below.

- The **principle of superposition** states that younger rock layers form on top of older rock layers. This principle allows geologists to determine that layers at the bottom of a rock-layer sequence are older than those at the top. This principle works in most cases, although it does not apply to rock layers that have been turned upside down by tectonic forces or other processes.

- The **principle of original horizontality** states that sediment is deposited in horizontal layers. Sedimentary rocks form as horizontal rock layers from this sediment. This principle allows geologists to recognize when rock layers have been moved from their original positions. For example, when a geologist finds rock layers that slant at an angle, he or she knows that the layers have been tilted from their original, horizontal position. Further, the geologist knows that the tilting event must have happened after the rocks formed. Thus, they know the age of the tilting event relative to the age of rock formation.

- The **principle of cross-cutting relationships** states that a geologic feature is younger than the features it cuts across. For example, a fault that cuts across rock layers is younger than the rock layers. The idea here is that the rock layers had to exist before the fault could cut across them. Another common example of cross-cutting is an igneous intrusion that cuts across other rocks. For example, a body of magma can force its way up through the Earth's crust, cutting across existing rock layers and cooling to form an igneous rock. This intrusive rock is younger than the rock layers it cuts across.

**Absolute dating** is a method in which the age of an object or event is estimated as an actual number of years. For example, a geologist might determine that a layer of volcanic ash is 20 million years old.

**Radioactive dating**, or radiometric dating, is a method in which the age of a rock, mineral, or fossil is calculated based on the amounts of certain radioactive substances in the sample compared to other substances in the sample. The proportion of an unstable, radioactive element in a mineral or fossil changes over time as the element decays. In the process of radioactive dating, scientists measure the amount of the radioactive element that is present and compare this to the rate at which the element decays. Together, these two pieces of information can allow scientists to determine when a rock or fossil formed.There are several different kinds of radioactive dating including radiocarbon dating. **Radiocarbon dating** is a type of radioactive dating that uses different types of carbon to measure the age of fossils or other materials. Radiocarbon dating relies on the fact that carbon-14 is radioactive and decays at a predictable rate. Since the initial amount of carbon-14 compared to carbon-12 in many samples is known, a scientist only needs to measure the amounts of carbon-14 and carbon-12 currently in a sample to calculate its age.

# Fossils

*Fossils are traces of past organisms preserved in the Earth's crust. They may include actual remnants of structures or just imprints of structures. Scientists study fossils to learn about the history of the Earth's surface, climate, and life forms.*

**Fossil Formation**
Fossils are most commonly found in **sedimentary rock**, which forms as layers of material settle upon each other, press together, and harden over time. As time passes, new layers form upon the older layers. This means that as time passes, fossils are buried deeper and deeper in the Earth. Therefore, fossils found in lower layers of sedimentary rock are older than fossils found in upper layers of sedimentary rock. The clues found in fossil layers provide valuable information about how Earth's organisms and the Earth itself have changed over time. Fossils can also provide information about how the Earth's surface has changed over time. If fossils of marine organisms are found in areas that are now dry land, scientists may assume that the area was once under water. This gives scientists important clues about land elevation, landforms, and sea level at various times in Earth's history. Fossils also show how the continents of the Earth have moved over time. Fossils that have been found in both Australia and in Asia show that these continents were connected in the past.

**Fossils & Organisms**
Fossils are remnants or traces of organisms that are preserved in layers of rock. If an organism gets buried under sediment, the soft parts will decay, while the hard parts (bones, teeth, etc.) undergo a chemical change to become preserved in the sediment, which later becomes rock. Some types of organisms that lived in the past are no longer alive on the Earth today. These organisms are said to be extinct. Fossils can show whether or not extinct organisms were similar to those that are living today. Fossils provide a variety of information that scientists can use to learn about the organisms that once lived on Earth.
**Index fossils**are fossils of organisms that were only found during very specific times in history. If a new fossil is found near an index fossil, it can be assumed that it is from approximately the same time period. Index fossils can also be used to date strata layers. Index fossils can help scientists decide what the climate was like during that time period.

# Adaptations

*Plants and animals have special characteristics, or **adaptations**, that help them survive in the environment that they live in. An adaptation could be a part of an organism's body or it could be a change in the organism's behavior.*

Adaptations are traits that increase the chance that a plant or animal will survive in a specific environment. Adaptations might help an organism find food or shelter, survive certain weather conditions, or protect themselves.
Some adaptations are traits that cause a behavioral or physical change as the seasons change. For example, some birds migrate to avoid the cold weather of winter.

**Getting Food or Energy**
Without food, animals cannot survive, so animals have adapted certain features that allow them to more easily obtain food. For example, the great white shark has a strong sense of smell that allows it to locate food, and it has sharp teeth that allow it to attack its prey. Lizards have long, fast-moving tongues that allow them to catch insects. Giraffes have long necks that allow them to reach high into trees to get leaves for food. Pelicans have enormous, pouched bills that they can expand to eat fish. Hawks have curved beaks that allow them to catch prey more easily. For example, Giraffes have long necks to reach leaves high in trees. Hawks have curved beaks to catch small prey. Animals may also have adaptations that help them respond to changes in the availability of food. For example, some types of squirrels store nuts for winter, while bats, hedgehogs, and some other animals *hibernate* in winter to survive the long period where there is little food available. Plants make their own food using energy from the Sun, so they need sunlight to survive. Many plants have adaptations that make sure that they always grow in the direction of the Sun to increase the amount of sunlight they receive.

**Finding Shelter**
Some animals have adaptations that assist them in finding or creating shelter. For example, woodpeckers make nests in the hollows of trees. These birds have adapted to have sharp beaks that make it possible for them to tunnel through the hard bark of trees and create hollows to live in.Many mammals that live in trees have adapted to have claws that allow them to climb easily. Other animals that live in burrows have feet designed for digging.

**Surviving the Weather**
Adaptations can help plants and animals survive certain weather conditions. For example, many plants grow during summer months and then stop growing during winter months to conserve energy. When the plants stop growing, they are *dormant*. Also, the seeds of most plants will not germinate until there is enough water and sunlight available. This helps ensure that the seed does not sprout until the conditions are right for the plant to survive. Animals can have adaptations that help them survive the weather conditions in their environment as well. For example, emperor penguins have adapted to have a thick layer of blubber that helps keep them warm in cold areas. Polar bears have thick fur and padded paws to help them survive the extreme weather of the Arctic. Flying birds, such as the tundra swan, *migrate* to survive cold winters and find food more easily during stressful environmental conditions.Some organisms have adaptations to help them survive hot or dry environments. Deserts have very little water, so animals that live in deserts must have adapted traits that allow them to survive without water for long periods of time.

**Protection**
Adaptations can also help plants and animals protect themselves. One method of protection is camouflage, which is where the animal's appearance helps it blend into its environment. Many stick insects, lizards, and frogs have adapted a form of camouflage that makes it hard for predators to see them.Animals can also behave in ways that help protect them. For example, snakes strike at predators, and owls spread their wings to appear larger and scare predators. Some animals protect themselves by *mimicking* other animals. One example is a type of wasp that does not sting but looks similar to a stinging wasp. Plants also have adaptations that help protect them. One example is the rose bush, which has thorns on its stems. These thorns stop predators from eating the plant and help it to survive.

# Diversity, Adaptations, Evolution & Extinction

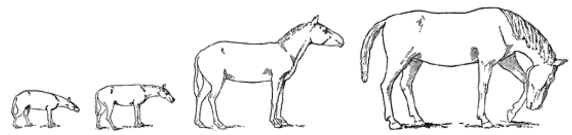
***Variations** exist in every population. When variations help an organism survive, more organisms with those variations are likely to be produced. This causes the characteristics of a species to **evolve** over time. When variations hinder an organism's ability to survive, fewer organisms with those variations are likely to be produced, which may lead to **extinction**.*

**The Diversity of Life**
Different environments and conditions have caused organisms to slowly change and adapt over time. Changes and adaptations increase the diversity among living things because they increase the number of different types of organisms that exist. Variations and diversity can also occur among organisms within the same population, or organisms of the same species that live in the same place at the same time. The diversity found within and between species is both the cause and result of natural selection.

**Natural Selection**
Natural selection is the tendency for more favorable traits to be selected by nature over less favorable traits. For example, imagine a population of rabbits living in a very cold environment. By chance, some rabbits have thicker fur than other rabbits. The rabbits with the thicker fur are more likely to thrive, reproduce, and pass on the trait for thicker fur to their offspring. The rabbits without the thicker fur are less likely to survive the cold environment, so these rabbits will not reproduce and pass on their traits. Thus, over time, the presence of the favorable trait increases within the rabbit population, and the presence of the unfavorable trait decreases within the rabbit population. The favorable trait is naturally selected over the unfavorable trait.It is important to note, however, that natural selection can only occur if there is variation, or diversity, within a population. If all of the organisms within a population are identical, then all of the individuals would possess the same traits, and it would not be possible for some traits to be more favorable than others.

**Evolution**
Evolution is the cumulative change in the characteristics of a population over time. The primary mechanism, or driving force, of evolution is natural selection. The theory of biological evolution explains the number of species on Earth, the variety of species, and the variability of organisms within a species. As a result of natural selection, organisms with more favorable traits are more likely to survive, reproduce, and pass on the favorable traits to their offspring. As these traits are passed on from generation to generation, the characteristics of a population evolve, so the majority of individuals within a population possess the favorable traits.

For example, the image shows four of the many stages in horse evolution. The image to the far left shows how horses looked approximately 47 million years ago. These horses were much smaller than the modern horse, they had toes instead of hooves, and they had smaller, weaker teeth. Over time, the horse evolved and developed hooves to better handle rougher terrain, longer legs to better run from predators, and stronger teeth to grind tougher grass.



The image to the far right shows how horses look today. These changes, or adaptations, occurred over millions of years and many generations, thus showing how small differences between parents and offspring can accumulate over time, so future generations can be very different from their ancestors.Fossil evidence is typically used to show the evolution of species over time.

**Extinction**
The fossil record can also show if a species ceased to exist, or became extinct. If no modern-day species resembles fossils that have been discovered, scientists can conclude that the species became extinct at some point in time. Extinction is a common event that occurs in Earth's history, and it can be caused by a number of factors, including sudden changes in the environment, disease, over hunting, and catastrophes. Most of the species that have ever existed are now extinct. Genetic variation is an important factor in preventing extinction. For example, imagine a population of deer that is infected by a disease. If at least some deer have a genetic variation that allows them to be resistant to the disease, then those deer could survive the illness, reproduce, and allow the species to continue to exist. A failure to adapt is also a cause of extinction. For example, if a population of squirrels prefers to eat nuts, but all of the nuts are removed from their environment, the squirrels would have to move to a different environment, adapt to be able to eat another type of food, or face extinction.

# Evolution - Evidence of Change

*Species change over time. The process through which these changes occur is known as **biological evolution**. Various forms of scientific evidence, including fossil records and biochemical, anatomical, embryological, and physiological similarities, allow scientists to classify organisms in order to show probable evolutionary relationships and common ancestry.*

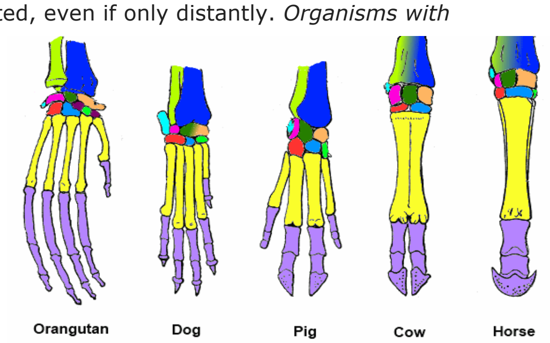
**Fossil Evidence**
A great deal of Earth's history can be determined using fossils. Fossils are remnants or traces of organisms that are preserved in layers of rock. If an organism gets buried under sediment, the soft parts decay, while the hard parts (bones, teeth, etc.) undergo a change to become preserved in the sediment. This sediment eventually hardens to becomes rock. Fossil records provide evidence for evolution, or changes in species over time. By studying the fossil record of a given species, it is possible to see the many changes that have taken place over multiple generations. These changes are called adaptations. Fossils can also show that organisms that are alive today evolved from earlier species. Or they can be used to show that two different species have common ancestry.

**Variations in DNA sequences**
One of the ways in which scientists judge whether two species are related is through **comparative biochemistry**, or the study of organisms' **DNA sequences**. Since each species has its own unique DNA sequence, it is possible to determine the relatedness of organisms by comparing their DNA. Sequences of related organisms are more similar than sequences of unrelated organisms. Scientists have also found that classifications based on variations in DNA sequences closely match organism classifications based on comparative anatomy as well as classifications based on evidence from fossil records. So, even though **related organisms evolved from a common ancestor**, at some point, the organisms changed to form different species.

**Comparative Anatomy**
Much can be learned by comparing the structural similarities and differences of living things. **Homologous structures** are structures found on one species that have the same basic structure and embryonic origin as those found on another species. If homologous structures are found on two different organisms, the species are related, even if only distantly. *Organisms with homologous structures share a common ancestor*, but at some point, mutations contributed to the rise of the new species.

The forelimbs of five mammals are presented above. The bones are color-coded to allow for easy comparison among the different species.

Sometimes, structures in different species appear to be homologous, but they are not. These structures are said to be analogous structures. **Analogous structures** have the same function, but do not share a common origin. Analogous structures evolve separately in unrelated species, and their presence does not imply that the organisms descended from the same ancestor. Because analogous structures evolved separately, their structure and arrangement arealso very different.



**Vestigial structures** are non-functional remnants of features that were once operational in a distant ancestor. These structures help establish evolutionary pathways for modern organisms. For example, the presence of vestigial pelvic girdles and femurs in snakes and whales implies that snakes and whales descended from animals that walked on land. Because the presence of these structures were not harmful to the organisms, there was no evolutionary pressure for the structures to completely disappear. Identification of vestigial structures can also indicate a relationship between two speciesThere are a number of vestigial structures found in humans. The following list provides some of the major examples:

- **coccyx** (tailbone) - attachment site for muscles that control tail movement
- **appendix** - an organ that helped with digestion of plant material, useful for hunter-gatherer ancestors
- **wisdom teeth** - remnants of a once larger jaw or replacements for lost teeth

**Comparative Embryology**
Comparative embryology is the study of similarities and differences in **embryologic development** among species. To a certain extent, the evolutionary history of organisms can be seen in the development of embryos. By locating similarities in development, scientists can determine if species are related, even if only distantly. For instance, gills are present in all vertebrate embryos at some stage in development. This common feature likely means that all vertebrates evolved from a common fish-like organism.

**Physiological Similarities**
The physiology of related organisms is extraordinarily similar. For example, certain organs, such as the liver, function the same way in all mammals. This indicates that all mammals evolved from a common ancestor whose liver functioned in the same way as the livers found in current mammalian species.

## <u>Catastrophes & Environmental Change</u>

*Changes in environmental conditions can affect the survival of individual organisms and entire species.*

Environmental conditions on Earth change constantly. Depending on the nature of the changes and the organisms involved, life has responded in different ways—some life forms have changed, some new life forms have evolved, and/or some life forms have become extinct. Events that have caused environmental changes in Earth's history include catastrophic events, such as floods, fires, volcanic activity, impacts of asteroids and comets, and climate change. Recent changes have also been influenced by human activity.

**Floods**
A flood is an overflow of water out of streams, lakes, and rivers across land that is normally dry. When flood water flows across land that is normally dry, it changes the Earth's surface through erosion and the movement of soil, rocks, and sand.

**Fire**
Fires are a natural part of the life cycle of ecosystems such as forests and grasslands. Fires can be started by lightning strikes, volcanic eruptions, or sparks from falling rocks. Regardless of how they begin, fires have the same effects:

- *Fires allow new plants to grow.*—Fires return the nutrients that were bound up in the plants to the soil, enriching it for new plant growth. Fire also clears out old growth that blocked the light, giving new plants a chance to gain a foothold.
- *Fires destroy vegetation.*—Fires can destroy the food sources of herbivores. By destroying ground cover such as grass, they increase the erosion of top soil.
- *Fires destroy animal habitats.*—Many animals become displaced while fleeing fires or are killed by the smoke, fire, or destruction of their food sources.
- *Fires release ash into the air.*—This can increase cloud formation and block sunlight from reaching the Earth.

**Volcanic Activity**
Volcanic activity has played a role in Earth's systems throughout most of Earth's history. In the early days of Earth, volcanic activity expelled gases from Earth's interior to help form the atmosphere. Volcanoes today continue this process by ejecting atmospheric gases, including greenhouse gases that make Earth habitable. Volcanic activity has also played a role in shaping Earth's surface throughout its history. New crust forms where lava erupts from Earth's surface. Volcanic activity can also be destructive when explosive eruptions destroy the habitats of life forms. Eruptions can also cause tidal waves that can destroy life forms and habitats in distant regions.Large-scale explosive eruptions can send ash and dust high into the atmosphere. As the dust is carried around the Earth, it can block sunlight for long periods of time and cause climate changes around the world. Large volcanic eruptions can result in thick layers of ash that can be observed in rock layers. Catastrophes like this can rapidly disrupt many of Earth's processes and ultimately the life forms that depend on those processes. In some cases, these catastrophes can cause extinctions and mark the end of one geologic era and the beginning of another.

**Asteroid & Comet Impacts**
Earth's atmosphere prevents most small meteoroids from hitting Earth's surface. Occasionally, however, asteroids and comets collide with the Earth and other planets. While these impacts are extremely rare, they can cause widespread catastrophes. Large impacts throw large volumes of dust into the atmosphere, which can block out the Sun and cause major climate change. Sudden changes like this can result in mass extinctions of life forms on Earth. Many scientists agree that an impact of an asteroid or comet caused the extinction of the dinosaurs and many other groups of organisms at the end of the Mesozoic era. This event also opened up niches for mammals and other organisms to flourish on the Earth. One piece of evidence that supports the idea that an asteroid impact caused the extinction of the dinosaurs is that a layer of iridium-rich debris has been found in the rock record. Iridium is often found in

meteorites, and layers of rock on top of the iridium debris do not contain any dinosaur fossils. The picture below shows NASA's interpretation of what the impact that caused the mass extinction of the dinosaurs might have looked like.

**Climate Change**
As discussed above, climate can change suddenly due to catastrophic events. Climate change can also occur gradually as a result of tectonic plate motion. As plates move to new areas of the planet over millions of years, they move through different latitudes and patterns of atmospheric movement. Gradual climate changes, like catastrophic events, can cause changes in Earth's life forms. For example, Earth has been influenced by many ice-age climate changes during Earth's current era, the Cenozoic. During the Cenozoic era, ice sheets and glaciers have advanced and retreated many times. Earth's climate has cooled during intervals of advance and warmed during intervals of retreat. Present-day Earth is in an interval of glacial retreat. During these warming and cooling intervals, life forms on Earth have changed. Sea level has risen and receded, causing plant and animal populations to relocate. In some cases, rising sea levels separated populations of organisms, causing *speciation*, or evolution of one species into two or more different species, to occur. Speciation can take place as mutations and natural selection gradually change the dominant traits of two geographically isolated populations so that each population is better adapted to its particular environment. Many mammals that thrived during the most recent major cooling interval, such as mammoths, have gone extinct. It is uncertain whether these animals went extinct due to climate change, hunting by humans, disease, or a combination of these factors. Regardless, many of these animals could not survive in Earth's current warmer climate.

**Human Impact**
There are over 6.5 billion humans on the Earth, and that number is constantly growing. As the number of humans increases, so does the consumption of natural resources and the rate at which forests and grasslands are transformed into farmland, home sites, roads, and parking lots. Human activity is the main cause of modern day extinction. The list below shows some of the ways in which humans impact the environment and thus impact the health of any given species.

- **Habitat destruction**—The loss of habitat can quickly lead to an organism's extinction. In fact, habitat destruction is the single-leading cause of extinction today. Humans can destroy habitats by clearing forests, filling in wetlands, and building dams and roads.
- **Habitat division**—When humans divide habitats into smaller areas (by building a highway, for example), this reduces the genetic diversity and the number of possible mates in an ecosystem, which contributes to extinction.
- **Pollution**—Pollution can also damage habitats and contribute to extinction. For instance, it is widely believed that the pesticide DDT caused the shells of certain bird eggs to weaken and collapse. This may have prevented the birds from reproducing successfully. Populations of the bald eagle, the peregrine falcon, and the brown pelican decreased in size to the point that the species became endangered.
- **Hunting**—Hunting organisms for recreation, food, and other reasons can also cause or contribute to extinction.

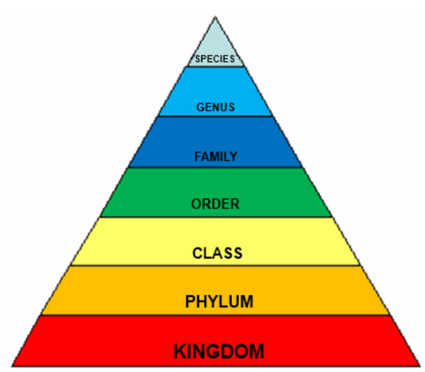
Although many human activities can negatively impact the health of Earth's living resources, humans can also do many things to make sure all these valuable resources continue to survive. Placing endangered organisms in special wildlife reserves helps increase population size. In addition, reducing the amount of chemical pesticides, herbicides, and fertilizers can keep animals and their habitats healthy.

## Diversity of Life & Organism Classification

*There are millions of different types of organisms that live on the Earth. These organisms can be classified into groups based on their characteristics.*

**The Diversity of Life**
Organisms have slowly adapted to different environments and changing conditions over time. New adaptations increase the diversity among living things because they increase the number of different types of organisms that exist. *Genetic mutations* and variations that come about as a result of *sexual reproduction* also contribute to the diversity of life.

**History of Biological Classification**
*Taxonomy* is the science of classifying organisms based on their traits. Scientists use classification systems to separate organisms into groups based on similarities and differences in their structural and genetic characteristics. These systems allow scientists to easily identify different kinds of organisms. The first classification system was developed by Aristotle. His classification system consisted of only two groups—Plants and Animals. Therefore, many organisms, such as fungi, did not fit neatly into either category. As late as the 18th century, there were still only two kingdoms (Plantae and Animalia). However, the two kingdoms were further subdivided into smaller groups by Swedish biologist, Carl Linnaeus, who is considered the father of biological classification. The flow chart below indicates the hierarchical levels of the Linnaean classification system.




As new organisms and new features of old organisms are found, the taxonomic system can be adapted to meet the changing needs for classification. These levels, known as the *Linnaean system of classification*, include very broad ranks (e.g., kingdoms) and more specific ranks (e.g., species). Organisms that are classified together in more specific ranks share more characteristics and are more closely related than organisms that are classified together in broader ranks. Modern classification systems place more importance on genetic information and organism-relatedness. Because organisms pass down their traits to future generations through reproduction, organisms that share many traits are often closely related. Recent technology has allowed scientists to compare the genetic make-up of organisms, and the DNA evidence has supported this concept.

# Habitats & Basic Needs of Organisms

*All living organisms have a set of needs that must be met in order for the organisms to live and grow. These are called* ***basic needs****. Organisms get their basic needs met in their* ***habitats****.*

**Habitats**
The place where a plant or animal lives is called its habitat. A living organism's natural habitat gives it what it needs to survive. Organisms depend on both living and nonliving parts of their habitats to meet their basic needs. Organisms interact with, and can be dependent upon, one another. For example, some insects use pollen and nectar from plants as food. When an insect lands on a plant to get pollen or nectar, some of the pollen from the plant will stick to the insect and be moved to the next plant. This helps the plant perform pollination so that it can reproduce. Both organisms benefit from this kind of interaction. The diversity of the habitats on the Earth means that organisms that live in these habitats must also be diverse. Every habitat has its own unique set of living conditions, and the ability of an organism to survive depends on the features and traits of that organism. The habitat in which a species of plant or animal lives will determine the adaptations that it will develop, over many generations, in order to survive there. Habitats can change or even disappear. If change is drastic or if the habitat disappears suddenly, such as when all the trees in an area of forest are cut down, the organisms may not be able to get their basic needs met, and they may move to another habitat or die off.

**Basic Needs of Animals**

- **Food** provides energy for animals. Animals get food by eating other living organisms. Some animals eat plants, while some animals eat other animals.
- **Water** is a basic need for all animals, and it is a nonliving part of an ecosystem. Some animals, like fish, live in water all of the time. Many other animals need to drink water every day to survive. A few kinds of animals can get enough water from the food they eat that they do not need to actually drink water.
- **Oxygen** is a gas that can be found in the atmosphere and dissolved in bodies of water. It is important for the survival of all animals. Land animals use lungs to get oxygen; water animals get it directly from the water. Once oxygen is taken in, it enters the blood stream and is used by the cells in the body to release energy from food.
- **Space** is the amount of room an organism needs to live and grow. All animals need space in which they can interact with the environment to meet their basic needs. When animals are in a space that is too small, they compete more strongly for resources. Animals crowded together may also be more likely to pass diseases from one animal to another.
- **Shelter** is important for most animals. It provides a place to escape predators and raise young, and it helps animals maintain a constant body temperature. Types of shelters vary greatly, but have one thing in common: they help an animal meet their basic needs. Some animals, such as badgers, moles, rats, and snakes, live in holes underground, or at ground level. Other animals, such as birds and wild cats, make nests or use the branches of a tree for shelter.

**Basic Needs of Plants**

- **Sunlight** is a basic need for plants because plants use energy from the Sun to make their own food.
- **Water** is a basic need for plants, just like it is for animals. Water is essential to plants because it helps transport nutrients from the soil to the plant's roots and because plant cells need it in order to release energy from molecules of food.
- **Nutrients** from the soil are necessary for a plant's survival. Different plants depend on different soil types for their needs.
- **Air** is a basic need for plants. During photosynthesis, plants use carbon dioxide from the air to make food molecules, then release oxygen into the air as a waste product. During cellular respiration, plants take in oxygen from the air and release carbon dioxide as a waste product.
- **Space** to grow is another basic need for plants. If space is not available, plants will compete for nutrients, and not all of the plants will survive.

**Niches**
A *niche* is, generally, how a species makes a living in its environment. More precisely, a niche is how a species responds to, and affects, the entire range of competitors and resources in its ecosystem. In other words, a niche refers to exactly how a species gets is needs met and how it meets the needs of other organisms in its environment. Factors that make up an organism's niche include where the species lives, what it eats, what eats it, how many of it there are, and what its reproductive patterns are. Generally, only one species can occupy any particular niche in a particular ecosystem.Similar niches (ways of making a living) can sometimes exist in different ecosystems. As a result, different organisms can sometimes play similar ecological roles in different ecosystems.

# Biotic & Abiotic Factors

*Ecosystems can be characterized by their biotic and abiotic factors.* ***Biotic factors*** *are the living components of an ecosystem.* ***Abiotic factors*** *are nonliving components of an ecosystem.*

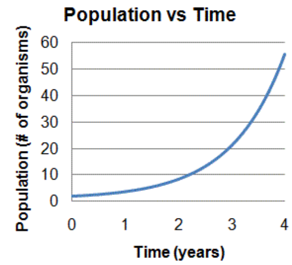
**Biotic Factors--** The biotic factors of an ecosystem are the living components. Plants, animals, and all of the other organisms that live in an ecosystem are biotic factors.
**Abiotic Factors--**The abiotic factors of an ecosystem are the nonliving components. These include rainfall, temperature, sunlight, water, soil, rocks, and air.

**Link Between Biotic & Abiotic Factors--** The biotic and abiotic factors of an ecosystem are interrelated. Living things interact not only with one another, but also with the nonliving parts of their ecosystems. The abiotic factors of an ecosystem often determine what living things can live there. For example, animals that can survive in the Arctic are adapted to cold climates, while animals that can survive in deserts are adapted to dry climates. The abiotic factors of an ecosystem also provide the most of the basic needs of plants and animals. Biotic factors can also impact abiotic factors in an ecosystem. For example, plants add oxygen to the atmosphere, worms living in the ground aerate the soil, and algae growing in lakes can reduce the sunlight reaching the bottom of the lake.

# Carrying Capacity & Population Dynamics

*The growth of a population in an ecosystem is limited by the availability of resources. Populations can only grow to a certain point before there are not enough resources available for all of the organisms to survive.*

**Population Growth**
Left to themselves (and assuming infinite resources), populations of organisms will experience *exponential growth*, in which the rate at which they grow is proportional to how many organisms there are. The image below shows an example of exponential growth.Populations do not experience exponential growth forever because they will eventually outgrow the resources available to them. The resource that limits the growth of a certain population is known as that population's *limiting factor*.




**Limiting factors** are things that limit a population's growth. These factors can be resources that organisms need in order to live and that are present in limited quantities. Or, they can be things that limit the growth of the population in other ways, such as a population's rate of reproduction or the presence of a disease. Limiting factors can be biotic or abiotic.For a plant population, a limiting factor might be the temperature, the availability of light, or it might be the availability of fertile soil. For a hyena population, a limiting factor might be competition for food with other predators, or it might be a low reproductive rate. The number of plants or hyenas in a specific ecosystem will be limited by the resource that is the population's limiting factor. Different ecosystems can have different limiting factors, even for similar populations.Limiting factors can be created by human activities. If there is a chemical spill that kills plant and animal life in an area, this could limit how successful the surviving populations can be. Humans also destroy large amounts of plant and animal habitats. So space is often a limiting factor for many wild plant and animal populations. All stable populations are subject to at least one limiting factor.The limiting factor of a population determines the population's **carrying capacity**, or the maximum number of this kind of organism that a specific ecosystem can support over a long period of time. The carrying capacity is limited by the available energy, water, air, space, food, and minerals. It is also limited by the ability of the ecosystem to recycle dead organisms through the activities of decomposers, such as bacteria and fungi.***When a population is less than the carrying capacity, it tends to grow. When a population is greater than the carrying capacity, it tends to shrink.***

**Patterns of Population Growth**
The pattern of population growth will vary as changes in environmental conditions arise. For example, variations might result from: a change in the food supply, a change in the water supply, a disease epidemic, the creation of new vaccines, a change in temperature, storms, earthquakes, and other natural disasters, crowding and competition, predator-prey relationships

**Competition**
Since there are limited amounts of resources in an ecosystem, if one organism gets a particular resource, another does not. This leads to **competition** as two organisms try to access the same resources. Food, water, sunlight, and space are examples of resources that organisms compete for. Plants and animals of the same species may compete for resources such as food, water, shelter, and space. Populations of different species will also compete with one other if their needs are the same as the needs of another population in that ecosystem. For example, trees in a forest compete for sunlight. As one tree grows taller, the shorter trees are shaded by it, and they receive less sunlight. The shorter trees may die as a result.

**Population Dynamics**
Populations in an ecosystem affect one another. A change in the number of one type of organism will cause a change in the number of other types of organisms. These changes can be studied by looking at the population dynamics of an ecosystem. The number of organisms within these populations will always be changing as some organisms are born and other organisms die. The population size of one species will also change in response to a change in the population size of another species. For example, if a drought in the ecosystem caused many of the trees to die, the antelope population would decrease because there would not be enough food for all of the antelope to survive. If the antelope population decreased, the number of African wild dogs and lions would also likely decrease because they would be losing a major food source. Another example would be if humans began hunting and killing many of the African wild dogs and lions. This would cause an increase in the antelope population because they would not have as many predators, which would lead them to eat more leaves from trees, and decrease the amount of this resource in the ecosystem. *All populations within an ecosystem are related in some way or another. This means that a change in even one population in an ecosystem can have drastic effects on the ecosystem as a whole.*

# Organism Interactions

***Plants and animals, including humans, interact with and depend upon each other to satisfy their basic needs.Common*** *organism interactions* ***include cooperation, competition, commensalism, mutualism, parasitism, predation, and scavenging.***

**Cooperation & Competition**
Organisms have many basic needs, including food and shelter. Sometimes, organisms *cooperate* with each other to obtain these basic needs. For example, a pack of wolves might cooperate with one another to kill a large bear that they can share as a meal, or a group of humans might work together to build a house that they can share for shelter. At other times, organisms *compete* with each other to obtain their basic needs. For example, one bird might fly faster than another bird, so it can catch prey before the other bird.

**Commensalism**
Commensalism is a kind of organism interaction in which **one of the organisms benefits while the other is not significantly harmed or helped** by the interaction. Often, the benefit that the organism receives is the ability to find food more easily or protection from other organisms. For example, large grazing herbivores, such as cattle and horses, often stir up insects as they graze on grass in fields and pastures. Birds known as cattle egrets often follow behind the grazing herbivores and eat the insects that have been displaced. Since the cattle egret benefits by being able to find food easily and the grazing herbivores are not affected by the presence of the egrets, their interaction is an example of commensalism.

**Mutualism**
Mutualism is a kind of organism interaction in which **both organisms involved receive a benefit**. Flowers and their pollinators are one of the most common examples of mutualism because many kinds of plants depend on insects, such as moths, bees, wasps, and beetles, to perform pollination in order to reproduce. Plants that rely on pollinators attract the pollinator by the shape, color, or smell of their flowers. As the pollinator feeds on the nectar or pollen from the flower, some of the pollen sticks to its legs and body. When the pollinator visits a second plant of the same species, the pollen from the first plant is transferred to the reproductive organs of the second plant, and pollination occurs. Both organisms receive a benefit from this interaction. The pollinator receives access to a food source and the plant is able to reproduce because of their relationship. Bees are pollinators that receive nectar or pollen from flowering plants. They also aid in the pollination of the plant, which makes the relationship mutualistic.

**Parasitism**
Parasitism is a kind of organism interaction in which **one organism benefits and the other organism is harmed** by the interaction. The organism that receives a benefit is known as a **parasite**. The organism that is harmed by the relationship is known as the **host**. The host species is usually impaired slowly over a long period of time.Parasites can live either inside the body of their host or externally. Common external parasites include fleas and mosquitoes which feed on the blood of their hosts. Internal parasites, such as tapeworms, live inside the body of their host and absorb nutrients from the host's body. In both cases, the parasite receives nutrients at the expense of the host and the host can no longer use these nutrients for its own life processes.

**Predation**
The biological interaction in which one organism (the **predator**) hunts, kills and eats another organism (the **prey**) for energy is known as predation. Predators use their prey as a source of food.Predation is different from parasitism because the prey is killed immediately for consumption. During parasitism, the host is kept alive for a long period of time so that the parasite can continue to receive nutrients from the host. An example of predation is a lion hunting, killing, and consuming a zebra.

**Scavenging**
Animals that are scavengers eat other animals that are already dead. Scavengers, unlike predators, are not directly involved in the hunting or killing of the prey. Vultures are common examples of scavengers. These birds fly around looking for animal carcasses to consume. They can often be seen on the side of a highway eating animals that have been run over.Other animals that will sometimes exhibit scavenger behavior include blowflies, remora fish, raccoons, hyenas, lions, dogs and crows. Most species are not strictly scavengers; being a scavenger is instead an opportunistic behavior that is exhibited by many different species.

# Energy in Ecosystems

*Organisms within an ecosystem are dependent upon the other organisms because **energy is passed from one organism to another as food**.*

Almost all food energy comes originally from sunlight. Producers absorb the Sun's energy and transform it into chemical energy when they produce sugars through the process of *photosynthesis*. The sugars are food for the producers. Producers can use the food immediately, or they can store it for later use. When the producers are eaten by consumers, this energy then passes to the consumers. Since producers get their energy from sunlight, and the Sun is constantly radiating this light, the energy in an ecosystem is always being replenished.The chemical energy in sugar molecules can change forms inside organisms. For example, sugars can be broken down in an animal's body to produce thermal energy used to maintain body temperature. Both plants and animals release energy that is stored in molecules of sugar by *oxidizing* the sugars during the process of *cellular respiration*.

**Producers**
Producers are organisms that use the Sun's energy to make their own food. Green plants are producers. They make their own food using energy from the Sun in a process called *photosynthesis*. Other producers include single-celled organisms such as algae, bacteria, and protists. Producers can also be called ***autotrophs***, which means "self-feeding," because they use energy from sunlight to manufacture their own nutrients. All of the other organisms in an ecosystem depend on producers for energy. This is because humans and other animals cannot make their own food. Some producers get the energy to make food from chemical compounds instead of from the Sun. These producers live in dark places, such as the ocean floor, where a supply of the chemical compounds they need is constantly produced by geologic features, such as hydrothermal vents.

**Consumers**
Consumers are animals that get energy by eating producers or other consumers. All animals, including humans, are consumers. Since consumers cannot feed themselves, they are considered ***heterotrophs***, or organisms that get their nutrition from others.

**Decomposers**
Decomposers are organisms that feed on wastes and dead plants and animals. The role that decomposers play in an ecosystem is very important. Decomposers "clean" the environment by returning nutrients contained in the bodies of dead plants and animals back to the soil, water, and air. The nutrients that decomposers release are then used by producers to make food, and all other organisms depend on this food. Decomposers are also important for the water, carbon, nitrogen, and oxygen cycles.Fungi, such as mushrooms, are examples of decomposers. Some kinds of bacteria and insects are also decomposers.

# Food Chains & Webs

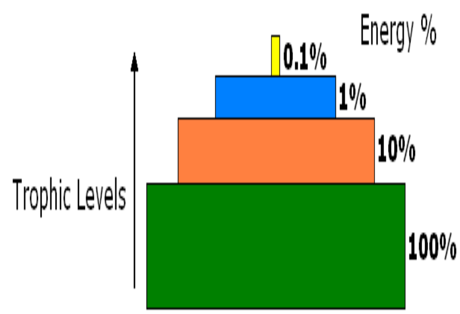
*A **food chain** shows one possible route for the transfer of matter and energy in an ecosystem. A **food web** shows how food chains that involve some of the same organisms may intertwine.*

**Food Chain Diagrams**

Ecologists use food chain diagrams to trace the flow of energy and matter through ecological communities and discover nutritional relationships. Each organism in a food chain represents a feeding level—sometimes called a *trophic level*. An example of a food chain diagram is shown below. The arrows in a food chain show the direction of energy flow. The arrows point from the organisms that are being consumed to the organisms that are receiving energy by consuming. For example, in the food chain above, an arrow points from the plant to the grasshopper. This means that the grasshopper is feeding on the plant and getting energy from it.


**Classification of Organisms in Food Chains**
Sunlight is the primary source of energy in most ecosystems. **Producers**, such as plants and photosynthetic microorganisms, capture this light energy and convert it to chemical energy stored in sugar molecules that they can then use as food. Producers are at the beginning of all food chains because they are the only organisms that can manufacture their own food from energy that does not come from another organism. In the food chain shown above, the producer is a plant.Organisms that feed on other living organisms are **consumers**. In a food chain, the second organism is a consumer that eats producers, although it may not necessarily feed on producers exclusively. Organisms that *do* feed exclusively on producers are called **herbivores**. Organisms that feed on both producers and other consumers are called **omnivores**. In the food chain shown above, this level is represented by the grasshopper.The next organisms in a food chain must be consumers that feed on other consumers, although they may feed on producers as well. The frog, snake, and hawk in the food chain above all feed on consumers. The frog is an omnivore, because it also feeds on plant material during at least part of its life cycle. The snake and hawk are *carnivores* because they eat only other animals.All organisms in the food chain are eventually broken down by **decomposers**, such as worms, bacteria, and fungi. Decomposers are frequently not shown in food chains, although the wastes and remains of all organisms in an ecosystem are eventually fed on by decomposers.

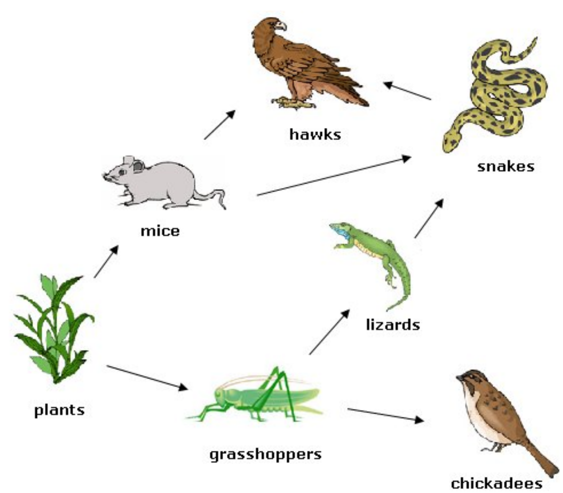
**Energy in Food Chains**
Producers and consumers both release the energy stored in food molecules through *oxidation*, which is part of cellular respiration. Some of the released energy is used by the organisms to perform the processes that are necessary for life. The rest of the energy remains in food parts that are excreted as wastes, or it is given off as heat.Because most of the energy in a food chain is used or lost to the environment as it moves up the chain, the bottom level of the food chain contains the most stored energy. In fact, this is where most of the energy in the entire ecosystem can be found. Only about 10% of the energy produced at each level is available to the one above it. For this reason, the higher up in the food chain an organism is, the smaller the size of its population. The diagram below represents the amount of energy available to organisms at four levels in a food chain. Interpreted in terms of the food chain shown above, snakes have access to only 0.1% of the energy present in all the plants in their ecosystem. Because they cannot make use of a larger amount of energy, and therefore there is less energy to sustain each individual snake, there are fewer snakes than plants, grasshoppers, or frogs. The hawks can access even less of the ecosystem's energy, so there are fewer hawks than snakes.




**Food Webs**
Most animals feed on more than one type of organism, and many plants and animals are fed upon by more than one kind of animal. If several food chains that include some of the same organisms are combined, they make a **food web**.A food web shows many different food chains for a particular ecosystem and how these food chains interrelate. The food web above includes the food chain discussed earlier. However, it also shows four other food chains:

- plants → mice → hawks
- plants → mice → snakes → hawks
- plants → grasshoppers → lizards → snakes → hawks
- plants → grasshoppers → chickadees

These food webs intertwine because many organisms eat, or are eaten by, many other types of organisms.



# Global Food Webs

*All organisms participate in two main interconnected global food webs.*

All organisms on Earth, including humans, are part of the two main interconnected global food webs—the ocean food web and the land food web. Each organism in these food webs directly or indirectly relies on other organisms in the webs. The ocean food web includes algae and other microscopic photosynthetic organisms, the animals that feed on them, and finally the animals that feed on those animals. The land-based food web includes plants, animals that eat plants, and animals that eat other animals. While a particular organism might not live on land, there is some connection between that organism and the organisms that do live on the land. The opposite is also true. For example, even though foxes live on land, they are part of the largely oceanic food web pictured. This is because foxes feed on puffins and kittiwakes, which spend part of their time in the ocean feeding off of fish and other marine organisms.Much of the interaction between the ocean food web and the land food web takes place in the *intertidal zones*, or the area of land between high and low tide. *Tide pools* form where there are depressions in the rock or sand, and starfish, mussels, and other animals that are submerged during high tide are stranded in the pools during low tides. In the pools, they are easy prey for birds and other consumers.

Humans depend on both the land and the ocean food web. Although humans are land creatures, we are one of many land creatures that heavily depend on the ocean's food web for survival. Humans consume large amounts of fish and crustaceans. In some regions of the world, these are the primary sources of food for large populations of human beings.

# Cycling of Matter in Food Webs

*Like energy, matter cycles through organisms in an ecosystem. Although matter may change forms as it cycles, it cannot be created or destroyed.*

**Matter in Living Organisms**
Humans and other animals are made up of *matter*. All matter on Earth is ultimately made up of one or more atoms of the over 100 different types of elements found on Earth. A few of these elements, however, are most frequently used by living organisms as building materials to construct their bodies. The elements most commonly found in living things include carbon, oxygen, hydrogen, nitrogen, phosphorous, potassium, calcium, and sulfur. Atoms of these elements can be combined to produce a few different types of compounds that are found in nearly all living organisms. These compounds are called *biomolecules*, and they can be classified into four main types: *carbohydrates*, *fats*, *proteins*, and *nucleic acids*. All forms of life on Earth are **carbon**-based. Each of the four types of biomolecules is made up of carbon bonded with atoms of other elements. All forms of life also require **water** to survive. Water is important both as a solvent for many of the body's solutes and as a key component in many metabolic processes. Water is the single most abundant compound in all living organisms. Around two-thirds of the weight of a cell is accounted for by water. **Nitrogen** and **oxygen** are also essential for life and found in significant quantities in the biomolecules that make up living organisms. Nitrogen is found in proteins and nucleic acids, such as DNA. Oxygen is a component of all four types of biomolecules. The primary source of the elements used to form biomolecules is food. Food is the way that matter is transferred from one organism to another. Food web diagrams can be used to show the feeding relationships in an ecosystem.

**Food Web Diagrams**
Food webs are commonly used to show the flow of energy through an ecosystem. However, they are useful tools for following the flow of matter. In food web diagrams, the arrows indicate the direction the energy and organic matter flow within an ecosystem. In one of the feeding relationships shown in this food web, organic matter from the grass—in the form of the sugars, proteins, and water that make up the grass's leaves—becomes incorporated into the grasshopper, which is transferred to the frog and finally to the copperhead. When the copperhead dies, its matter will be broken down by decomposers into smaller molecules which can be released into the atmosphere or become part of the soil. Ultimately, the atoms in the released molecules will be used by other organisms to build body structures.

**Flow of Matter through Ecosystems**
Just as **producers** are the vectors by which energy enters an ecosystem, they also begin the cycle of matter. At the beginning of the cycle, producers perform photosynthesis by using sunlight to convert carbon dioxide gas from the atmosphere and water and nutrients absorbed from the soil into carbohydrates (sugars) and other types of biomolecules. The producers then incorporate these biomolecules into structures such as leaves, stems, and roots.

**Consumers** eat producers or other consumers and transform the matter they obtain into building materials for their own bodies. The matter needed for a consumer to grow larger comes from the organisms they consume.

**Decomposers** break down animal wastes and the remains of dead plants and animals. Through this process, matter from these materials is converted back to water and nutrients which are in the form of elements and small simple molecules. These nutrients are then returned to the soil and the atmosphere, where producers can use them to begin a new matter cycle.

**Matter is Conserved in Closed Systems**
Energy, in the form of sunlight, is constantly entering the Earth's atmosphere. This energy is converted by producers into chemical energy. As this energy moves from the producers through the food web, it changes forms many times, and some of the energy is lost to the atmosphere as heat at each step. Eventually, excess heat is radiated by the atmosphere out into space. Therefore, Earth is *not* a closed system in terms of energy; energy enters and exits the Earth "system." However, the Earth *is* essentially a closed system in terms of matter. With the exception of the occasional addition of matter by asteroids and meteoroids that enter the atmosphere and fall to Earth, and a small number of atmospheric molecules that drift off into space, no matter enters or exits the Earth system. The atoms of carbon, nitrogen, oxygen, and other elements on Earth today have been in the Earth system since the planet formed.Ecosystems are *not* generally closed systems in terms of matter. Organisms in an ecosystem give off gases, water, and other wastes that may find their way into the atmosphere or other ecosystems. Likewise, when producers take in carbon dioxide

and produce sugars with them, they are taking new matter into the ecosystem from the surroundings.However, matter *is* conserved as it moves from one step in a food chain or web to another. For example, if a bird swallows a grasshopper, all of the matter that made up the grasshopper's body is inside the bird's body. Some of the matter will be used to make new building and energy-producing materials for the bird's body. The rest of the matter will be converted into waste materials that are eliminated from the bird's body and deposited back into the environment as urine, feces, and waste gases.

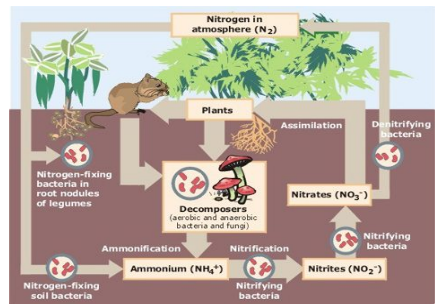
## Nitrogen Cycle

***The** nitrogen cycle **describes the movement of nitrogen throughout the atmosphere, lithosphere, and biosphere.***

Nitrogen is an essential part of proteins and genetic material. Therefore, all organisms require nitrogen to survive. Even though nitrogen is the most abundant gas in the atmosphere, most organisms are unable to use this form of nitrogen. However, there are a few microscopic organisms and natural processes, such as lightning, that can convert unusable nitrogen in the atmosphere to usable forms of nitrogen in the lithosphere and biosphere.

**Steps in the Nitrogen Cycle**

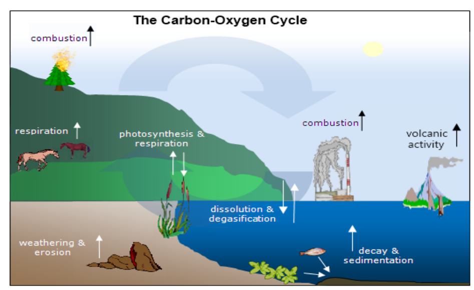
During the nitrogen cycle, atmospheric nitrogen ($N_2$) is **fixed**, or converted into a usable nitrogen-containing compounds called *nitrates*, by certain types of microorganisms. Plants can then absorb the nitrogen compounds from the soil and use it to form chlorophyll and other important biological building blocks.Consumers must obtain nitrogen from the organisms they consume. Herbivores receive their nitrogen from the plants that they eat, and carnivores get their nitrogen from the animals they consume. However, all organisms depend on the ability of nitrogen-fixing microorganisms to convert atmospheric nitrogen into a form of nitrogen that plants can *assimilate*, or take in and use.Finally, nitrogen is returned to the atmosphere through the combustion of fossil fuels or when decomposers break down the nitrogen found in fertilizers, urine, and dead plants and animals.




## Carbon-Oxygen Cycle

*Carbon and oxygen are necessary for all organisms. These elements move between producers, consumers, and the atmosphere in a continuous biogeochemical cycle.*

The carbon and oxygen cycles are sometimes discussed separately. However, these cycles can also be addressed together since they are dependent upon each other for proper operation. This combined, interdependent cycle is known as the carbon-oxygen cycle.There are several processes that either store carbon dioxide or release it into the environment.




Processes that Release Carbon Dioxide into the Atmosphere

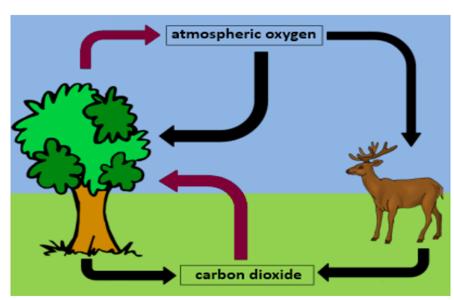
- Cellular respiration is a natural process in which substances are broken down to create energy.
- **Decay** is a natural process in which organic matter, like dead organisms, *decomposes* or breaks down.
- **Volcanic activity** is a natural process involving the eruption of hot gases and rock material from within the Earth.
- **Weathering** is the process by which stones at the Earth's surface are broken down, either physically or chemically.
- **Degasification** is the release of carbon dioxide, once dissolved in water, into the air. It is a natural process, but it has increased due to higher global temperatures. Warm water can hold less dissolved gases than cooler water. This is why a can of soda goes flat when it gets warm
- **Combustion** is a reaction in which a substance burns in oxygen.
    - It can be natural, such as a forest fire started by lightning.
    - It can be man-made, such as burning wood and fossil fuels.

**Processes that Store Carbon Dioxide**

- **Photosynthesis** is a natural process in which carbon dioxide and water are converted into sugar.
- **Sedimentation** is a natural process in which pieces of rock and other matter settle out of water and are buried.
- **Dissolution** is a natural process in which carbon dioxide from the atmosphere dissolves into water.

**Photosynthesis & Respiration**

The two most important natural processes that drive the carbon-oxygen cycle are photosynthesis and cellular respiration. Each of these processes must take place in order for the cycle to function properly. This is because the end products of one process are starting materials for the other.*The black arrows represent the flow of oxygen and carbon dioxide due to cellular respiration. The magenta arrows represent the flow of gases due to photosynthesis.*




**Photosynthesis:**

***carbon dioxide + water →sugar + oxygen***

The end products of photosynthesis are sugar and oxygen. These substances are the starting materials of cellular respiration.

**Cellular Respiration:**

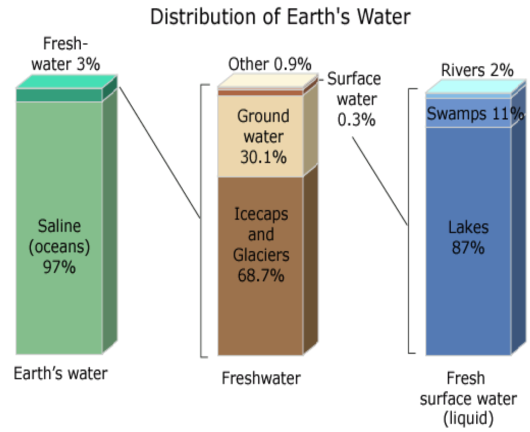
***sugar + oxygen →carbon dioxide + water***

The end products of cellular respiration are carbon dioxide and water. These substances are the starting materials of photosynthesis.

# The Hydrosphere

*The hydrosphere is composed of the Earth's supply of moisture in all its forms: liquid, frozen, and gaseous.*

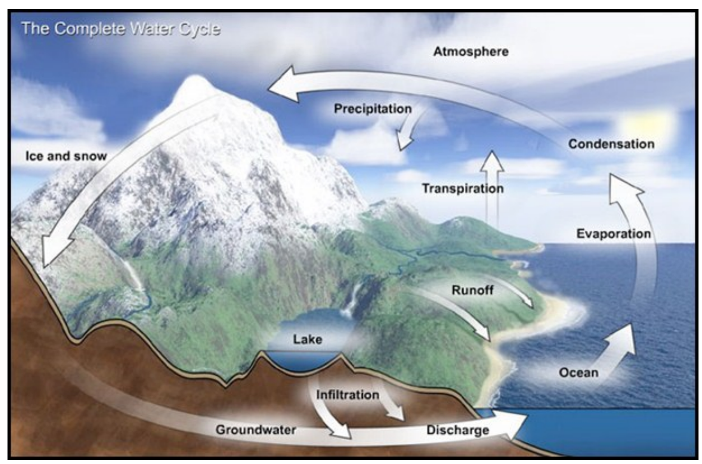
**Hydrosphere Components & their Locations**
The hydrosphere includes surface water, underground water, frozen water, and water vapor in the atmosphere. Most of the hydrosphere is composed of liquid water and ice. Only a small amount of the hydrosphere is water vapor. The frozen water on Earth makes up the *cryosphere*, which is usually considered to be part of the hydrosphere. The hydrosphere covers about 71% of the Earth's surface. The water in the hydrosphere changes from liquid water to water vapor and moves from one location to another through a process called *the water cycle*. The water cycle keeps a constant amount of water in the hydrosphere as water changes state (liquid to gas, etc.) and location in the atmosphere. The cycle is mainly driven by solar energy. Most of the water in the hydrosphere is saltwater and is contained in the oceans and seas (97%). The next largest amount of water is found as ice in glaciers and the icecaps (2%). Of the freshwater, which is the water that is not in oceans or seas, thirty percent is groundwater. Rivers, lakes, and streams make up less than one percent of freshwater found in the hydrosphere. (see figure below)




# The Water Cycle

*Water and energy are transferred throughout the hydrosphere, lithosphere, and atmosphere during **the water cycle**.*
*The amount of water on Earth remains constant, but it continuously changes forms as energy from the Sun drives the cycle.*

**Movement of Water During the Water Cycle**
The water cycle describes the continuous movement of water on, above, and below the surface of the Earth. This movement of water in the cycle can have a great influence on weather patterns. There is much more water being stored at any given time than is moving through the cycle. Water may be stored for a short time as water vapor in the atmosphere, for days or weeks in a lake, or for thousands of years in a polar ice cap. However, most of the Earth's water is stored in the oceans.




The water cycle is a cycle with no beginning or end. It includes the following processes:

- **Condensation** is the changing of gas to a liquid (water vapor to water) and is crucial for the formation of clouds. Clouds form in the atmosphere when air containing water vapor rises and cools. Water vapor can be present in the air even when clouds are not visible. Clouds become visible when water particles combine with each other around tiny particles of dust to form water droplets.
- Water returns to the Earth as **precipitation**. Precipitation is the process by which water vapor in the air condenses to form drops heavy enough to fall to the Earth's surface.
- During **infiltration** water fills the porous spaces in the rock and soil that makes up the lithosphere. This is one of the main sources of groundwater.
- **Surface runoff** occurs when no more water can be absorbed into the ground and gravity pulls it downhill until it joins a body of surface water, such as a river, stream, or lake. Some of this surface water may seep downward and become groundwater. The rest of the water in a flowing water body, such as a river, eventually empties into the ocean.
- **Evaporation** takes place largely from the oceans. It often happens as a result of heat produced by the radiant energy from the Sun–liquid water is heated until it turns to a gas (water vapor) and is released into the atmosphere.
- **Transpiration** is similar to evaporation in that it is the process by which water is carried through plants, from roots to leaves, where it changes to water vapor and is released to the atmosphere.
- **Sublimation** is the changing of water from a solid directly to a gas with no intermediate liquid stage. The opposite of sublimation is **deposition**, when water vapor changes directly to a solid. Snowflakes and frost are examples of deposition.

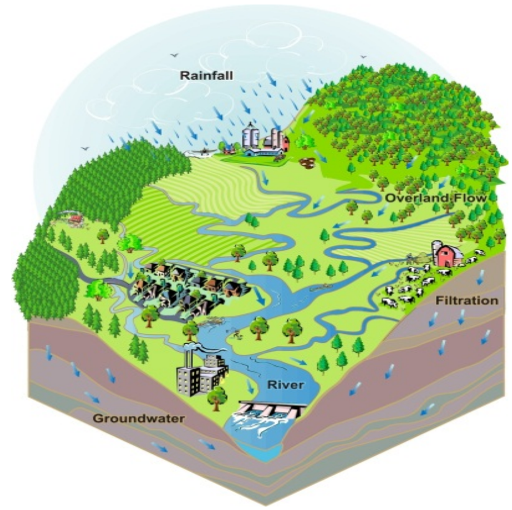
**Life and the Water Cycle**
Ecosystems and living organisms depend on the water cycle. Most living organisms, including humans, depend on the water cycle and actually take part in it. Land animals, for example, need to consume fresh water to remain hydrated. Without fresh water to drink, land animals quickly die. But the vast majority of water on Earth is saltwater and undrinkable. Fortunately, the water cycle supplies fresh water on land through the process of evaporation and precipitation. When water from the Earth's saltwater oceans evaporates, it leaves the salt behind. The freshwater travels by wind over land and falls as precipitation. This process makes it possible for animals to survive on land. Animals, including humans, make use of the water cycle in other ways as well. When a

person sweats (perspires) the water on his or her skin evaporates. This has the effect of keeping the person cool. Many other animals, including dogs, use panting to keep cool, which also involves the evaporation of water.

## Watershed Systems

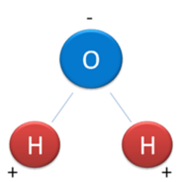
> *A **watershed** is a region of land where rain or snow (along with sediments and dissolved materials) drains downhill into a particular body of water, such as a river, lake, sea, ocean, or wetland.*

**Watershed Structure**
The area of land where water is drained downhill into a body of water is known as a drainage basin, or **watershed**. When precipitation falls onto land surfaces, it can either soak into the ground or become runoff, which is surface water that travels downhill and drains into streams and rivers. The components of a watershed include lakes, streams, rivers, wetlands, and groundwater. Water can flow among all of the components of a watershed, including between groundwater and surface features, such as lakes.




Watersheds are separated from adjacent watersheds by a water *divide*, which is the high ground between two watersheds. At the point of the divide, water that falls on one side of the divide will drain into one watershed, while water that falls on the other side will drain into another. A divide is often a geographical feature, such as a ridge, hill, or mountain. Often, the body of water into which a watershed drains is a *river basin*. Eventually, all rivers, and therefore all watersheds, drain into the ocean.

**Water as a Solvent**



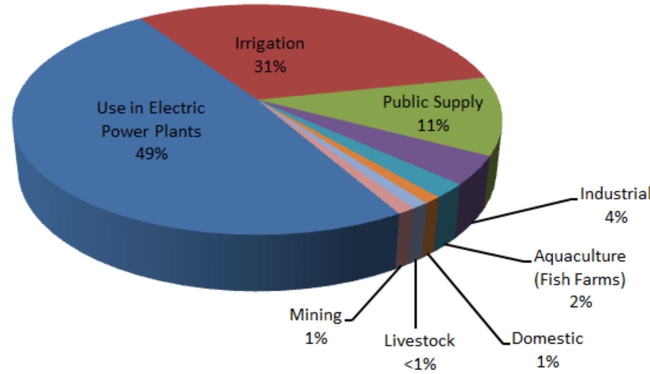

Water is an excellent solvent because of the shape of its molecules and the presence of small electrical charges on each of the molecules' atoms. Water is known as the **universal solvent** because it dissolves such a large number of substances. More substances are soluble in water than in any other liquid. The partial electrical charges on the different parts of a water molecule allow water to dissolve many different substances.
As water flows downhill in a watershed, either underground or on the surface, it dissolves and carries away some of the substances it passes over or through. Water passing over or through limestone rock may dissolve some of the calcium and magnesium that compose the rock. Water passing through cultivated land may dissolve and carry away soluble components of fertilizers, such as potassium and phosphorous compounds.

## Use & Importance of Water

> ***Earth is a unique planet because of the presence of water. Water is essential to support life on Earth. Plants, animals and humans all rely on water for survival.***

**Locations & Characteristics of Water**
Water exists on Earth in many different places and forms. Liquid water can be found underground in aquifers. Liquid, solid, and gaseous water can be found in the atmosphere, and liquid and solid water can be found on Earth's surface. Water found in oceans and seas is salt water. This water is rich in dissolved nutrients and salts. It is too concentrated in these materials for humans to use for drinking. Water found in streams, rivers, ponds, and most lakes is fresh water. Fresh water contains minerals but does not have high levels of dissolved salt. Once it has been purified, is suitable for human consumption. The most common sources of drinking water are aquifers and lakes. However, not all cities are located close enough to one of these for it to be a practical drinking water source. To solve this problem, some cities build *reservoirs*, or artificial lakes, often by damming a river as shown in the photo. Much of the drinking water for North Carolina's cities comes from reservoirs and groundwater. Drinking water for more rural communities comes from wells.

**Water Usage**
Humans need to drink water in order to survive. But in addition to consuming water for life processes, humans use water in many other ways. Power plants account for almost half of the water usage in the United States. Coal-burning and nuclear power plants require water to generate power. Both types of power plants capture rising steam to create electricity. The second largest use of water in the United States is agriculture. The use of water for crops, or *irrigation*, requires trillions of gallons of water each year.The amount of fresh water that communities have available determines how they use their water. For example, a city near a river may choose to build a dam and use the river to generate electricity with a hydroelectric power plant. They can also choose to allow industries to build factories on the river and use water from the river for cooling or waste disposal. Communities that have lakes and rivers nearby may use them for recreation, allowing citizens to swim, ski, boat, and fish in the water. Where water supplies are plentiful, lawns and landscapes may be watered regularly. However, in places where water supplies are finite, people must landscape with native, drought-tolerant plants that do not need to be watered with an



irrigation system.**Water Usage in the United States (2005)**

# The Ocean

*The ocean is the dominant physical feature of our planet.*

There is one ocean with many ocean basins, such as the North Pacific, South Pacific, North Atlantic, South Atlantic, Indian, and Arctic. The ocean covers about 70% of the Earth or about 225 million square kilometers.The ocean can be divided up into three main regions: the *shore*, the *open ocean*, which is the surface layer at the top of the ocean, and the *deep ocean*, which is the area located toward the ocean's floor in deeper waters.A fourth distinctly different, but related, region is the *estuary*. An estuary is an area where fresh water and salty ocean waters mix together. These areas may include bays, mouths of rivers, salt marshes, and lagoons.

**Shore**
The shore, or the *intertidal zone*, is the area of the ocean where the water meets the land. This area is exposed to the air during low tide and is covered in water during high tide. This part of the ocean receives high exposure to sunlight. This area includes only the part of the ocean floor that lies between tide markers and is alternately submerged and exposed based on the ebb and flow of the tide.

**Open Ocean**
The open ocean, or *pelagic zone*, is any water in the ocean that is not close to the bottom. This zone includes all of the water in the ocean from the surface almost to the bottom. The pelagic zone can be further divided into layers based on depth.

**Deep Ocean**
The deep ocean, or *abyssal zone*, ranges from 2,000-6,000 meters in depth. Sunlight cannot penetrate this deep in the ocean, so it is constantly in darkness. Many organisms that live in this layer are blind or have their own sources of light. The organisms that live in this layer must also be able to withstand the extremely high pressure and low temperature of these ocean depths. Since little sunlight can penetrate to the depths of the oceans, photosynthetic organisms cannot survive there. Many organisms in this layer of the ocean survive on whatever falls from above. However, other organisms, living near hydrothermal vents, submarine hot springs, and methane cold seeps survive by performing *chemosynthesis*. Chemosynthesis is the process by which organisms, such as bacteria without access to sunlight, use chemical energy to produce food.

**Estuary**
An estuary is an area in which fresh water and salty ocean water mix together at salt marshes, mouths of rivers, bays or lagoons. These brackish (salt mixed with fresh) water ecosystems are affected by tides. Each high tide brings a new supply of nutrients and small organisms. Marsh grasses take up these nutrients and thrive in the environment. The dense clumps of plants and their roots create shelter for marine life, birds, and other wildlife. Often, sea animals go to estuaries to breed and produce their young. The young sea animals live within the relative safety of the estuaries during the first parts of their lives, until they are strong enough to survive in the open ocean. Estuaries perform functions that help to promote the health of the environment and human populations. They help protect the environment by filtering sediment and pollutants from river and ocean water. They also produce more plant and animal life than many other types of ecosystems on Earth. Many of the animal species that are fished as human food sources spend at least part of their lives in estuaries.

# The Ocean as a Reservoir

*Earth's ocean is a reservoir of life forms, minerals, nutrients, and dissolved gases.*

**Biological Diversity**
Earth's ocean is a major reservoir of life forms. About 80% of all of the life forms on Earth live in the ocean or on its floor. Coral reefs, found in shallow ocean waters, are some of the most biologically rich ecosystems in the world, containing thousands of different species of fish, coral, and sponges.

**Minerals**
The ocean is a major reservoir of salts and minerals. It contains a large amount of sodium chloride (3.5%), resulting in the salty nature of ocean water, which is called *salinity*. Other minerals found in the ocean include potassium, magnesium, sulfur, and calcium.Most elements found in the ocean were carried there in water after the weathering of rocks. This process, along with emissions from underwater volcanoes and hydrothermal vents, help keep the ocean's salinity levels relatively constant. However, humans extract salt from ocean water for use in cooking and manufacturing. Sea salt, as shown in the photo, is obtained from sea water by evaporating the water from holding tanks. Ocean water also contains nutrients such as phosphates and nitrates that are critical to plant growth. In a process called *upwelling,* warm surface water is blown out to sea by prevailing winds and cold, nutrient-rich water from the deep ocean rises to the surface to take its place. Many of the organisms living in areas where upwelling takes place feed off of the nutrients brought to the surface by the upwelling. The presence of these organisms provides scientists with strong proof that deep ocean water is rich in minerals and other nutrients. These nutrients are not only important to the plants and animals found within the ocean, but also to the estuaries near the ocean. Upwelling, ocean currents, tides and surface winds all play a role in distributing gases and nutrients to estuaries and different parts of the ocean.

**Microorganisms**

Just 100 mL of ocean water contains millions of bacteria and hundreds of thousands of phytoplankton, such as algae. Phytoplankton and many kinds of marine bacteria are photosynthetic producers. These two kinds of producers are at the base of almost every aquatic food web in the world.

**Dissolved Gases**

The ocean is a major reservoir of gases. The ocean absorbs gases from the atmosphere or gives off gases to the atmosphere to help the concentration of gases to stay in equilibrium. The gases dissolved in the ocean include nitrogen (N), carbon dioxide ($CO_2$), argon (Ar), and oxygen ($O_2$). The amount of gases dissolved in ocean water depends on the gas's solubility as well as the water's depth and temperature. The solubility of gases can be determined by looking at the amount and ratio of gases present in the air as compared to the amount and ratio of the same gases dissolved in the surface layer of the ocean. Oxygen and argon appear in approximately the same proportions in ocean surface water as in the air; this indicates high solubility. Contrastingly, there is about half as much nitrogen found in ocean surface water as in the air; this indicates lower solubility of nitrogen than of oxygen and of argon. The amount of dissolved gases in the ocean also changes with distance under the ocean's surface. Plants and other photosynthetic organisms live primarily near the surface of the ocean because that layer of the ocean receives more sunlight than those deeper in the ocean. As plants grow, they take in carbon dioxide and give off oxygen. Therefore, there is more oxygen near the surface of the water, because the plants living there have more sunlight to use for growth. Some of the oxygen stays in the water, and the rest enters the atmosphere. The photosynthetic organisms in the ocean produce 70% to 80% of the world's oxygen. Another property of gases is that they dissolve more easily in cold water than in warm water. Therefore, water in colder regions of the world contains larger amounts of dissolved gases. When the water warms, the ocean releases gases into the atmosphere.

## Humans & the Oceans

*Earth's ocean is rich in resources, such as minerals, nutrients, and dissolved gases. Many aspects of modern human life depend on resources obtained from the ocean.*

**The Ocean as a Resource**

Earth's ocean is a valuable source of resources. The following list includes some of the ways the ocean influences human lives.

- **Transportation**: For most of human history, the oceans have been the main routes used for exploration, trade and shipping, and even warfare.
- **Air**: Half the oxygen in the entire world is produced in the ocean.
- **Minerals**: Materials that can be extracted from ocean water or mined from the bottom of the ocean include salt, potassium, magnesium, gold, tin, titanium, and diamonds. Salt from the ocean or from old ocean deposits is used in many industries, including textiles and dying, metal processing, rubber manufacturing, oil and gas drilling, paper making, animal hide processing, leather tanning, and soap making.
- **Weather and Climate**: The ocean controls weather patterns across the entire world. It is the site of much of the evaporation that begins the water cycle and provides fresh water for people and animals living on land.
- **Medicines**: The ocean, and coral reefs in particular, are sources of minerals and chemical compounds that may have utility as the active ingredients in medicines.
- **Food**: The ocean is the primary source of food for people in some nations. Some organisms that can be used for food include seaweed, algae, fish, shrimp, and crabs.

**Threats to Oceans**

The ocean provides natural resources that benefit humans, plants, and animals. The most obvious natural resources from the oceans are the fish and other marine life that provide food for humans and animals. There are several other marine resources that are less obvious, such as sand and gravel for building; salt for seasoning; and tidal motion, oil, and gas for energy production. Many of the ocean's resources, such as electrical energy produced from tidal motion, are renewable. However, even renewable resources such as fish can be over-harvested, or their environments can be polluted, resulting in reduced numbers. Some fish species are now very difficult to find because their numbers are so low. Populations of some types of marine animals—such as turtles, dolphins, and sharks—are also shrinking because the animals get caught in drift nets that are used for fishing. The photo shows a drift net that has accidentally caught a sea turtle. Coral reefs are also being endangered by human activity. Runoff carrying soil eroded as a result of farming and construction enters the ocean and deposits the soil onto coral reefs. This blocks sunlight that the algae living in the coral needs to survive. The ocean plays a vital role in recycling energy and matter; many earth materials and geochemical cycles originate in the ocean. In addition, ocean waters can, to some extent, absorb air and water pollutants produced by human activities. However, the capacity of the ocean to absorb these materials without being affected is limited. When this limit is reached, environmental consequences become apparent. In response to the changes that have been observed and are believed to result from human activities, efforts have been made in the United States to help protect marine animals and create National Marine Sanctuaries with laws protecting natural areas and resources.

## Technology for Exploring the Ocean

**Sonar**

Sonar is a measuring instrument that sends out an acoustic pulse (sound) in water and measures distances in terms of the time for the echo of the pulse to return. Sonar is an acronym that stands for "sound navigation ranging." Sonar is very good for providing underwater explorers with information about the shape or makeup of underwater structures or objects. This information is usually displayed on a computer screen, where it can be interpreted. But sometimes an actual visual image is needed. This can be provided with a submarine or submersible

**Submarines**

Submarines are watercraft capable of navigating to specific depths beneath the surface of the water. They are used in deep oceanic explorations to not only see the ocean floor but also to see the creatures that live at these great depths. Some of these submarines are capable of holding people, but some are entirely robotic. Many of them have robotic arms that can be used for obtaining samples of sea life from the ocean depths.

**LIDAR**

LIDAR is a technology that is currently being used to map the bottom of the ocean. LIDAR data is collected by satellite or aircraft by sending a laser beam to the Earth and measuring the depth of the ocean. Computer programs can use this data to map the features of the ocean floor.

# Water Quality

*Water monitoring is a necessary step in ensuring good water quality for all living things in a watershed. Monitoring the water allows scientists and public health officials to make necessary changes to improve water quality.*

**Types of Water Pollution**

**Point source pollution** is that which can be traced back to its origin. It occurs when harmful substances are added directly to a body of water. An example of point source pollution is when pipes delivering wastewater from factories or sewage treatment facilities discharge directly into a lake, stream, or the ocean. Sewage from septic tanks and broken or inadequate sewage systems is a common source of groundwater pollution.

This pipe delivering waste water directly into the river is an example of point source pollution.

**Non-point source pollution** can be far more difficult to treat because it cannot be traced back to one source. It is most often the accumulation of runoff containing various substances from different locations. When rain water carries substances such as lawn chemicals, fertilizers, motor oil, or animal waste into storm sewers or rivers, this is non-point source pollution.The heavy growth of algae in this pond could be the result of non-point source pollution, such as runoff containing fertilizer or animal wastes.Stormwater runoff is a serious problem in many urban and suburban areas. The problem is complicated by artificial surfaces, such as buildings, parking lots, and paved roads. These impervious areas not only decrease the groundwater quality by prohibiting natural filtration through the soil, they also increase the risk of flooding and contamination of surface water by allowing leaves and other organic debris to accumulate. Dirt, oil, and debris that collect in parking lots and paved areas can be washed into the storm sewer system and eventually enter local water bodies.

**Water Quality Characteristics**

Water quality can be affected by biotic and abiotic factors. Water can be tested and characterized with regard to these factors. Testing often includes evaluation of dissolved oxygen, conductivity, clarity, pH, temperature, nutrients, and life forms.

- **Dissolved oxygen** indicates how much oxygen is available for animals and plants living in the water to use for respiration. A low dissolved oxygen level is a sign of poor water quality, because it can result in reduced animal or plant population size.
- **Conductivity** is a measure of the amount of nutrients in the water in the form of dissolved solids. This measurement can show high or low levels of salts or minerals in a water body.
- **Clarity** is a measure that indicates how much light is able to penetrate the water. Light penetration is a requirement for photosynthesis of bottom-dwelling plants. This water quality characteristic is also called *turbidity*. Water is turbid if it contains high levels of suspended solids, such as fine particles of silt or large amounts of algae or bacteria. Increased turbidity can increase water temperature at the surface and decrease temperature in deeper waters.
- **pH** is a measure of how acidic or basic the water is. Healthy, natural water systems usually have a pH of between 6.5 and 8.5. Low (acidic) pHs can be damaging to water-dwelling animals and plants. Certain pollutants and acid rain can cause the pH of a body of water to be lowered.
- Water **temperature** can greatly affect aquatic life. Temperature affects the rate of photosynthesis and the metabolic rates of aquatic organisms. Temperature can further affect aquatic organisms by influencing the amount of dissolved solids and gases the water can hold. Gases are less soluble in warm water and more soluble in cooler water. In contrast, salts and minerals tend to be more soluble in warm water and less soluble in cooler water.
- **Nitrates and phosphates** are nutrients that come from both natural and human sources (e.g. fertilizer runoff, septic systems, improperly treated wastewater). Their presence determines the productivity of a water body. Although needed in small amounts in a healthy aquatic environment, too much of either of these nutrients will result in *eutrophication*.
  During **eutrophication**, excess nutrients in the water cause rapid growth in algae populations. In large quantities, the algae may produce substances that can be toxic to people and animals. In addition, after the large algae population depletes the excess nitrates and phosphates, it quickly dies off. As bacteria in the water work to decompose the dead algae, they use up a large fraction of the oxygen dissolved in the water. As a result, the aquatic plants and animals may not have access to enough oxygen to perform respiration, and they may die.
- The presence of some types of **bacteria** can indicate pollution is entering the body of water. For example, coliform bacteria can mean that untreated human or animal wastes are entering the water. Farms located near streams, lakes, or rivers can be sources of this type of pollution. Since it is impossible to see bacteria and some other types of pollution with the naked eye, water in streams or other bodies of water should not be assumed to be safe for consumption.
- **Macroinvertebrates**, including aquatic insects, crustaceans, and other visible invertebrates can be strong indicators of the presence or absence of certain types of water quality issues. Every species has a certain range of physical and chemical

conditions in which it can survive. Some organisms can survive in a wide range of conditions and are more tolerant of pollution. When pollution enters a system, some types of these organisms disappear, while other types become more abundant. Thus, these living "indicators" are referred to as *indicator organisms*.

Water quality can be determined by comparing the number of pollution-tolerant organisms with the number of pollution-intolerant species. However, the mere presence of pollution-tolerant organisms does not imply that the system is unsafe. These organisms can be found in both polluted and unpolluted waters.

**Measuring Water Quality**
Water quality can be measured using a variety of methods and with many different tools. Research scientists and professionals commonly use a digital water quality instrument that records different characteristics such as dissolved oxygen, conductivity or salinity, turbidity or clarity, pH, and temperature when placed in the water.

**Wetlands and Water Quality**
Wetlands are capable of improving water quality and are very important ecosystems in a watershed. Wetlands hold water during floods and slowly release it after flood events. These valued ecosystems restore the groundwater while holding water. Wetlands contain plants that are specialized to grow in water. These plants add oxygen to the water, reduce water temperature through shade, and remove pollutants or extra nutrients from the water.

**Water Quality Regulation**
Water is valuable to human populations because humans use water for drinking, household use, industry, manufacturing, and recreation. However, water loses its value economically and aesthetically when it becomes polluted. Pollution in water supplies can threaten our health and even our food supply.There are ways to monitor and improve the health and purity of our water. For example, most cities in the U.S. now treat their sewage at a wastewater treatment plant, whereas in the past, raw sewage was sent directly into a nearby body of water. Regulatory agencies have helped to promote healthy water by setting minimum water quality standards. Water quality standards help to prevent water pollution and to identify water quality problems and correct them.These standards dictate, according to the United States' Clean Water Act, maximum allowable toxicity levels of waste discharge. There are three types of criteria: biological criteria describe the desired aquatic community, based on the populations of organisms expected to be present in a healthy body of water; nutrient criteria protect against over-enrichment of water due to excess nutrients; sediment criteria outline conditions that will avoid detrimental amounts and types of sediments.There are many reasons to strive for improving water quality; however, there are also economic hurdles to addressing water pollution issues. The Clean Water Act tries to protect our clean water, but some individuals and groups find it cost prohibitive to treat wastewater to meet current standards. Sometimes groups or companies can be excused from adhering to water quality standard requirements if they can demonstrate that the cost of the required water treatment will result in significant negative social and economic impact. Individuals, especially those obtaining water for drinking and household use from wells, can take responsibility for maintaining safe water quality. It is recommended to have drinking water tested regularly at a certified lab. Water quality can be affected by either primary contaminants (chemicals/organisms that may cause disease or long-term health problems) or secondary contaminants (contaminants causing bad odors or tastes or other problems that do not pose a health risk).

Source:

All information contained within this booklet was obtained from StudyIsland.com.  Please use responsibly.