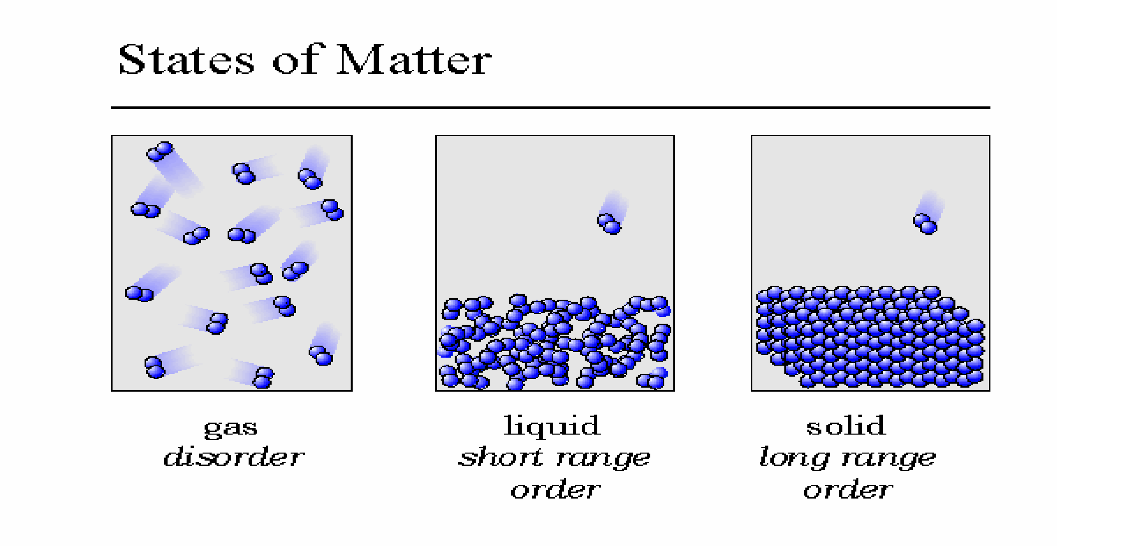
D1. *Describe the effects of adding energy in terms of the motion of atoms and molecules, and the resulting phase changes.*

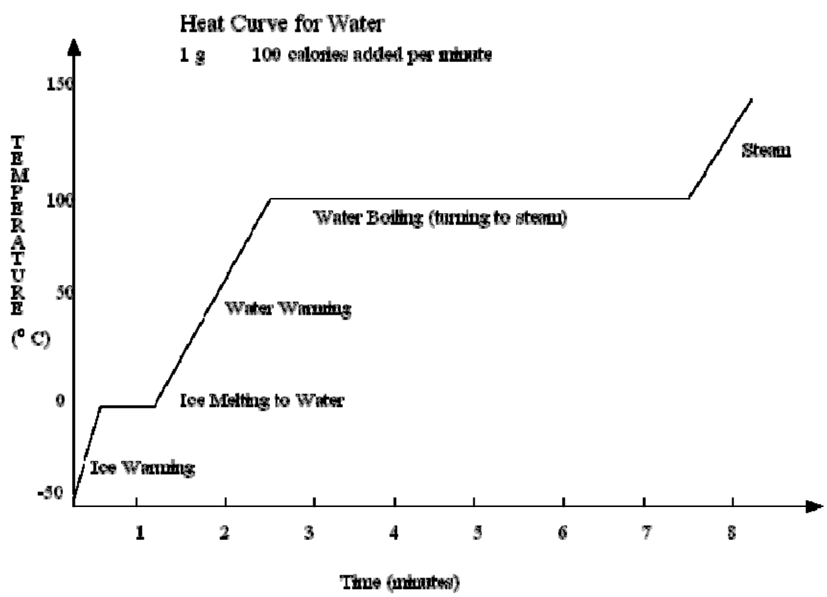
All **matter** (anything having both mass and volume) can exist in three main phases or states: solid, liquid and gas.

Phase or state of matter	Physical Definition
Solid	Keeps is own shape, does not fill container
Liquid	Takes shape of container, does not fill it completely
Gas	Takes shape of container, fills it completely

All matter is made up of atoms and molecules. All atoms and molecules attract each other and the greater the attraction the denser (closer) they become. All atoms and molecules are in constant motion and the greater the temperature, the more freely and faster they are moving. In a solid, the particles are packed tightly together and their attraction for each other is great enough to keep them rigidly in place. The only motion they can have is vibration. In a liquid, the particles have more energy. This energy is enough to overcome some of the attractions among the particles and they can move around each other and flow. This lack of rigidity allows a liquid to take the shape of a container. Lastly in a gas, the particles have enough energy to break all of the attractions among them and separate completely from each other. This total separation allows a gas to spread out and fill any shape or size container.



Imagine a block of ice at -20^{o}C that is slowly being heated at a constant rate. (The amount of heat absorbed during a given time is the same.) The temperature of the block of ice will gradually increase. This is because the more energy the particles have the more they can vibrate. **Temperature** is the measure of how much the particles are vibrating. So, the more heat is added, the more the particles will vibrate, and the more they vibrate, the more the temperature goes up. This continues until the amount of vibration is great enough to break some of the attraction among the particles and ice will begin to melt. **Melting** is the change from a solid to a liquid, and the temperature at which this occurs is the **melting point**. Even though more heat is added during the melting process, the temperature will remain constant and does not change. All of the added heat is goes to overcome the attractions among the particles. When the block of ice has completely changed into liquid water, the added heat again goes to increasing the amount of vibrations and the temperature begins to rise again. The temperature continues to rise at a constant rate until the amount of vibrations is so great that the remaining attractions among the particles can be totally overcome and the particles separate completely. The liquid water turns into gaseous water (water vapor or steam). The process of going from a liquid to a gas is called **vaporization**. The temperature at which vaporization occurs is the **boiling point**. For the same reasons mentioned above, the temperature remains constant until the liquid has been totally converted to gas. When a substance is changing phases the temperature is constant, and when the temperature is changing, the phase of the substance does not change. The reverse can also occur. The process of changing a gas into a liquid is called **condensation** and the temperature at which this occurs is the **condensation point**. Note that the condensation point is always the same as the boiling point. Likewise, **freezing** is the process of turning a liquid into a solid and the **freezing point** (the temperature at which this happens) is always the same as the melting point.

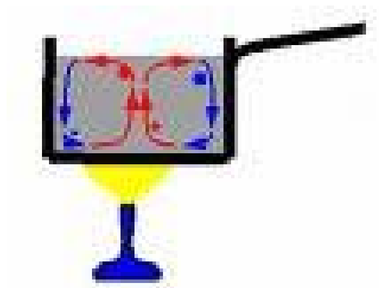


There is another type of phase change that can occur under special circumstances. **Sublimation** is the process of changing a solid directly into a gas. This occurs in a home freezer to keep it frost free.

D2. ***Explain how energy is transferred by conduction, convection and radiation.***

Energy can be transferred between objects in three ways. **Conduction** is the transfer of energy, usually thermal (heat) energy, from a warmer object to a cooler one by direct contact. The particles in the warmer substance are moving faster than those in the cooler substance and when they collide, energy is lost from the faster moving particle, slowing it down, and gained by the slower moving particle, speeding it up. This continues until all the particles are at the same temperature. Examples include touching a hot pot or putting ice cubes in a drink. Here, heat is passed from the warmer liquid to the ice. The ice absorbs the heat energy and melts while the liquid loses the heat energy and cools down.

Convection occurs when a fluid (a liquid or a gas) is unevenly heated or cooled and energy is transferred through a resulting current. The air touching a stove burner will get hot by conduction. As it gets hot, the particles move faster and spread apart. As they spread apart the warmer air becomes less dense. The cooler air above it is more dense and sinks, pushing the less dense warm air up. As the warm air is pushed up, it loses energy to the cooler air by conduction. The particles slow down and the attractions cause the particles to come closer together until it becomes denser than the air under it and sinks. The same process occurs in heating a pot of water eventually transferring heat energy throughout the water.



Radiation is the transfer of energy through electromagnetic waves. These include light, radio and TV waves, x rays, ultraviolet light and microwaves. The transfer occurs when an object absorbs radiation. The radiation energy is absorbed by an electron in a low energy electron shell. The additional energy pushes the electron into a higher energy shell. This is unstable and the electron drops back to its original position giving off the energy it originally absorbed. This emitted (given off) energy can be in the form of light, heat or another form of radiation. In a black light (ultraviolet radiation which cannot be seen by the human eye) energy is absorbed and given off as visible light. Radiation from the Sun is absorbed by the Earth. It is reemitted as heat and is the major source of warmth and energy for the planet.

D3. *Describe energy transformations among heat, light, electricity and motion.*

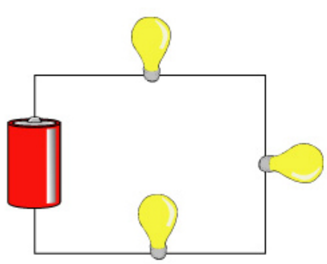
Energy comes in many forms. There is **kinetic energy**, the energy related to motion and movement and there is **potential energy**, the energy related to the position and/or shape of an object. A rock on the top of a cliff has potential energy which is transformed to kinetic energy when it is pushed off. A spring has potential energy when it is compressed which can be transformed into kinetic energy when it is released. There are other types also such as: **radiation** or **radiant energy** including light and solar, thermal or heat energy which depends on how hot an object is, sound energy, nuclear energy, **electrical energy** which is caused by moving electrical charges, and chemical energy which is stored in the chemical bonds in an object.

Think of the following scenario. A boy kicks a soccer ball, which accidentally breaks a window. All of the following energy transformations are necessary for this to occur. Radiation from the Sun (solar energy) is necessary to grow the food the boy had for lunch and is now stored as chemical energy. If heat was used in either the processing or the preparation of the food, then it too is stored in the chemical bonds. The boy eats the food and the chemical energy is transformed into heat and kinetic energy which allows him to kick the ball. The kinetic energy of his foot is transferred to the ball which is transferred to the kinetic energy of the breaking glass. Lastly, potential energy of the glass window from its position above the floor is transformed into kinetic energy as the pieces of glass fall to the floor. In this process no energy has been lost or created. It has only changed its form. Electrical energy can also be transformed in other types of energy. (See D5 and D7.)

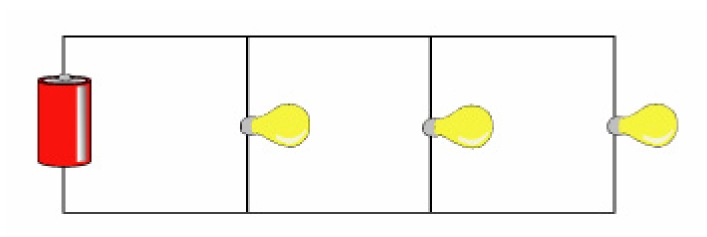
D4. *Explain the relationship among voltage, current and resistance in a simple series circuit.*

Electricity or electrical energy is a form of energy caused by moving electrical charges. **Electrical charge** is a property, like size and mass, of particles that make up all atoms. The electrical charges can be negative (electrons) or positive (protons). Opposite charges attract each other (positive and negative) while like charges repel (positive from positive or negative from negative). **Static electricity** is the build up of either positive or negative charges on an object. It is *static* because these charges stay on the object and do not move. Static electricity is often caused by friction. For example, if you scuff your feet on a carpet on a very dry day and then reach for a doorknob, you will probably get a small shock. The friction between your shoes and the carpet transfers electrons to your shoes making your body slightly negative in charge. When reaching for the metal doorknob, these extra electrons are attracted to positive charges in the metal atoms which cause the spark. Lightning is another example of static electricity between the clouds and the Earth.

Common electricity is the flow of electrons (negative charges) from one thing or place to another. To make a simple circuit (path) for the electrons to travel, there must be an electrical source. This could be a battery, a generator or an electrical outlet. Electrons do not flow through air so metal wires are used to conduct the electrons to a light bulb, TV or other machine. Another wire goes from the light bulb or the appliance back to the source creating a single loop. A switch is often inserted into this loop. When the switch is closed the loop in intact (closed circuit) and the light bulb or appliance operates. When the switch is open, there is a break in the circuit (open circuit), the electrons cannot complete the loop and the appliance is off. A **series circuit** has only a single loop. More than one light bulb can be included in a series circuit. However, when any of the light bulbs burn out, the electrons cannot pass through that light bulb, the circuit is broken and all of the other light bulbs go out. It is possible to arrange a number of light bulbs in a different manner with multiple loops. A circuit with more than one loop is called a **parallel circuit**. With a parallel circuit when a light bulb burns out, the other light bulbs remain lit.



Series Circuit



Parallel Circuit

Electricity is the continuous flow of electrical charge (electrons). The rate of flow, the amount of electrical charge that passes through any part of the circuit in a second, is called the **current**. The standard unit for current is the **ampere** or **amp (A)** and the symbol for current is the letter I. The **resistance (R)** measures how hard it is for the electron to travel through the circuit. Substances that have a low resistance and allow electrons to flow through them easily are called **conductors** (most metals). Substances that have a high resistance causing the flow of electrons to be difficult are called **insulators** (such as wood, glass and plastics). The standard unit for resistance is the **ohm (Ω)**. The **voltage (V)** is how hard the electrons are being pushed through the circuit or the 'electric pressure.' The current, the resistance and the voltage are related through **Ohm's Law**:

$$\textbf{Current} = \frac{\textbf{Voltage}}{\textbf{Resistance}} \quad \text{or} \quad \mathbf{I} = \frac{\mathbf{V}}{\mathbf{R}} \quad \text{thus,} \quad \mathbf{V = IR}$$

The amount of current gets larger as the voltage or push on the electrons increases. Likewise, as the resistance goes up making it harder for the electrons to pass through the circuit, the current goes down. Also, if the resistance is kept constant and the current flow is increased, then the 'push' on the electrons becomes greater and the voltage goes up.

D5. *Explain how electricity is used to produce heat and light in incandescent bulbs and heating elements.*

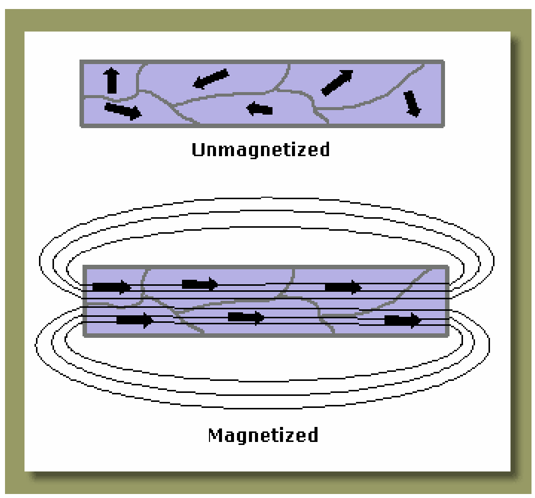
In an incandescent light bulb electricity goes through a very tightly coiled wire called the filament, which is usually made of tungsten. Energy from the electrons in the electrical current is absorbed by the electrons in the tungsten atoms. This added energy raises the electrons in the tungsten atoms to a higher level. The electrons cannot remain at this higher level and they fall back to their original positions giving off energy. The energy emitted (given off) is in the form of radiation which can be either visible or infrared (heat). This is why light bulbs also get very hot.

In a heating element or coil the same process occurs. Most of the radiation given off is infrared radiation but some is visible giving the coil a reddish or orange glow. Here however, the filament is a wire with a high resistance. Energy is also transformed into heat as the electrons are physically forced through the atoms of the filament.

D6. ***Describe the relationship between current and magnetism.***

Any moving charge (current) creates a magnetic field at a ninety degree angle to the direction of the flow. This magnetism is called **electromagnetism**. The strength of the magnetism gets larger as the amount of current increases. The magnetism can also be increased by coiling the wire around an iron bar or nail. The more coils, the stronger the magnetism. The opposite is also true. If a wire is moved through a magnetic field or if a magnet is spun inside a coil of wire, a current will be created in the wire.

A permanent magnet can be made from certain metals, iron being the most common. The electrons spinning around an iron atom create a very small magnetic field with a north and a south pole. These atomic sized magnetic fields are pointed in all directions so there is no overall magnetic field to the piece of iron. In some instances the atoms in a microscopically small area are aligned and this is called a **magnetic domain**. But since these domains can point in any direction there is still no overall magnetism. However, when placed in a strong magnetic field, these domains can be made to align and the result is a permanent magnet.



D7. *Explain how heat is used to generate electricity.*

As noted above in D6, a magnet spinning inside a coil of wire produces an electric current (electricity) in the wire. A machine that will do this is called a **generator**. The only major difference among types of generators is the source of energy used to turn the magnet. Wind can be used to turn the blades on a windmill or rushing water can be used to turn a paddlewheel. Even the changing levels of the ocean caused by tides or waves have been used. But in most areas of the world, these resources are not available and another source must be used. That source is heat. Heat can be used to boil water to form steam, which can be used to spin the magnet. The heat can be produced by burning coal, oil, natural gas or biomass (wood, corn stalks, garbage, etc.). Nuclear energy can also be used. **Radioactivity**, the spontaneous decomposition of an atom, can produce great amounts of heat.

D8. ***Describe the availability, current uses and environmental issues related to the use of fossil and nuclear fuels to produce electricity.***

Fossil fuels are organic substances that are burned to run motors, generate electricity or produce heat. They were formed over millions of years from decaying and compressed plant and animal matter. Fossil fuels include: oil, coal and natural gas. Fossil fuels can be found in many regions on Earth. Oil can be found in the Middle East, Russia, Eastern Europe, parts of Africa, Texas, Alaska and under the oceans in places like the North Sea and the Gulf Coast. Coal is common in Russia, China and the US. Natural gas is a side product of oil formation and is found in the same areas. As is also the case for nuclear fuels (see below), fossil fuels are generally not found in areas where they are mostly used and must be imported. This is expensive and extremely inefficient, as fuel-wise, the transportation, preparation for consumer use and distribution uses more energy then they provide to the population. The burning of fossil fuels also produces a number of pollutants. The most common pollutant is carbon dioxide (CO_2) which increases the greenhouse effect and is a major cause of global warming. Other pollutants produced in the burning of these fuels include SO_x (sulfur oxides such as SO_2 and SO_3) and NO_x (nitrogen oxides such as N_2O, NO_2 and NO_3) all of which increase acid rain and are the major components of smog and air pollution. Oil spills pollute both land and water. Strip mining to dig for coal produces an acidic run-off which contaminates rivers and ground water, and the strip mines themselves need to be restored to match the environment.

Nuclear fuels produce energy from the spontaneous decomposition of the nucleus of certain kinds of atoms. These are found in specific types of rock or ore and must be mined. But only a very, very small amount of the mined material is suitable for use as fuel. Some of the areas where these rocks occur are in Australia, Canada, Russia, parts of northern Africa and the western US. To get a nuclear fuel that can be used in a power plant the material must be purified and concentrated. This is a very difficult and expensive procedure. A ton (2000 pounds) of mined material will produce less than a pound of useable fuel. Pollution is a serious problem. Hundreds of tons of highly radioactive water and spent fuel rods need to be safely stored for tens of thousands of years or longer. A serious accident could kill thousands and contaminate hundreds of square miles for a millennium or longer. The steam that drives the generator needs to be cooled and recycled and this releases thermal pollution into the environment. Finally, the strip mines where the original material was found need to be restored.

D9. *Describe the availability, current uses and environmental issues related to the use of hydrogen fuel cells, wind or solar energy to produce energy.*

In a system that is similar to a battery, **hydrogen fuel cells** react hydrogen gas with the oxygen gas in air to produce water and electricity. The electricity can then be used to power automobiles, engines or anything that requires electricity. These fuel cells are non-polluting since water vapor is the only product. They are also considered renewable energy sources because the supply of hydrogen gas is basically infinite since it can be produced from water. Water can be broken down into hydrogen and oxygen gases using electricity. However, it takes more energy to produce the hydrogen gas than can be made in the fuel cell. Hydrogen fuel cells are not readily available and stations to purchase hydrogen are still extremely scarce.

Wind is a totally renewable source of energy. Wind (kinetic energy) can turn the blades of a windmill (mechanical energy), which can spin the magnets of a generator to produce electricity (electrical energy). There are no chemical pollutants produced. The windmills do need a relatively steady wind and have been criticized for noise and scenic pollution. The windmills also interfere with local bird life and migration routes.

Solar energy can be captured by different kinds of solar cells or panels to produce either heat or electricity. It is a totally renewable energy source which is available everywhere on Earth and is non-polluting. Solar cells produce electrical energy to power a calculator or run a car. Solar panels use solar energy to heat homes or water. Large solar panels can be used to produce steam to drive generators to produce electricity. The only major drawback to solar power is that it is not effective at night or in cloudy weather.

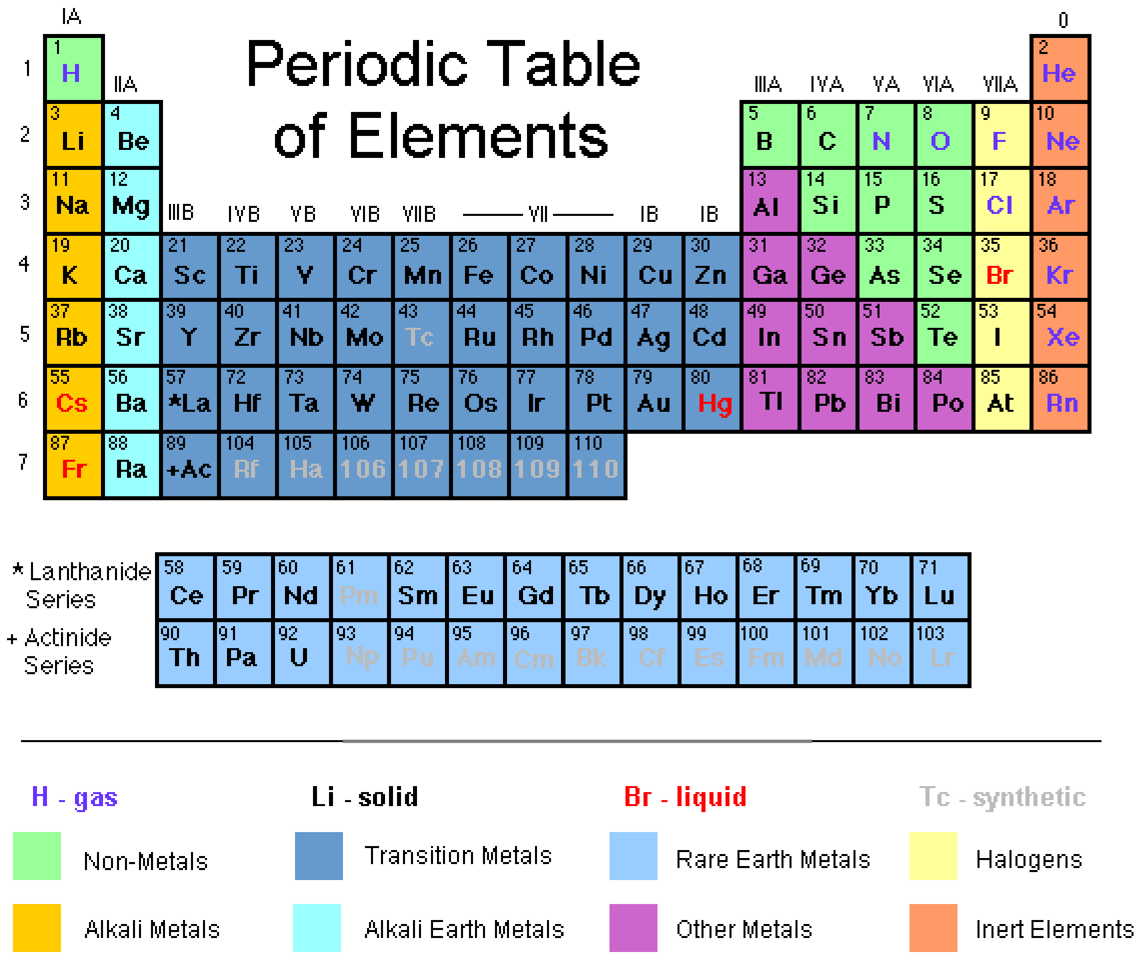
D10. ***Describe the general structure of the atom, and explain how the properties of the first twenty elements in the Periodic Table are related to their atomic structure.***

All matter is composed of atoms. The atoms themselves are made of even smaller particles including protons, neutrons and electrons. **Protons**, with a positive charge, and **neutrons**, with a neutral charge, are clumped together in the nucleus, located in the center of the atom. The **electrons**, with a negative charge, are located at specific distances from the nucleus called **energy levels**. The areas where the electrons are mostly found are called **electron clouds**.

An **element** is a pure substance that contains only one type of atom. The number of protons in an atom determines which element it is. For example, all atoms having six protons are carbon. In an element, some of the atoms may have a different number of neutrons and these are called **isotopes**. Isotopes have the same physical and chemical properties but can differ in such things as radioactivity. The electrons on the outside of the atom control the chemical and physical properties of the atom. These properties are determined by both the number and the location of the electrons. In an atom the number of protons (positive charge) always equals the number of electrons (negative charge) making the total charge of that atom zero.

In a simplified diagram of an atom, the nucleus, containing all the protons and neutrons, is in the center. The electrons travel in various energy levels or **shells** at specific distances from the nucleus. The further away from the nucleus the more energy an electron in that level will contain. The first energy level can only contain two electrons and is then said to be filled. The second energy level can hold up to eight more. The third can also hold eight electrons while the fourth can have as many as eighteen. All of the elements can be arranged in order of the increasing number of protons (the **atomic number**) in a chart called the **Periodic Table**. The letter(s) in the box stand for the name of each element and the number is the atomic number. Since an atom is electronically neutral (the positive and negative charges are equal) the number of electrons equals the number of protons.

The chemical and physical properties of every element are determined by the number of **valence electrons** which are those electrons in the outermost energy level. The number of valence electrons can be determined using the Periodic Table. The numbers down the left side of the table are the number of each energy level. There are only two elements at the first energy level, hydrogen and helium. That is because the first energy level can only hold two electrons. In lithium, with three electrons, the first two go into the first energy level which is then full and the third electron has to go into the second energy level which can accommodate eight electrons. Notice there are eight elements in the second row beginning with lithium and ending with neon. The number of valence electrons for elements 1-20 can be found by simply counting across the row until the desired element is reached. For example, find carbon on the table and count across row two. It is the fourth element in that row, so carbon has four valence electrons. It can also be found by looking at the Roman numeral at the top of the column (I – VIII). The number of valance electrons for elements with more than twenty



electrons gets much more complicated. (Note: some newer Periodic Tables use a different numbering system which does not use Roman numerals but the numbers 1-18. The number of valance electrons can still be found by counting across the row.)

The position on the Periodic Table tells a lot about the elements physical and chemical properties. Elements in the same column or family (for example H, Li, Na and K or F, Cl, Br and I) have the same number of valence electrons as the other elements in that column and therefore similar properties. The properties of the elements change drastically from the right side to the left side of the table although this change is gradual for the higher energy levels.

Name Symbol	Number of Protons	Valence Electrons	Properties	Sample Compound
Hydrogen H	1	1	Gas, lighter than air, flammable	H_2O Water
Helium He	2	2	Gas, lighter than air Chemically inert	None
Lithium Li	3	1	Metallic solid, soft	Li_2CO_3 Lithium carbonate Drug- mental illness
Beryllium Be	4	2	Metallic solid	$Be_3Al_2(SO_3)_6$ Emerald- gem stone
Boron B	5	3	Semi-metallic solid	H_3BO_3 Boric acid- eye wash
Carbon C	6	4	Non-metallic solid Diamond/graphite	CO_2 Carbon dioxide- soda
Nitrogen N	7	5	Non-metallic gas (N_2) 78% of atmosphere	NH_3 Ammonia- cleaner
Oxygen O	8	6	Non-metallic gas (O_2) 21% of atmosphere	H_2O Water
Fluorine F	9	7	Non-metallic gas Pale yellow, extremely reactive	NaF Sodium fluoride- Tooth paste
Neon Ne	10	8	Non-metallic gas Chemically inert	None Used in light bulbs
Sodium Na	11	1	Soft metallic solid, Yellowish	NaCl Sodium chloride- Table salt
Magnesium Mg	12	2	Metallic solid Very flammable	$MgSO_4$ Magnesium sulfate- Epsom salts
Aluminum Al	13	3	Metallic solid Light weight	Al_2O_3 Aluminum oxide- Rubies and sapphires
Silicon Si	14	4	Semi-metallic solid Silvery black	SiO_2 Sand
Phosphorus P	15	5	Non-metallic solid Red, white or black Very reactive	$Ca(H_2PO_4)_2$ Calcium phosphate monobasic- Fertilizer, matches
Sulfur S	16	6	Non-metallic solid Yellow	SO_2 Sulfur dioxide- smog

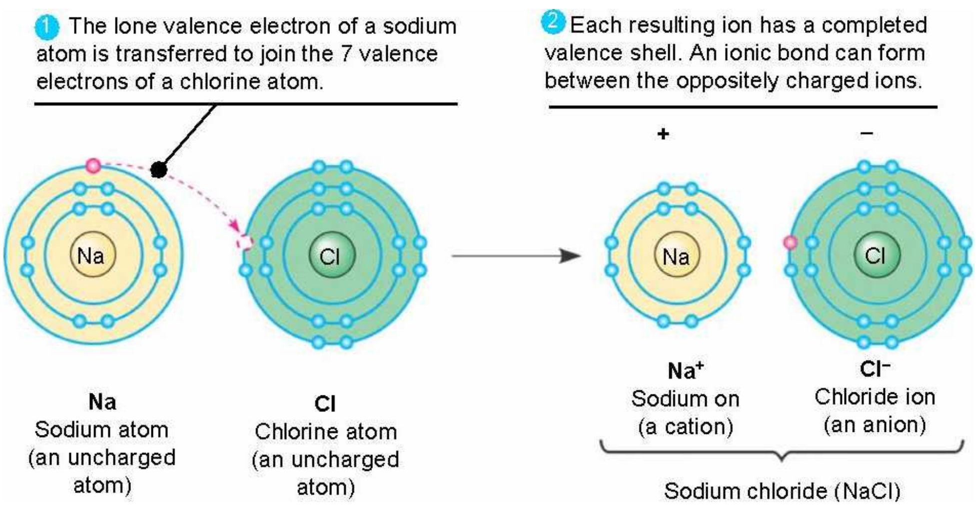
Chlorine Cl	17	7	Non-metallic gas Greenish, very reactive	NaCl Sodium chloride- Table salt
Argon Ar	18	8	Non-metallic gas, inert 1% of atmosphere	None Used in incandescent light bulbs
Potassium K	19	1	Metallic solid Soft, extremely reactive	KNO_3 Potassium nitrate- Used in explosives
Calcium Ca	20	2	Metallic solid White-light gray	$CaCO_3$ Calcium carbonate- Limestone, chalk

D11. ***Describe how atoms combine to form new substances by transferring electrons (ionic bonding) or sharing electrons (covalent bonding).***

Two or more different elements can combine (bond together) to form a **compound**. This can be done in two different ways. In an **ionic bond**, one or more electrons are transferred from one atom to another. The element giving up the negatively charged electron(s) becomes positively charged, and the element accepting the electrons becomes negatively charged. These charged particles are called **ions**. Since positive and negative charges attract each other these two ions stick together and form a bond.

All elements like to have their outer electron level completely filled. Remember the number of valence electrons in the first three levels are 2-8-8. For example, sodium has one valence electron in the third energy level. If a sodium atom donates that electron it becomes positively charged and now has a filled second energy level with eight valence electrons. A chlorine atom has seven valence electrons in the outer third energy level. If it accepts an electron it will complete its outer electron energy level with eight electrons and now becomes negatively charged. The positive sodium ion and the negative chlorine ion attract each other forming the compound sodium chloride.

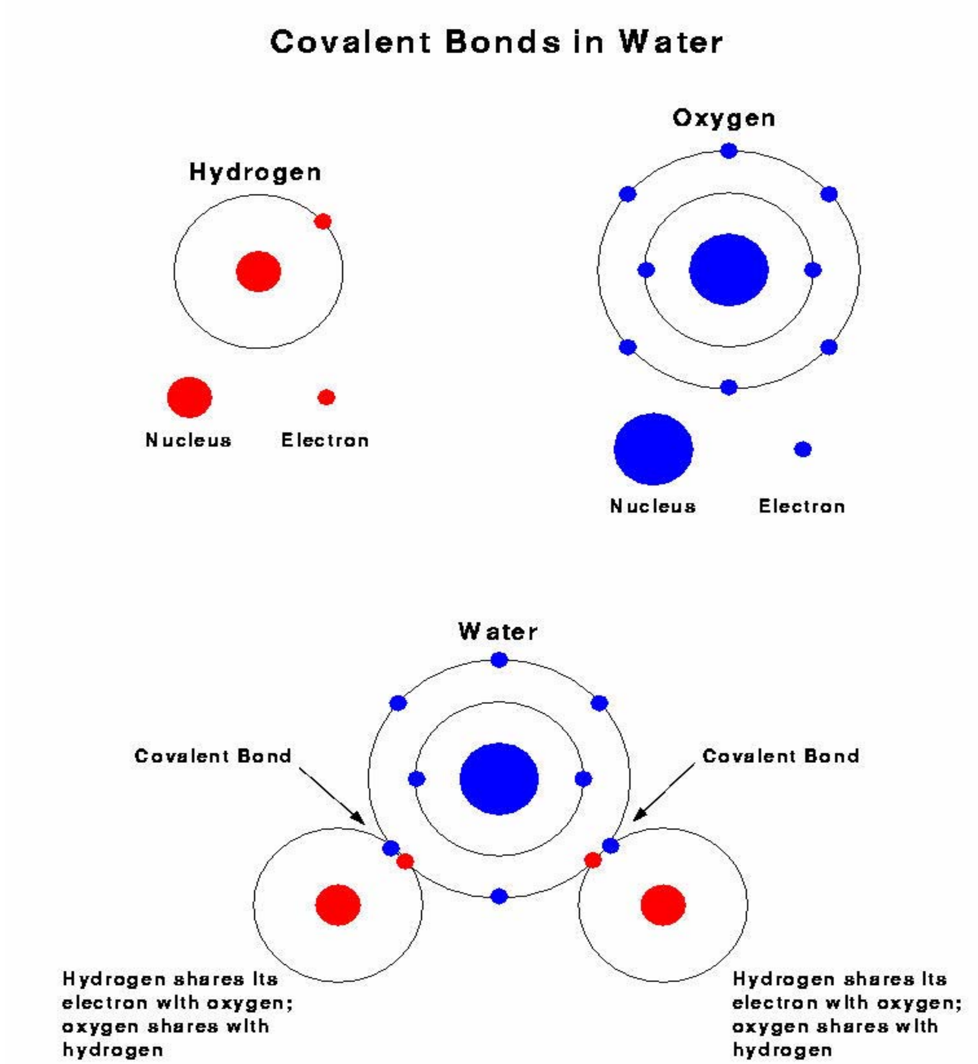
The



Octet (group of eight) Rule states that all elements try to get eight valence electrons in the outer energy level. There are two exceptions: hydrogen usually donates its one electron so that there are no electrons around its nucleus, although it can sometimes gain a second electron to completely fill its first energy level, and helium which already has a full first energy level of two electrons. The number of electrons in the valence shell predicts the element's chemical activity. Elements with a full energy level are chemically non-reactive. There are no known naturally occurring compounds of helium, neon, argon or any of the other elements in column VIII. Elements in column I have only one valence electron and are very reactive. Elements in column II with two valance electrons in energy levels two or three are somewhat less reactive. Likewise, elements in column VII which need only one electron to complete the octet are also extremely reactive while those in column VI, which need two electrons to fill the octet, are less reactive.

There is a second way in which atoms can form bonds. In **covalent** (‘co’ meaning shared or together and ‘valent’ from valence electrons) **bonds** atoms share one or more electrons to complete the octet. (Remember hydrogen tries to complete its first energy level shell with two electrons.) In a water **molecule**, two or more atoms held together with covalent bonds, each hydrogen atom shares its electron with the oxygen atom completing its valence electron level of two electrons, and the oxygen atom shares one electron with each of the hydrogen atoms filling its outer shell with eight electrons.

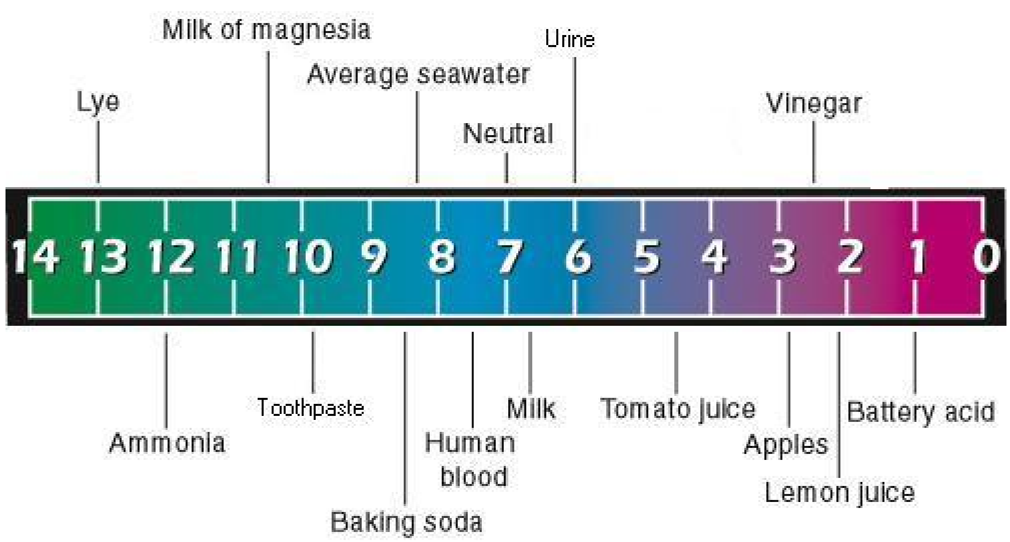
In the same manner, carbon, with four valence electrons, can share two electrons each with two oxygen atoms. The oxygen atoms can each share two electrons with the carbon atom forming carbon dioxide. The carbon atom now has its four electrons plus four more from the two oxygen atoms for a total of eight. Each oxygen atom has six valence electrons and shares two from the carbon giving each a total of eight outer electrons.



D12. ***Explain the chemical composition of acids and bases, and explain the change of pH in neutralization reactions.***

An **acid** is a substance that produces a hydrogen ion (H^+) when dissolved in water. Acids taste sour and turn blue litmus paper red. **Bases** are substances that produce hydroxide ions (OH^-) or remove hydrogen ions from an aqueous (water) solution. Common bases taste bitter, feel slippery and turn red litmus paper blue.

The strength of an acid or base solution is measured by a scale called **pH**. This scale indicates the amount of hydrogen ions in the solution and typically has a range from 1 to 14. In an aqueous solution both hydrogen ions and hydroxide ions coexist. When there are more hydrogen ions than hydroxide ions, the solution is acidic and when the hydroxide ions outnumber the hydrogen ions, the solution is basic. When the concentration of hydrogen ions equals the concentration of the hydroxide ions the solution is said to be **neutral** and the pH is equal to 7, as in pure water. As the pH gets smaller (towards a pH of 1) the solution gets more and more acidic. Likewise as the pH increases in value (towards 14) the solution gets more basic or **alkaline**.



When hydrogen ions are mixed with hydroxide ions they react to form water.

$$H^+ + OH^- \rightarrow H_2O$$

When a strong acid, such as hydrochloric acid (HCl) is mixed with an equal amount of sodium hydroxide (NaOH), a strong base, a **neutralization reaction** occurs producing water and a salt, in this case sodium chloride (NaCl) or table salt.

$$HCl + NaOH \rightarrow H_2O + NaCl$$

The resulting solution is **neutral**, neither acidic nor basic. The general reaction is:

Acid + Base → Water + Salt

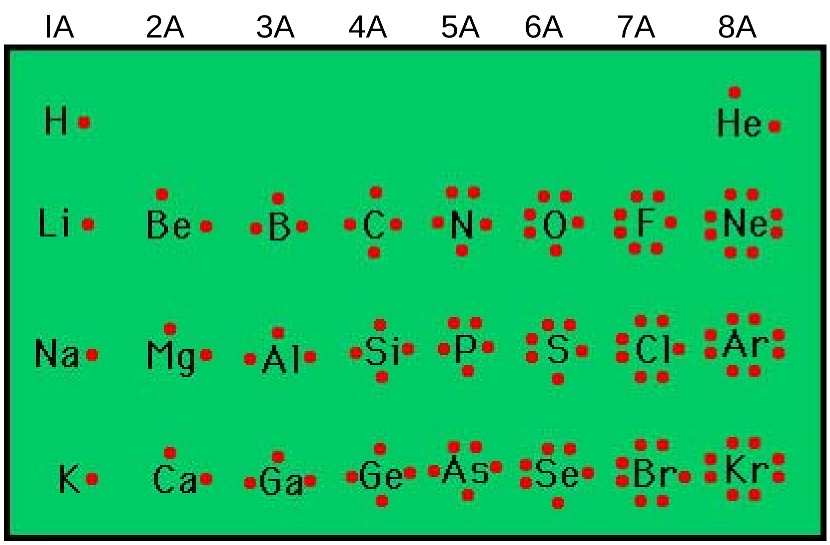
A **salt** is the non-aqueous product in an acid-base reaction or the product which is not water. For each different acid or base a different salt will be formed.

D13. ***Explain how the structure of the carbon atom affects the type of bonds it forms in organic and inorganic molecules.***

Carbon has four valence electrons which it can use to bond with other elements in both ionic (extremely rare) and covalent bonding. Carbon also has the rare ability to bond covalently with other carbon atoms almost infinitely. In a diamond each carbon atom is covalently bonded to four other carbon atoms. In covalent bonding, carbon can share one, two or three electrons with another atom but not all four. The number of electrons a carbon atom shares with each other atom determines the shape of the molecule.

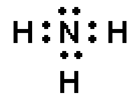
An **organic compound** is any type of chemical compounds whose molecules contain carbon, with exception of carbides, carbonates and carbon oxides and which comes from or came from living things. **Inorganic compounds** of carbon have ions containing covalently bonded carbon which are usually bonded to metal ions. Examples of these ions include carbides (C_2^{-2}) such as calcium carbide (CaC_2), carbonates (CO_3^{-2}) found in calcium carbonate ($CaCO_3$, limestone) and oxides such as carbon dioxide (CO_2) and carbon monoxide (CO).

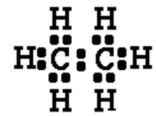
Lewis Dot Structures are an easy way to predict how atoms will bond together. In a Lewis dot structure each valence electron is represented as a dot around the sides of a chemical symbol for an element. See table below.



All elements, with the exception of hydrogen and helium, try and complete their outer electron shell with eight electrons (see D11). Hydrogen wants to share a single electron to complete the first energy level with two electrons. For example, hydrogen, with a single electron (one dot) can share this electron with the unpaired electron on a chlorine atom. This now gives the hydrogen atom two electrons and the chlorine eight forming a stable molecule of hydrogen chloride (Fig. 1). Carbon with four single electrons can share one to each of four hydrogen atoms to complete its octet in methane (Fig. 2). Likewise nitrogen can share three in ammonia (Fig. 3) and oxygen can share two for form water (Fig. 4).

(1) 

(3) 

(5) 

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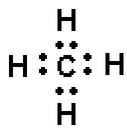
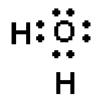
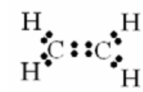
(2) 

(4) 

(6) 

In ethane (Fig. 5) each carbon atom shares one electron with the other carbon atom and each of the remaining three with three hydrogen atoms. Carbon can share more than one electron with another carbon atom. In ethene (ethylene, Fig. 6), each carbon atom shares two electrons with the other carbon atom and the remaining two with two hydrogen atoms. In ethyne (acetylene, Fig. 7), each carbon atoms shares three electrons with the other carbon and one with a hydrogen atom. Carbon cannot share all four electrons with another atom because of the geometry of the electrons in the atom.

D14. ***Describe combustion reactions of hydrocarbons and their resulting by-products.***

Hydrocarbons are organic compounds that contain only carbon and hydrogen. Some common hydrocarbons are gasoline (a mixture of many hydrocarbons including octane (C_8H_{18})), natural gas (methane, CH_4), propane (C_3H_8) and butane (C_4H_{10}). During **combustion** or burning the hydrocarbon reacts with oxygen gas (O_2). If the combustion is complete, the only products are carbon dioxide (CO_2) and water (H_2O).

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

In the absence of enough oxygen, combustion can still occur but the burning is not complete and carbon monoxide (CO) and black soot (C) are also produced. This can often be seen in the exhaust from a truck or a bus.

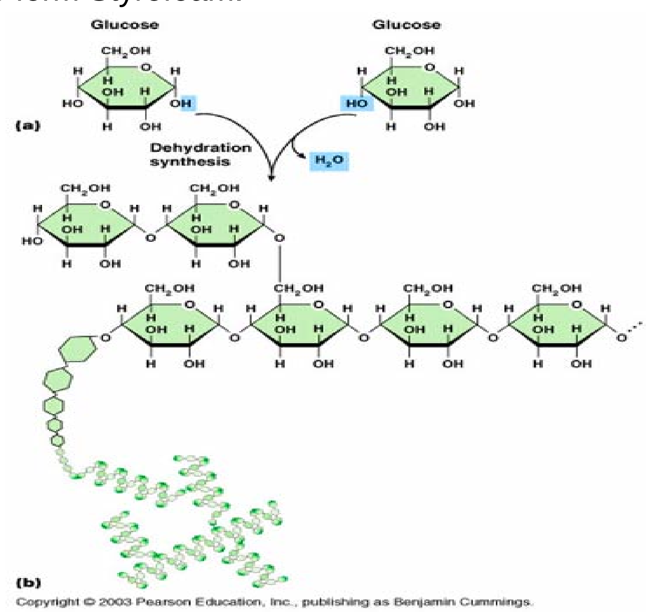
D15. ***Explain the general formation and structure of carbon-based polymers, including synthetic polymers, such as polyethylene, and biopolymers, such as carbohydrate.***

A **polymer** is a large naturally occurring or synthetic molecule made up of a linked series of repeated simple units (monomers). The word polymer comes from ‘poly’ meaning many and ‘mer’ meaning unit. The units in a polymer may be identical or they may be different. Synthetic polymers are found in rubber, fabrics (nylon, Dacron, polyester) and plastics (polystyrene, polycarbonate and polyethylene). In polyethylene (many ethylenes or ethenes, see D13), ethylene molecules are linked together to form a long chain.

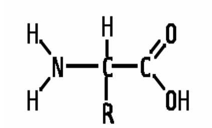
```
H       H        H       H            H   H   H   H
 \     /          \     /             |   |   |   |
  C = C     +      C = C      →     – C – C – C –C –
 /     \          /     \             |   |   |   |
H       H        H       H            H   H   H   H

Ethylene         Ethylene              Polyethylene
```

Polystyrene is very similar to polyethylene but has one hydrogen on each ethylene replaced with a benzyl (C_6H_5) group. It is a hard non-brittle plastic. If however, when it is produced and air is pumped through it, little balloon-like particles form which can be pressed together to form Styrofoam.

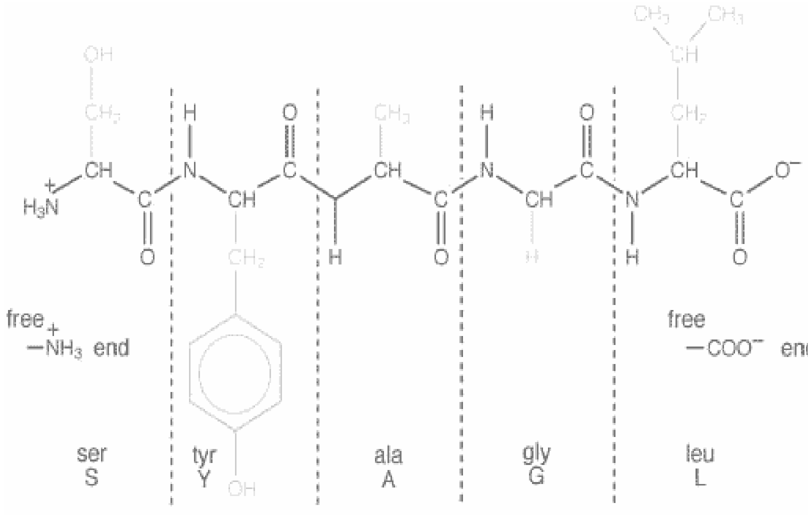
Natural polymers are mostly found in three main types: carbohydrates, proteins and nucleic acids. **Carbohydrates** are a group of organic compounds found in all living cells that include sugars, starches and celluloses. They can be used for energy storage in the form of sugars and starches in plant and animal cells or in cellulose for structure in plant cells. They are polymers which use simple sugars as the repeating units.



Proteins are found in all cells and are polymers of amino acids. They are essential for the structure, growth and functioning of all cells. Amino acids are small organic molecules with an amino group (NH_2) and an acid group (COOH) bonded to a central carbon. The amino acids only differ in the R group.

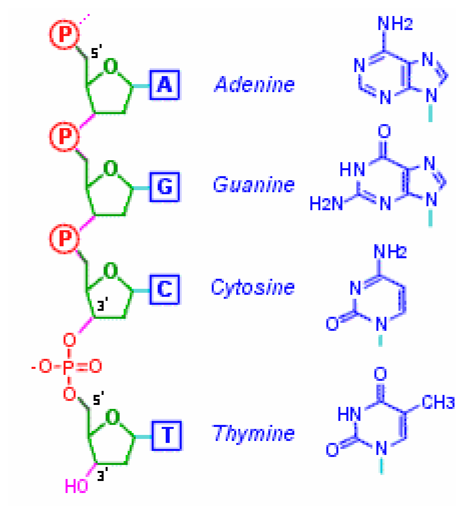


Amino Acid



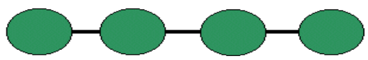
Nucleic acids are used in storing and transmitting genetic information and in the synthesis (making) of proteins.

These are extremely large polymers where the repeating units contain a simple sugar and a phosphate (PO_4^-) group attached to various nitrogen bases. The units differ only in the structure of the nitrogenous base.

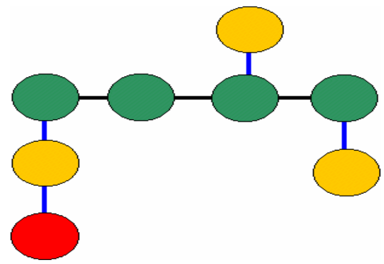


D16. ***Explain how simple chemical monomers can be combined to create linear, branched and/or cross-linked polymers.***

Most of the polymers discussed in D15 are linear polymers. They are made by taking a monomer (one unit) which can react at two places, only at each end. The result is a polymer that resembles a piece of string. In some polymers a different chemical is added to the polymer mix. This chemical mixes in with the normal units and allows the chain to branch. A **branched polymer** is one which can grow at more than two places.

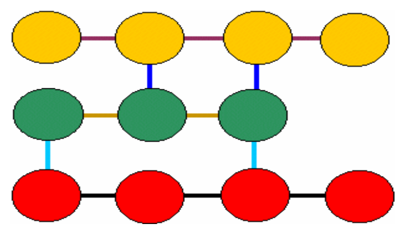


Linear



Branched

Other chemicals can be added to the polymer synthesis which cause the different chains to become linked together. This is called **crosslinking**.



Crosslinked

D17. *Explain how the chemical structure of polymers affects their physical properties.*

The physical properties of a polymer depend upon the chemical structure of the individual units that make up the polymer and upon the shape of the polymer molecule as a whole. Polyethylene can form in long linear chains. These chains can pack together very tightly and have a relatively high density (>0.94g/cm^3). This form of polyethylene is called **high density polyethylene (HDPE)**. HDPE can be melted and molded into shapes which are very strong when cooled. HDPE can be re-melted and reused. Polymers that can be melted and cast into shapes are called **thermoplastics** (‘thermo’ means heat). Polyethylene can also be made to have various amounts of branching. Branched polymers do not pack as tightly as linear ones and are less dense. **Low density polyethylene (LDPE)** (0.91-0.94g/cm^3) is not as strong as HDPE but it is very ductile. (**Ductile** is the ability to be stretched into threads.) LDPE can also be molded into shapes and reused. HDPE and LDPE are commonly used for milk bottles (HDPE) and plastic bags (LDPE).

Polymers with crosslinking behave very differently since the polymer chains are chemically linked with each other and behave as a single molecule. They must be synthesized in the mold and are very rigid. They have very high melting points and cannot be reshaped by re-melting and cooling. Polymers with a lot of crosslinking are called **thermosets**. They tend to be very hard and brittle. The first thermoset was discovered by Goodyear who accidently heated natural latex (rubber), a very soft and sticky substance with sulfur. The result was a very rigid crosslinked polymer that kept its shape and had very high melting point. This vulvanized rubber is now used in all tires. Many types of adhesives require two substances to be mixed before using. The final result is a highly crosslinked polymer.

Elastomers are another type of polymer. **Elastomers** consist of mostly linear chains with very little branching. The polymer molecules are wrapped around each other with no particular order. When stretched, the polymer molecules are forced to align with each other but the molecules return to their original disorder when the stretching is reversed.

D18. ***Explain the short- and long-term impacts of landfills and incineration of waste materials on the quality of the environment.***

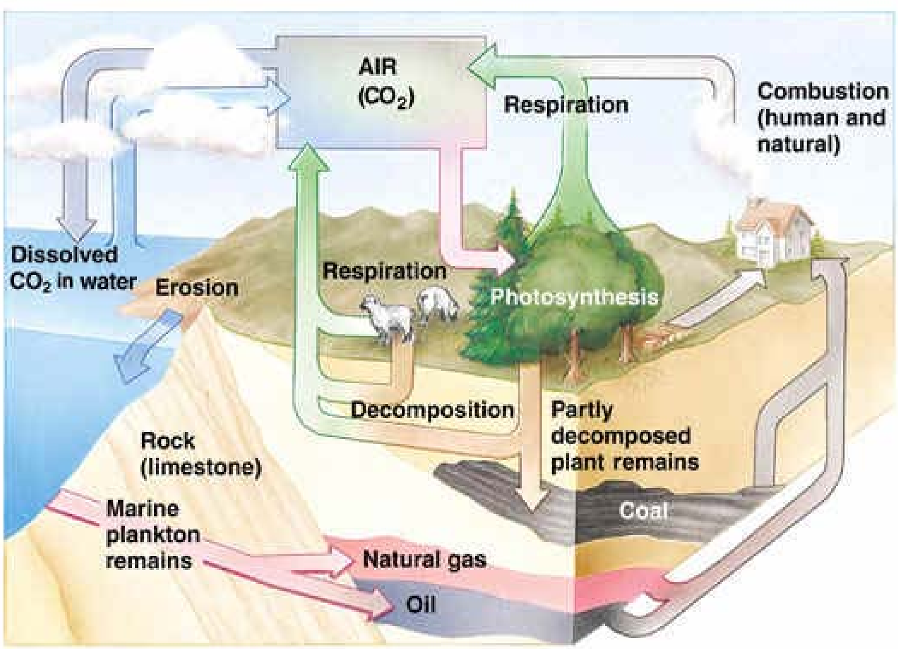
Present day civilizations generate a tremendous amount of trash and **landfills** (garbage dumps) are a necessity. In the short-term, landfills are unsightly, smell bad, attract wild animals, breed disease and take up a lot of space. In the long-term, decomposing garbage and trash produces methane gas (CH_4) which is flammable and contributes to global warming, and a liquid runoff which is usually toxic that needs to be contained so it does not poison the surrounding land or the ground water supply. The vast use of plastics and other synthetic polymers (tires and disposable diapers for example) create materials which are chemical inert (do not react) and will not decompose. Heavy metals such as mercury, lead and cadmium, from electronics, batteries and paint, become concentrated and are highly poisonous.

Incineration (burning) of trash and garbage can be both useful and dangerous. The heat energy from burning garbage can be used to generate electricity and the volume of the material which remains after incineration is much less. Incineration produces greenhouse gases which can increase global warming and numerous toxic gases which can lead to increased air pollution and other health risks. The ash or flyash that remains after the incineration contains a concentration of heavy metals and other toxic substances. This ash can be used in road paving, which eventually releases these substances into the environment, or put into a landfill.

D19. ***Explain how chemical and physical processes cause carbon to cycle through the major earth reservoirs.***

Carbon can be found everywhere in nature and travels from one environment to another in the **carbon cycle**. Plants take in carbon dioxide and through the process of photosynthesis, produce sugars, starch and cellulose to make their food and to build new cells. Many kinds of animals eat the plants (herbivores) for food and get energy in the process of respiration which gives off carbon dioxide. Other meat-eating animals (carnivores) eat the herbivores also releasing carbon dioxide. Waste matter and the dead animals themselves are decomposed by bacteria and fungi. The decomposed organic matter goes into the soil where it can eventually form into coal and oil. The coal, oil, wood and other biomass can be burned producing carbon dioxide to heat buildings or power engines or generators. Carbon dioxide in the air can also dissolve in lakes and oceans. Here it can be utilized by water plants for photosynthesis, or by animals to produce calcium carbonate found in shells. Carbon dioxide can also be found in many rocks in the form of carbonates. This carbon dioxide can be released into the atmosphere by volcanic eruptions or by chemical weathering (the chemical breaking down of the stone).

Raven/Berg, Environment, 3/e
Figure 6.2

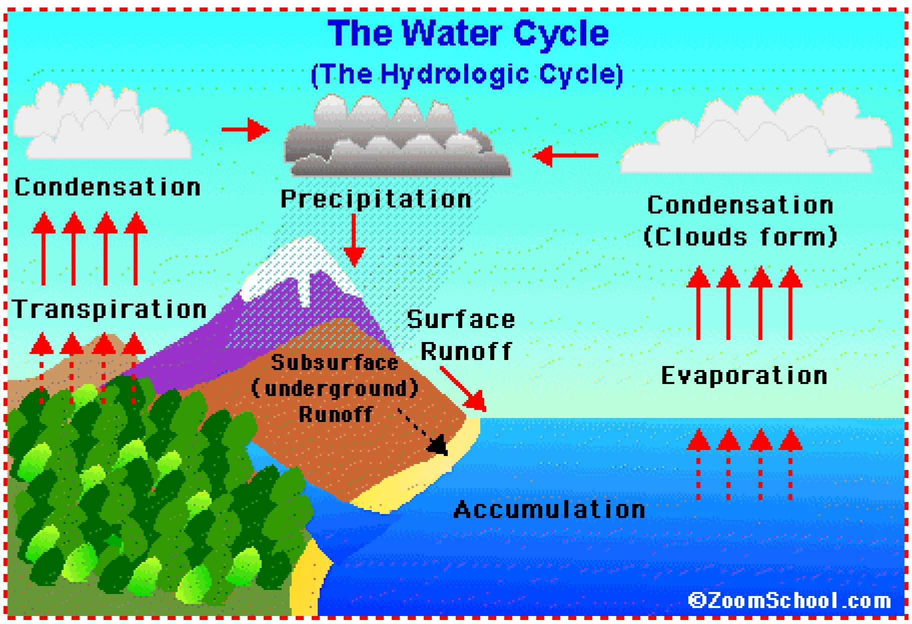


Harcourt, Inc.

D20. ***Explain how solar energy causes water to cycle through the major earth reservoirs.***

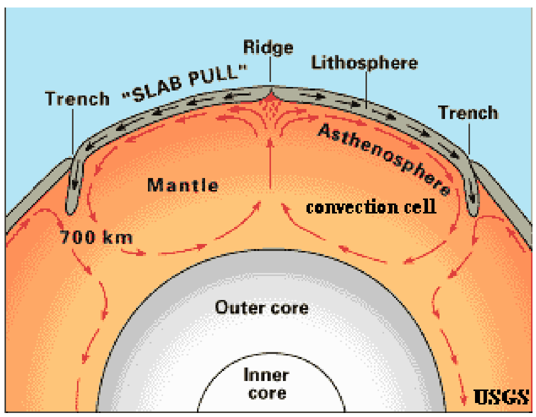
The **water cycle** (hydrologic cycle) is the constant movement of water from the Earth's surface into the lower atmosphere and back to the surface of the Earth. Water leaves the Earth's surface by two different processes. **Evaporation** occurs when energy from the Sun is absorbed by standing water turning it into a gas. Convection currents cause this water vapor to rise into the atmosphere. Moisture in the air is also produced by transpiration. In **transpiration**, water vapor is released into the air from the leaves of green plants. Wind currents can blow this water vapor great distances.

As the moist air rises, the temperature get colder and the water vapor will condense. **Condensation** is the process of turning vapor into liquid. Very small droplets of liquid water are formed producing clouds. If there is a lot of water vapor in the air, these tiny droplets will continue to grow until they get too large and heavy to remain in the atmosphere. **Precipitation** occurs when these drops return to Earth in the form of rain or snow. The cycle is completed as the water returns to the oceans and lakes via rivers, snow melt or ground water.

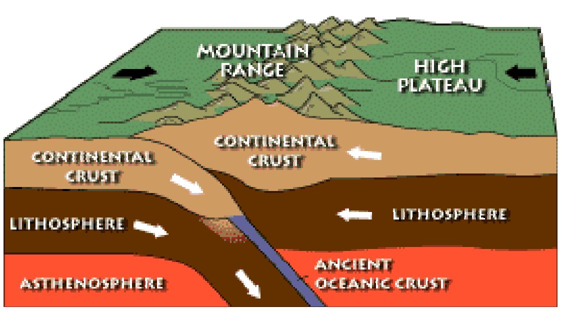


D21. ***Explain how internal energy of the Earth causes matter to cycle through the magma and the solid earth.***

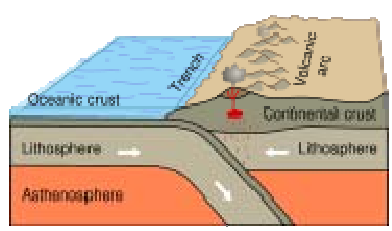
Heat, mostly from radioactive decay, causes the inside of the Earth to be very hot, over 7000°C which is hotter than the surface of the Sun. The **inner core** is a solid sphere of iron and nickel while the **outer core** is a molten liquid of the same metals. Above the outer core is the **mantle** containing high concentrations of silicon, oxygen, magnesium, iron, aluminum and calcium. Most of the mantle is a slowly moving liquid. Differences in temperatures from the hot inner core to the much cooler upper mantle cause this molten material (**magma**) to form convection currents. On top of this liquid is the **lithosphere** which includes the Earth's crust and the solid portion of the outer mantle. The Earth's crust is divided up into seven major and several minor plates which float and move on the molten magma.



The regions where the edges of these plates meet are called **plate boundaries**. At a **convergent boundary** two plates collide. When two continental plates converge one of the plates is pushed over the other creating mountains such as the Alps and the Himalayas.



Convergent Boundary

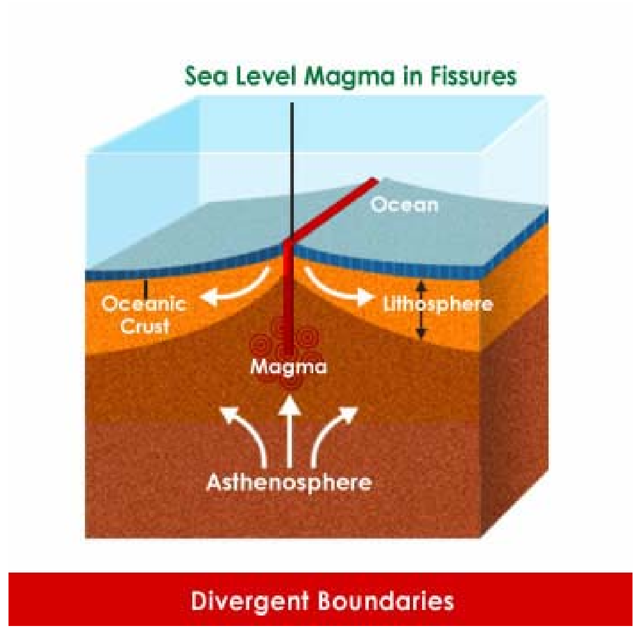


Subduction

Continental crust is much thicker than oceanic crust. When a continental plate converges with a thinner but more dense oceanic plate, the oceanic plate is pushed under the continental plate. **Subduction** is the movement of one plate under another. As the oceanic plate is forced down, a deep trench is created. The oceanic plate is forced deeper and deeper into the Earth and begins to melt.

Pressure can force this molten rock to the surface along with great amounts of steam forming volcanoes. Magma that reaches the Earth's surface is called **lava**. The oceanic plate eventually completely melts joining the magma in the mantle. This process is occurring along the west coast of South America and along the Pacific Rim. When two oceanic plates collide a similar process occurs. The denser of the two plates is subducted and volcanic islands such as the Aleutians are formed.

When two plates move away from each other a **divergent boundary** is formed. Most divergent boundaries occur under the oceans. As the two plates pull apart, **seafloor spreading**, molten magma seeps through the cracks and cools forming new rock and mountains on the sea floor. This occurs along the Mid-Atlantic Ridge and is causing the country of Iceland to split in two.



Thus, molten magma can reach the surface through seafloor spreading forming new crust. But at the same time plate subduction causes a different plate to melt and rejoin the magma pool.

D22. *Explain how the release of sulfur dioxide (SO_2) into the atmosphere can form acid rain, and how acid rain affects water sources, organisms and human-made structures.*

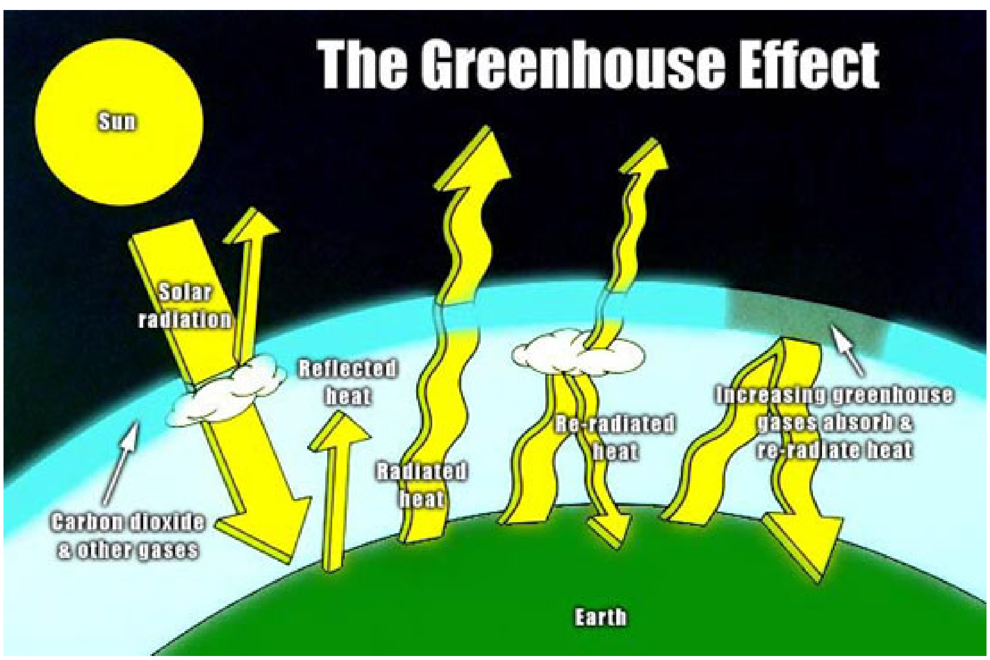
Fossil fuels such as oil or coal contain trace amounts of sulfur. When these fuels are burned in factories and automobiles, the sulfur is released in the form of sulfur dioxide (SO_2). The sulfur dioxide combines with the water vapor in the atmosphere to form sulfurous acid (H_2SO_3) and sulfuric acid (H_2SO_4). Natural rain has a pH of about 5.6, which is slightly acidic, due to dissolved carbon dioxide which forms carbonic acid (H_2CO_3). **Acid rain** is rain (or snow) with a pH of less than 5.4.

Acid rain has a severe effect on both land and fresh water ecosystems. When acid rain falls on land, it lowers the pH of the soil which changes the solubility of minerals which are needed for plant life. Forest soils are inhabited by fungi which fix nitrogen from the air into the soil. An acidic environment kills the fungi and promotes the growth of bacteria completely changing the composition of the soil. Acid rain also damages the surfaces of the leaves or needles making trees more susceptible to frost, insects and disease. The most acidic rain ever recorded in the US had a pH of 1.5 (10,000 times more acidic than natural rain). Acid rain is very damaging to fresh water lakes and ponds. Run-off concentrates the acid rain in these bodies of water and the acidity increases. Most fish cannot survive in water with a pH of 5 or less. Thousands of lakes in northern New York are crystal clear and support no fish or plant life as their pH is less than 5. Acid rain also corrodes metal structure such as buildings and automobiles. Many buildings and monuments, both ancient and modern, are made from marble, granite or limestone. These building materials literally dissolve in acid rain reducing their strength and destroying their history. This effect is easily seen on old gravestones which are very difficult if not impossible to read.

D23. ***Explain how the accumulation of carbon dioxide (CO_2) in the atmosphere increases Earth's "greenhouse" effect and may cause climate changes.***

The Earth receives most of its energy from the Sun. Much of this solar radiation is absorbed by the Earth and transformed into heat (infrared radiation). This heat energy can then be radiated into the atmosphere where some is lost into space. Most of this energy is absorbed (trapped) in the atmosphere by the so-called "greenhouse gases." Carbon dioxide is the major greenhouse gas but water vapor and methane (CH_4) also play a part. It is the greenhouse effect that keeps the Earth warm enough for human life to exist. Without the greenhouse the estimated temperature would be -18^oC. However, the amount of carbon dioxide has risen over 7% in the last fifty years and the average Earth temperature has steadily increased. Eleven of the twelve hottest years have occurred between 1994-2006. Most of this increase in carbon dioxide can be attributed to the burning of fossil fuels such as oil and coal.

An increase of only 3-4^oC in the average yearly temperature of the Earth will have drastic effects on the environment. Most animals and plants are adapted to a specific temperature range and will die or be forced to move as the environment gets hotter. Much of the equatorial land areas could become deserts and uninhabitable. Farming areas would be shifted to more temperate climates. As the polar ice caps melt, the oceans will become warmer and less salty. Eventually the major ocean currents could shift or cease to flow. Lowland coastal



areas would be flooded as the ocean levels rose an estimated 10 meters or more. There is no general agreement on the future rate of increase of carbon dioxide in the atmosphere or to the extent of global warming which will occur.

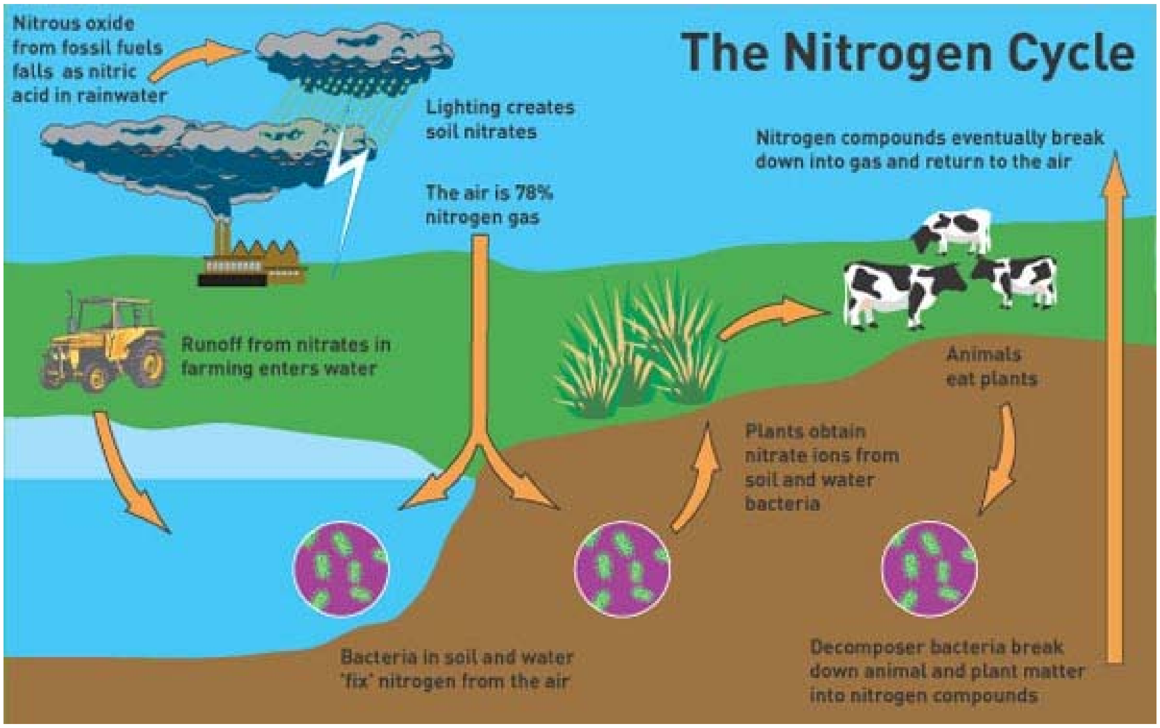
D24. ***Explain how the accumulation of mercury, phosphates and nitrates affects the quality of water and the organisms that live in rivers, lakes and oceans.***

Mercury and other heavy metals are not part of any animal's normal diet and are poisonous even in very low concentrations. Mercury, a byproduct in plastic production and electricity generation, used to be dumped into rivers for disposal. Bacteria changed the mercury into a soluble form which was then absorbed by tiny creatures living in the mud. These creatures were eaten by bigger ones, which in turn were eaten by even larger ones. In the process of **biological magnification**, substances are concentrated up the food chain. When the concentration reaches a certain point, that animal or person will die.

Phosphates (PO_4^{-3}) are essential to all life. However, too much phosphate is detrimental to the environment. Phosphate is a common component in fertilizer. If it is applied in an improper manner or too close to a body of water, the runoff into that lake, river or pond will increase the concentration of phosphates. Plant growth increases and the water can become clogged with weeds. Higher phosphate levels often causes an explosive increase in tiny photosynthetic creatures. Large blooms of algae may occur increasing the amount of dissolved oxygen during the day but drastically reducing it at night due to plant respiration. This lack of oxygen can be fatal to larger organisms.

Nitrogen is an essential element in all life forms. The atmosphere is 78% nitrogen, but very few living things can utilize nitrogen directly from the atmosphere. The nitrogen gas must first be changed into forms that plants and animal can use. These are usually nitrogen oxides (NO_x, such as nitrates (NO_3^-) or nitrites (NO_2^-)). The process of changing nitrogen gas into useable compounds is called **nitrogen fixation**. Most of the nitrogen fixation is done by bacteria in the soil or water. Some plants, called **legumes**, contain nitrogen fixing bacteria in their roots. Lightning can produce nitrogen oxides by causing the nitrogen to react with the oxygen in the air where they are then washed to the ground. Once in the ground, the nitrogen can be utilized by plants which are in turn eaten by animals. The nitrogen is returned to the atmosphere as different bacteria help decompose organic matter. Factories and power plants that use fossil fuels release nitrogen oxides directly into the air and also contribute to acid rain.

Nitrogen, in the form of nitrates, is the other common component in fertilizer. Runoff from farming areas into rivers and ponds concentrates the nitrates. High concentrations of nitrates can inhibit animal growth and ultimately cause death.


The Nitrogen Cycle
Nitrous oxide from fossil fuels falls as nitric acid in rainwater
Lighting creates soil nitrates
The air is 78% nitrogen gas
Nitrogen compounds eventually break down into gas and return to the air
Runoff from nitrates in farming enters water
Animals eat plants
Plants obtain nitrate ions from soil and water bacteria
Bacteria in soil and water 'fix' nitrogen from the air
Decomposer bacteria break down animal and plant matter into nitrogen compounds

D25. *Explain how land development, transportation options and consumption of resources may affect the environment.*

The Earth's supply of natural resources is limited. This includes the land. New England was once totally covered by forest. The first step in land development is to cut down the trees to clear the land for housing and farming. Creatures that need to live in the forest and those that feed upon them will leave the cleared areas effectively changing the local environment. Deforestation (removing the trees) causes increased erosion and soil loss. Farming takes a large amount of fertilizer which can pollute local bodies of water as well as the ground water (See D24). Further development from a farming to an industrial society requires a high population density and the problems of supplying water, transportation, electricity and of removing garbage, human and industrial waste and noise.

With the invention of the automobile, people did not have to live in the industrial cities. Suburbs developed and people commuted to work. Mass transportation was developed in some major cities but the Unites States is so large that it is uneconomical in most areas. Some smaller countries, notably those in Western Europe, have well developed mass transportation systems, but their use is declining as people prefer the automobile for its independence.

Most of the high level economic countries are consumer societies using more than they produce. This produces a tremendous amount of trash and garbage which has to be disposed of someplace. For the most part, those places are dumpsites. In the US, this trash amounts to about 4.5lb/day per person, or almost 1.5 tons of solid waste per year. The tallest landform in Ohio is a trash dump. New York City dumps thousands of tons of trash and garbage into the ocean on a daily basis. Trash sites have a huge affect on the environment (see D18).

D26. *Describe human efforts to reduce the consumption of raw materials and improve air and water quality,*

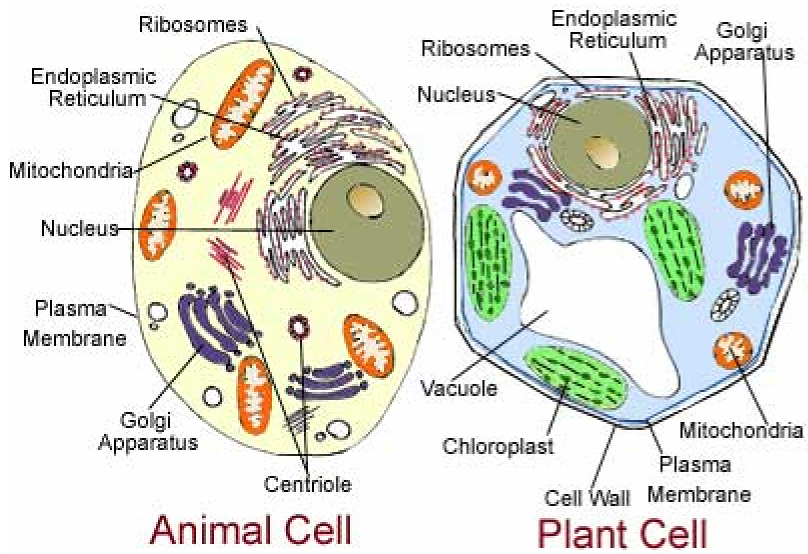
The two major things that are being done in this country to reduce consumption of raw materials is to recycle and to improve the efficiency of the initial extraction and processing of those raw materials. New drilling and mining procedures have increased the efficiency of producing oil and minerals but this can only help for a finite period of time as these resources are limited.

The best way of improving air and water quality is to reduce the amount of waste by recycling. Approximately three fourths of all disposable material can be recycled but only about one fourth is. Increasing this amount would have a tremendous affect on the environment. If all the newspapers in the US were recycled, it would save 250,000,000 trees/yr. It costs more to make a new aluminum can than to recycle an old one, and the US produces 80,000,000,000 soda cans a year. Over 25 trillion Styrofoam coffee cups are used each year, most of which are incinerated as biomass. Recycling these cups would save twice the amount of energy as they produce on burning. The most common item found in trash dumps is the disposable diaper. The average baby uses 10,000 diapers. The effect of switching to reusable diapers would be substantial. Packaging accounts for about a quarter of all disposable trash. Eliminating individually wrapped items, especially food, and fancy boxes would greatly decrease the amount tossed into landfills.

Finally, governmental agencies and congress have the ability to pass and enforce legislation to control pollution. However, the limits set and the amount of enforcement are too often more political than scientific.

D27. *Describe significant similarities and differences in the basic structure of plant and animal cells.*

Plant and animal cells have many similarities. Each is surrounded by a cell membrane which allows some materials to pass through but not others. The membrane is filled with a gel-like substance called **cytoplasm**. Located near the center of the cell is the **nucleus** which contains the genetic information to produce new cells and control the cell's functions. Protecting the outside of the nucleus is the **nuclear membrane** and inside the nucleus is the **nucleolus** which produces ribosomes. **Ribosomes** are attached to the **endoplasmic reticulum** as well as scattered throughout the cytoplasm. Together they produce proteins, fats and other essential products for the cell. **Vacuoles** are liquid-filled storage vessels for food and waste products. **Golgi bodies** move the products formed in the endoplasmic reticulum around or out of the cell. **Mitochondria**, found throughout the cytoplasm, react oxygen with food to produce the cell's energy.

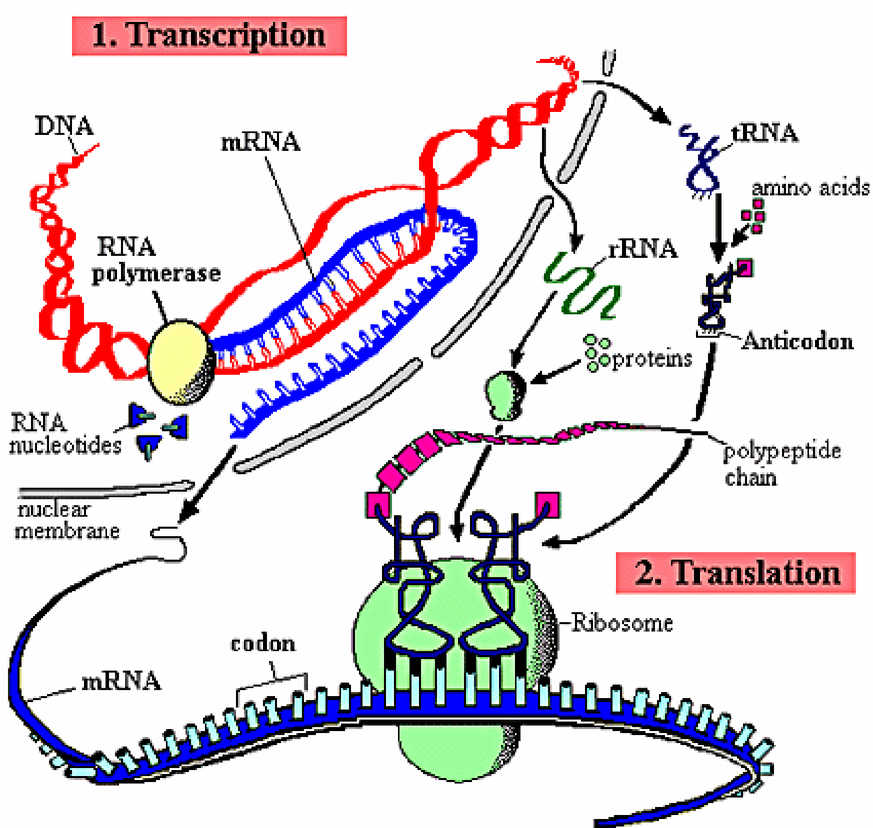


There are some major differences between plant and animal cells. Animal cells tend to be round or oblong while plant cells are more angled or rectangular. Plant cells also contain two structures what are not found in animal cells. The first is the **cell wall** which provides protection for the cell while giving it shape and support. The second are **chloroplasts** which contain chlorophyll to produce the cell's food through photosynthesis.

D28. ***Describe the general role of DNA and RNA in protein synthesis.***

The chromosomes found in the cell nucleus are made of DNA (deoxyribonucleic acid) which contains all the information necessary to reproduce the cell and synthesize proteins. This information needs to be transported to the ribosomes where the protein synthesis occurs. In **transcription** the two strands of DNA, which code for the protein, separate. One strand is used as a template to form a strand of messenger ribonucleic acid (mRNA). The nucleotides in DNA include adenine (A), thymine (T), guanine (G) and cytosine (C). In RNA the thymine is replaced with uracil (U). The enzyme mRNA-polymerase uses nucleotides in the nucleus to translate the DNA information into mRNA. The mRNA passes through the nuclear membrane and attaches to a ribosome. Ribosomes are made from over fifty proteins and ribosomal RNA (rRNA) and are the site of protein synthesis.

Another type of RNA, transfer RNA (tRNA), is used to translate the nucleic acid code into the correct amino acid sequence for the protein. Each amino acid has one or more specific **codons** consisting of a triplet of nucleotides, such as CGU. The tRNA has a three letter sequence called an **anticodon**. In RNA the pairing between nucleotides is very specific: only G can bond with C and only A can bond with U, so the anticodon to CGU would be GCA. Each amino acid is attached to its specific tRNA. The anticodon on the tRNA recognizes the corresponding codon on the mRNA and an enzyme in the ribosome detaches the amino acid from the tRNA and links it with the growing protein chain in a process called **translation**. This process continues until the entire sequence is complete.

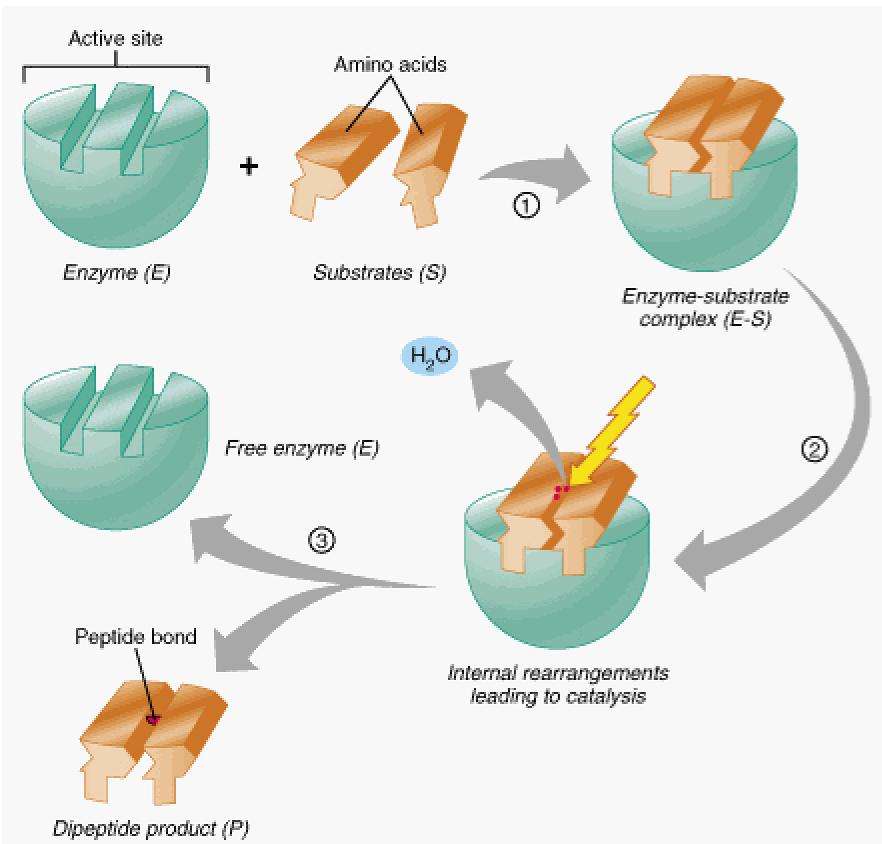


Protein synthesis

D29. ***Describe the general role of enzymes in metabolic cell processes.***

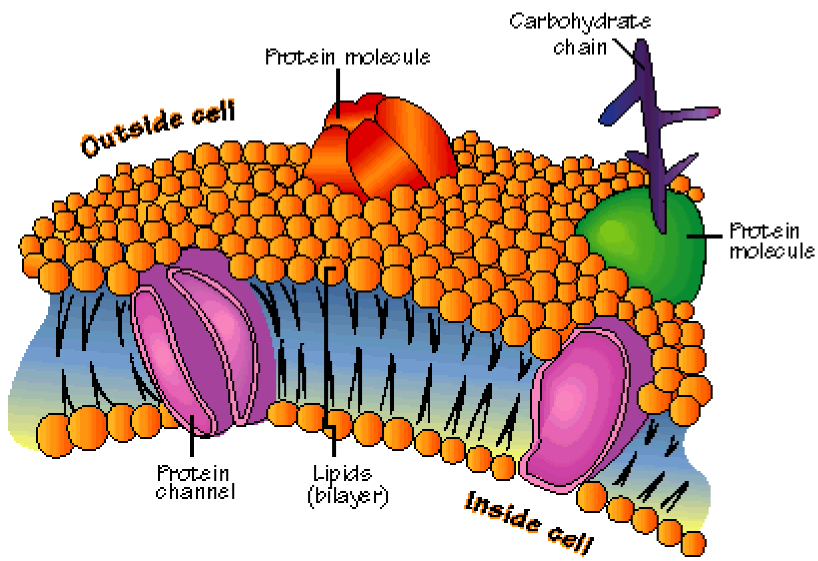
Metabolism is all of the cell's activities including the breakdown of food, the elimination of wastes and the synthesis of necessary chemicals. An **enzyme** is a protein that serves as a catalyst in a chemical reaction. A **catalyst** is a substance that speeds up the rate of a chemical reaction and which is not consumed in the process. Almost every chemical reaction that occurs in living organisms involves an enzyme. Enzymes break down molecules and build other molecules. Each separate reaction involves a specific enzyme.

An example of an enzyme is in protein synthesis (see. D28). The polymerase enzyme has at active site that is shaped specifically for the reactant(s). **Reactants** are the starting chemicals in a reaction and the **products** are what is produced. The chemical(s) that bond to the enzyme are call the **substrate** and every enzyme is designed to bond to only one specific substrate or type of substrate. When substrates bond to an enzyme, they form a complex. A chemical reaction can now occur between the substrates, in this case linking them together. The resulting product has a different structure than the original substrates and is released into the cell. The enzyme is now free to repeat the process. Many enzymes can do thousands of reactions a second.



D30. ***Explain the role of the cell membrane in supporting cell functions.***

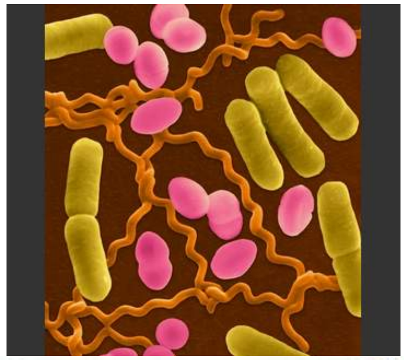
The cell membrane holds the cell together and allows certain substances to enter or exit the cell. It is a **selectively permeable** membrane that allows some chemicals to pass through it but not others. A cell membrane consists of three major parts: the phospholipid bilayer, proteins and carbohydrates. A phospholipid has a long fat molecule made from carbon and hydrogen atoms with a phosphate group (PO_4^{-3}) on one end. In water, and cells are mostly water both inside and out, these phospholipids align themselves with the phosphate end on the outside towards the water and the long fats directed inward away from the water. Protein molecules are embedded in this layer and short chain carbohydrates are bonded to both the phosphates and the proteins on the outside of the membrane. Certain molecules can cause the phospholipids to slightly separate creating a channel that will allow a molecule to cross the membrane in a process known as **diffusion**.



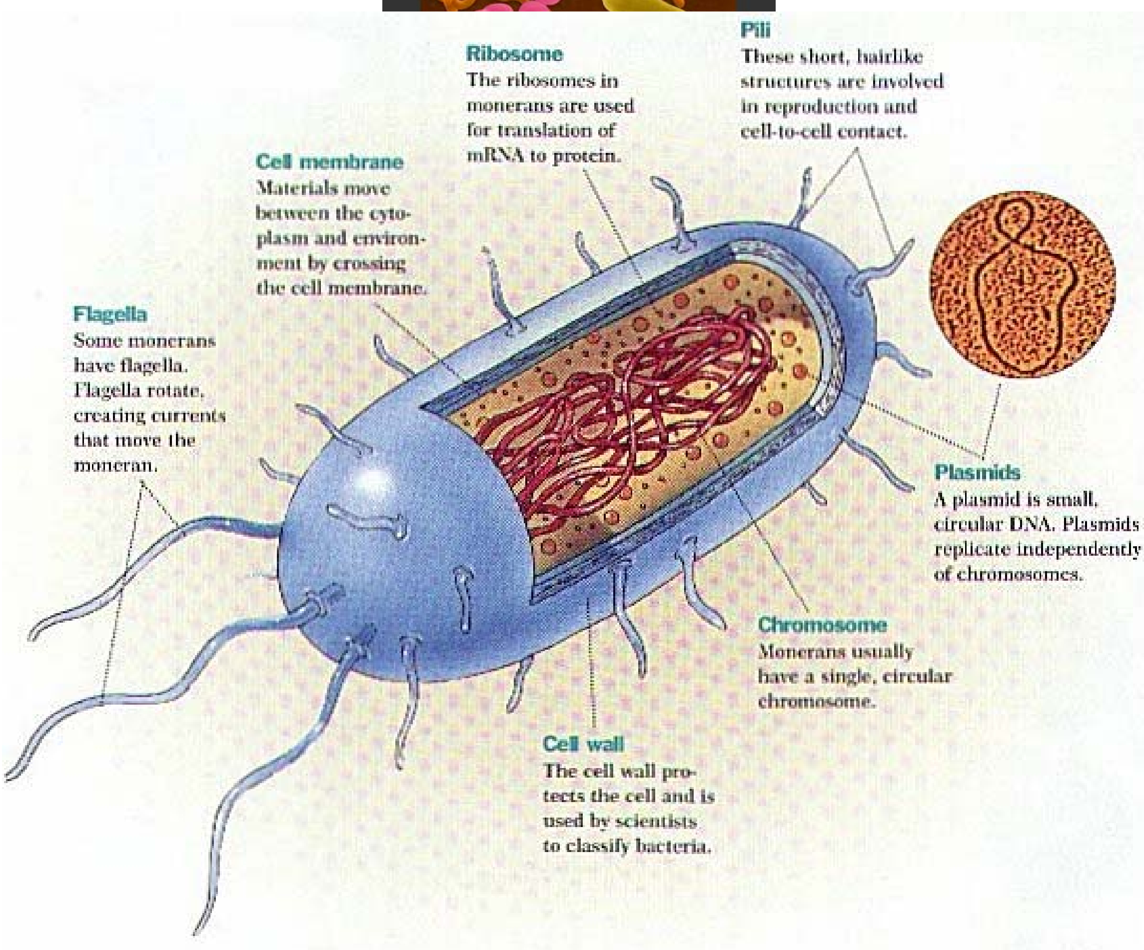
Other molecules cannot diffuse into the cell by themselves. These molecules can attach themselves to a protein in the membrane and the cell uses its own energy to get them across in **active transport**. The short chain carbohydrates on the outside of the membrane allow the cell to recognize other cells and determine if they are the same type or different.

D31. ***Describe the similarities and differences between bacteria and viruses.***

Bacteria can be found in every environment on Earth. Bacteria are **prokaryotes (monerans)**, single celled organisms which lack a nucleus. There are three types of prokaryotes that can be identified by their shapes: bacilli (rods), cocci (spheres) and spirilla (spirals or corkscrew-like).



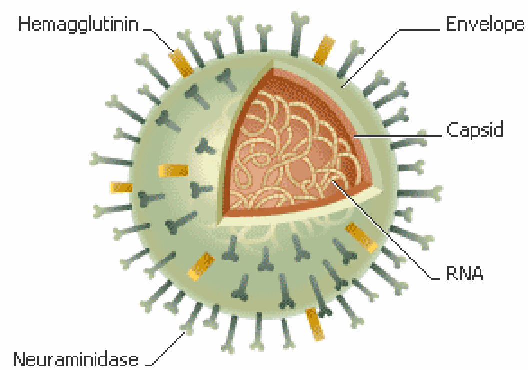
Like plant cells, bacteria have a cell wall, a cell membrane and ribosomes. The **pili** are hair-like protein structures, which allow the cell to adhere to a surface or attach to another cell. **Plasmids** are small pieces of DNA, which can be transferred between bacteria, changing the genetic characteristics of the

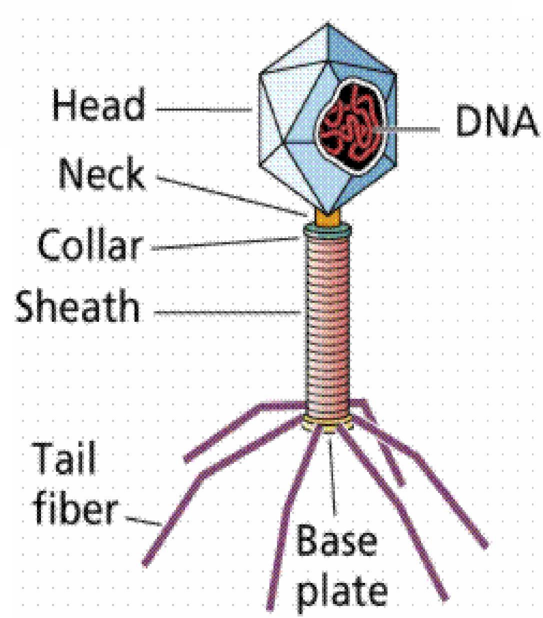


receiving cell. This allows the cell to adapt to a changing environment and pass along resistance to **antibiotics** (drugs that destroy bacteria). When the environment changes drastically, the bacteria cell can produce an **endospore** by surrounding the single chromosome with a hard coat of protein. This protects the DNA and even if the bacteria cell dies, the endospore can survive for many years. When conditions become favorable, the endospore will germinate (begin to grow) and produce a new bacteria cell. This is not a form of reproduction since only one cell is produced and the new cell is the same as the old one.

Bacteria reproduce by **fission** where the single chromosome replicates and the bacteria splits into two identical cells. All bacteria need energy to survive. Some, blue-green algae, contain chlorophyll and produce their own food by photosynthesis, while others eat and decompose the dead remains of plants and animals. Some bacteria are important to all life as they fix nitrogen from the air into useable forms for plants and animals. Other bacteria live inside other creatures. In humans, bacteria help the digestion process and synthesize necessary chemicals for human survival such as vitamin K, which is needed in blood clotting. Many foods are made using bacteria including cheese and yogurt. They have also been used to clean up oil spills and in the synthesis of medicines including antibiotics and insulin.

Viruses come in many different shapes and are much smaller than bacteria. They are not cells but simply a strand of genetic material, DNA or RNA, wrapped in a protein coat. This protein coat (head) is called the **capsid**. Viruses cannot replicate themselves and in order to reproduce they must enter a host cell. The virus attaches to the outer membrane of the host cell. In some cases, the entire virus enters the cell where the capsid is dissolved, releasing the genetic material (top figure). In other viruses the genetic material is injected into the host cell through the base plate like a microscopic needle (bottom figure). Once in the cell, the genetic material can be duplicated in two different ways. In the **lytic cycle**, the DNA or RNA is rapidly copied by the host cell which also uses that genetic material to make new capsids and necessary viral enzymes. New virus particles are assembled and are transported out of the cell or cause the cell to burst releasing the new viruses to infect other cells. This cycle is fast, usually a matter of a few days. An example of this is the common cold. The other method is the **lysogenic cycle** that only uses DNA carrying viruses. Here the DNA in inserted into the DNA of the host cell where it can remain dormant for months or even years. At some future time, the viral genes are activated which cause the cell to enter the lytic cycle. Viruses that contain RNA (**retroviruses**) use a different method to





reproduce. Along with the RNA, an enzyme that can transcribe DNA also enters the host cell. The enzyme uses the viral RNA as a template to make viral DNA which enters the cell's nucleus and combines with the DNA of the host cell in the lysogenic cycle. While viruses can multiply and evolve over time, they are not considered to be alive as they cannot reproduce by themselves and require a cell host. While they are used in research, there are no major beneficial uses of viruses.

D32. ***Describe how bacterial and viral infectious diseases are transmitted, and explain the roles of sanitation, vaccination and antibiotic medications in the prevention and treatment of infectious diseases.***

An **infectious disease** is one which can be passed from one organism to another. A **pathogen** is something that causes an infectious disease such as bacteria and viruses. For a pathogen to spread there needs to be a source and a method of passing them from one object to another. Humans are the main source of pathogens that affect other humans, but animals, food and non-living things such as water and soil can also be the original source. Diseases can be transmitted by many means including direct contact (shaking hands, kissing, sexual activity), indirect contact in the air (sneezing, coughing), indirect contact by using the same object (sharing a toothbrush or toys, body fluids) or by **vectors** (disease carrying animals, such as mosquitoes, flies, rabid animals, etc).

Sanitation can help prevent disease transmission in many ways. Treatment plants for human waste, both garbage and biological, help destroy the pathogens and keep them away from the human population. Cleaning up dumpsites removes breeding sites for mosquitoes such as old tires and lessens their attraction to vermin. Personal cleanliness kills and removes bacteria from the skin, as does careful washing of dishes and countertops.

Vaccination or **immunization** is the introduction of a dead, weakened or synthetic form of a pathogen into the body to stimulate the body to produce chemicals that will cause the body to become immune. Vaccination decreases the risk of getting the disease or decreasing its severity. There is a chance of contracting the disease after a vaccination but it is extremely slight. An **antibiotic** is a drug used to kill or inhibit bacteria. Antibiotics are totally ineffective against viruses. They are used mostly as a cure or sometimes for prevention as in the use of antibiotic creams for cuts and scratches. Over the years, many bacteria have evolved and are now not affected by the common antibiotics. Prevention of viral infections is best accomplished by regular hand washing, covering the mouth when coughing or sneezing and avoiding contact with anyone who already has a viral infection.

D33. ***Explain how bacteria and yeast are used to produce foods for human consumption.***

There are two general types of respiration: Aerobic (with oxygen) and anaerobic (without oxygen). While aerobic respiration is the typical pathway that we use (unless over-exerting ourselves), bacteria and yeast respire anaerobically producing lactic acid and alcohol (ethanol) respectively. Anaerobic respiration uses less energy (ATP) than aerobic respiration.

Bacteria are used in many kinds of food production. The most common is in making cheese. Bacteria are added to milk where they begin lactic acid fermentation, changing lactose (milk sugar) into lactic acid. The acid causes the milk to curdle (clump) and this curd is then made into cheese. The flavor of many cheeses (brie and blue cheese for example) is produced by the addition of simple fungi (molds). Sour cream and yogurt are made by fermenting cream or milk with bacteria. The sugar in cabbage can be fermented using bacteria to produce the sour tasting lactic acid to make sauerkraut. Soy sauce and pickles are made in similar fashion. Bacteria are used in chocolate processing to break down the hard outer shell of the cocoa bean and in making food supplements such as vitamin B12 and riboflavin. Expensive steaks are also aged so mold can break down the protein to make them tender.

Yeast is the dried form of a single celled fungus. Yeast causes alcoholic fermentation producing ethanol (C_2H_5OH) and carbon dioxide. Yeast cells in the dry form are dormant, but when placed in a moist environment, they rapidly begin to grow and multiply. Yeast is used in bread making. The carbon dioxide formed during fermentation in the dough causes little bubbles to form and the dough rises. The ethanol formed is evaporated off during baking. Yeast is also used in fermenting fruit and vegetables to produce beer, wine and other alcoholic beverages.

D34. ***Describe, in general terms, how the genetic information of organisms can be altered to make them produce new materials.***

Permanent changes in the genetic sequence are called **mutations**. These changes occur naturally, although infrequently. Sometimes the wrong nucleotide is inserted into the growing nucleic acid and this change will be passed on as the cells multiply. In other cases, a molecule resembling a nucleotide is inserted which makes it impossible for the nucleic acid to replicate. This change cannot be passed on to future generations of cells. Certain chemicals and radiation, including sunlight, called **mutagens**, can cause mutations causing genetic damage and disease. Not all mutations are bad. Natural genetic mutations are the driving force of evolution allowing the beneficial traits to accumulate through natural selection.

Transgenic organisms are organisms that carry a gene or genes from another organism. They can be made in the laboratory by taking a strand of DNA from the host and chemically adding or inserting a fragment of DNA from another source. **Recombinant DNA** is DNA from two or more different sources. The process of doing this is called **genetic engineering**. Another way of accomplishing this is used in gene therapy. This process is used to correct mutated genes in humans and animals that cause disease. Here a normal gene is inserted into the genetic material of a harmless virus that is injected into the host. This new genetic material is released into the cells and combines with the DNA of the host thereby replacing the damaged gene.

Transgenic plants such as corn, soybeans and cotton have been developed to produce their own insecticides and herbicides. Peanuts are being developed which will not cause an allergic reaction. Other plants now produce vitamins and other nutrients that are not found in the original plant. Other plants have been made so they can grow in different environments. Many animals also carry altered genes that make them more resistant to disease. Other animals have been genetically engineered to produce complex molecules used in medicine. Bacteria have been genetically engineered to produce medicines, to protect crops from frost damage and to clean up oil spills.

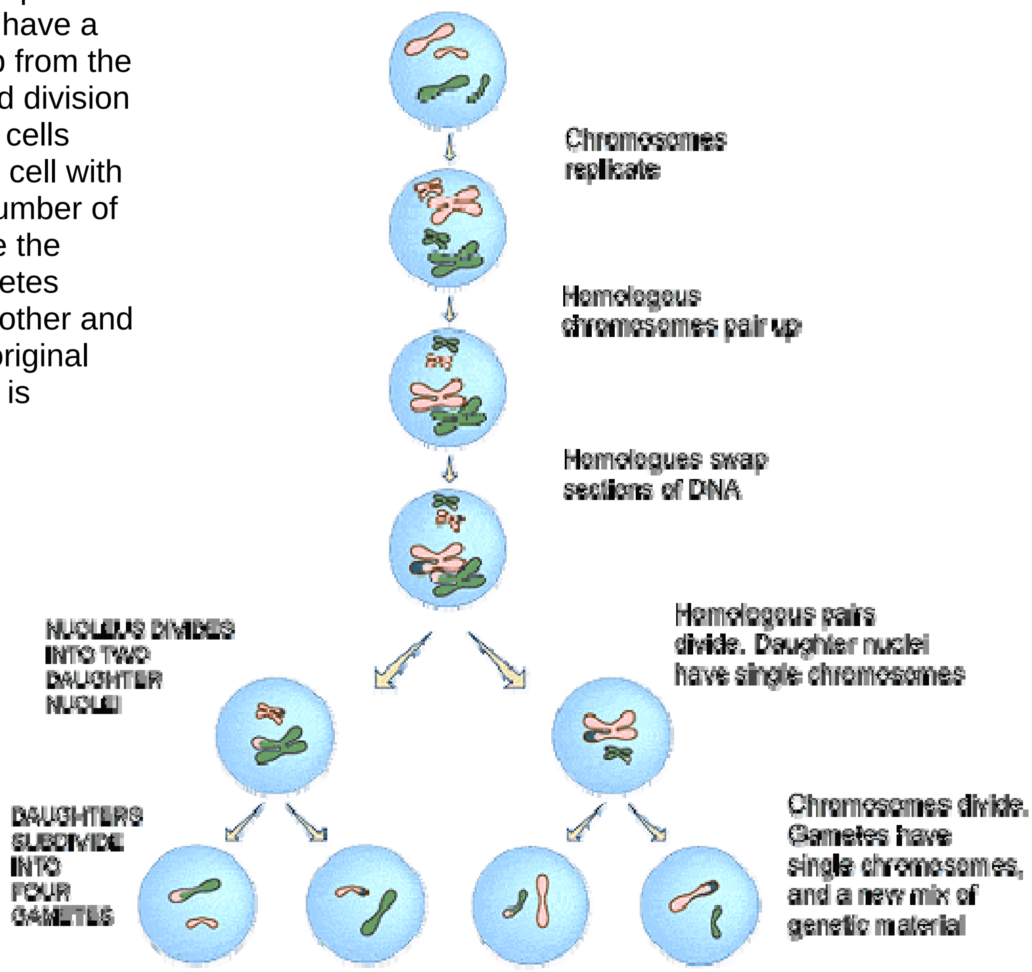
D35. ***Explain the risks and benefits of altering the genetic composition and cell products of existing organisms.***

Man has been altering the genetic composition of plants and animals for thousands of years through selective breeding and new species have been created. Animals have developed to grown bigger or in miniature, stronger and healthier. Plants have been developed to produce more seed or fruit, to grow in other environments and to have fancier and more colorful flowers. Genetic engineering has sped up this process and allows scientists to replace or insert specific genes. For example, a glow-in-the-dark rabbit was produced when a gene from phosphorescent bacteria from the ocean was spliced into rabbit DNA. Some of the benefits of genetic engineering are discussed in D34.

Scientists do not agree on whether all genetically engineered plants and animals are good or bad and there are valid arguments both pro and con. The US government is trying to control the manufacture and distribution of genetically modified (GM) plants and animals. Plants are the most difficult to control since pollen blows in the wind and can pollinate non-GM species and bees and butterflies cannot tell the difference. Hardier plants may be good some places but in others they could drive out the native species. Plants that produce insecticide to give a better crop could also kill beneficial insects such as bees and butterflies. Plants with a resistance to bacteria might actually pass this trait to bacteria making them tolerant to antibiotics. Plants that produce vitamins and other dietary supplements may cause physical problems or diseases that develop in humans over a lifetime. Food crops or herds that grow bigger and faster could ease the world food shortage. Food containing a gene against yellow fever and malaria could save millions of lives a year. There is no one single answer and each case needs to be carefully studied by scientists and not politicians.

D36. ***Explain how meiosis contributes to the genetic variability of organisms.***

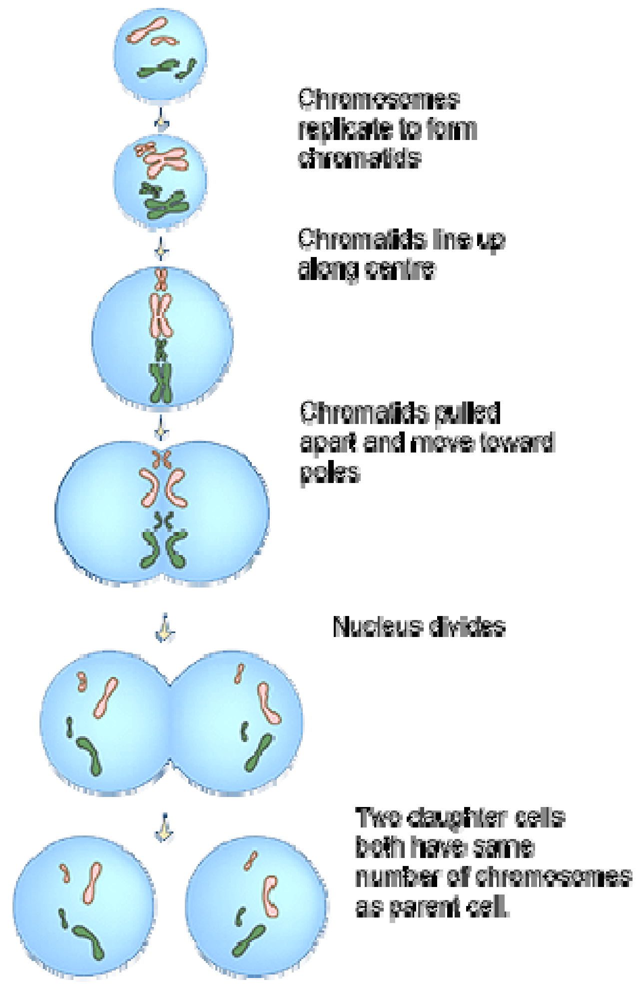
Meiosis is the process of forming **gametes** (sex cells, eggs and sperm). This process reduces the number of chromosomes by half and is also referred to as reduction division. Meiosis involves two consecutive cell divisions. In the first, the chromosomes replicate and then pair up at the cell equator. At this stage, **crossing over**, the swapping of genetic material from one chromosome to another, occurs. The cell splits into two daughter cells which have a different genetic make-up from the original cell. In the second division each of the two daughter cells divides leaving each new cell with only half of the original number of chromosomes. These are the gametes. When two gametes combine, one from the mother and one from the father, the original number of chromosomes is restored.



In meiosis, how the chromosomes line up at the equator of the cell is a random process and gametes with different combinations of chromosomes are formed. The amount of crossing over will also vary so that the probability of having identical gametes is rare. Variety in the embryos is also increased in that any two gametes can combine to form an embryo.

In humans, each gamete contains 23 single chromosomes. The number of chromosomes is usually symbolized by **n**. A cell with n chromosomes is called a **haploid** cell. When a human egg and sperm combine, the total number of chromosomes doubles to 2n or 46. Cells with 2n chromosomes are called **diploid** cells.

Mitosis is a different process. In **mitosis** the DNA is replicated and the cell divides into two daughter cells, each with the exact same DNA. The two cells are genetically identical. Mitosis occurs as an organism grows. In the initial step of mitosis, the chromosomes replicate producing exact copies of themselves. The chromosomes then move to the cell's equator where they separate and move towards the poles of the cell. Finally the cell splits into two identical daughter cells which are also identical with the parent cell. This allows each cell to carry the same genetic information as the previous generation.



MITOSIS	MEIOSIS
One cell division occurs	Two different cell divisions occur
No crossing over occurs	Crossing over does occur
Two cells are produced, each with 2n chromosomes, diploid	Four haploid cells formed each with n chromosomes, haploid
Daughter cells are identical	Daughter cells all different
Occurs only in body cells	Occurs only in reproductive cells
Involved in cell growth and repair	Gamete production providing genetic variation due to crossing over

D37. ***Use the Punnet Square technique to predict the distribution of traits in mono- and di-hybrid crossings.***

A **Punnet Square** is a way of showing what different genetic combinations can be formed and in what statistical proportions when an egg and a sperm combine. An **allele** is an alternative form of a single gene for a particular trait. A genetic **trait** (a distinguishing characteristic), such as eye color, is expressed by two alleles, each represented by a letter where each letter represents the allele from one parent. An upper case letter represents the **dominant** trait, the trait that will mask the **recessive** trait (the trait that will be covered up) which is represented by a lower case letter. When the two gametes combine, each cell will then have two letters to indicate the results of the combining gametes. For example, B represents the allele for brown eyes and b represents the allele for blue eyes. If a person receives a B from each parent (BB) then s/he will have brown eyes. If a person receives a B from one parent and a b from the other, the resulting Bb will still produce brown eyes because B is dominant over b. Only if the child receives a b from each parent will it have blue eyes. The **phenotype** is the observed characteristic that can be produced by various alleles, and the **genotype** is the actual gamete pair.

A monohybrid cross shows the predicted results for the genetic cross on a single gene. Again for eye color: A man with brown eyes (BB) has a child with a woman with blue eyes (bb). What are the chances of the baby having blue eyes?

Begin with a box (blue) and write the male trait on top of the box and the female trait on the left.

	Male BB		
Female			
bb			

Take the gamete types and separate them into the boxes directly above the shaded area for the male, and to the left for the female

	Male BB		
		B	B
Female	b		
bb	b		

In the shaded area, write the letter for the gamete from each parent. The dominant trait is always written first.

	Male BB		
		B	B
Female	b	Bb	
bb	b		

Complete the remainder of the table.
All the possible combinations are Bb so all of the offspring have the same genotype with brown eyes.

	Male BB		
		B	B
Female	b	Bb	Bb
bb	b	Bb	Bb

What are the chances of an offspring having blue eyes with a male (Bb) and a female (bb)?

Completing the chart as above shows that two of the offspring will have brown hair (Bb) and two will have blue eyes (bb).

	Male Bb		
		B	b
Female	b	Bb	bb
bb	b	Bb	bb

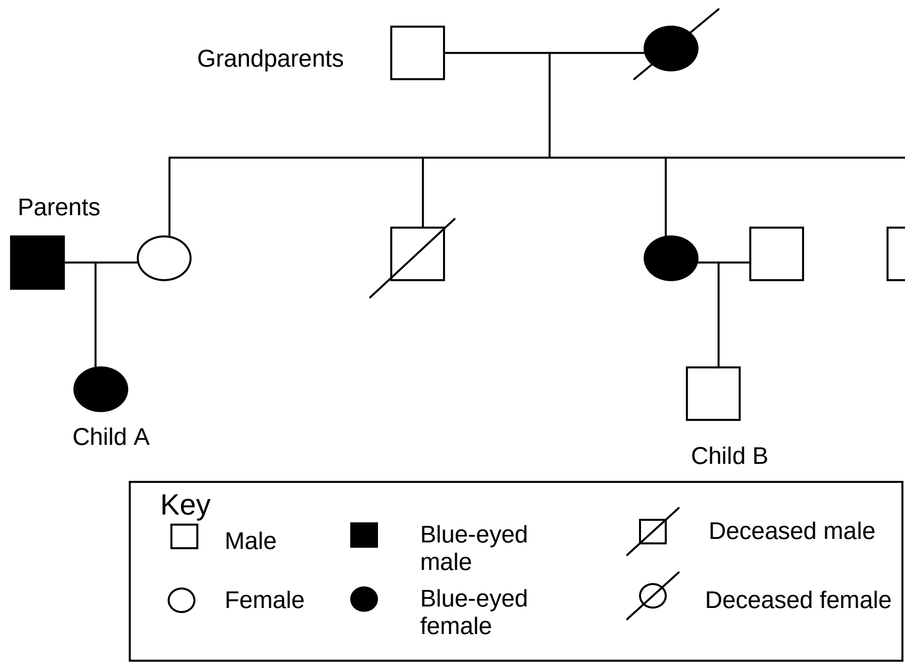
In a di-hybrid cross, two different traits are considered. In hair color, brown (H) is dominant over blond (h). The Punnet Square is developed in the same manner except the various gametes have to be shown in all their possibilities. A brown eyed (Bb), brown haired (Hh) person would have these possible gamete pairs to give to an offspring: BH, Bh, bH and bh. If a male (BbHh) with these traits had offspring with a brown eyed, brown haired female (BbHh) the chart would look like this:

		Male BbHh			
		BH	bH	Bh	bh
Female BbHh	BH	BBHH Brown eyes Brown hair	BbHH Brown eyes Brown hair	BBHh Brown eyes Brown hair	BbHh Brown eyes Brown hair
	Bh	BBHh Brown eyes Brown hair	BbHh Brown eyes Brown hair	BBhh Brown eyes Blond hair	Bbhh Brown eyes Blond hair
	bH	BbHH Brown eyes Brown hair	bbHH Blue eyes Brown hair	BbHh Brown eyes Brown hair	bbHh Blue eyes Brown hair
	bh	BbHh Brown eyes Brown hair	bbHh Blue eyes Brown hair	Bbhh Brown eyes Blond hair	bbhh Blue eyes Blond hair

Of the sixteen possibilities, nine will be brown-eyed with brown hair, three will be brown-eyed with blond hair, three will be blue-eyed with brown hair and only one will have blue eyes and blond hair. This is because different combinations of gametes can produce the same traits.

D38. ***Deduce the probable mode of inheritance of traits (e.g., recessive/dominant, sex-linked) from pedigree diagrams showing phenotypes.***

Pedigree diagrams trace the inheritance of a trait through several generations. Using eye color (D37) the blue-eyed grandmother must have the two alleles bb and is **homozygous** (both alleles are the same). The grandfather must have the alleles Bb since one daughter has blue eyes. The three sons must be **heterozygous** (the two alleles are different) with Bb. Child A is homozygous (bb) receiving her two recessive genes from her blue-eyed father and recessive mother while Child C's parents must have both been heterozygous (Bb). It is not possible to determine whether Child B's father was BB or Bb.



Note: If the pedigree diagram is used to follow a disease, the shaded individuals will have the disease and display the symptoms of that disease.

Sex-linked are those genes that are located on either the X or Y chromosome. The X chromosome (female) is much larger than the Y chromosome (male) and contains many more genes. Since males (XY) have only one X chromosome, any allele on the X chromosome will be expressed even if it is recessive.

D39. ***Describe the difference between genetic disorders and infectious diseases.***

Genetic disorders are diseases or physical deformities caused by errors in the inherited genetic code or by prolonged exposure to radiation. They are specific to an individual and can only be passed on to that person's offspring. Genetic disorders can be either dominant or recessive. A person only needs one copy of a dominant disease gene to display symptoms of the disease or the deformity. A person with a recessive disorder will not show any signs of the disease or deformity if s/he has a genotype of Aa, but can pass the trait(s) on to offspring. A recessive disorder can only be displayed if the genotype is aa. There is no cure at this time in the US since gene therapy is banned although there are treatments for some disorders. Infectious diseases are caused by bacteria or viruses (see D32). They spread easily from person to person either by personal contact or through the air. There are cures for many infectious diseases.

D40. ***Explain how the processes of genetic mutation and natural selection are related to the evolution of species.***

An **adaptation** is a characteristic or trait that helps an organism to better survive in its environment. Adaptations in nature can include size, beak shape, coloring or flower shape, enzyme efficiency and many, many more. Adaptations can occur through genetic mutations that occur randomly over time, or in response by existing traits to a change in the environment. Sometimes the physical changes caused by the mutation are harmful or fatal and do not get passed along to another generation. Other mutation can cause beneficial effects that allow the organism to better survive and reproduce, passing this new trait on to future generations. Adaptations can be beneficial, neutral or harmful. The theory of **natural selection** explains why adaptations are passed on to future generations. There are three aspects to the theory of natural selection: (1) individuals in a species population show variations and these variations can be inherited, (2) organisms have more offspring than can be sustained by the environment. and (3) any variation that increases the reproductive success of that organism has a greater chance of getting passed on to future generations. The accumulation of genetic mutations and adaptations over time is known as **evolution**.

D41. ***Explain how the current theory of evolution provides a scientific explanation for fossil records of ancient life forms.***

Fossils are the preserved parts or the impressions of parts of ancient organisms. Scientists have found that rocks of different ages preserved different combinations of fossils, and that these combinations succeeded one another in a regular order. The simpler fossils were found in the lower layers of rock (older) while the more complex fossils were found in the upper (more modern) layers. The placement of these fossils over time is the **fossil record**. The fossil record shows how species have changed over time and provides a history of life on Earth. There are two classes of traits used in studying fossils. **Derived traits** are the newly evolved features and **ancestral traits** that are the traits that do appear in the more ancient forms. By knowing the ages of the fossils and by observing the appearance and disappearance of certain traits the evolutionary history of a species can be derived.

The fossil record shows that of all species that once existed over 95%have died out. It is possible to trace their evolution over time. Some species existed for only a relatively short period of time while other species, for example the horseshoe crab and the cockroach which still exist, originated before the dinosaurs. Examining the fossil record also shows the ancestors of present species. It is now believed that birds evolved from some form of feathered, non-flying, four-legged dinosaur.

D42. ***Describe how structural and behavioral adaptations increase the chances for organisms to survive in their environments.***

An **adaptation** is an inherited trait or characteristic that allows a species to better survive in its environment. Organisms must be able to get air, food and water; defend themselves from natural enemies; reproduce and respond to changes around them such as temperature and light. These changes occur through natural selection. **Structural adaptations** are changes in the anatomy of a species that increase its chances of reproducing. The development of wings and the ability to fly is an example of structural adaptation. This allowed birds a rapid means of fleeing predators, searching for food and migrating to various climates. The ability of cacti and camels to store water allows them to live in areas with little water away from their enemies. **Behavioral adaptations** are genetic (instinct) or learned traits and are an animal's way of responding to a stimulus (a change in the environment that has a direct effect on that animal). When cornered by an enemy, an opossum will 'play dead' hoping it will be ignored by a predator. Cold-blooded creatures, such as snakes and lizards, will lie in the sun or on a dark rock to keep warm in the evening and hide in the shade if it gets too hot during the day. Penguins group in a circle to protect their young and keep them warm. Many birds have specific calls or songs to attract a mate, mark a territory or call alarm.

D43. ***Describe the factors that affect the carrying capacity of the environment.***

The **carrying capacity** is the greatest number of a species that can be supported for the long term by a specific environment. The carrying capacity is limited by the amount of energy (including sunlight), water, oxygen and food available. When a population is just beginning in an environment the resources are plentiful and the population grows rapidly with more births than deaths. As the carrying capacity is approached, the resources become limiting until that number is exceeded. Then the number of deaths becomes larger than the number of births and the population decreases. Eventually the population of a species remains relatively constant unless affected by a change in the environment. If a population exceeds the carrying capacity the whole population might become affected due to a lack of resources that can weaken the entire population. The carrying capacity of an environment will vary for different species in different habitats and can increase or decrease with changes in the environment.

Some of the limiting factors that control population size are: competition for food and space, an increase in predators, climate changes such as drought or temperature changes, the outbreak of disease or parasitism and changes to the environment caused by man. All animals require food for survival. A more dense population decreases the amount of food available for the individual. Likewise, different species require specifics locations to breed and raise their young and the denser the population the less room there is for everyone. The introduction of a predator into the environment decreases the population until the predator is removed or until new traits, either biological or behavioral, are developed that aid the survival. As a population becomes more dense, diseases and parasites are spread more easily and can decrease the population far below the carrying capacity.

D44. ***Explain how change in population density is affected by emigration. Immigration, birth rate and death rate, and relate these factors to the exponential growth of human populations.***

The **population density**, usually given as the number of people residing in a square mile, is a measure of how close together people are living in a specific region or area. **Emigration**, the movement of people away from an area, decreases the population density while **immigration**, the movement of people into an area, increases it. The birth rate is affected by the number of children each woman has, and her age when she begins to have them. The younger the mother, the more likely she will live to see grandchildren and even great grandchildren. An increase in the birth rate will cause a rise in the population density. On the other hand, the death rate is slowly decreasing due to better diet and medical treatment.

The study of human populations is called **demographics**. For most of the last ten thousand years, up until about 1500 AD, the human population remained fairly constant with a high birth rate and high death rate. Families had many children in the hope that some would survive. Disease, poor nutrition and lack of good shelter killed over half the population before middle age. An increase in agriculture and available shelter raised the carrying capacity of the land and allowed humans to live in harsher environments. Advances in sanitation and medicine raised the birth rate and decreased the death rate and the population began to increase rapidly. Most of the countries of the world are in this situation today. However, in some modernized western countries including the US, families began to have fewer children and the birth rate decreased. This decrease is expected to continue until the birth rate and the death rate are about equal. This change from high birth rate and high death rate to a low birth rate and a low death rate is called the **demographic transition**.

D45. ***Explain how technological advances have affected the size and growth rate of human populations throughout history.***

For most of human history environmental conditions limited the population to below the Earth's carrying capacity. Unlike other animals that must adapt to their environment, man adapts the environment to himself. Humans learned how to farm and domesticate animals for a better and secure food supply. They learned how to build shelters to protect themselves and which allowed then to live in previously unpopulated regions. Advances in medicine and technology increased life expectancy and decreased the reliance on manual labor. Clean drinking water and better sanitation increased the birth rate and lessened the death rate. Electrification allowed for better food storage and made survival in harsh climates possible. Development of insecticides and herbicides have increased the per acre amount of food produced, decreasing the amount of farmed land and leading to the development of cities with high population densities.