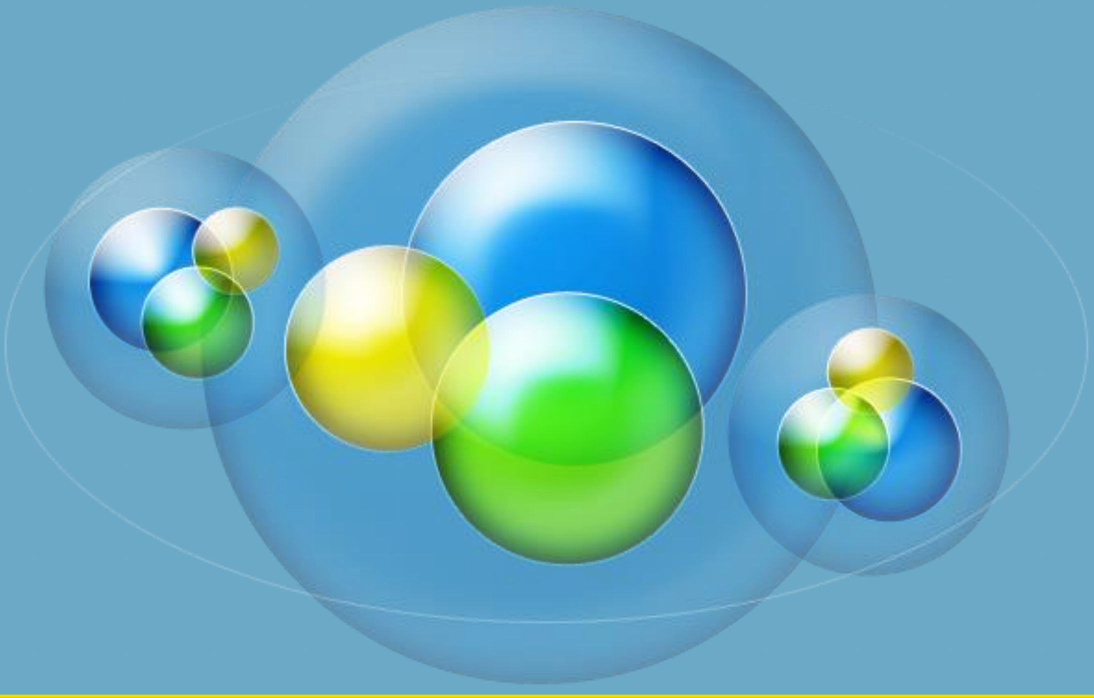


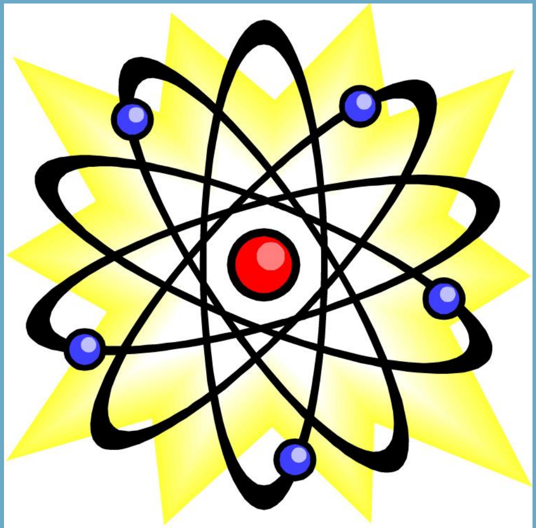
The Chemistry of Biology

Life depends on chemistry!

Life depends on chemistry.

Living things are composed of chemical compounds.

In order to understand biology, one must first understand

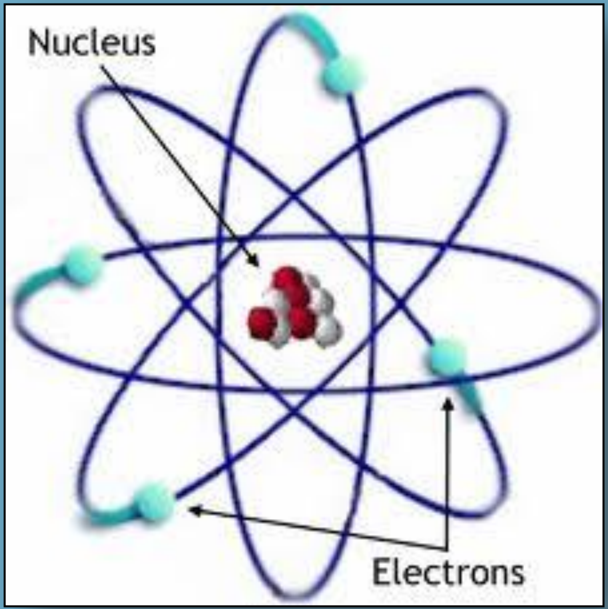


The Atom

1. An atom is the basic unit of matter.
2. The atom is the smallest particle of a substance that still retains the properties of that substance.
3. Atoms are composed of subatomic particles:
   Protons, neutrons, and electrons.
4. Protons and neutrons have about the same mass and together form the nucleus of the atom.
5. Electrons have a mass of about 1/1840th the mass of a proton and are in constant motion in the space surrounding the nucleus.

The subatomic particles have charges:

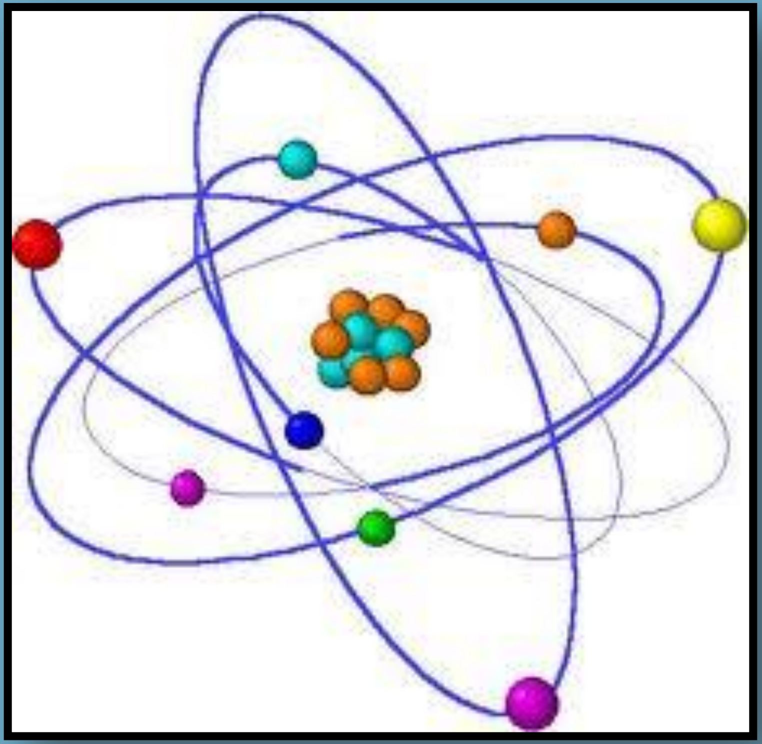
Protons have a positive charge.



Electrons have a negative charge.

Neutrons have no charge.

Elements

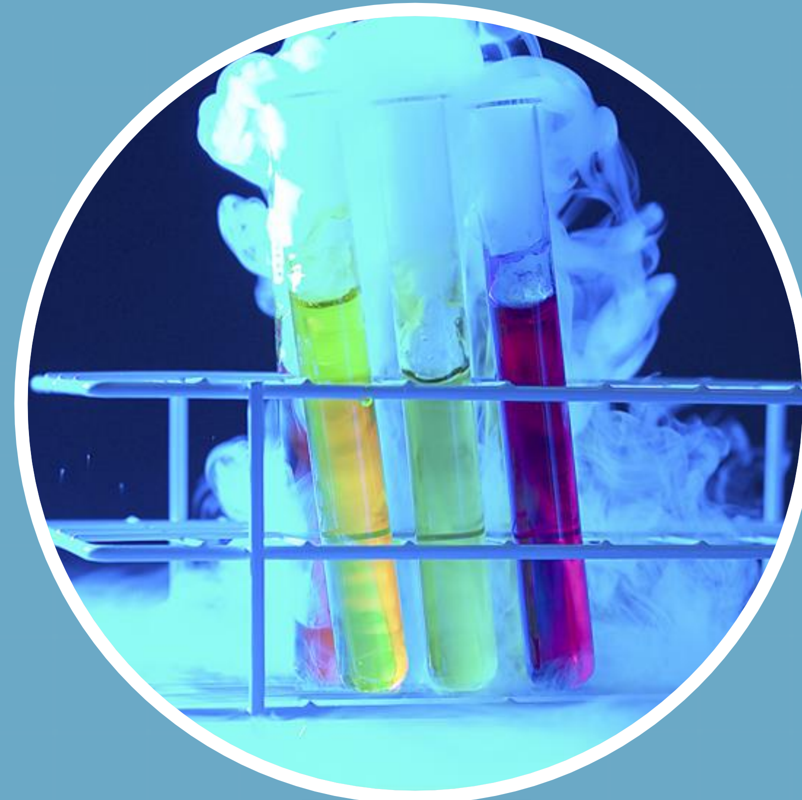


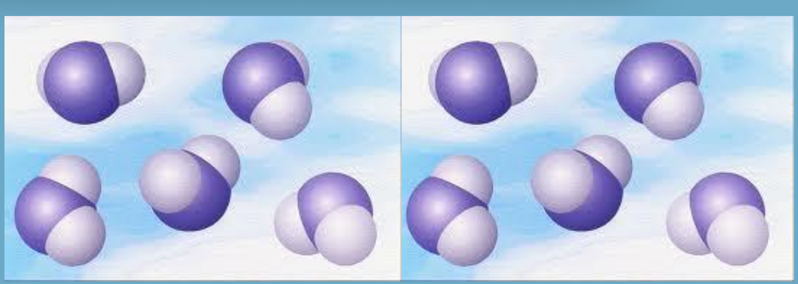
An element is <u>a pure substance consisting of all the same type of atom.</u>

There are more than 100 known elements, but only about 20-24 are commonly found in living organisms.

Compounds

A compound is __the chemical combination of two or more elements in definite proportions.__

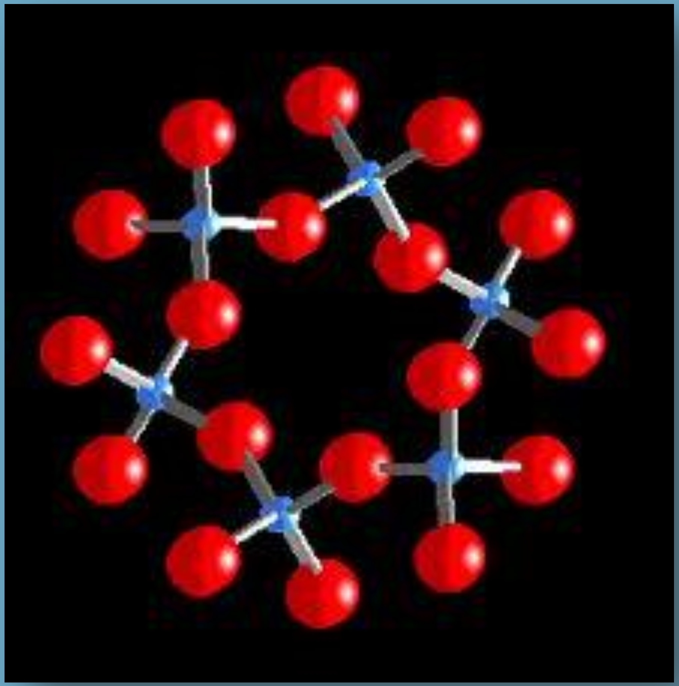




For example: The formula of water is H_2O. There are 2 hydrogen atoms bonded to one oxygen. This definite ratio is always present in water.

The atoms that compose compounds are held together by chemical bonds.

Bond formation always involves the electrons that surround the nucleus of each atom.



There are two main types of bonds:

Ionic
Covalent

Chemical Bonds

An ionic bond is formed when one or more electrons are:

transferred from one atom to another.

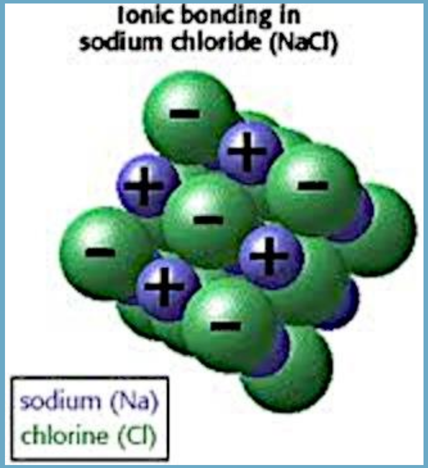
When electrons are gained or lost, **ions** are formed. Ions are atoms that have either gained or lost electrons.

If an atom loses electrons, it will then have a _positive_ charge.

If an atom gains electrons, it will then have a _negative_ charge.

An ionic bond is formed when . . . .

. . . . ions of opposite charges are attracted to one another.

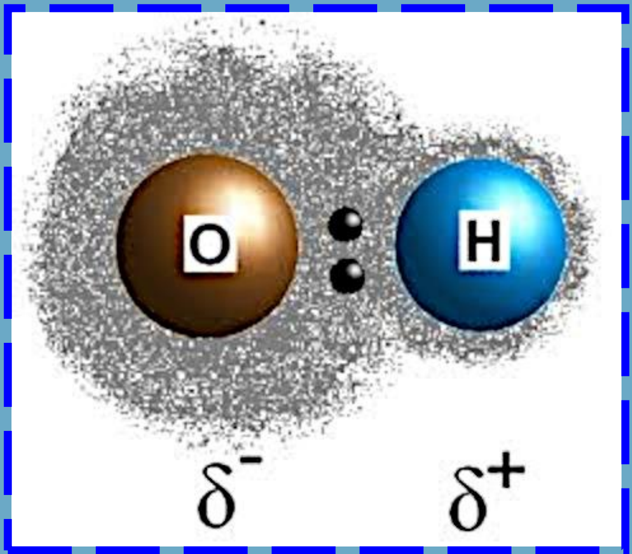


The attraction between <u>oppositely charged ions</u> is an ionic bond.

For example: Sodium tends to lose an electron and becomes a Na^{+} ion. Chlorine tends to gain one electron and becomes a Cl^{-} ion. These two ions are then attracted to one another because they have opposite charges. The compound NaCl is formed.

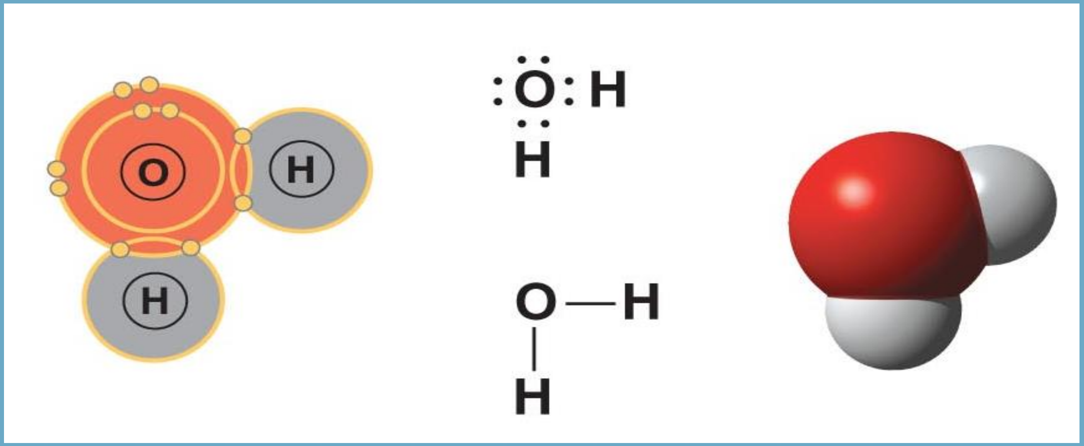
Covalent Bonds

Sometimes electrons are <u>shared</u> between atoms instead of being transferred.



When electrons are shared between two atoms, the shared electron spends time traveling around the nuclei of both atoms.

A covalent bond is formed when electrons are shared between atoms.



For example: In a water molecule, each hydrogen atom shares electrons with the oxygen atom.

The shared electrons spend part of the time traveling around the _hydrogen_ nucleus and part of the time traveling around the _oxygen_ nucleus.

When atoms are joined together by covalent bonds, _molecules_ are formed. A molecule is the smallest unit of a compound.

Polar Molecules

North Pole

When covalent bonds are formed between atoms of different elements, there are different degrees of ….

… attraction for the shared electrons.

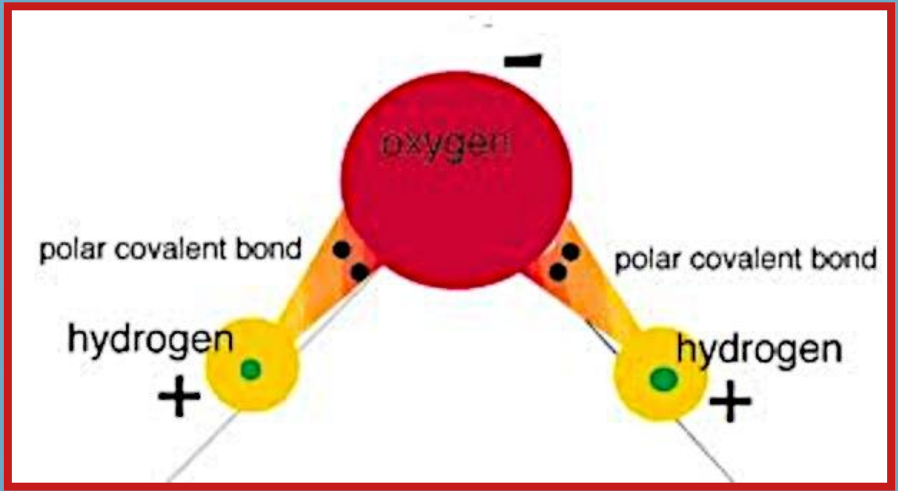
Polar molecules don't have anything to do with cold temperatures, but these molecules do have opposite ends …. Or poles!

Some atoms have a stronger attraction for electrons than do other atoms. As a result, the electrons are not shared equally.

South Pole

In covalent bonds formed between atoms of different elements, the electrons are not ….

….shared equally between the atoms involved.



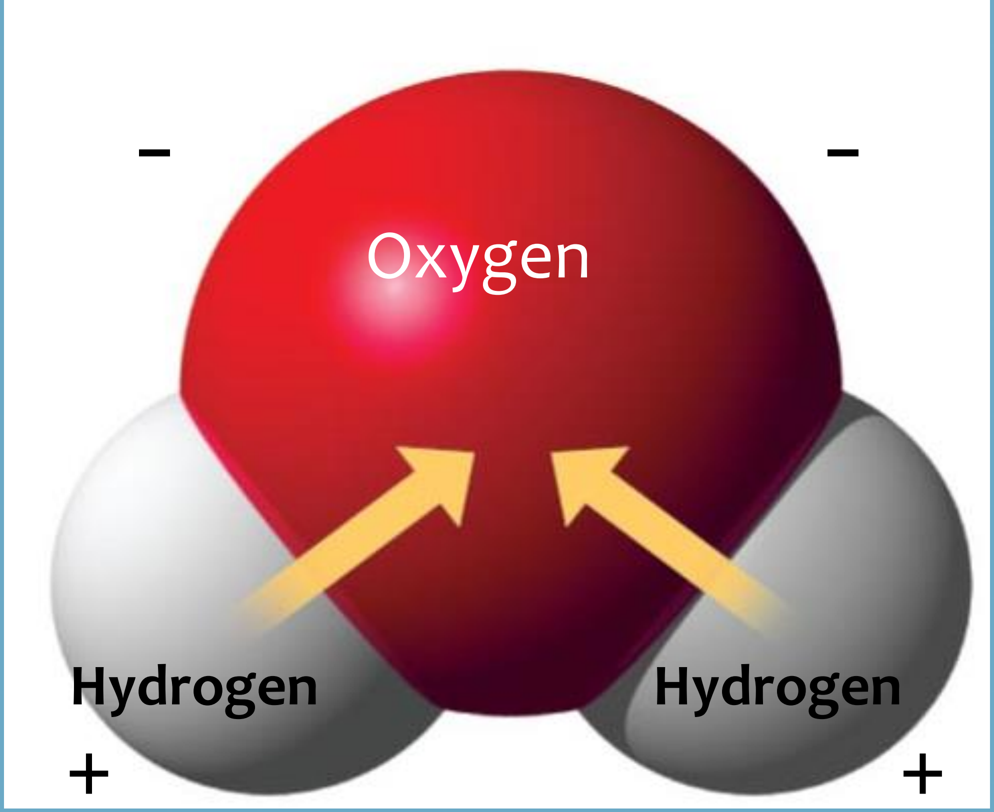
The atom around which the electrons spend the most time will have a _slightly negative_ charge, and the atom around which the electrons spend the least time will have a _slightly positive_ charge.

Polar Covalent Bonds:

Covalent bonds in which electrons are shared unequally resulting in a molecule which has poles -- part of it is negative and part of it is positive.

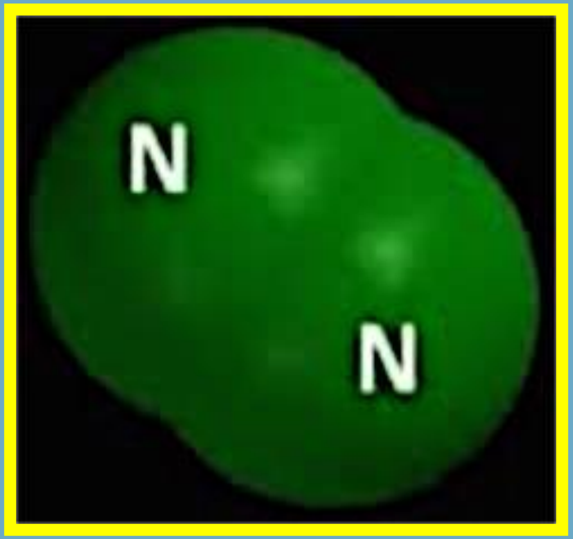
In a water molecule, oxygen has a <u>stronger attraction</u> for the shared electrons. The shared electrons spend more time around the <u>oxygen</u> atom, so the oxygen atom has a <u>slightly negative</u> charge.

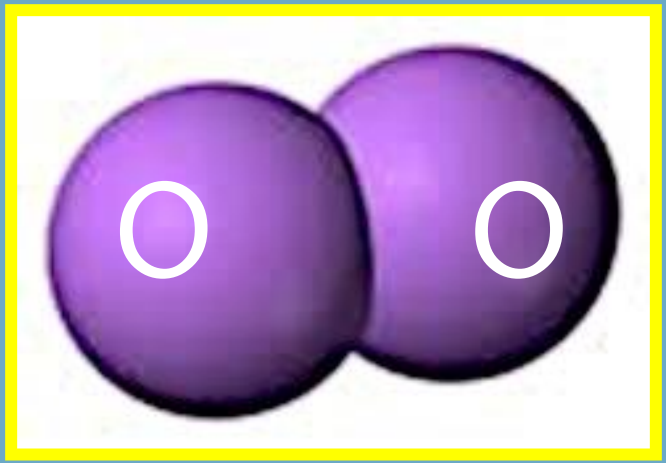
The shared electrons spend less time around the <u>**hydrogen**</u> atom, so the hydrogen atom has a <u>**slight positive**</u> charge.



A water molecule is: polar because one end is positive and one end is negative.

Nonpolar Covalent Bond: The electrons are shared <u>equally</u>. These bonds exist between identical atoms such as H_2, Cl_2, O_2, and N_2.





Water – We Can't Have Life Without it!

The polarity of water is so important!
Let me say this one more time!!

In a water molecule, an oxygen atom has a much <u>stronger attraction</u> for electrons than does the hydrogen atom. At any given time, there is a greater probability of finding the shared electrons near the <u>oxygen</u> atom than near the <u>hydrogen</u> atom.

As a result, the oxygen end of the molecule has a slight negative charge and the hydrogen end of the molecule has a slight positive charge.

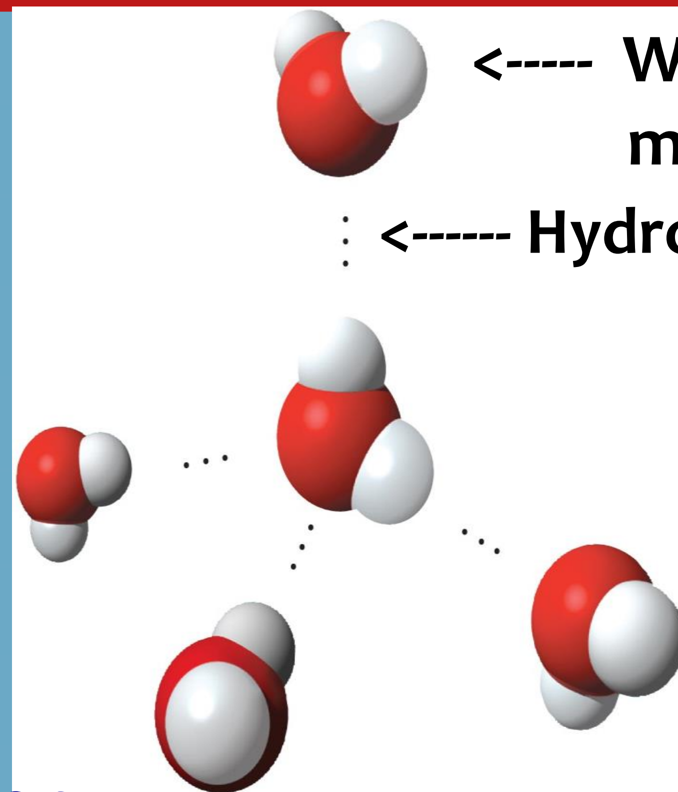
A molecule that is positive at one end and negative at the other end is called a **polar molecule.**

A water molecule is polar because there is an uneven distribution of electrons between the oxygen and hydrogen atoms.

Hydrogen Bonding

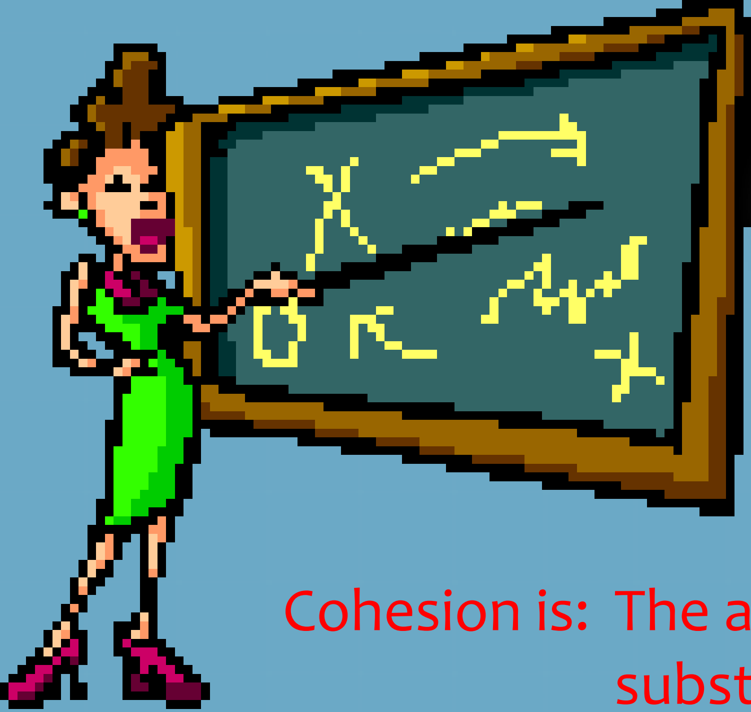
Water molecules stick together because the opposite charges of the molecules attract one another.

This force of attraction forms <u>hydrogen bonds</u>.



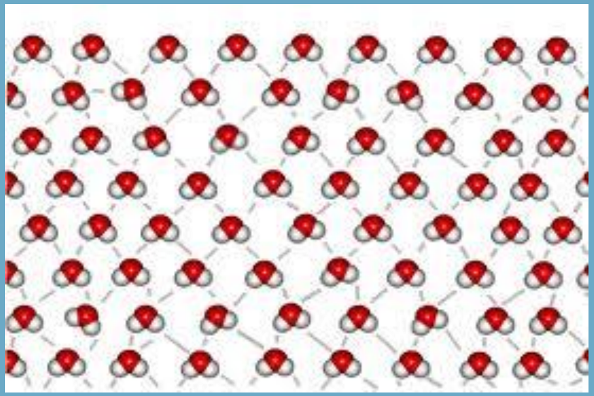
The attraction between **the oxygen of one water molecule and the hydrogen of a different water molecule forms a hydrogen bond.**

A single water molecule can form up to **4** hydrogen bonds with other water molecules are the same time. This is responsible for many of the unusual properties found in water.



I am finally getting to the point!!
Let me tell you about cohesion and adhesion!

Cohesion is: The attraction between molecules of the same substance.



Water molecules stick to one another because of cohesion.

Adhesion is:

an attraction between molecules of different substances.

When water sticks to other substances beside itself, it does so because of adhesion.

Solutions and Suspensions

Mixture:

A substance composed of two or more elements or compounds that are physically mixed together but are not chemically combined.

Homogeneous Mixtures:

The parts of the mixture are very evenly mixed.

Heterogeneous Mixture

The parts of the mixture are unevenly mixed such as in oil mixed with water.

A solution is a homogeneous mixture. The parts of the solution are evenly mixed.

The two parts of a solution are:

Solute: the substance that is dissolved

Solvent: the substance that does the dissolving.

For example: Salt crystals will dissolve when placed in water. Salt is the solute and water is the solvent.

S
U
S
P
E
N
S
I
O
N
S

Suspension:

A mixture of water and undissolved materials

Example:
Your blood is a suspension.

Some materials do not dissolve in water, but separate into pieces so small that they do not **settle** out. These small pieces remain **undissolved** and are "**suspended**" in the solution.

Water Makes Life on Earth Possible

Without water, life on Earth would not be possible. Here are the reasons why life on Earth is dependent on water.

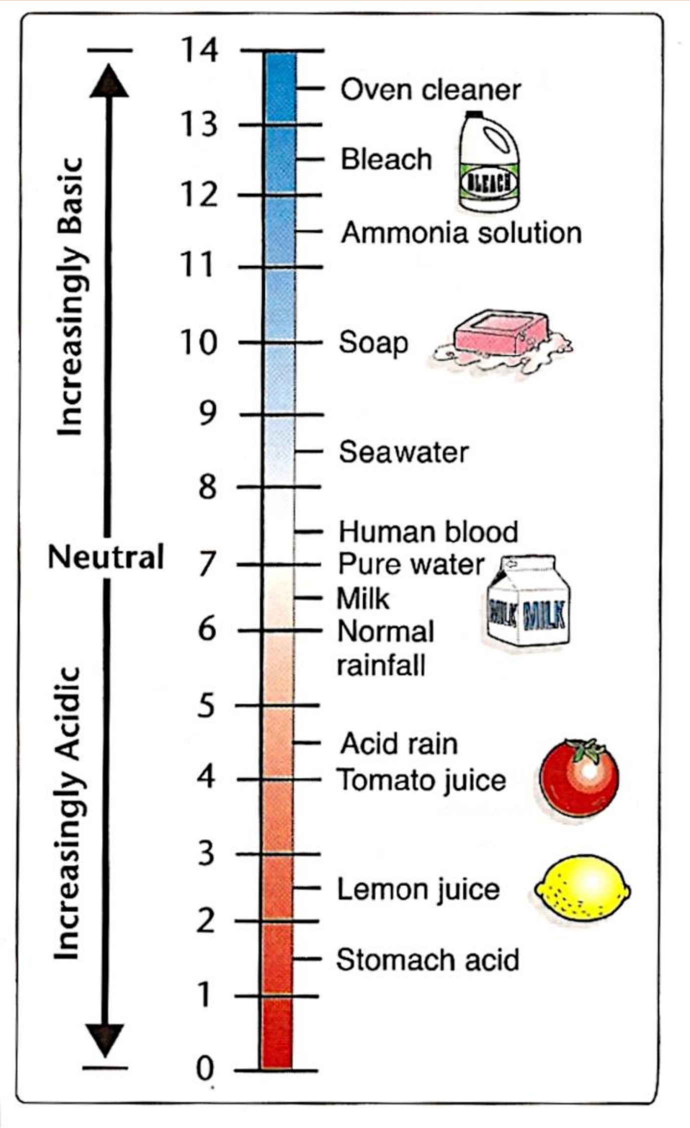
Water is cohesive. This means that water molecules like to stick together. At a wide range of temperatures, this sticking together of water molecules makes water liquid. If the temperature gets too high, hydrogen bonds are broken and water molecules will escape into the atmosphere as a gas.

Water stabilizes temperatures on Earth. Water is a very good "heat bank" because it can absorb or release a large amount of heat with only a slight change in its own temperature. Life could not exist in bodies of water if there were drastic changes in temperature. Temperatures on land are stabilized by bodies of water. Large bodies of water absorb heat from the sun during the day, cooling landmasses. Large bodies of water release heat at night warming the landmasses. This stabilizes temperatures on land as well as in the water.

Water is the solvent of life. Water is able to:

dissolve a wide variety of substances.

Acids, Bases, and pH



The pH scale

The pH scale is a measurement system used to indicate the concentration of H^+ ions in a solution.

The pH scales ranges from 0 to 14.

A pH of 7 is a **neutral** solution. This is neither acidic nor basic. Pure water has a pH of 7.

Solutions with a pH below 7 are considered **acidic**.

Solutions with a pH above 7 are considered basic.

Acid:

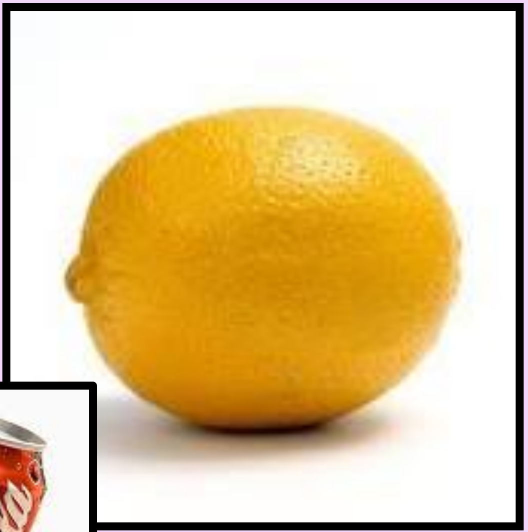
Any compound that forms H^+ ions in a solution.

Acidic Solutions:

Have a greater H^+ ion concentration that pure water.

Acids have a pH of **below 7.**

Examples include: lemon juice, tomato juice, carbonated drinks, vinegar



Base: Any compound that forms OH^- ions in a solution

Basic Solutions: Have a lower H^+ ion concentration than pure water

Bases have a pH of above 7

Examples include: ammonia, soaps, bleach, sodium bicarbonate.

Buffers

The pH of most human cells should generally be between 6 and 8.

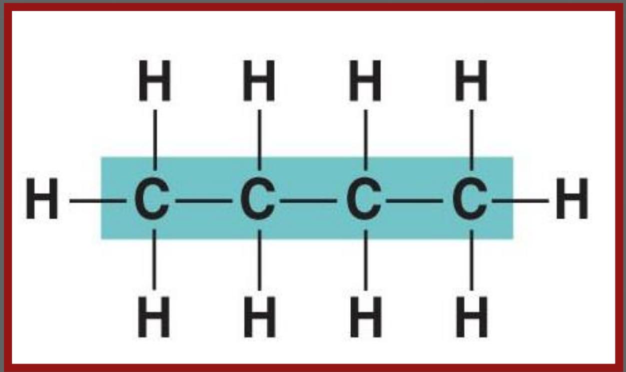
If the pH gets too high or too low, it affects the chemical reactions that take place within cells.

Cells must be able to control their pH.

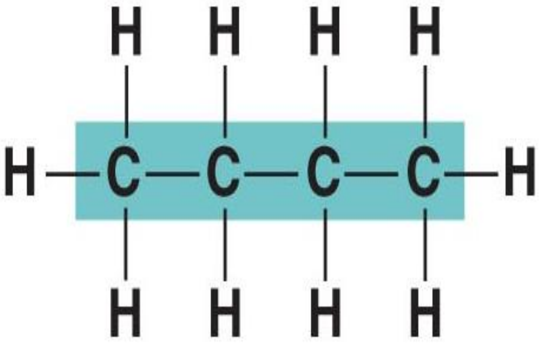
Buffers are substances produced by cells that prevent sharp, sudden changes in pH.

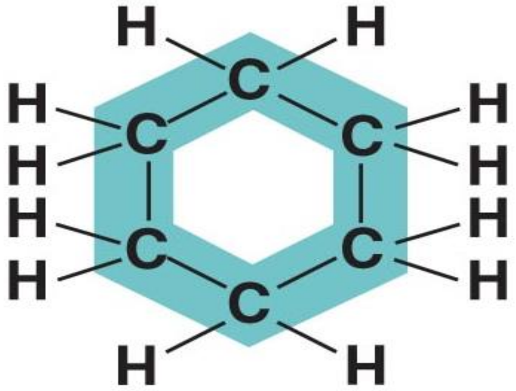
Carbon Compounds

Compounds that contain carbon atoms bonded to other carbon atoms.



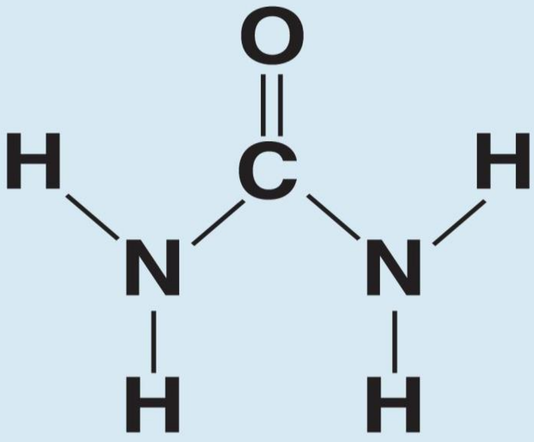
Characteristics of Carbon Include:



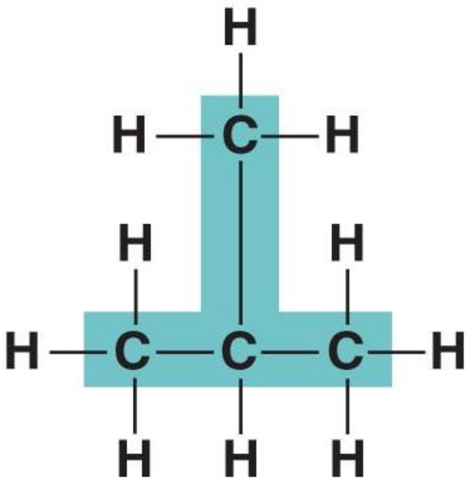


Carbon forms strong and stable bonds.

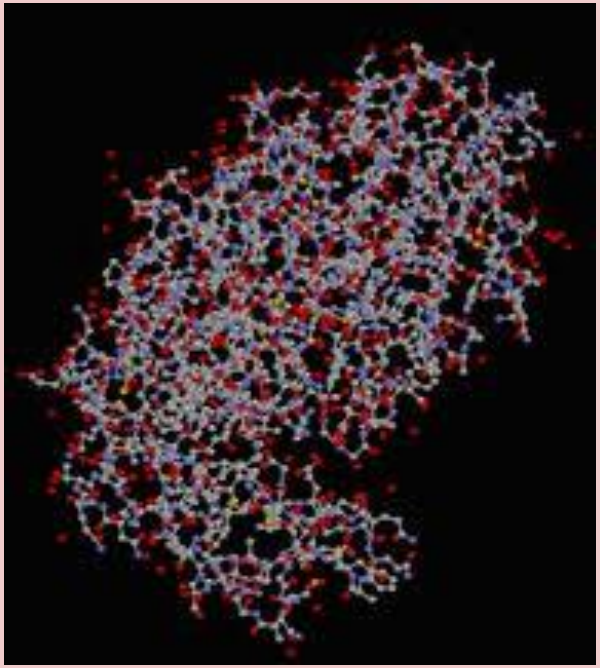
Carbon can form bonds with other carbon atoms as well as a variety of other elements such as oxygen, hydrogen, nitrogen, sulfur and phosphorus.



Carbon can form chains that are almost unlimited in size. Carbon can form chains or rings.



Macromolecules



Many of the molecules in living cells are so ___large___ that they are known as ___macromolecules___. This means "___giant molecules___".

Macromolecules are made from <u>thousands of smaller molecules</u>.

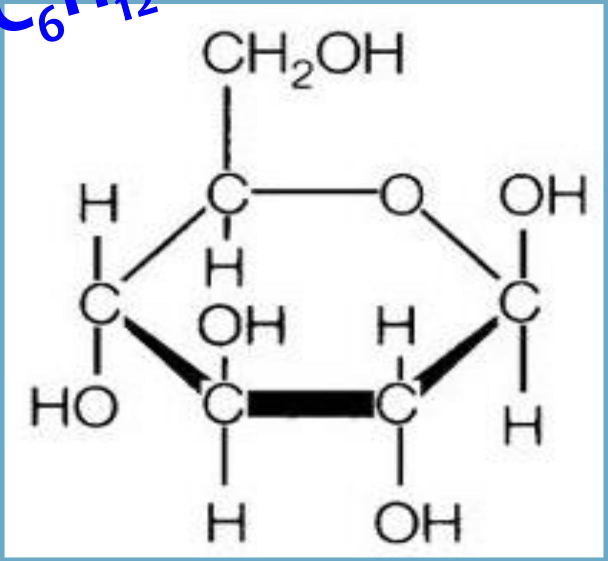
The four groups of organic compounds found in living things are:

Carbohydrates Lipids

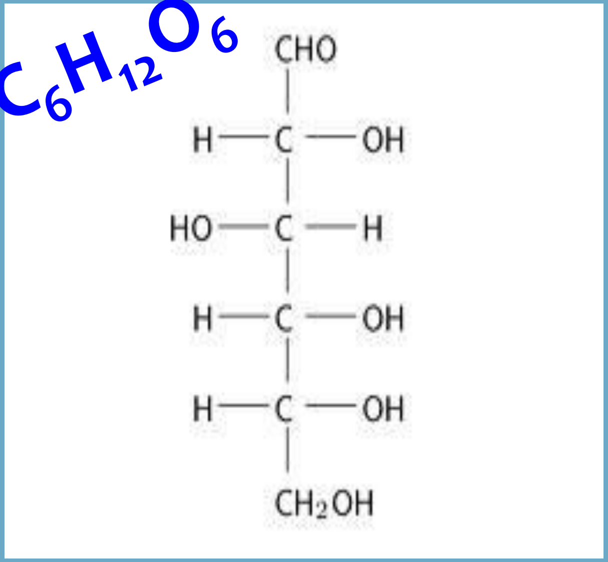
Proteins Nucleic Acids

Characteristics of Carbohydrates

$C_6H_{12}O_6$



$C_6H_{12}O_6$



These compounds are made up of carbon, hydrogen and oxygen

in a ratio of 1:2:1 .

Look at the top picture. Count the number of carbon atoms you see.

Now count the number of hydrogen atoms you see.

Finally, count the number of oxygen atom you see. What is the formula? $C_6H_{12}O_6$

Now do the same thing for the bottom picture.

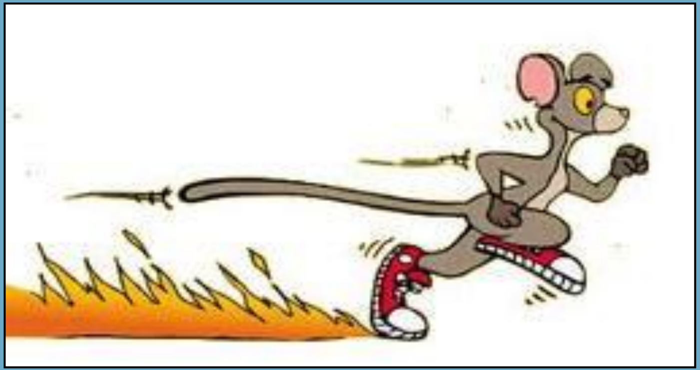
Examples of carbohydrates are:

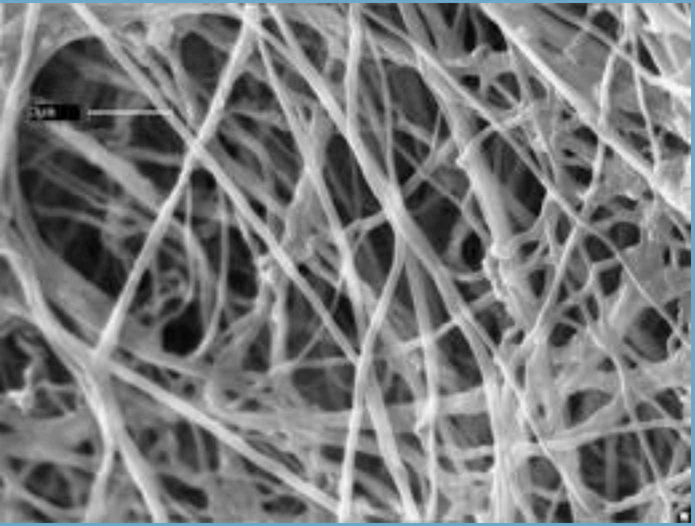
sugars, starches, and celluloses.

The carbohydrates are known as the "quick energy" foods because <u>they are very quickly converted to energy by the cells</u>.

There are two main functions of carbohydrates:

Living things use carbohydrates as their main source of energy.





Some plants and animals use carbohydrates for structural purposes.

The smaller molecules that make up the carbohydrates are……

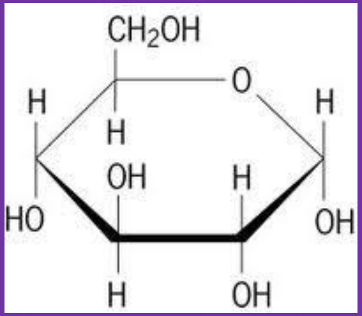
……simple sugars such as glucose.

The Sugars

Carbohydrates are classified according to …

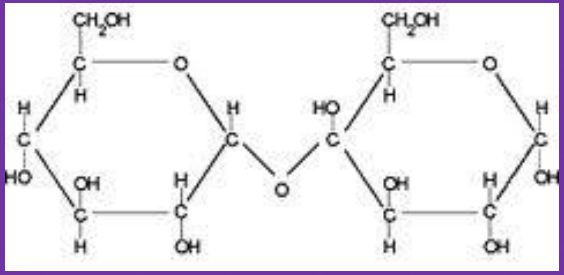
… the number of sugar molecules they contain.

Monosaccharides



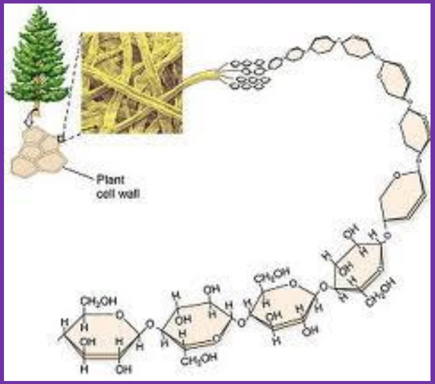
Monosaccharides contain only one molecule of sugar.

Disaccharides



Disaccharides are composed of 2 molecules of sugar bonded together.

Polysaccharides



Polysaccharides are composed of many molecules of sugar bonded together.

Three Common Polysaccharides

Starch

Only found in plants.

This is the way that plants store excess glucose.

Many, many molecules of glucose are bonded together to form starch.

Glycogen

Only found in animals.

This is the way that animals store excess glucose.

The liver bonds together many, many molecules of glucose to form glycogen.

Cellulose

Cellulose is the stringy, fibrous material found in the cell wall of plants.

It gives strength to the plant cell wall.

Cellulose is the major component of wood and paper.

Lipids

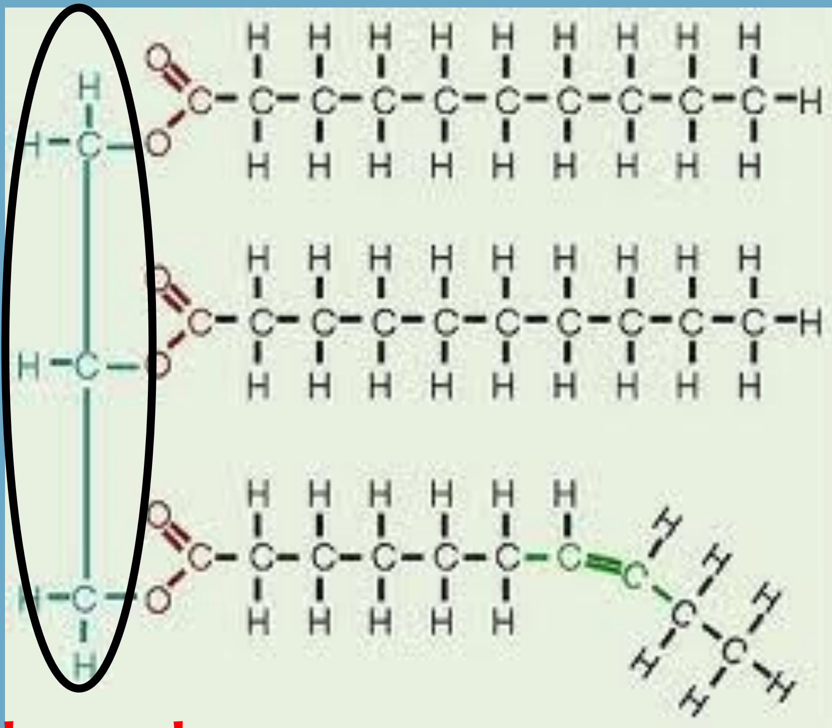
Examples of lipids are fats, oils, and waxes.

These compounds are generally not <u>soluble</u> in water.

Lipids contain the elements <u>carbon</u>, <u>hydrogen and oxygen</u>, but not in the <u>1:2:1</u> ratio seen in the sugars.

There are two building blocks of lipids: fatty acids and glycerol

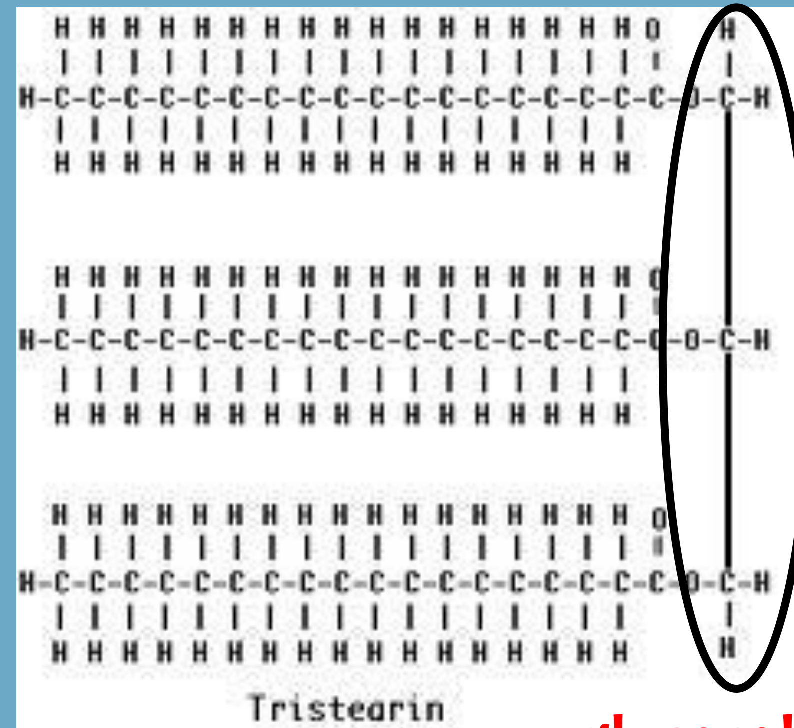
A lipid has <u>one molecule of glycerol and three fatty acid tails</u>.



<-fatty-> acid

<-fatty-> acid

<-fatty-> acid



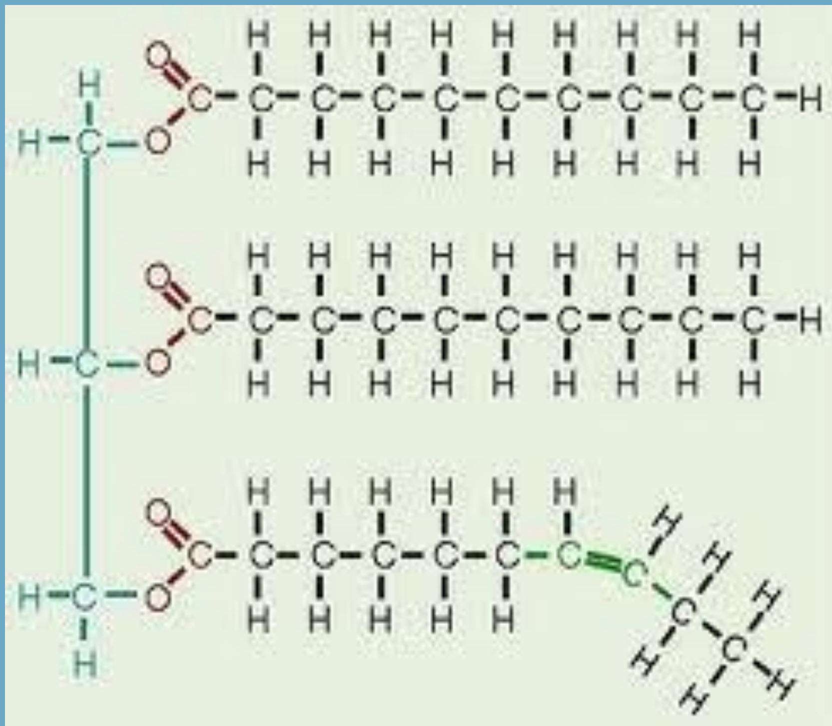
glycerol

glycerol

Circle and label the glycerol molecule in each of the above drawings.

Label the three fatty acid tails in each drawing.

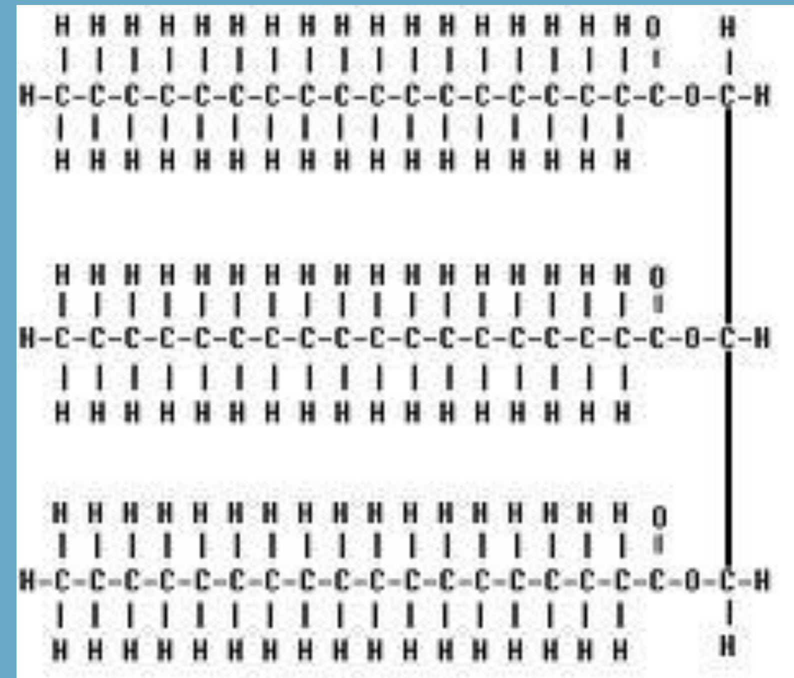
A lipid has <u>one molecule of glycerol and three fatty acid tails</u>.



<-fatty-> acid

<-fatty-> acid

<-fatty-> acid



Tristearin

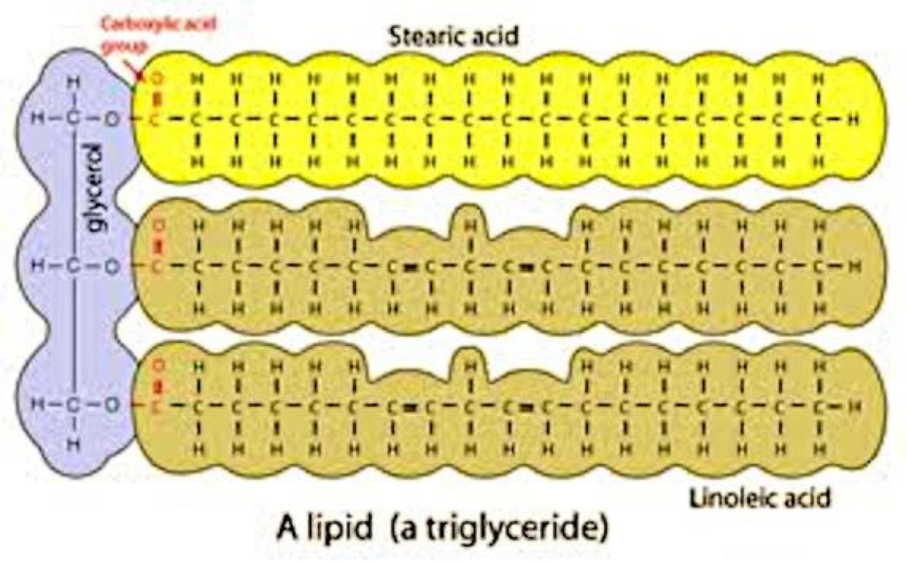
Unsaturated fat

Saturated fat

If a fatty acid tail has at least one <u>carbon-carbon double bond</u>, it is said to be an <u>unsaturated</u> fat.

If a fatty acid tail has no <u>carbon-carbon double bonds</u>, it is said to be a <u>saturated</u> fat.

Which of these drawings is a saturated fat? Which is an unsaturated fat?



Is this a saturated or an unsaturated fat?

It is unsaturated.

Unsaturated fats tend to be _liquid_ at room temperature. Examples are olive oil and vegetable oil.

Saturated fats tend to be _solid_ at room temperature. Examples are:

shortening, lard, or butter.

Uses of Lipids

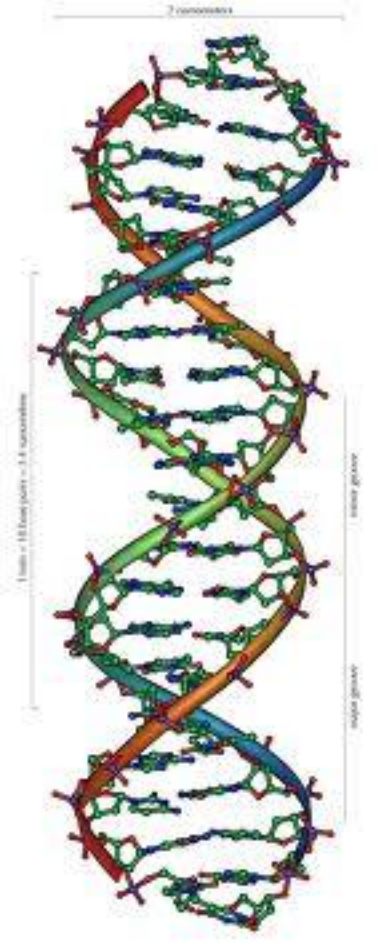
They are used to store energy.

They are an important part of the cell membrane.

They form waterproof coverings on feathers, fruits, leaves, etc.

They cushion and insulate the internal organs.

Nucleic Acids



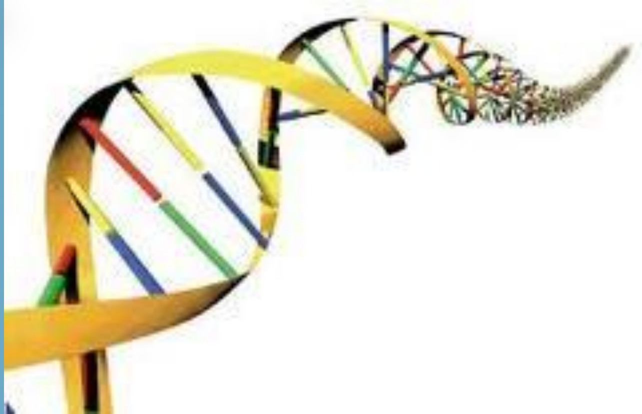
Nucleic acids are macromolecules containing the elements…

Carbon, hydrogen, oxygen, nitrogen, and phosphorus

There are two kinds of nucleic acids: DNA and RNA

The building blocks of the nucleic acids are nucleotides.

Nucleic acids store and transmit genetic information.



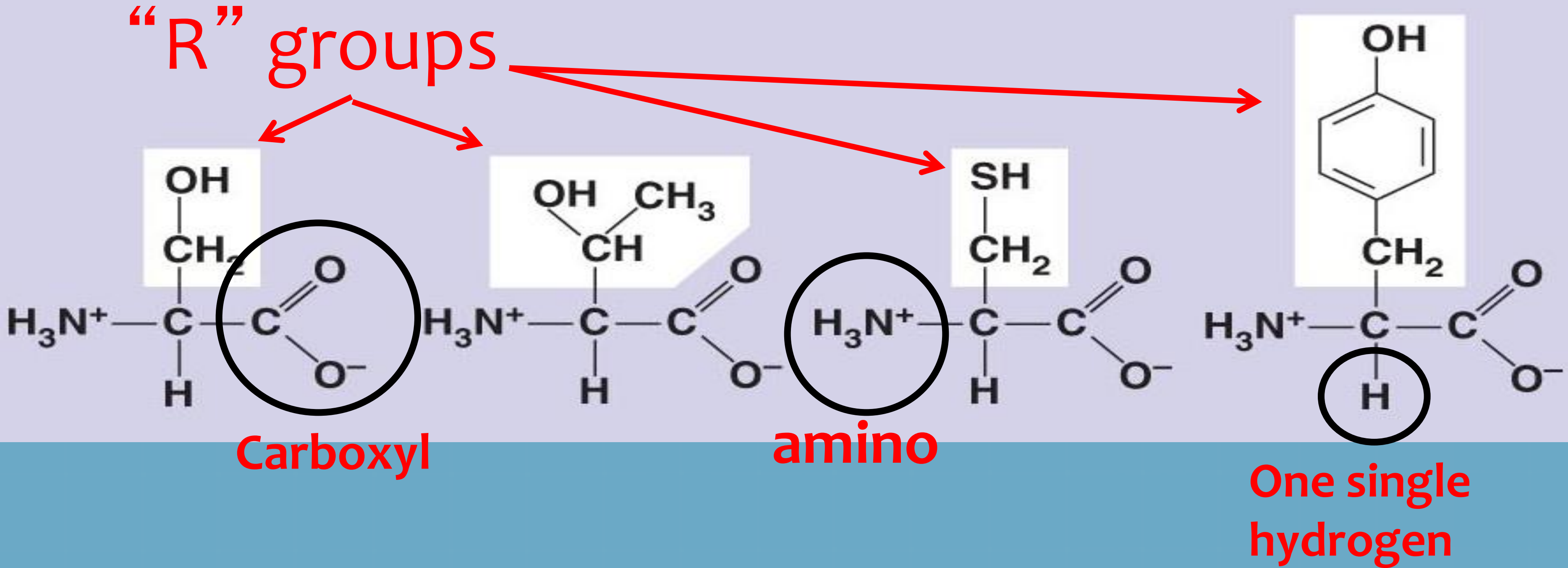
Proteins are macromolecules that contain...

...carbon, hydrogen, oxygen and nitrogen.

Proteins

The building blocks of proteins are amino acids.

There are 20 different amino acids.



Each amino acid has four parts. Label these groups on the drawing above.

Carboxyl group

An amino group

One single hydrogen

An "R" group which is different on every single amino acid.

There are many, many uses for proteins

1. enzymes
2. hormones
3. transport proteins such as hemoglobin
4. contractile proteins such as in muscle tissue
5. antibodies
6. membrane proteins
7. structural proteins such as bones and muscles

Enzymes and Chemical Reactions

Living Cells depend on them!

Life depends upon the chemical reactions that occur within the cell.
Living organisms undergo thousands of chemical reactions as part of their life processes.

Enzymes ….
Amazing topic!
Let's get started!!

These reactions are important to the:
growth, development, and the very survival of a cell.

The reactions of a cell involve both the building of molecules, and the breaking down of molecules.
The role of enzymes is to greatly enhance the SPEED!! of these reactions.

Chemical Reactions

A chemical reaction is a process that:
changes one set of molecules into a new set of substances.

A chemical reaction occurs when chemical bonds between atoms are __broken__ or __formed__, resulting in the production of __one or more new substances_____.

Reactants: The elements or compounds that enter into a chemical reaction.

Products: The elements or compounds produced by a chemical reaction.

Chemical reactions always involve changes in the ______**chemical bonds** that join atoms together in compounds.

Bonds are first broken. Atoms are then rearranged to form new substances.

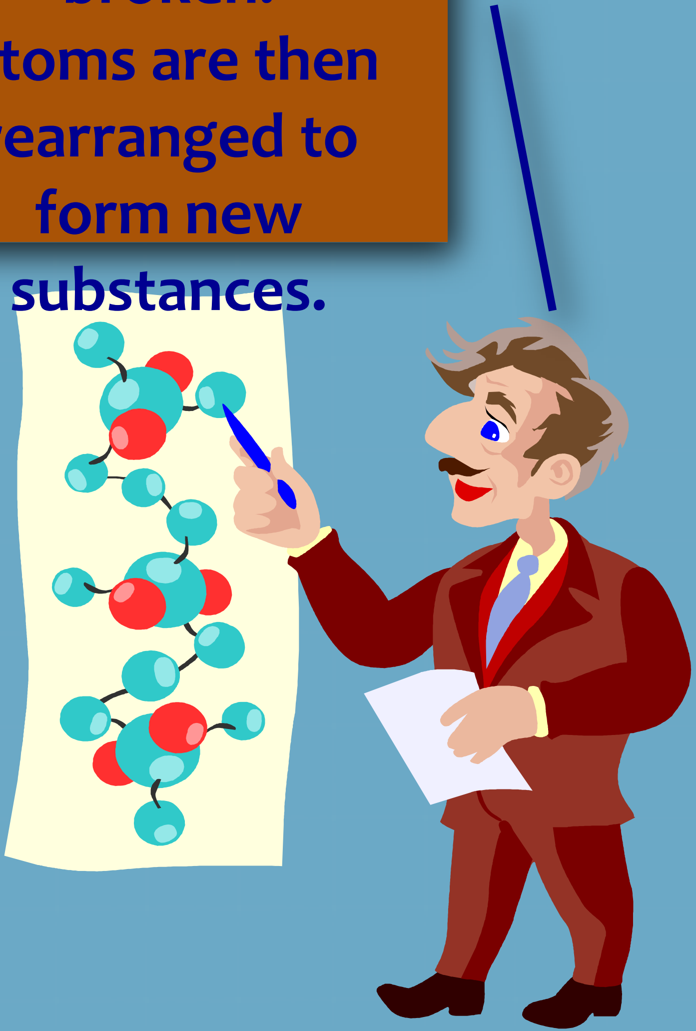
Examples:

1. CO_2 + H_2O → H_2CO_3

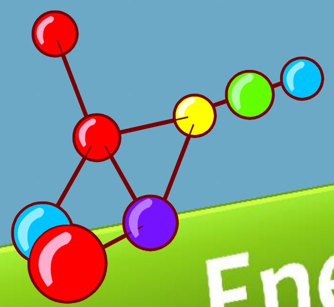
reactants product

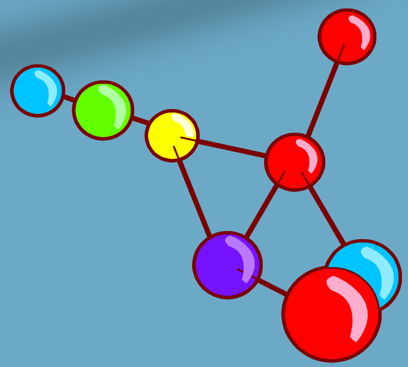
2. $2H_2O_2$ → $2H_2O$ + O_2

reactant products



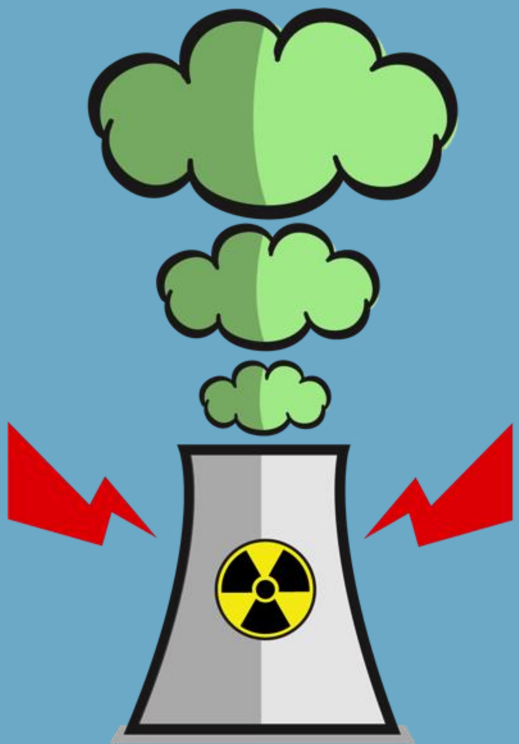
Energy in Reactions





Whenever chemical bonds form or are broken, energy will be released or absorbed.

The forming and breaking of bonds involves changes in energy.



Some chemical reactions absorb energy.

Other chemical reactions release energy.

Living organisms carry out a great variety of chemical reactions. Many of these reactions release energy, while many others absorb energy.

Regardless of whether energy is released or absorbed by the reaction, starting the chemical reaction:
requires an initial investment in energy.

In order for the reaction's products __________ to form, existing chemical bonds ________________ in the reactants must first be broken _________. This will require energy _________.

Activation Energy

1. The energy needed by the reactants in order to start a reaction.

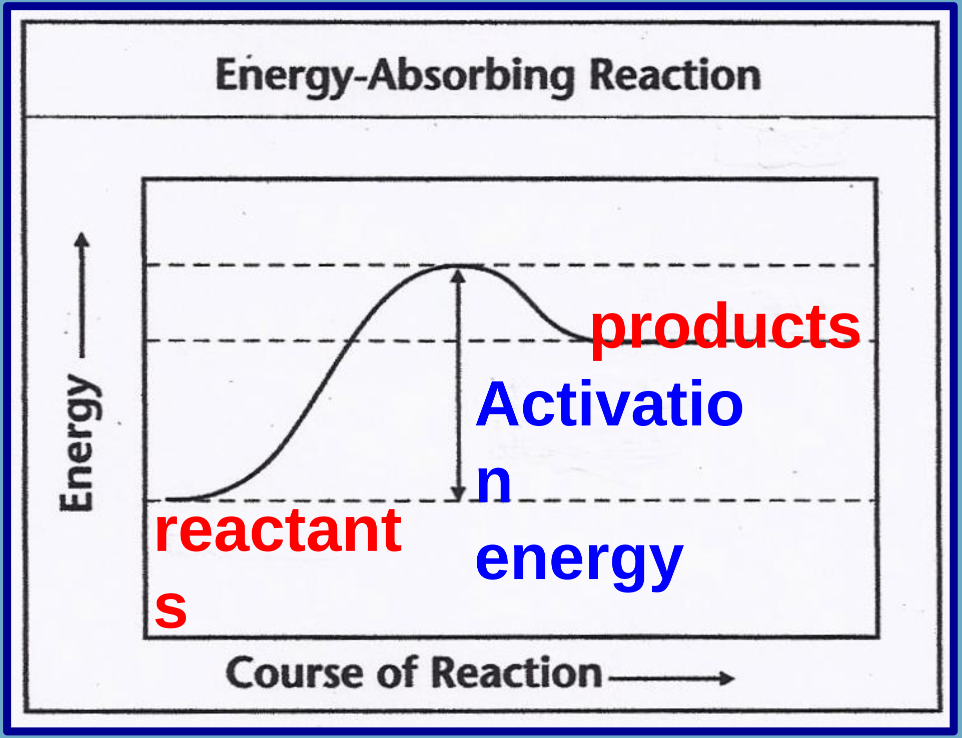
2. It is the initial investment of energy for starting a reaction.

3. It is the energy required to break bonds in the reactant molecules.

Energy-Absorbing Reactions

1. The reactants have less energy than the products.

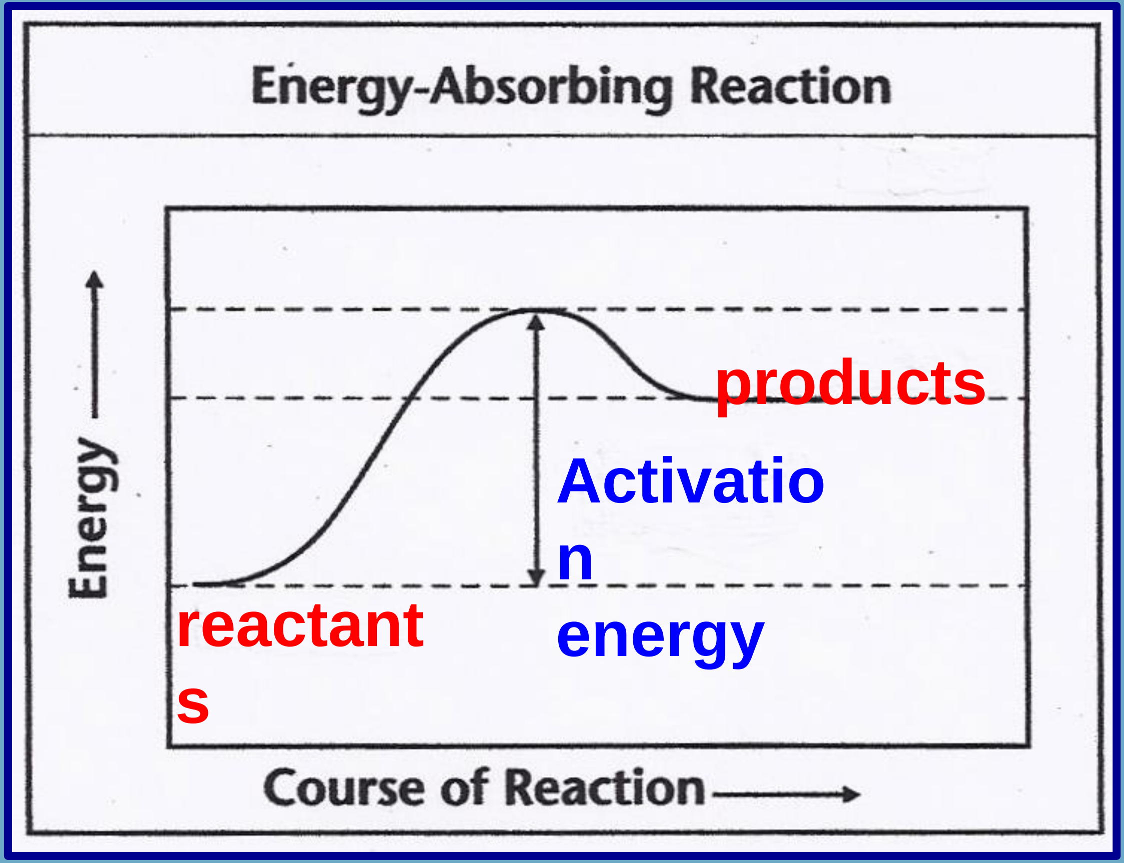
2. The bonds of the _reactant___ molecules will have to be broken. New bonds will be formed during the formation of the _products__.



This reaction requires more energy than it gives off.

Energy-Absorbing Reactions

The activation energy is…

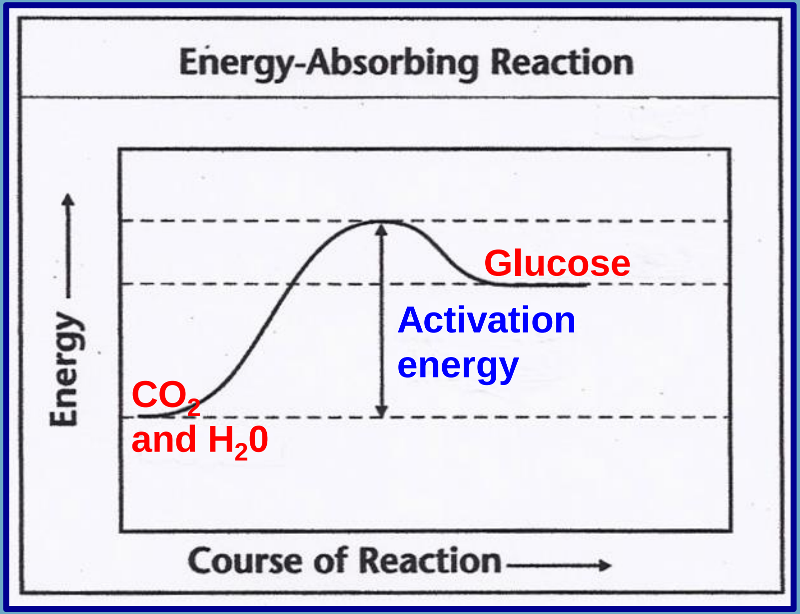


…..the amount of energy that the reactants will have to absorb in order to break the bonds holding the atoms together.

4. An example of an energy absorbing reaction in living cells is the process of photosynthesis.

The reactants are CO_2 and H_20.

These reactants have less energy than the product, which is glucose.

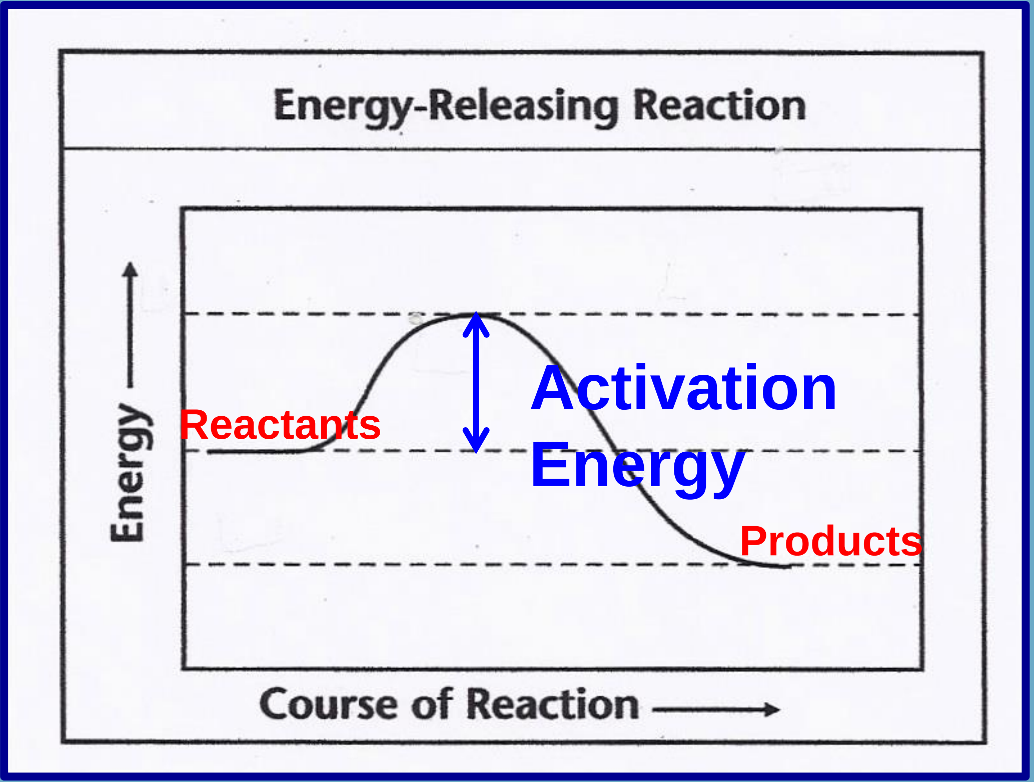


The energy that is absorbed by the reactants is stored in the bonds forming the glucose molecules.

Energy-Releasing Reactions

1. The reactants have more energy than the products.

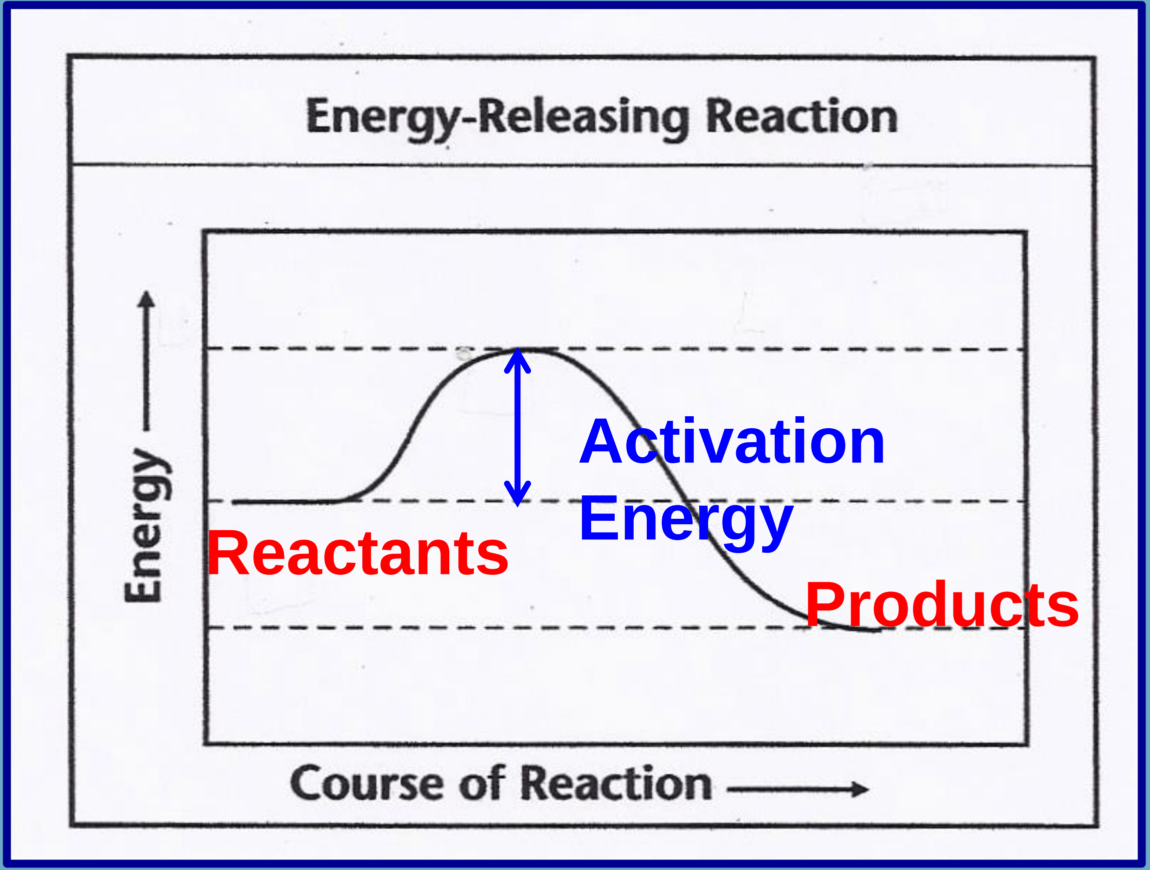
2. An energy investment will still be required in order to break the bonds in the reactants.



This reaction gives off more energy than it requires.

Energy-Releasing Reactions

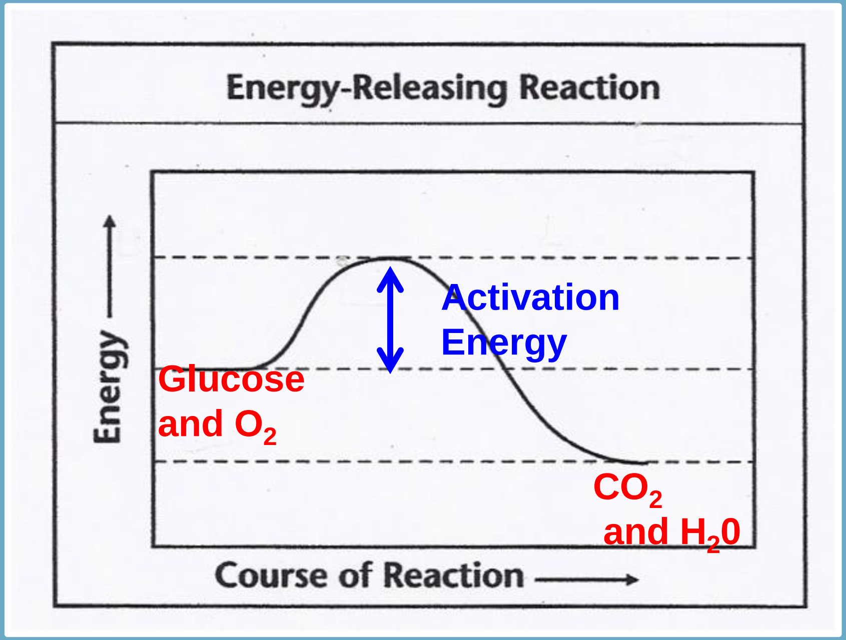
The activation energy is the amount of energy that must be….



……absorbed by the reactants in order to break the bonds holding the atoms together.

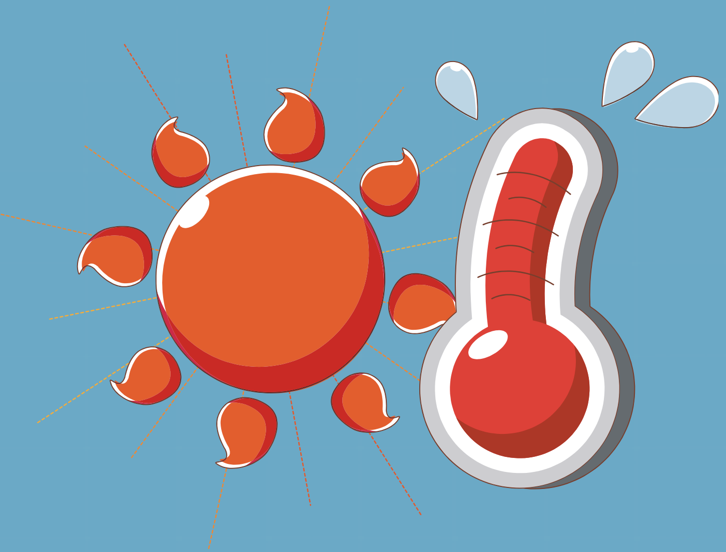
4. An example of an energy releasing reaction in living cells is the process of ___respiration___.

The reactants are: glucose and oxygen.



It will require a small ___investment___ of energy (activation energy) in order to break the bonds of glucose.

However, once the reaction begins, more energy will be released than was required to start the reaction.



This activation energy is usually in the form of ___heat___ that the reactant molecules absorb from the ___surroundings___.

The bonds of the reactants break only when the molecules have:
absorbed enough energy to become unstable.

Activation energy is the amount of energy needed to push the reactants over an energy barrier or "hill" so that the "downhill" part of the reaction can begin.

Many of the chemical reactions of a cell proceed too ______ slowly to be of use to the cell.

The activation energy required for these reactions is simply too _______. high

The cell must have a way to make these reactions occur _______ faster and at lower ________________ temperatures.

How is this done???

ENZYMES!!

ENZYMES

A. Enzymes are:
organic molecules that act as catalysts.

1. A catalyst is:
a substance that will make a chemical reaction take place more rapidly and at a lower temperature.

2. Enzymes are proteins that act as biological catalysts.

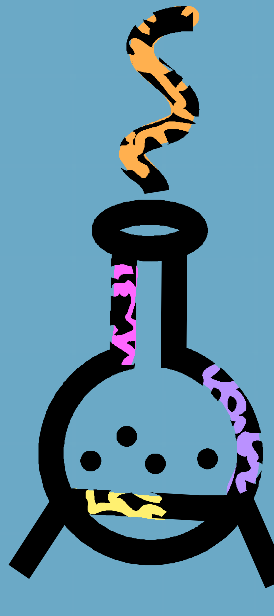
3. Enzymes are essential for the functioning of any cell.

Enzymes speed up the chemical reactions that take place inside cells.

Many of the reactions inside cells take place:
too slowly to be of any use to the cell.

ENZYMES:

Lower the activation energy for a chemical reaction.



Lowering the activation energy makes the reaction take place much ______ **faster** and at a: **lower temperature.**

Without enzymes, cells would soon __die__.
The chemical reactions required in living cells would take place too…..
…..slowly to keep the cell functioning.

Example: **Sucrose will spontaneously break down into __glucose and fructose__, but it will take __years__ to do so. If a small amount of the enzyme __sucrase__ is added to the solution, all of the sucrose will be broken down within __seconds__.**

Enzymes are so specific for their substrate that they can only catalyze one chemical reaction. In the above example, sucrase speeds up the breakdown of sucrose, and it can do no other job.

Because enzymes are so specific, their name is usually derived from:

....the reaction they catalyze.

What does the enzyme lactase do?

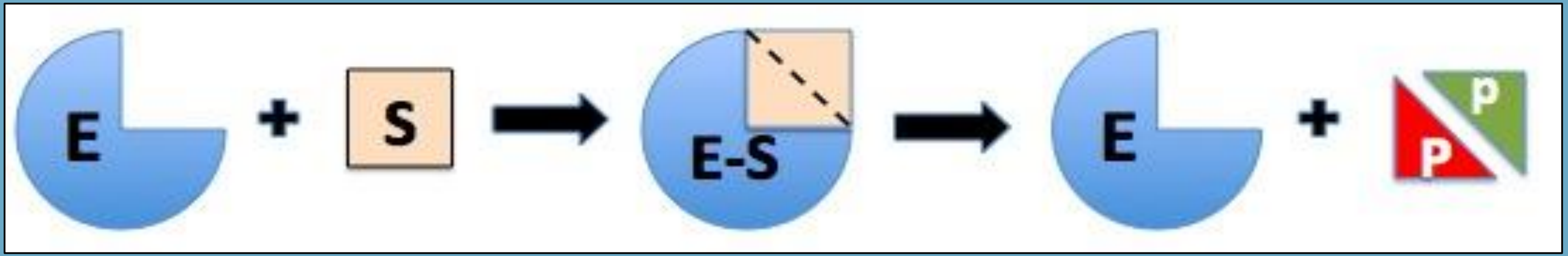
It speeds up the breakdown of the disaccharide sugar, lactose, into the individual sugars, galactose and glucose.

Comparison of Enzymes and Catalysts

Enzymes	Catalysts
1. Enzymes are proteins.	1. Catalysts are not proteins.
2. Enzymes are specific for just one reaction.	2. Catalysts will speed up many different reactions. They are not specific.
3. Each enzyme has an optimum temperature at which it functions best.	3. Catalysts are not affected by temperature. They generally work at any temperature.
4. Enzymes require water to function.	4. Catalysts do not require water.
5. Enzymes are not consumed or used up during the reaction.	5. Catalysts are not consumed or used up during the reaction.

How Enzymes Work

This is a simple equation illustrating how an enzyme works:



Enzyme + Substrate → Enzyme-Substrate Complex → Enzyme + New Products

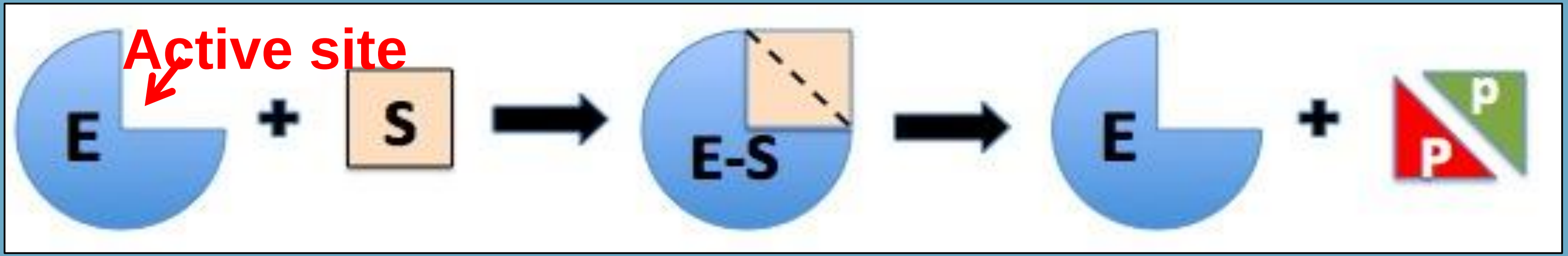
Substrate:

The reactants of an enzyme-catalyzed reaction.

The enzyme will speed up the conversion of the substrate to new and different products.

How Enzymes Work

This is a simple equation illustrating how an enzyme works:



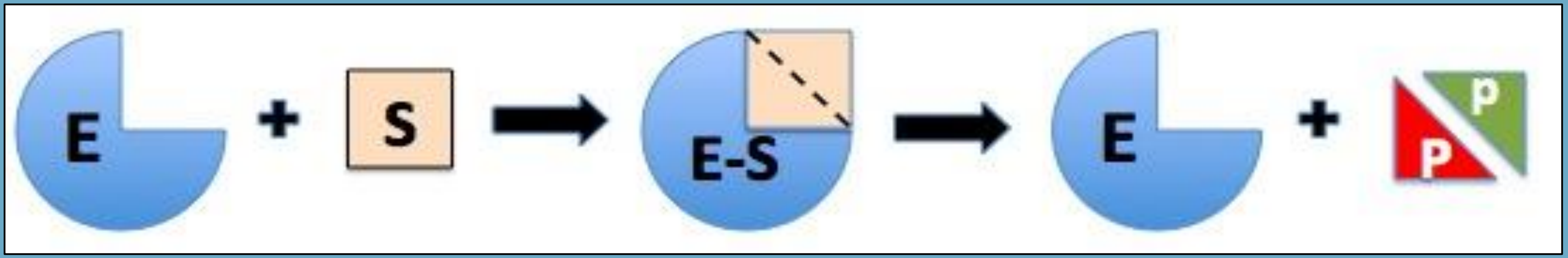
Enzyme + Substrate → Enzyme-Substrate Complex → Enzyme + New Products

Enzymes have:
a pocket or groove into which the substrate(s) must fit.

The pocket or indentation is called the:
active site.

How Enzymes Work

This is a simple equation illustrating how an enzyme works:



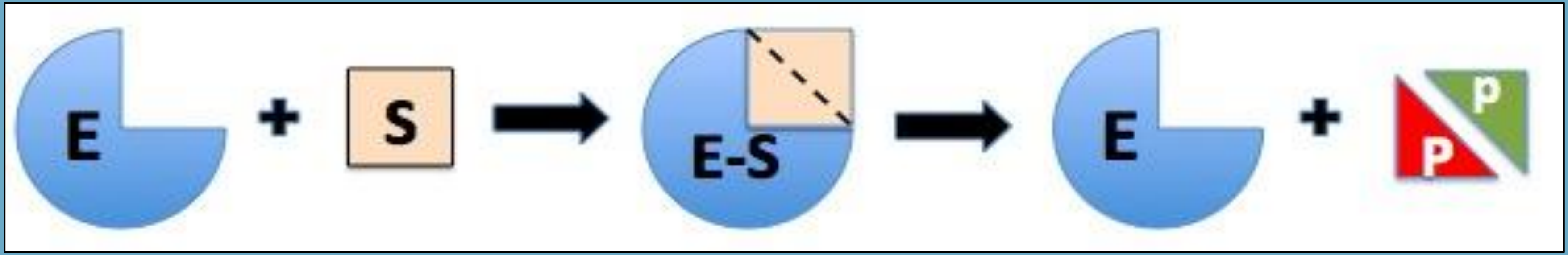
Enzyme + Substrate → Enzyme-Substrate Complex → Enzyme + New Products

For the enzyme to speed up the reaction, there must be a complimentary fit between the enzyme and its substrate molecule.

The fit is so precise that the active site and substrates are often compared to a "lock and key".

How Enzymes Work

This is a simple equation illustrating how an enzyme works:



Enzyme + Substrat e → Enzyme- Substrat e Complex → Enzyme + New Products

Intermolecular forces bind the enzyme and substrate together to form the ____________________ enzyme-substrate complex

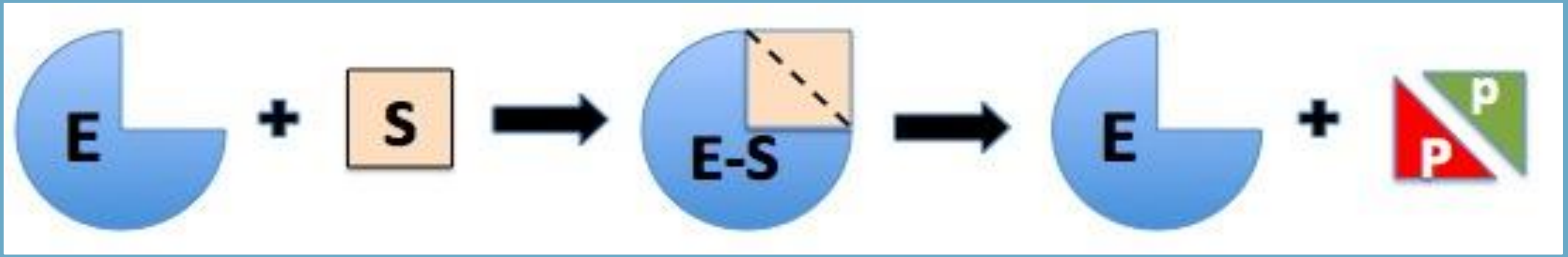
They remain bound together until the reaction reaches completion.

During the enzyme-substrate complex, the bonds:

of the reactants are broken and new substances are formed.

How Enzymes Work

This is a simple equation illustrating how an enzyme works:

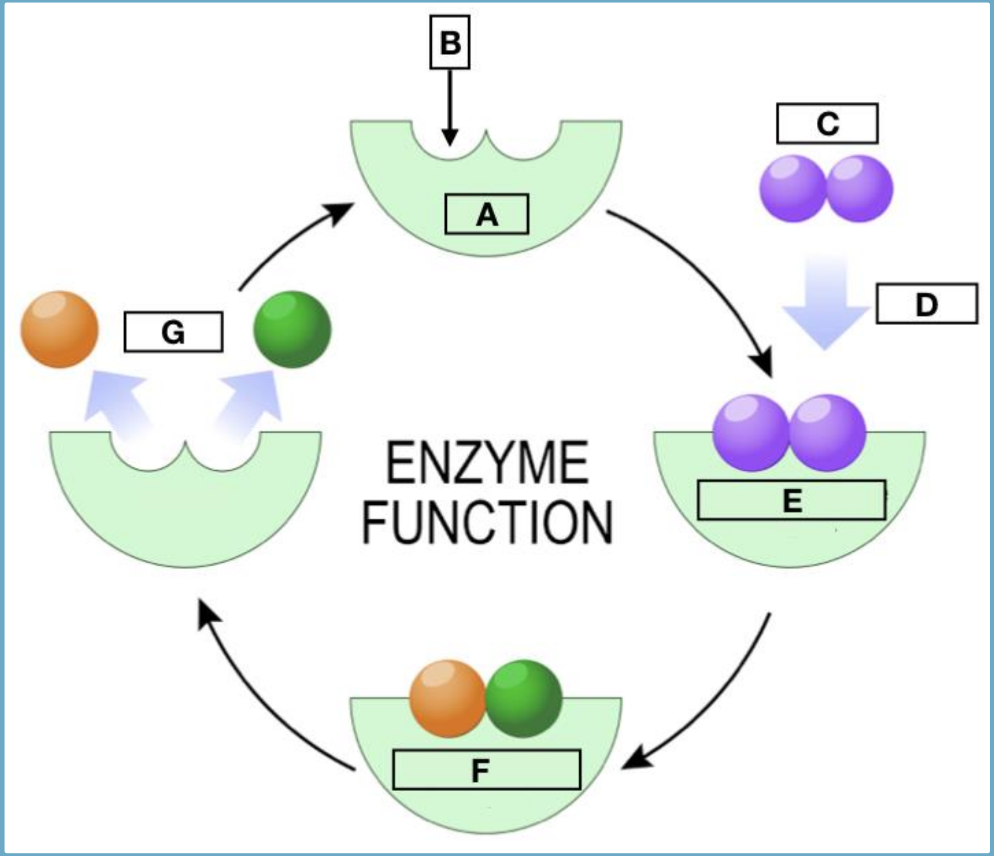


Enzyme + Substrate → Enzyme-Substrate Complex → Enzyme + New Products

At the end of the reaction, the <u>new products</u> are released.

The enzyme is free to start the process again.

Diagram of an enzyme-catalyzed reaction.



A: Enzyme

B: Active Site

C: Substrate Molecules

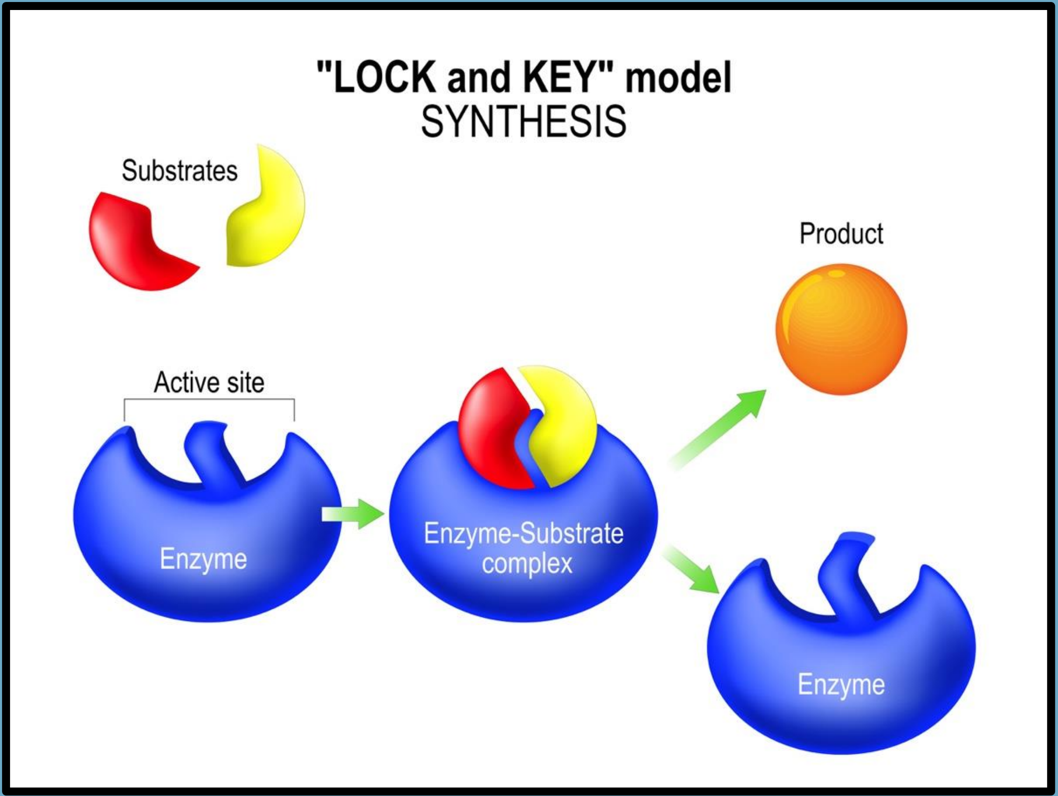
D: The substrate molecules fit into the active site of the enzyme.

E: Enzyme-Substrate Complex

F: Bonds in the reactants are broken and new bonds are formed to create new and different products.

G: The new products are released from the active site. The enzyme is available and can be used again.

Diagram of an enzyme-catalyzed reaction.



The joining together of the enzyme and the substrate causes a slight change in the enzyme's ________. shape

This shape change allows the enzyme to conform to the shape of the substrate and probably weakens some chemical bonds in the substrate, which is one way that enzymes reduce activation energy.

Let's summarize the facts about enzymes:

1. Enzymes are __proteins__ that speed up the __chemical reactions__ of the cell.

An enzyme may accelerate a reaction by making it happen 10,000,000,000 times faster!

This means that a reaction that would take 1,500 years to complete without the enzyme can be completed in just 5 seconds with the enzyme.

Let's summarize the facts about enzymes:

2. Enzymes do not…
   …cause reactions to happen.
   They simply speed up the reactions that __already occur__.

3. Enzymes make reactions take place __faster__ and at __lower temperatures__.

Let's summarize the facts about enzymes:

4. Without enzymes the reactions of the cell would proceed __so slowly__ that the cell would __die__.

5. Enzymes are very __specific__. They can only carry out __one job__, but they do that one job extremely well.

Let’s summarize the facts about enzymes:

6. Enzymes are never __used up__ in the reaction. They can be used __over and over__ again.

7. 2000 enzymes are now known. Each is responsible for a specific chemical reaction

Let's summarize the facts about enzymes:

8. The shape of the enzyme is so specific that only one shaped substrate can fit.

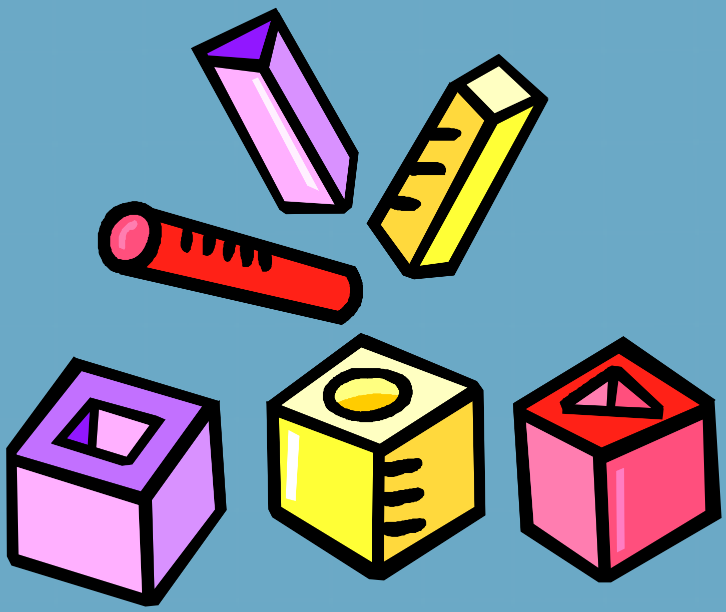
9. A specific enzyme is required for each reaction in a cell.

10. Enzymes catalyze … …both the forward and the reverse of the same reaction.

Factors that affect enzyme functioning:

Anything that changes the <u>shape</u> of the enzyme will affect:
the ability of the enzyme to function.

Every enzyme has an <u>optimum temperature</u> at which it will function the <u>best</u>.

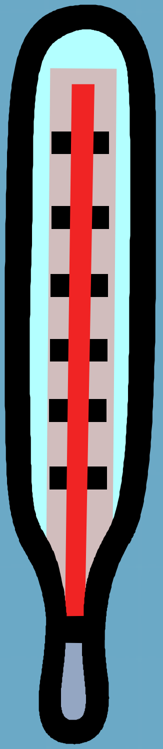


One factor that affects enzyme functioning is <u>temperature</u>.

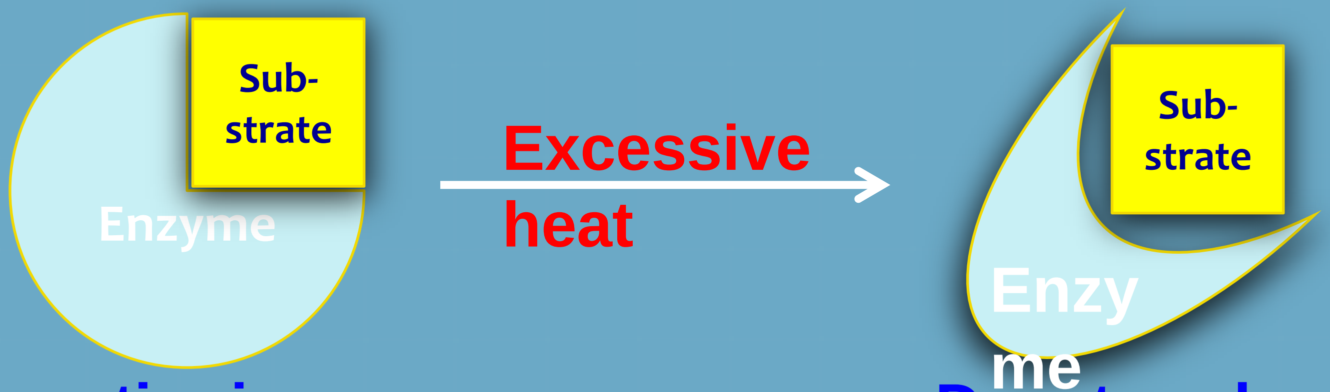
Factors that affect enzyme functioning:

For most enzymes, the optimum temperature is __35 - 40°__ Celsius.

If the temperature exceeds the optimum, the enzyme may become __denatured__.
The bonds that determine the shape of the enzyme are altered, changing:
the shape of the enzyme.



Factors that affect enzyme functioning:



Functioning enzyme **Denatured enzyme**

A denatured enzyme has lost its particular shape.

It no longer has a complimentary fit to its substrate.

When an enzyme is denatured, it cannot function or participate in the chemical reaction.

Factors that affect enzyme functioning:

Another factor that affects enzyme activity is __pH__.
Every enzyme has an optimum pH at which it functions the best.
A pH value outside of this range can cause **the enzyme to denature.**

As you might expect, most enzymes function best in a pH range of ___6 to 8 Exceptions to this are the enzymes found in the __stomach__. These enzymes function best at a pH level of around __2 to 3__. At a neutral pH, these enzymes would be denatured.