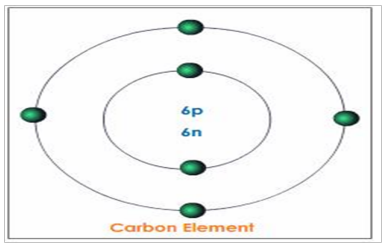
Section 2.3 Life Substances

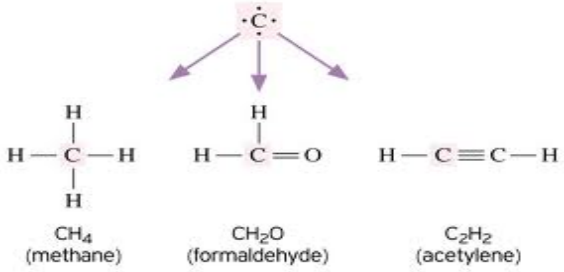
I. The Role of Carbon in Organisms

Organic chemistry = branch of chemistry that deals with the structure, properties, and reactions of compounds that contain carbon.

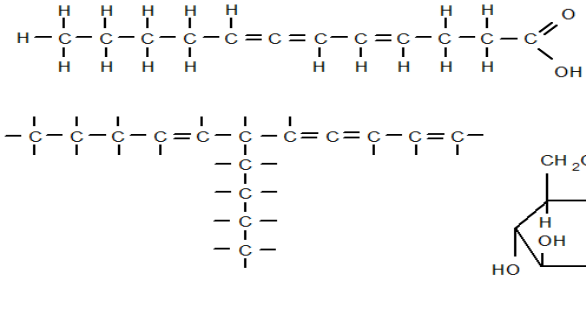
***Since carbon has 6 electrons, it has *4 electrons in its outermost energy level*.** It is unique because it can potentially form four bonds with other elements.



*Single, double, triple bonds can be formed.

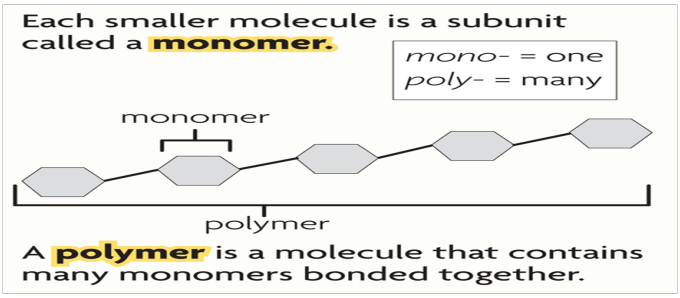


*When carbon atoms bond with each other, they can form ***chain, branched, or ring formations***.

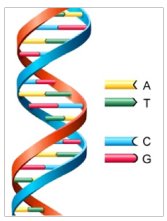


A. Molecular chains

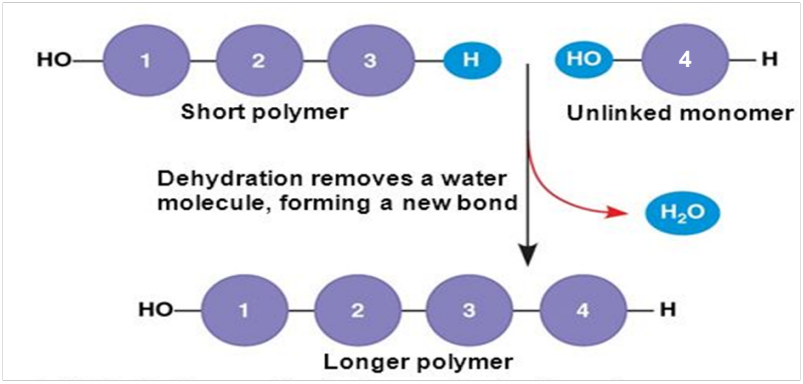
1. Biomolecule = ***large organic compounds*** **(**contains 10s, 100s, to 1000s of carbon atoms)**.**
2. Isomer = compounds with ***same*** chemical formula but ***differ molecular structure***
   ex: glucose and fructose
3. Polymer = a ***large*** molecule formed when many ***smaller molecules (monomers) bond together***.



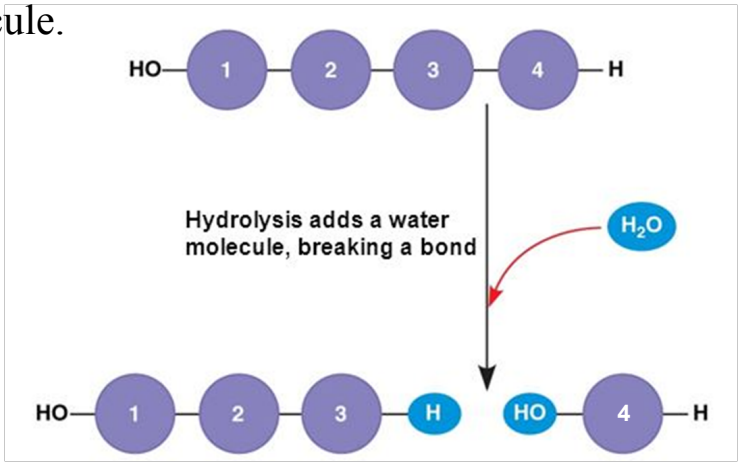
Four Categories of Biomolecules

Carbohydrates	Lipids
	
Proteins	**Nucleic Acids**
	

*When a polymer is formed, the chemical reaction is called ***dehydration*** **(condensation) synthesis** and a ***H_2O molecule*** **is removed**.



*When a polymer is broken down, the chemical reaction is called ***hydrolysis*** and a ***H_2O molecule*** is added to **separate** the molecule.



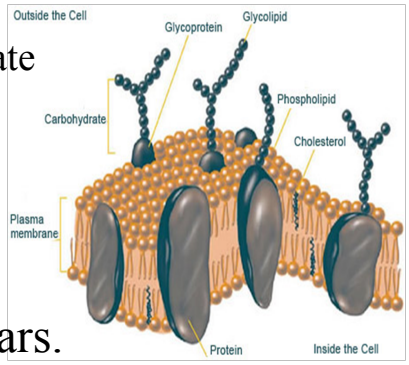
B. The structure of carbohydrates

1. Carbohydrate = a biomolecule composed of **carbon, hydrogen, and oxygen *in a 1:2:1 ratio (C:H:O)***

-The word carbohydrate literally means "watered carbon".

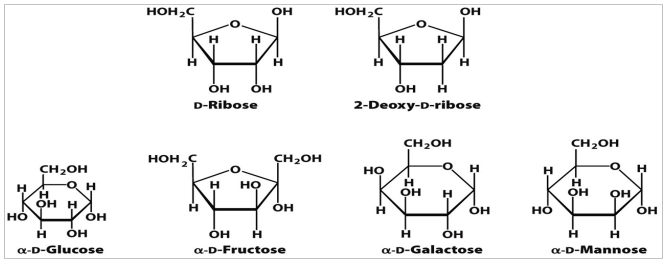
-The prefix "***glyco-***" refers to ***sugar***.

- glycoproteins are proteins with carbohydrate chains attached
- glycolipids are lipids with carbohydrates attached

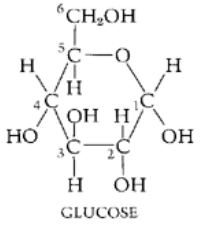


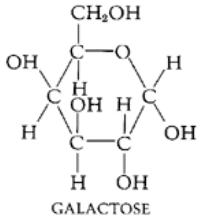
-The suffix "***-ose***" is used to name sugars.

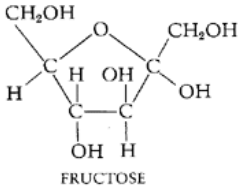
- many monosaccharides end in **-ose**



2. **Function of carbohydrates:**
   immediate energy source
   short-term energy storage
   structural support
3. **Types of carbohydrates**
   a. A ***monosaccharide*** is a **simple (small) sugar.**
   Ex: isomers - ***glucose & fructose***

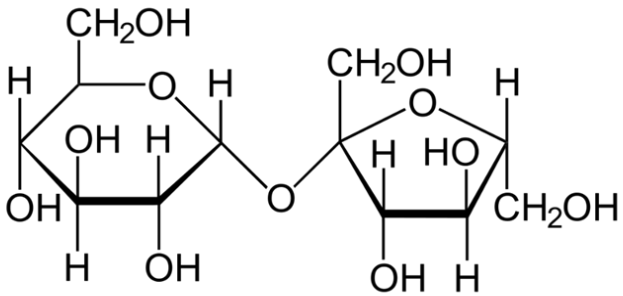

GLUCOSE


GALACTOSE


FRUCTOSE

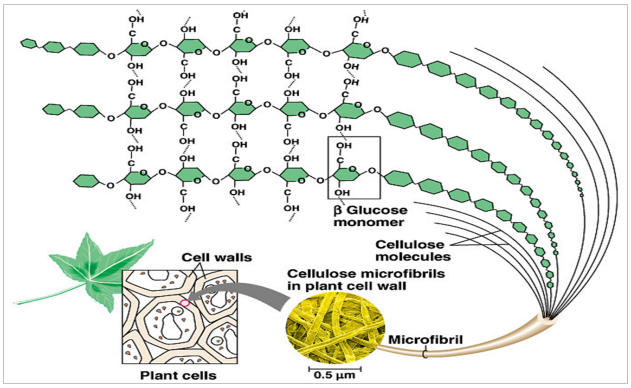
b. A ***disaccharide*** is two monosaccharides linked together.

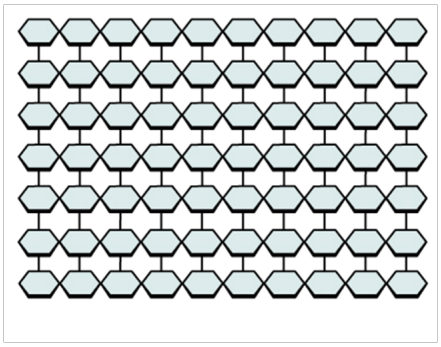
Ex: dehydration reaction of ***glucose + fructose = sucrose*** (table sugar)


sucrose, $C_{12}H_{22}O_{11}$

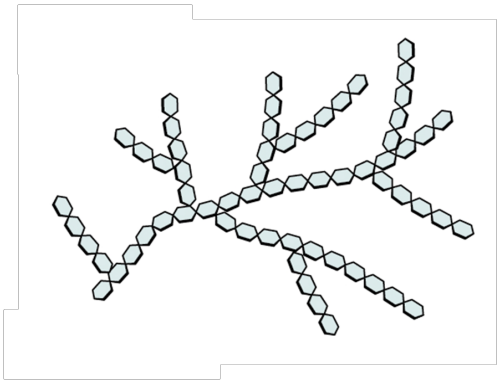
c. ***Polysaccharides*** = polymers composed of ***many*** monosaccharide subunits.

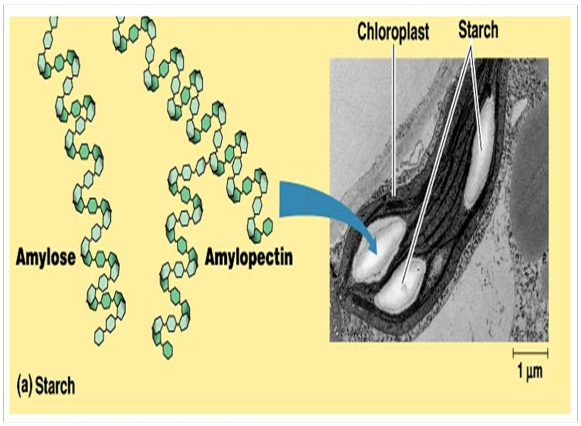
- ***Cellulose***, a glucose polymer used by plants for ***structural support***, is made of long chains arranged like a chained link fence.



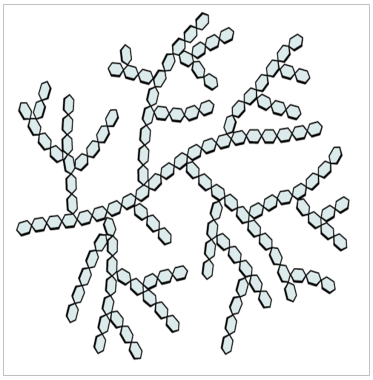


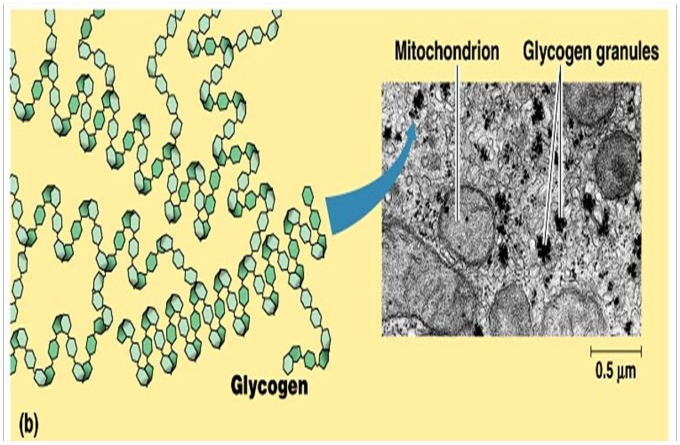
- ***Starches***, glucose polymer arranged in branched chains. Used by plants for ***energy storage*** and food for ***seeds and bulbs*.**



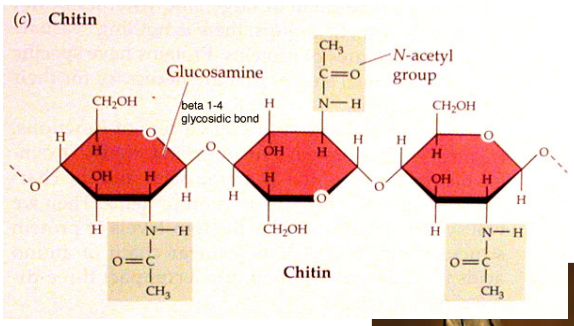


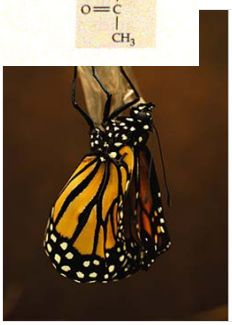
-***Glycogen***, a highly branched glucose polymer, is ***stored energy*** in the liver & muscles by mammals.





-***Chitin*** (structural polymer) used in the ***exoskeletons*** of arthropods and cell walls of ***fungi.*** **(Also, used as internal sutures.)**





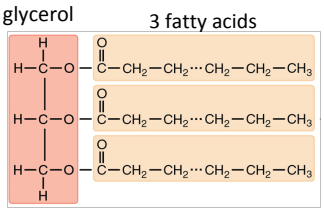
C. The structure of lipids

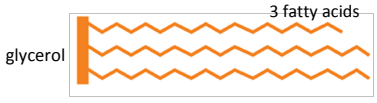
1. ***Lipid*** = large biomolecules that are made mostly of ***carbon and hydrogen with a small amount of oxygen***. It **can't be reduced to a 1:2:1 ratio.**

2. They are ***insoluble in water*** because their molecules are ***nonpolar*** and repel water.
   Ex: ***fats, oils, waxes, and steroids***

3. **Function** of lipids***: long term energy storage, insulation, protective coverings, communication***

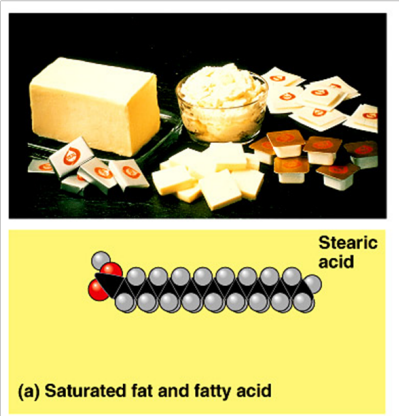
4. **Components** of a lipid:
   a. ***Three fatty acids***
   b. ***One glycerol molecule***
   c. Referred to as a ***triglyceride*.**
   d. Most contain long chains of carbons and hydrogens, called ***hydrocarbons***

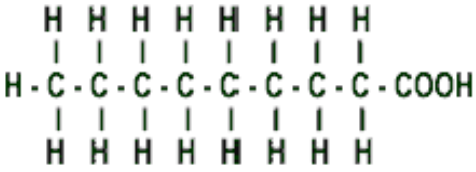




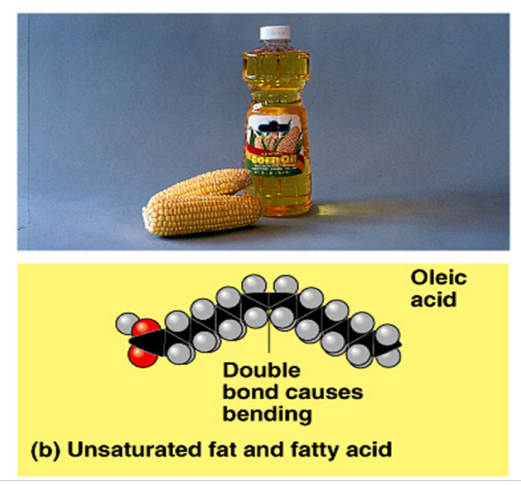
5. Lipids can be **saturated, unsaturated, or polyunsaturated.**

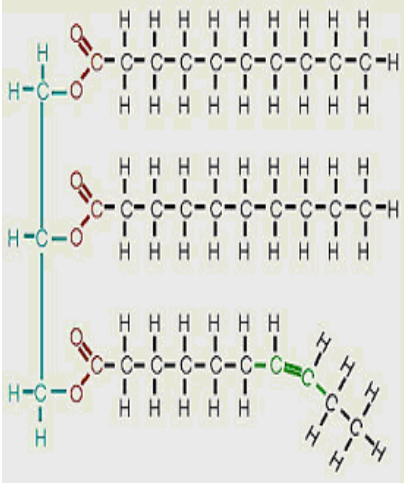
-Saturated = all of the carbon atoms are ***single bonded together.***



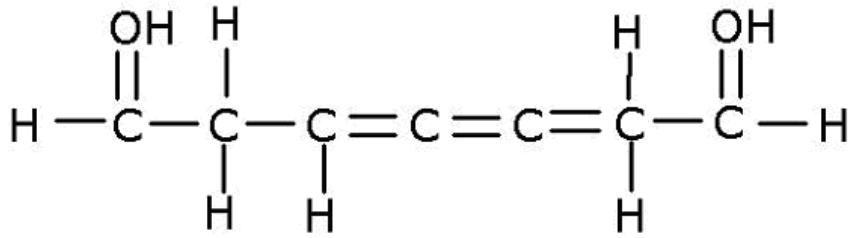


-Unsaturated = when a ***double bond exists between carbons;*** less hydrogen is present now.





-Polyunsaturated = has more than ***one double bond between carbons***.



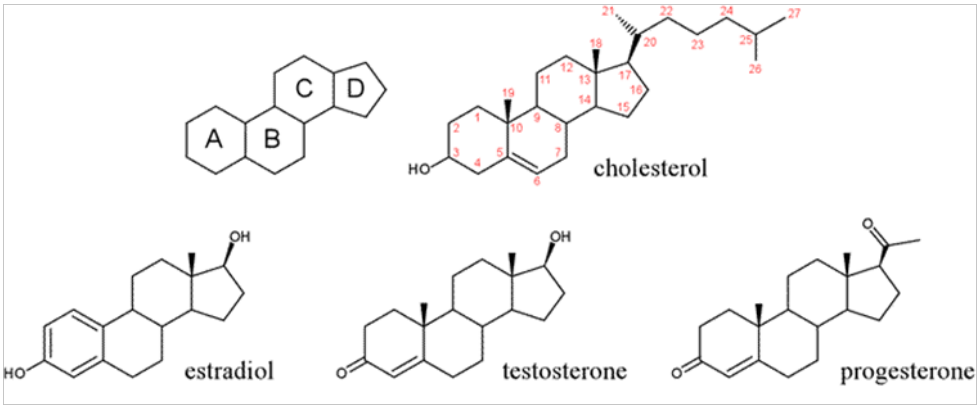
Polyunsaturated fatty acid

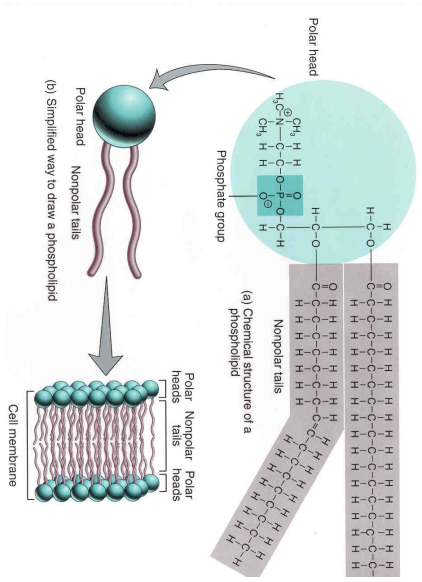
**WHY is this important healthwise?

Less H^+ ions to clog blood vessels.

Ex: ***Steroids*** are polyunsaturated

- **steroids** include ***cholesterol*** and sex ***hormones*** (testosterone, estrogen, progesterone)

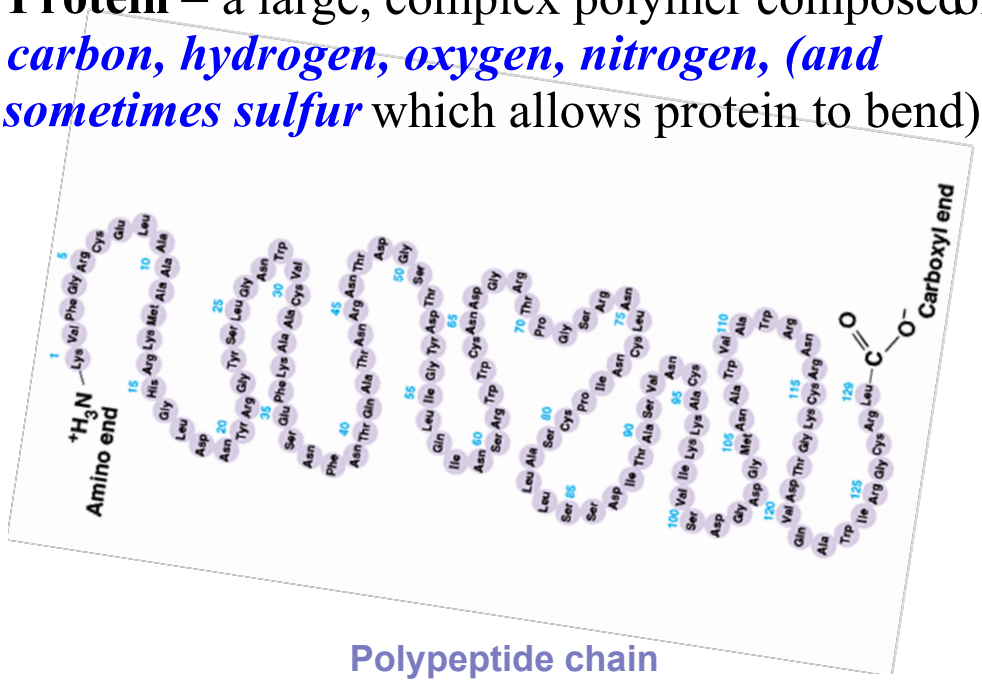




-Phospholipids are a class of lipids that are a ***major component of all cell membranes*** as they can form lipid bilayers. Most phospholipids contain a ***diglyceride*** and a ***phosphate group***. The polar "head" is ***hydrophillic*** and the nonpolar "tails" are ***hydrophobic***.

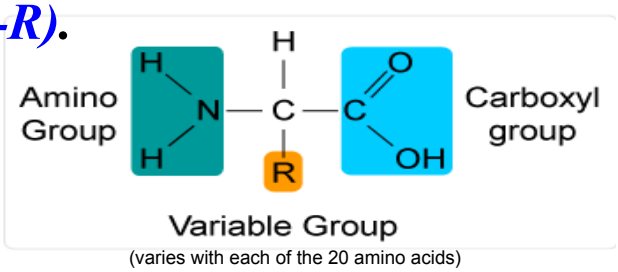
D. The structure of proteins

1. **Protein** = a large, complex polymer composedbf ***carbon, hydrogen, oxygen, nitrogen, (and sometimes sulfur*** which allows protein to bend).

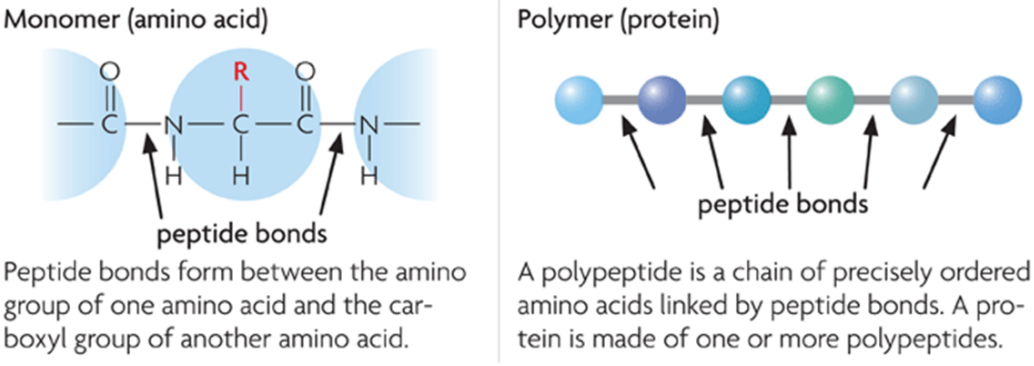


Polypeptide chain

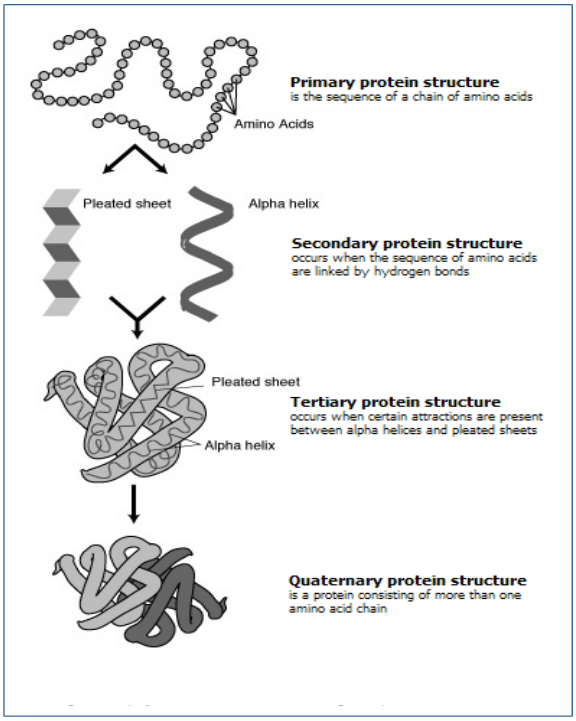
2. Components of a protein are **monomers** called ***amino acids***, which are composed of
a ***central carbon atom***
attached to a ***carboxyl group (-COOH)***,
a ***hydrogen*** atom,
an ***amino group ($-NH_2$)***,
and a variable group ***(-R)*.**



3. Amino acids are linked together by***peptide bonds***.



4. Proteins come in a large variety of shapes and sizes. The number (only ***20*** amino acids for all proteins) and ***order*** of the amino acids determines its ***function***.

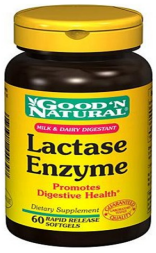


5. Functions of proteins:

a. Proteins ***catalyze*** **metabolic reactions**

- Many proteins are ***enzymes***, which catalyze metabolic reactions in living organisms.

ex: lactase is an enzyme which digests lactose (milk sugar), some people lack this enzyme, and cannot digest lactose, which is found in dairy products



b. Proteins act as ***chemical messengers***

-Peptide *hormones* are chemical messengers composed of proteins that send chemical messages throughout the body

ex: **insulin** is a peptide hormone that regulates blood sugar

c. Proteins make up many ***structural*** **components** found in living things.

ex: **keratin** is the key structural component of hair and nails

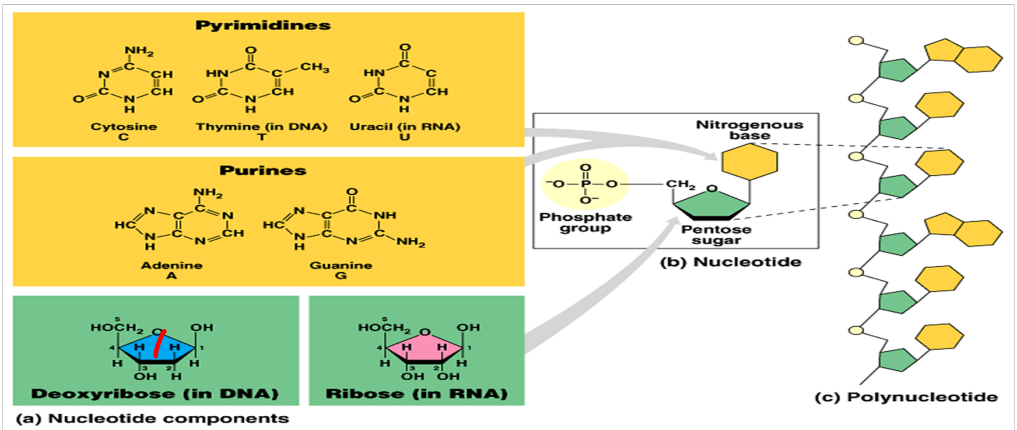
& **collagen and elastin** are two proteins found in connective tissue (bones, muscle, skin, & tendons, blood vessels)

E. The structure of nucleic acids

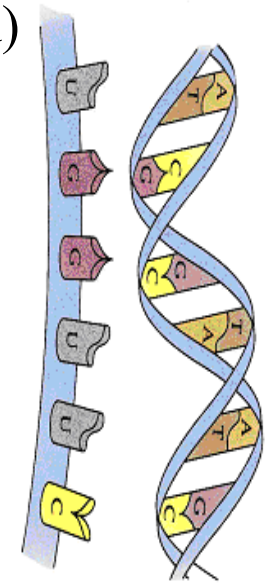
1. Nucleic acid = a complex biomolecule that ***stores cellular information*** in the form of a code.

2. Components of an nucleic acid are **monomers** called ***nucleotides*** (which have **C, H, O, N, *P***)

3. A nucleotide is made up of:
   a. ***sugar*** (deoxyribose or ribose)
   b. ***nitrogenous base*** (cytosine, guanine, adenine, thymine or uracil)
   c. ***phosphate group***



Ex: DNA (Deoxyribonucleic acid)
- ***contains our genetic code***
(how to make all our proteins)
*shape = ***double*** helix



RNA (Ribonucleic acid) -
takes the code from DNA
and actually takes part in
making our proteins.
*shape = ***single*** strand

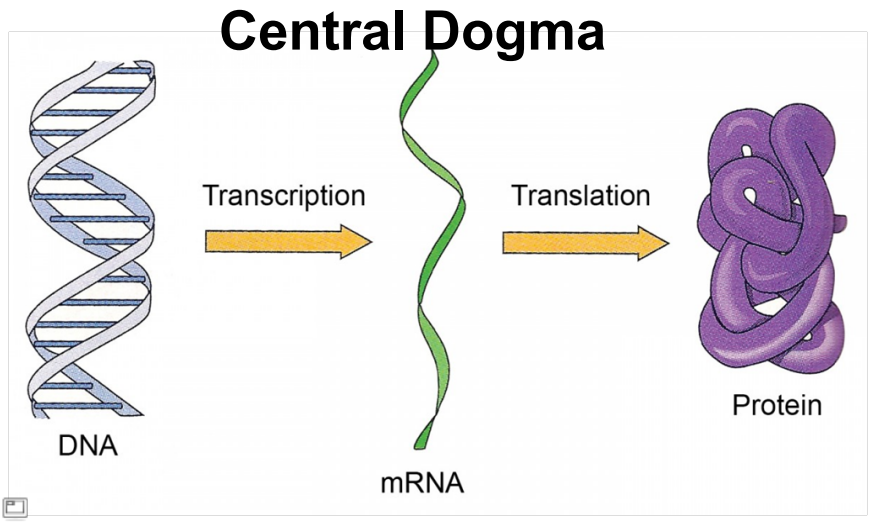
4. **Nucleic acids** provide two main functions.

genetic information storage
protein synthesis

5. Nucleic acids store an organism's **genetic information**.
*every known organism on earth uses ***DNA*** to carry its genetics information
*genetic information is passed ***from parent to offspring*** through DNA

6. Nucleic acids are necessary for the ***protein synthesis*.**
   *the ***genes*** found in an organism's DNA hold instructions to make proteins

   *proteins carry out ***necessary life functions***



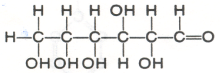
Identifying Chemical Compounds

A. Study the rules and formulas below. Then, on the first line under each formula, tell whether the substance is organic or inorganic. On the second line, indicate whether the substance is a carbohydrate, fat or oil, protein or amino acid, or none of these.

Rules

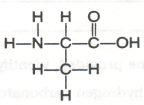
1. All organic compounds contain carbon. Most inorganic compounds do not contain carbon. Carbon dioxide is an exception.
2. In carbohydrate molecules, the ratio of hydrogen to oxygen is 2:1.
3. In fats and oils, the ratio of hydrogen to oxygen is much greater than 2:1.
4. Amino acids contain an amino group (—NH_2 or H—N—) and an organic acid group (—COOH or —C—OH, with O)

Formulas

1. 

2. CO_2

3. $C_{12}H_{22}O_{11}$

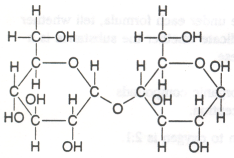
4. 

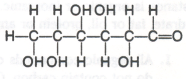
5. $Mg(OH)_2$

6. CH_4

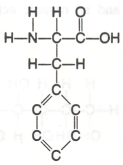
7. $C_{18}H_{34}O_3$

8. CH_3COOH

9. 

10. 

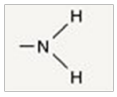
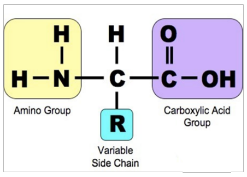
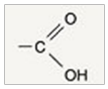
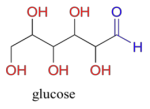
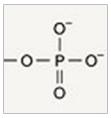
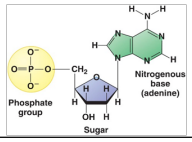
11. NaCl

12. 

13. $C_3H_5(C_{17}H_{35}O_2)_3$

B. On the line provided, identify the common name for these compounds.

1. Sodium hydrogen carbonate _____
2. Solid carbon dioxide _____
3. Sucrose _____
4. Calcium carbonate _____
5. Magnesium hydroxide _____
6. Methane _____
7. Ascorbic acid _____
8. Acetic acid _____
9. Maltose _____
10. Sodium chloride _____

Functional Group	Formula	Found in	Example
Amino		Proteins	Amino acids 
Carboxyl		Proteins	
Hydroxyl	—OH	Carbohydrates	Sugars  glucose
Phosphate		DNA, ATP	Nucleotides 

2.4 Chemical Reactions

Bonds break and form during chemical reactions.

- Chemical reactions change substances into different ones by breaking and forming chemical bonds,causing substances to ***recombine into different substances***.

  -Reactants are ***changed*** during a chemical reaction.

  -Products are ***made*** by a chemical reaction

Reactants→ Products

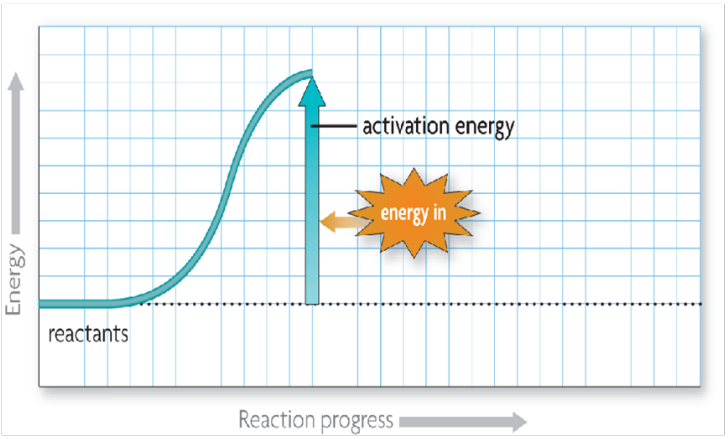
(starting materials)→(ending materials)

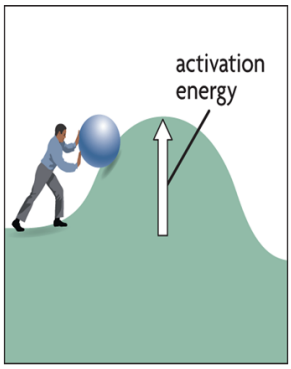
In chemical reactions, it is important to understand that atoms are ***neither created or destroyed, they are rearranged.***

- ***Bond energy*** is the amount of energy that breaks a bond.
  -Energy is ***added to break*** bonds.
  -Energy is ***released*** when bonds form.
- A reaction is at ***equilibrium*** when reactants and products form at the ***same rate***.

$$CO_2 + H_2O \rightleftharpoons H_2CO_3$$

- **Chemical reactions release or absorb energy.**
  -***Activation energy*** is the amount of energy that needs to be ***absorbed to start*** a chemical reaction.

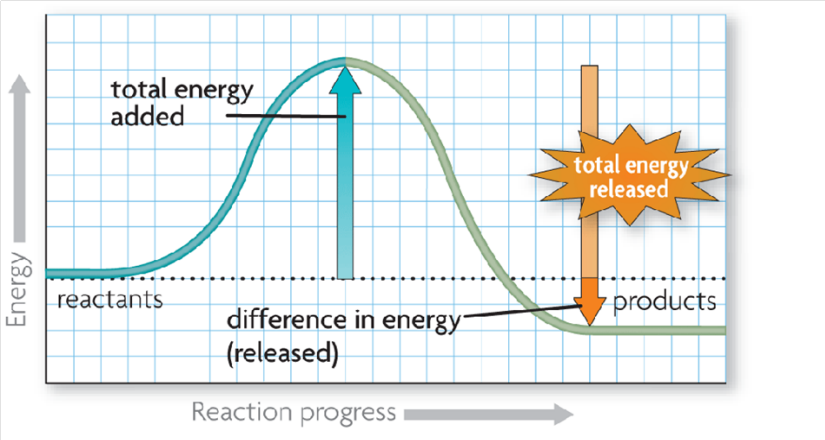




- ***Exothermic reactions release*** more energy than they absorb.

  -***Reactants*** have ***higher bond energies*** than ***products***.

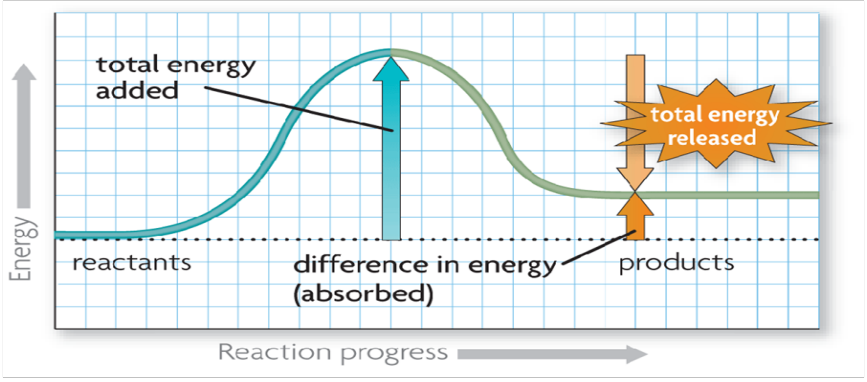
  -***Excess energy*** is ***released*** by the reaction.



- ***Endothermic reactions absorb*** more energy than they release.

  -***Reactants*** have ***lower bond energies*** than ***products***.

  -***Energy*** is ***absorbed*** by the reaction to make up the difference.



2.5 Enzymes

An enzyme is a protein that changes the rate (***catalyzes***) a chemical reaction.

a. Without enzymes, chemical reactions necessary for life would not occur at a rate ***sufficient for sustaining life*** .

b. Enzymes are protein (***organic***) catalysts.

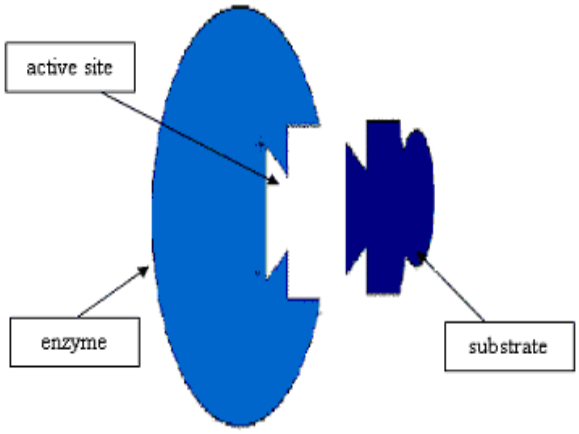
Catalyst = Substance that ***alters*** a chemical reaction to ***lower the amount of activation energy*** thus ***increases reaction rate*** .

Activation energy is the "***kick in the pants***" to get the reaction started.

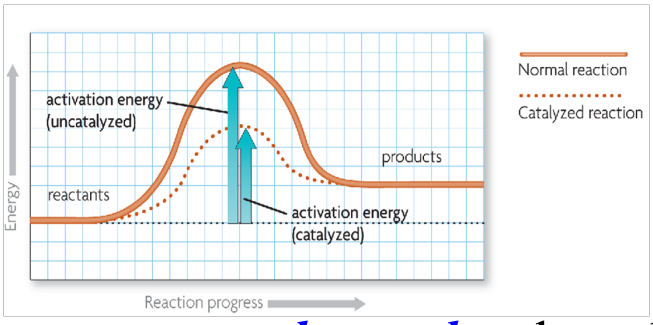
c. Specific shapes of enzymes bind to specific ***shapes of substrate*****;** they fit like a **lock and key**

Substrate = ***The reactant molecules that bind to the enzyme***

Active site = ***the site where substrate binds to an enzyme.***



d. Enzymes ***lower*** the **activation energy** by **breaking** the bonds of the substrate ***and allows the reaction to occur faster***



e. Enzymes ***are not changed*** and can be ***recycled*** and used again for the ***same type*** of reaction

f. Named with the name of the substrate with the action it performs and adding the suffix -"***ase***"

g. Have an optimum ***temperature*** and ***pH*** beyond which they will be ***denatured***, ***the peptide*** or hydrogen bonds can break.

h. Increasing the ***concentration*** of an enzyme speeds up its action.

i. Process of using a catalyst is ***catalysis.***

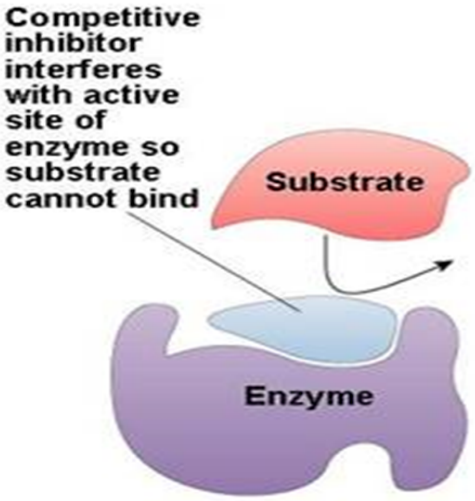
A ***coenzyme*** is a substance that works with an enzyme to ***initiate*** **or** ***aid*** the function of the enzyme.

Coenzymes ***cannot function*** **on their own** and **require** the presence of an enzyme.

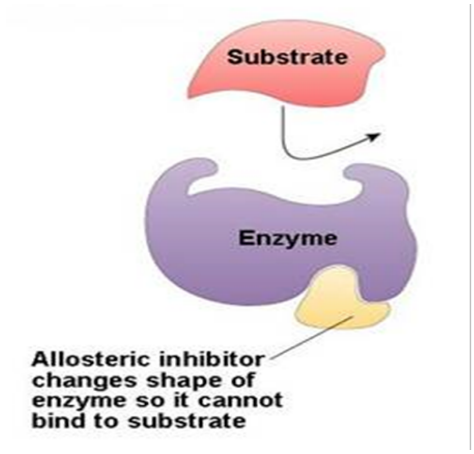
Ex: *B vitamins serve as coenzymes essential for enzymes to form fats, carbohydrates and proteins.*

The **activity of enzymes can be inhibited**.

> a ***competitive inhibitor*** binds the active site on the enzyme and **prevents binding** of the substrate



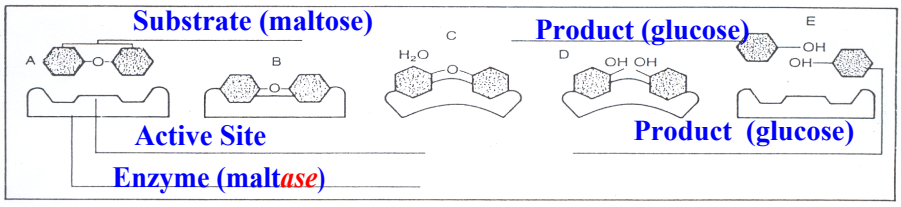
- a ***noncompetitive*** **inhibitor (*allosteric* inhibitor)** binds to a location other than the active site on the enzyme, inducing a shape change in the enzyme
- substrate can ***no longer bind*** to the active site



Enzymes

Most chemical reactions require energy to proceed. Most of the reactions needed to run the cell's machinery require levels of energy that are harmful to the cell. Cells, therefore, employ enzymes, which lower the energy required for a reaction to take place. Each reaction involves a unique enzyme, which is not consumed during the reaction.

- Study the diagram below, which shows the enzyme-aided breakdown of maltose. Fill in the missing labels and then complete the chart.



Reaction Phase	What is happening?
A	Enzyme approaches substrate.
B	Substrate "fits" enzyme - bonds at active site.
C	Enzyme distorts - makes bond easy to break.
D	As bond breaks, *hydrolysis* rxn takes place. (H_2O is a reactant.)
E	Enzyme releases product - goes after next substrate.

- Study the graph to the right, which shows the energy required to break down maltose in the absence of the proper enzyme. Draw a line on the graph to show the energy required for the reaction when the proper enzyme is present. Then answer the questions on the left.

1. The presence of the enzyme lowers the activation energy of the reaction.
2. Because enzymes change the rate of chemical reactions without being used up, they act as catalysts.
3. Some enzymes contain a nonprotein coenzymes, i.e. vitamins molecule attached near the active site.