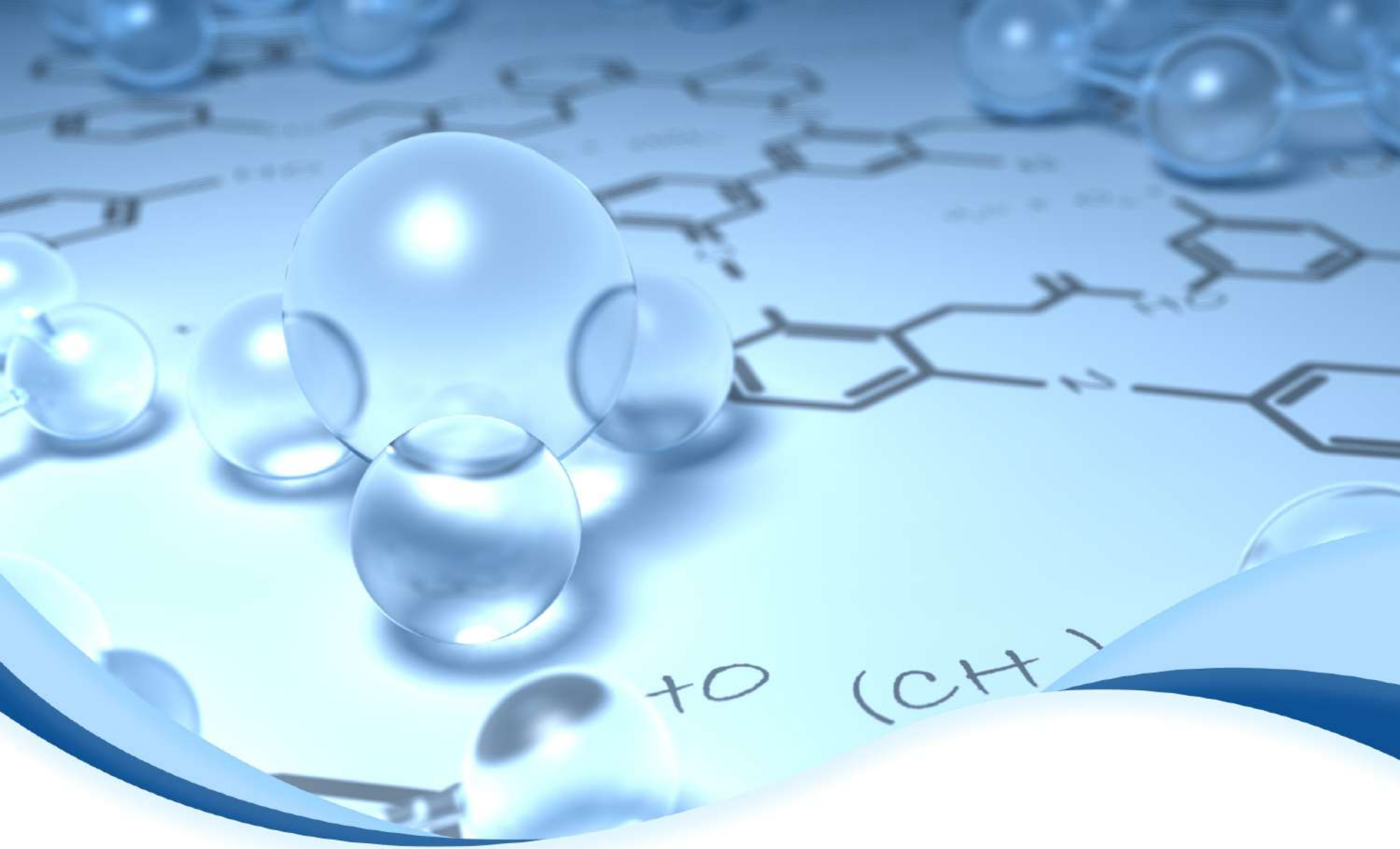


The Chemistry of Life

Day 1

What is biochemistry?

- Biochemistry is the study of **structure, composition (what things are made up of), and chemical reactions** that occur in living things.
- Living things (biotic factors) depend on **chemistry for life**…so biology and chemistry are closely related!

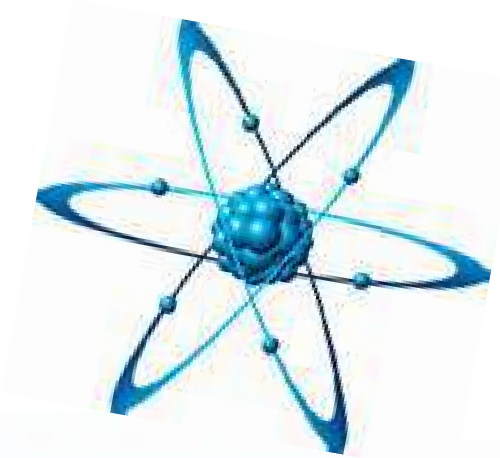
Composition of Matter

- Matter – everything in the universe is composed of matter.
  - Matter is anything that **occupies space or has mass**.
    - Mass is the **quantity of matter** an object has.
    - Weight is the **pull of gravity** on an object.

States of Matter

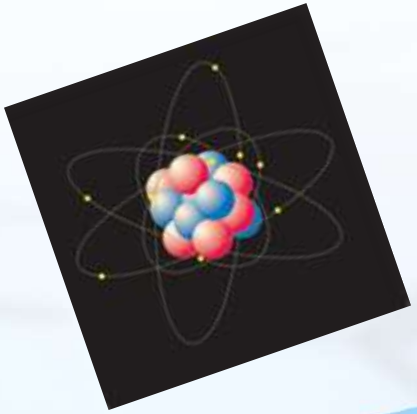
States of Matter

Atoms



•The **simplest particle of an element** that retains all the properties of that element.

- All atoms consist of 3 types of smaller particles:
  - **Proton** = has a + charge
  - **Neutron** = has no charge
  - **Electron** = has a - charge

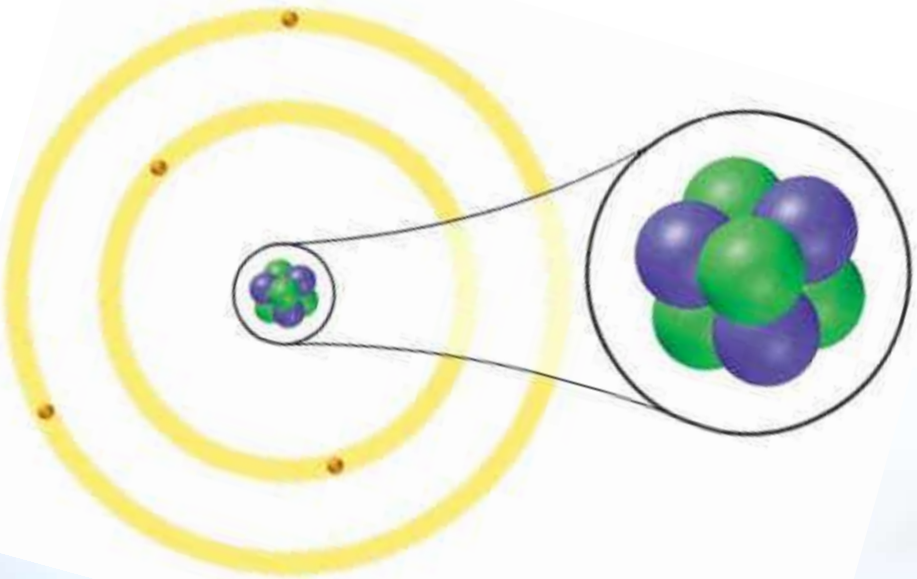


•Properties of atoms determine the **structure and properties** of the matter they compose.

•Our understanding of the structure of atoms is based on scientific models, not actual observation.

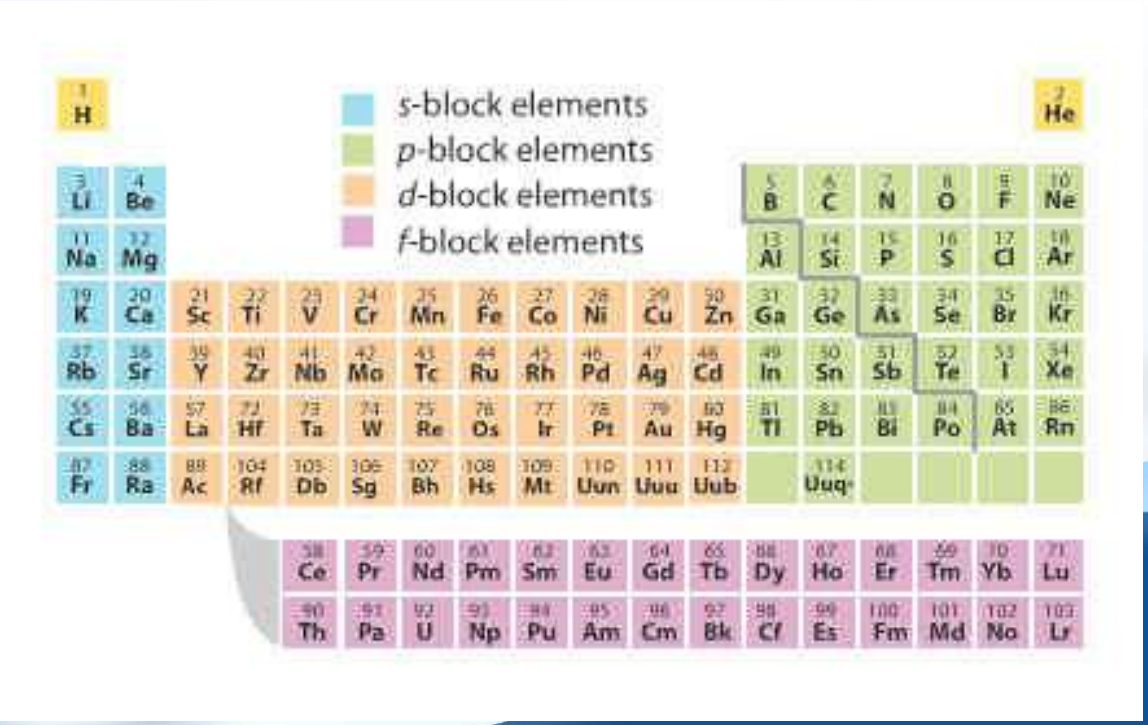
The Nucleus

- **Central core**
- Consists of positive charged protons and neutral neutrons
- Positively charged
- Contains most of the mass of the atom



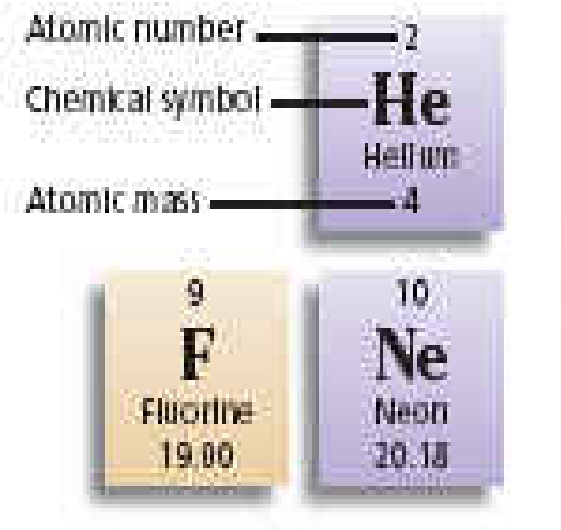
Elements

- Pure substances that **cannot be broken down** chemically into simpler kinds of matter.
  - Made of only **1** type of atom
- A group of atoms of the **"same"** type.
- More than 100 elements (**91** are naturally occurring)



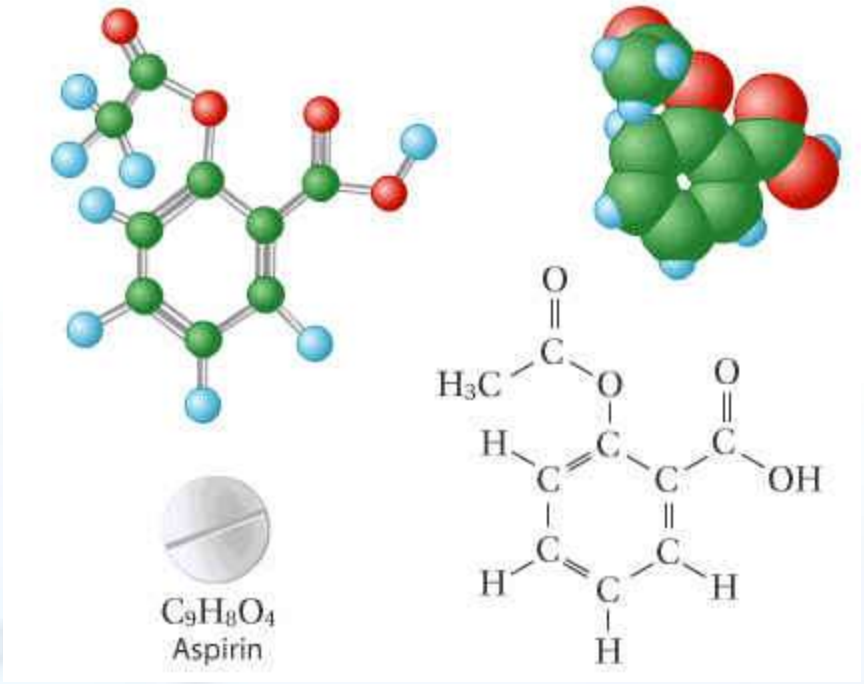
More on Elements

- **96 %** of the mass of an organism is composed of 4 elements (oxygen, carbon, hydrogen, and nitrogen)
- Each element has a unique chemical symbol:
  - Consists of **1-2** letters
  - First letter is always capitalized



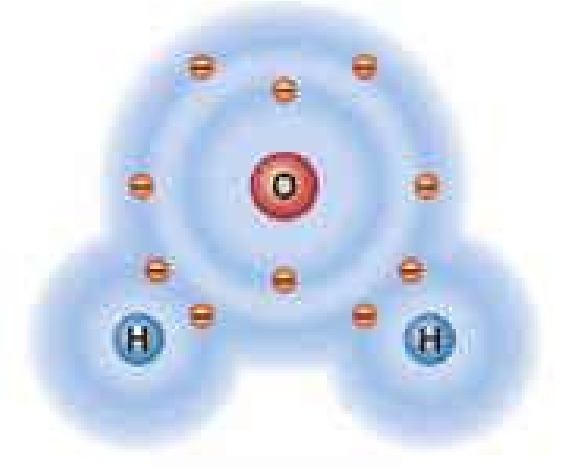
Compounds

- Is a substance made of atoms of **different** elements bonded together in a certain ratio.
  - Examples: **H_2O and CO_2**
- Most elements do not exist by themselves
- Readily combine with other elements in a predictable fashion



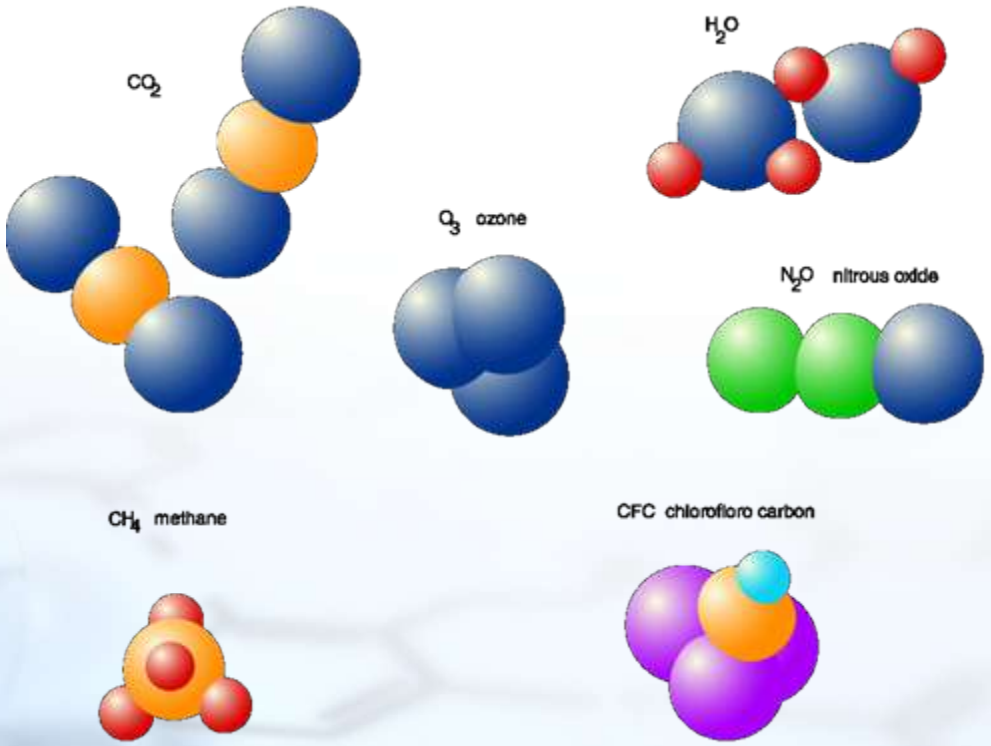
More on Compounds

- A compound is a pure substance made up of atoms of **two or more** elements.
  - The proportion of atoms are **always** fixed.
- Chemical formulas show the **kind and proportion** of atoms of each element that occurs in a particular compound.



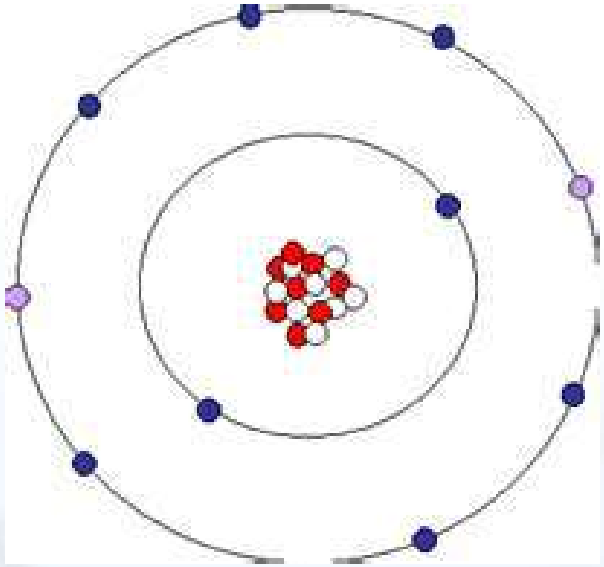
Molecules

- Is **two or more** atoms held together by **covalent** bonds.
- Are the **simplest part** of a substance that **retains all** of the properties of the substance and exists in a free state.
- Some molecules are large and complex.



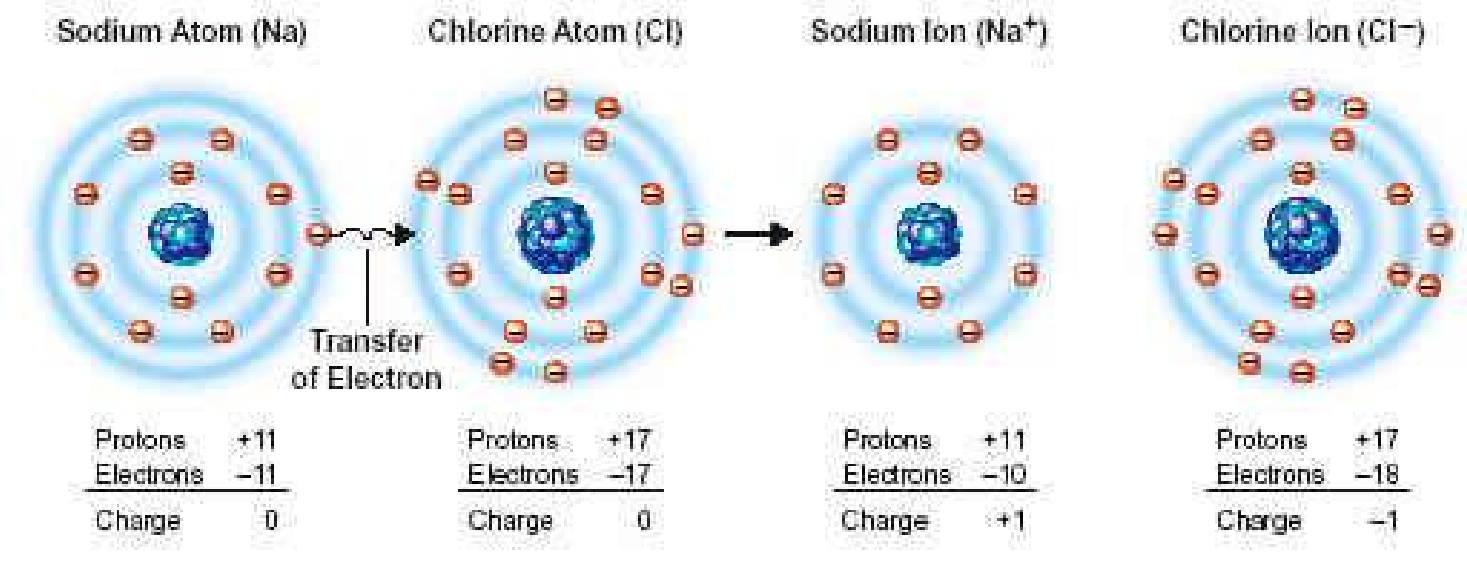
Ions form when atoms gain or lose electrons

- Ion is an atom that has **gained or lost** one or more electron.
- It forms because an atom is more stable when its outermost energy level is **full**.
  - The gain or loss of electrons results in a full outermost level.
- An atom becomes an ion when its number of electrons **change and it gains** an electrical charge.
- Can be positively or negatively charged.



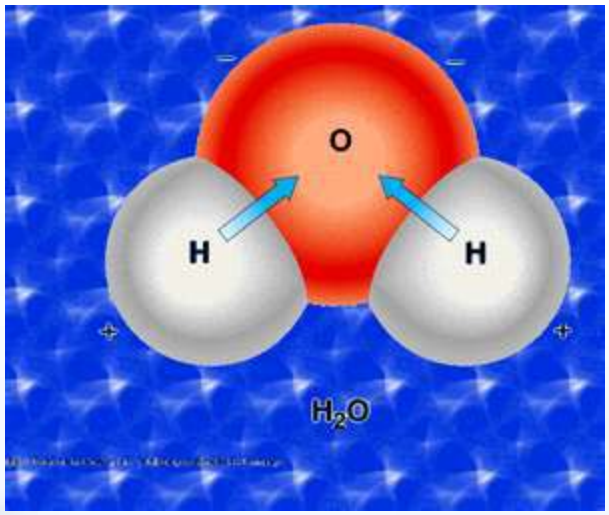
Ionic Bond

- Some atoms become stable by **losing or gaining electrons.**
- Atoms that lose electrons are called **positive ions.**
- Atoms that gain electrons are called **negative ions.**
- Because positive and negative electrical charges attract each other **ionic bonds** form.



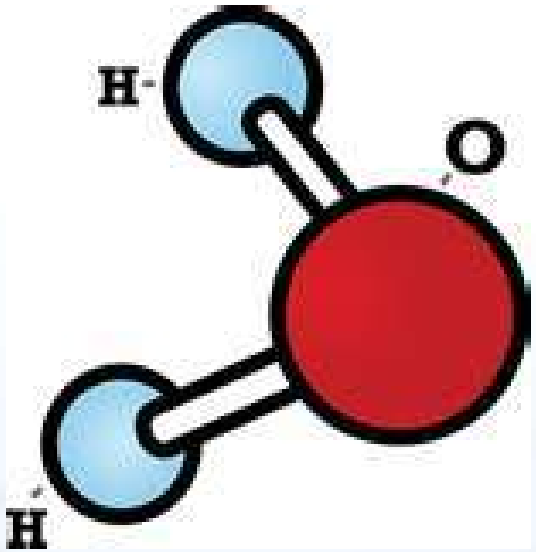
Atoms share pairs of electrons in covalent bonds.

- Not all atoms gain or lose electrons easily.
- Some atoms **"share"** pairs of electrons.
- Shared pairs of electrons fill the outermost energy levels of the bonded atoms.
  - A covalent bond is formed when atoms **share a pair of electrons**.
  - This type of bond is **very strong**.



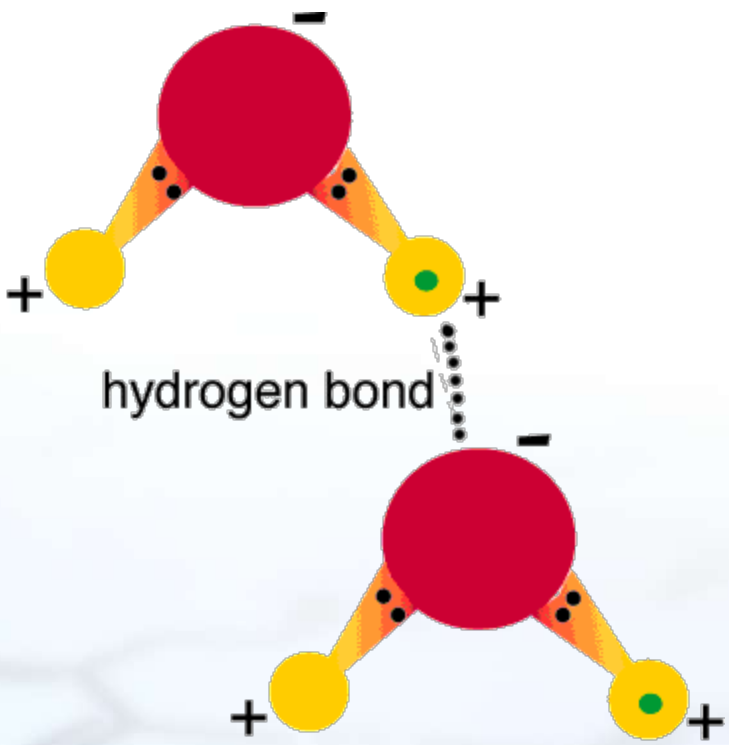
Properties of the Water Molecule

- Water molecule (H_2O) is made up of three atoms – one oxygen and two hydrogen
- The oxygen atom attracts more than its **"fair share"** of electrons.
- Oxygen end **"acts" negative**
- Hydrogen end **"acts" positive**
- Causes the water to be **polar**
  - Think of it as **two magnets** attracted to one another.
- Water is **neutral** (equal number of electrons and protons)
  - **Zero net charge**



Life depends on hydrogen bonds in water

- Polar water molecules act like magnets and attract each other
- Hydrogen bonds –
  - Is an attraction between a **slightly positive hydrogen atom and a slightly negative atom**, often oxygen or nitrogen.
- They are strong bonds that form between molecules like CO_2 and H_2O



Bonding Animation

Bonding Relationships

Homeostasis

- Ability to maintain a **steady state** despite changing conditions
- Water is important to this process because:
  - **Makes a good insulator**
  - **Resists temperature change**
  - **Universal solvent**
  - **Coolant**
  - **Ice protects against temperature extremes** (insulates frozen lakes)

Properties Related to Hydrogen Bonds

- High specific heat:
  - Water **resists** changes in temperature.
  - Must absorb **more** heat energy to increase temperature
  - Helps **regulate** cell temperatures

Properties Related to Hydrogen Bonds

- Cohesion –
  - Attraction among molecules of the **same** substance
  - Makes water molecules **stick** to each other
  - Produces **surface tension**, makes kind of skin on water

Properties Related to Hydrogen Bonds

- Adhesion
  - Attraction among molecules of **different** substances
  - Water molecules **stick** to things
  - Responsible for the **upward curve** on the surface of the water in a test tube
  - Helps plants transport water from their **roots to their leaves**

Properties Related to Hydrogen Bonds

- Capillary action
  - Allowing water to travel **upwards** against gravity

Solutions - Review

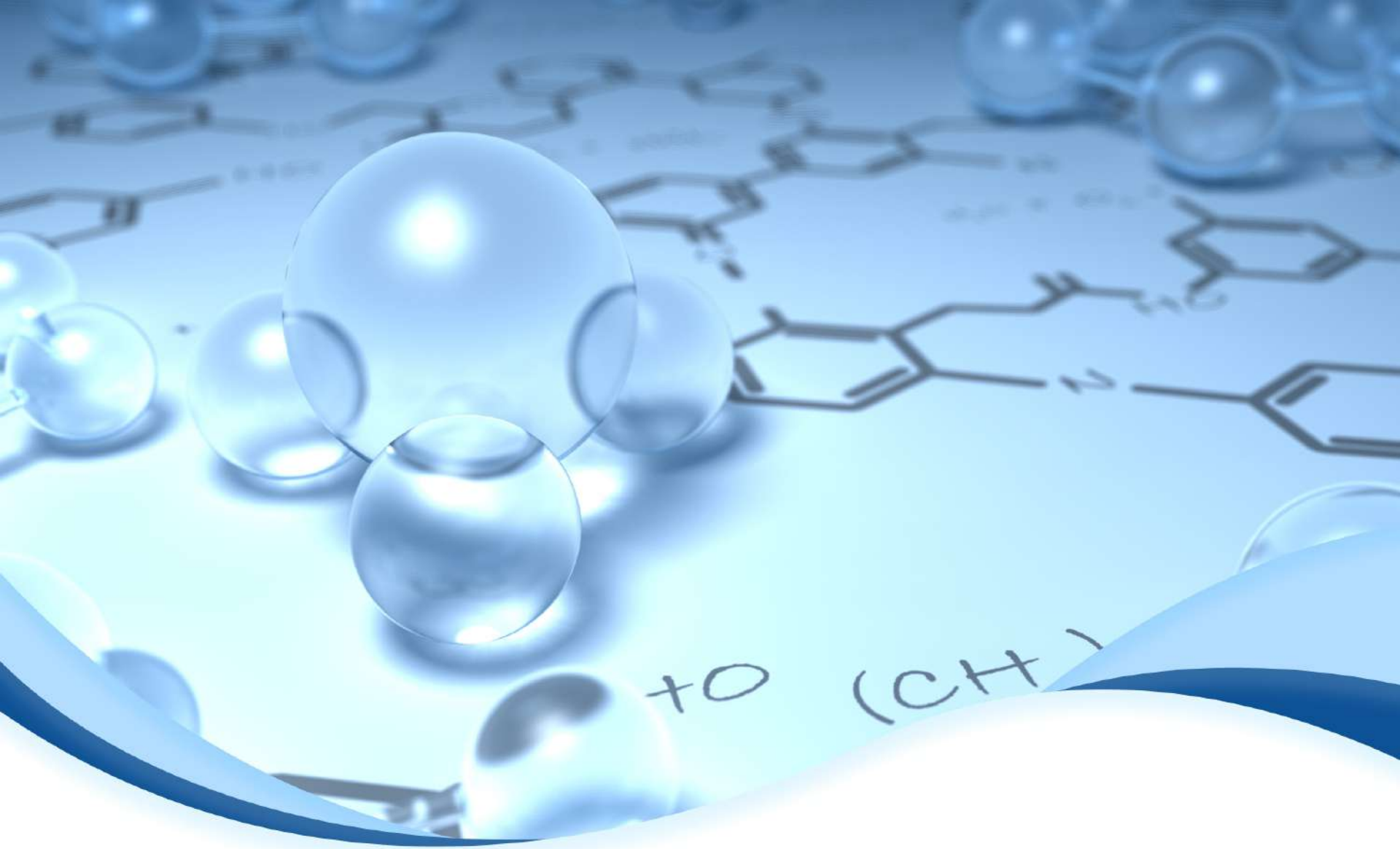
Solutions Animation

BrainPop - Review

BrainPop Acids and Bases

Ticket Out the Door

1. What is biochemistry?
2. What is matter?
3. List the charges for protons, neutrons, and electrons.
4. What is the difference between an element and a compound?
5. Describe the difference between ionic and covalent bonds.
6. On the pH scale where do acids AND bases fall?

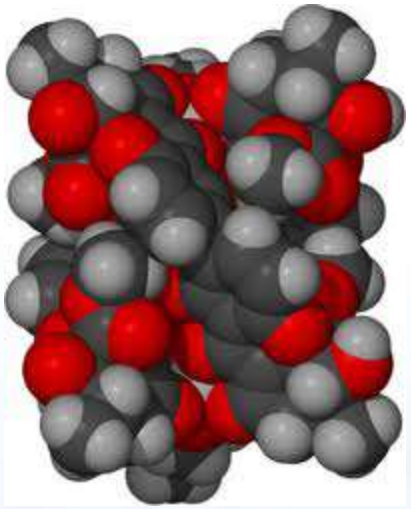


The Chemistry of Life

Day 2

What is a macromolecule?

- These are **organic compounds that contain carbon**, and are considered to be “giant molecules”.
- A process called **polymerization** combines smaller molecules together to form these larger macromolecules.
- These compounds are the **building blocks of living things**…in other words without them there would be no you!



Examples of Macromolecules

- There are four groups of macromolecules that make up living things:
  - **Carbohydrates**
  - **Lipids**
  - **Proteins**
  - **Nucleic acids**

Six Major Elements associated with making up these macromolecules

- These **6** elements make up your body, and they are also important in creating these organic compounds.
- So what are these 6 major elements important to life:

The Big Six -> CHONPS

- **Carbon (C)**
- **Oxygen (O)**
- **Phosphorus (P)**
- **Hydrogen (H)**
- **Nitrogen (N)**
- **Sulfur (S)**

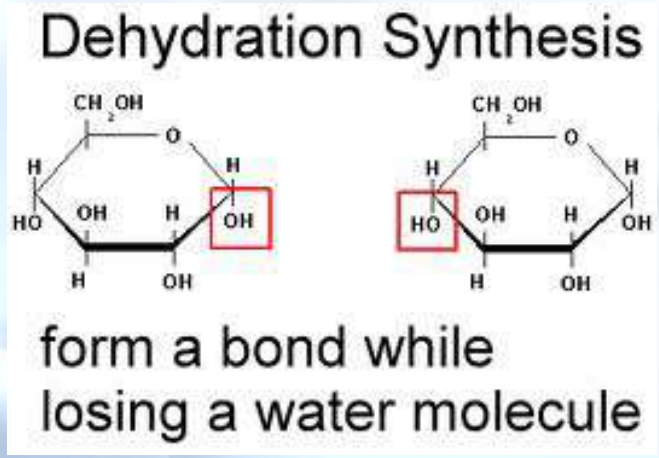
So how are these the building blocks of living things?

- The macromolecules are the LARGER MOLECULES…so like a house, you need "bricks" to build/make them!
  - **Monomer** – smallest unit of a large molecule (building blocks of things)
  - **Polymer** – the large molecule; formed by joining monomers (the product/the thing made = this is the macromolecule!)
- **2 or more** monomers make a polymer!

Formation of Macromolecules

•Monomers are connected by a reaction in which 2 molecules are bonded to each other through the **loss of a water molecule**.

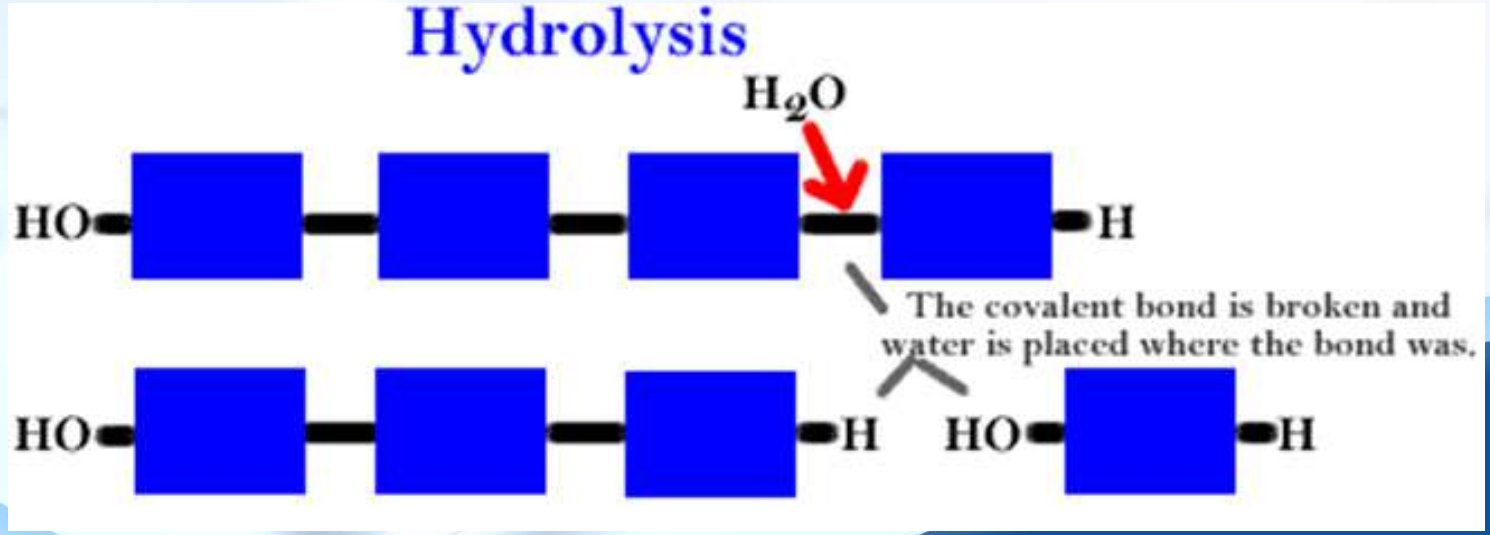
- Called a **condensation reaction or dehydration reaction** because a water molecule is lost.



Formation of Macromolecules cont.

•Polymers are disassembled (broken up) into monomers by **hydrolysis**, a process that is essentially the reverse of the dehydration reaction.

- Hydrolysis means **"to break with water"**. Bonds between monomers are broken by the addition of water molecules.



Four Major Classes of Organic Molecules

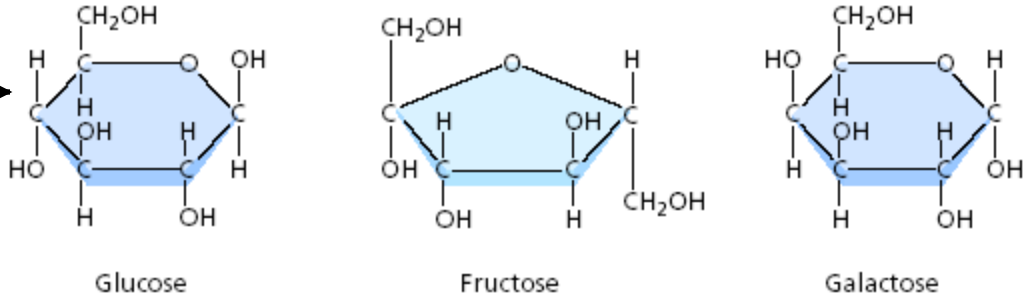
1. **Carbohydrates**
   - **Main source of energy for living things**
   - Plants and some animals use carbohydrates for **structural purposes**
   - Made up of sugars
     - **Monosaccharide** (monomer) = 1 single
     - **Disaccharide** = 2 sugars
     - **Polysaccharide** = many/more than 2 sugars

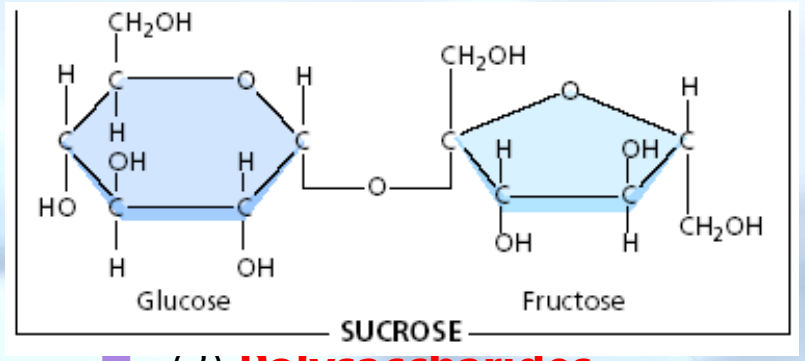
Organic Compounds: Carbohydrates

- The elements that make them up → **C, H, & O**
- Glycosidic bonds attach the sugar monomers together
- 3 types –

(1) **Monosaccharides**

($C_6H_{12}O_6$ = glucose, galactose, & fructose)





(2) **Disaccharides**

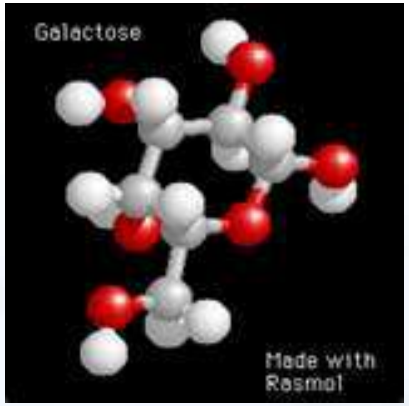
(2 monosaccharides joined; ex: sucrose)

- (3) **Polysaccharides**

(long chain of monosaccharides; ex: starch)

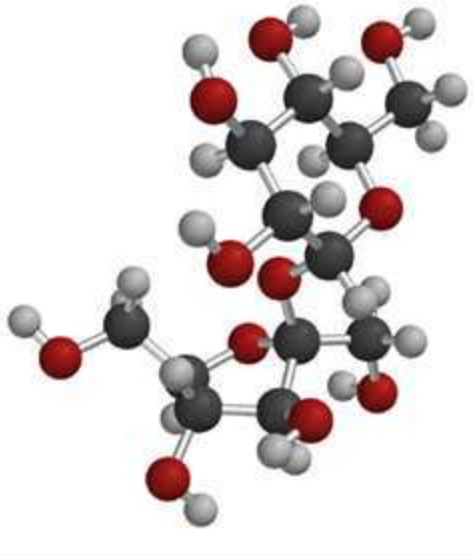
Glucose, Fructose, and Galactose (Monosaccharides)

- **Glucose**:
  - Made during photosynthesis
  - Main source of energy for plants and animals
- **Fructose**:
  - Found naturally in fruits
  - Is the sweetest of monosaccharides
- **Galactose**:
  - Found in milk
  - Is usually in association with glucose or fructose



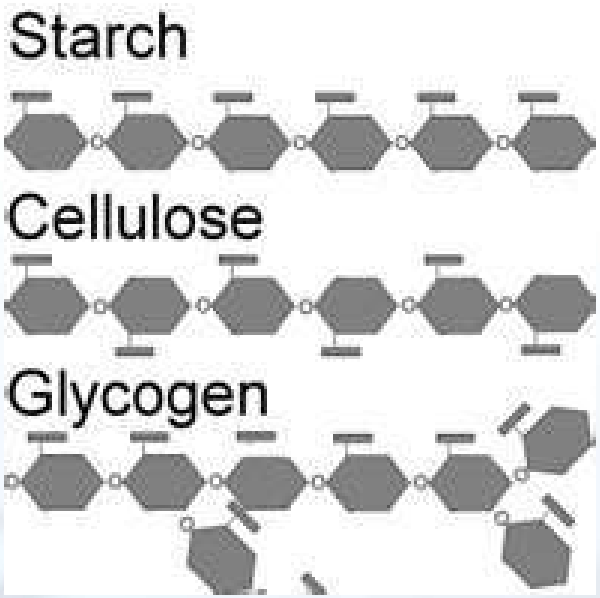
Disaccharide

- **Disaccharide** – two monosaccharide bonded together
  - **Table sugar (sucrose)** = made up of glucose + fructose bonded together
  - **Milk sugar (lactose**) = made up of glucose + galactose bonded together



Polysaccharide

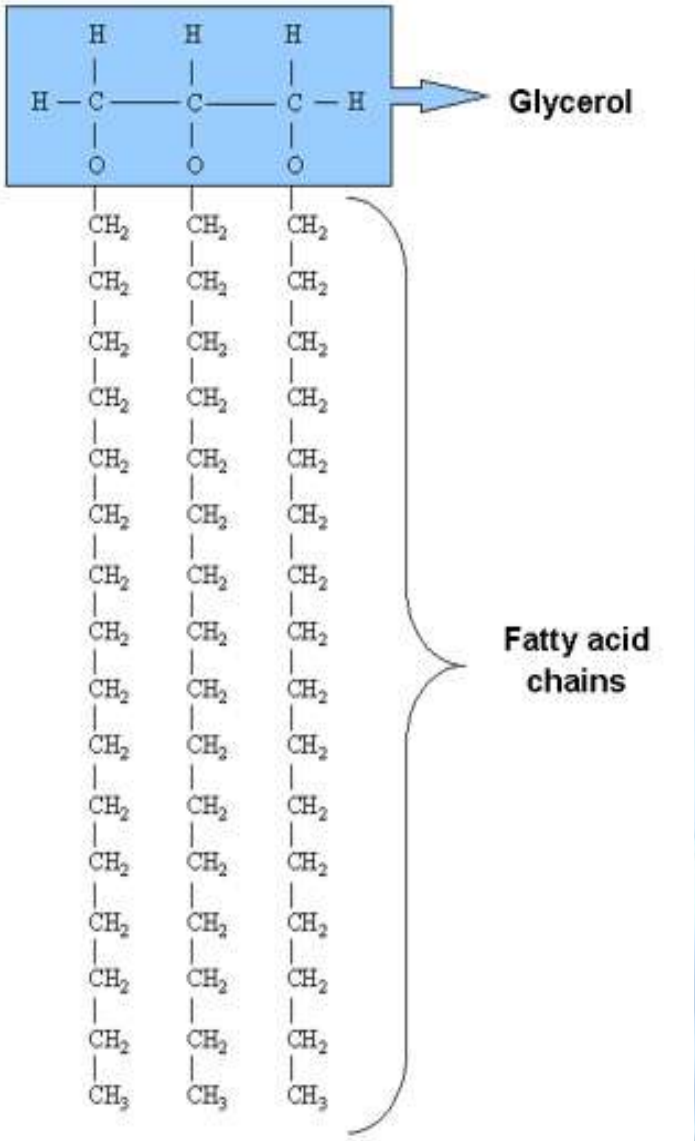
- **Polysaccharide** = more than two monosaccharide bonded together by glycosidic bonds
  - Serve as **storage material or building material**
    - Storage (examples**: starch, glycogen**)
    - Structural (examples: **cellulose, chitin**)
- A complex carbohydrate is a polysaccharide with **12 or more** monosaccharide units.
  - Pasta and starches are polysaccharides
    - **Potatoes** are a starch



Carbohydrate Animation

Carbohydrate Animation

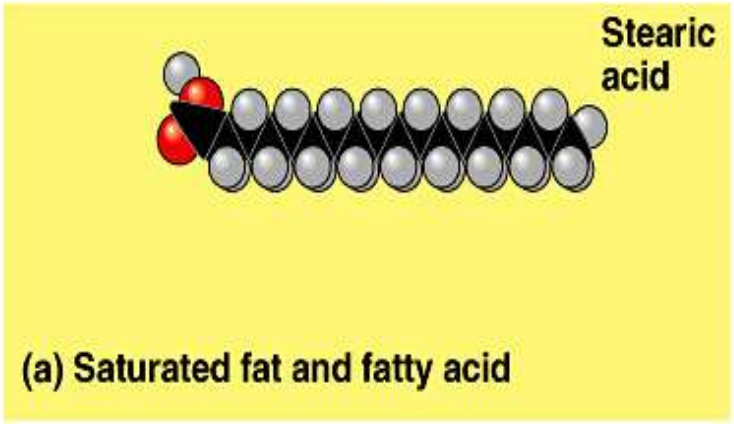
4 Classes of Organic Cmpds cont'd…

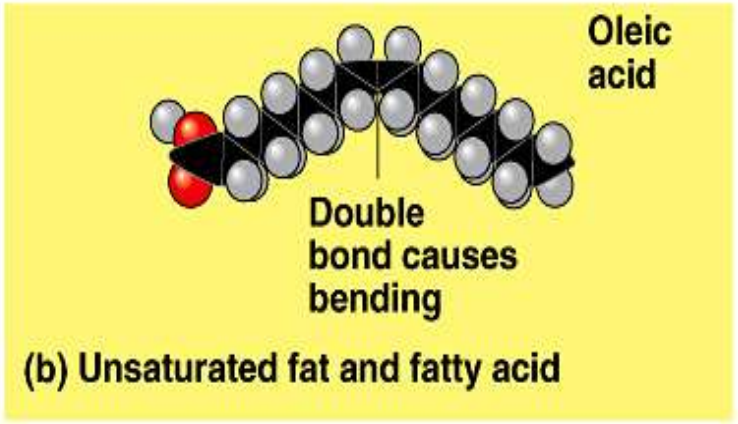


2. **Lipids**
   - Used to **store energy** (for the long term)
   - Important in **making your cell membranes & waterproofing** the certain coverings in the body
     - Example: Cell Membranes
   - **Insulates/ protects your bodies organs (like a cushion)**
   - *Examples* → Fats, Oils, and Waxes

Organic Compounds: Lipids

- The elements that make them up → **C, H, & O**
- **Nonpolar (*NOT soluble* / will not mix with water - Hydrophobic)**
- The building block for lipids includes **1 glycerol molecule and 3 fatty acid molecules**.
- There two ways lipids can be represented in the body:
  - **Saturated Fat** – fatty acids are "full" of Hydrogens; all carbon *bonds are single* (animal products)
  - **Unsaturated Fat** – at least 1 *double bond* between carbons (plant products)



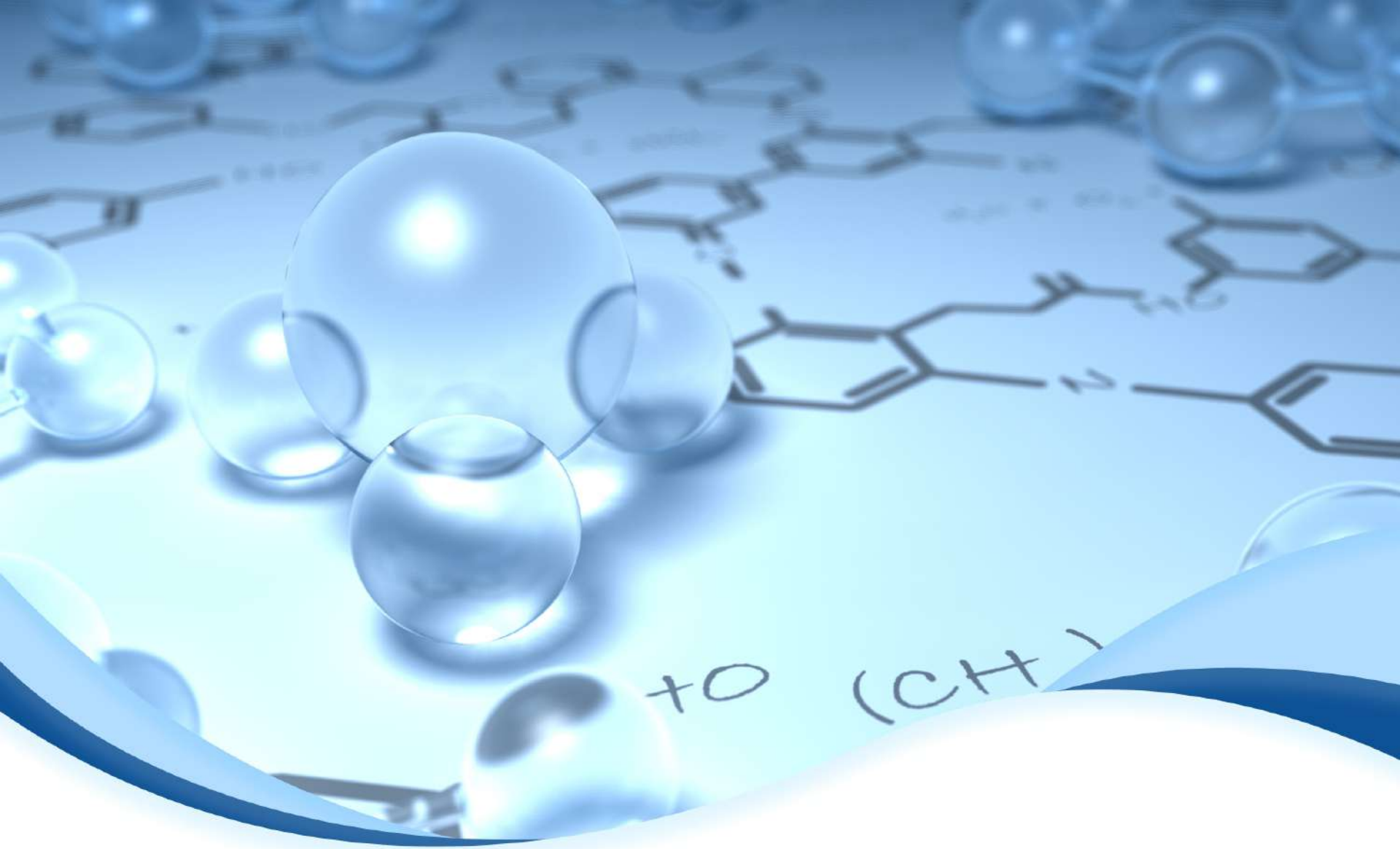


At room temperature, the molecules of a saturated fat are packed closely together, forming a solid.

At room temperature, the molecules of an unsaturated fat cannot pack together closely enough to solidify because of the kinks in their fatty acid tails.

Ticket Out the Door

1. What is a macromolecule?
2. List the 4 major groups of macromolecules.
3. What are the 6 major groups of elements found in macromolecules?
4. What is the difference between a monomer and a polymer?
5. What are carbohydrates used for?
6. What lipids used for?
7. What is the difference between a saturated and unsaturated fat?



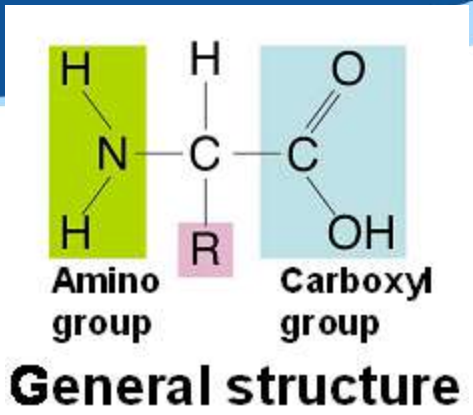
The Chemistry of Life

Day 3

More on the 4 Classes of Organic Compounds …

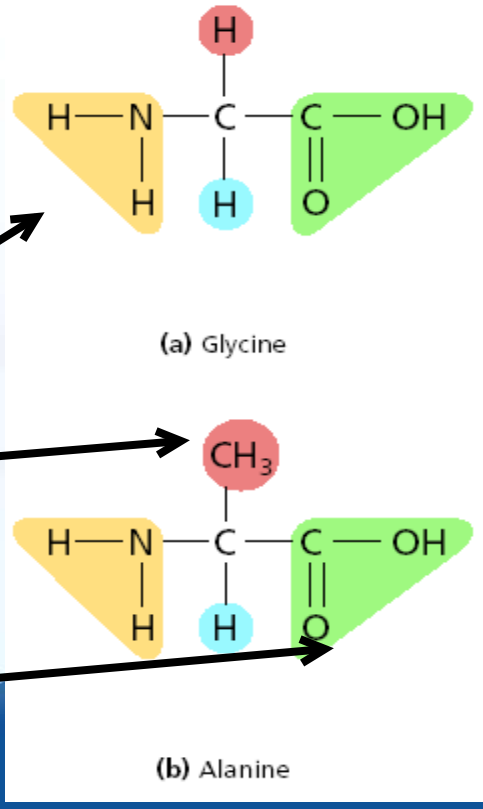
3. **Proteins**
   - The majority of the processes that take place in the body occur because of proteins!!!
   - The elements that make up proteins are **C, H, O, & N**
   - **Amino Acids (aa) are the monomers of proteins**

Organic Compounds: Proteins



- There are **20** different amino acids found in nature

- Amino Acids are made up of 3 functional groups:
  - **An AMINO GROUP ($-NH_2$)**
  - **An R GROUP (different per amino acid)**
  - **A CARBOXYL GROUP (-COOH)**



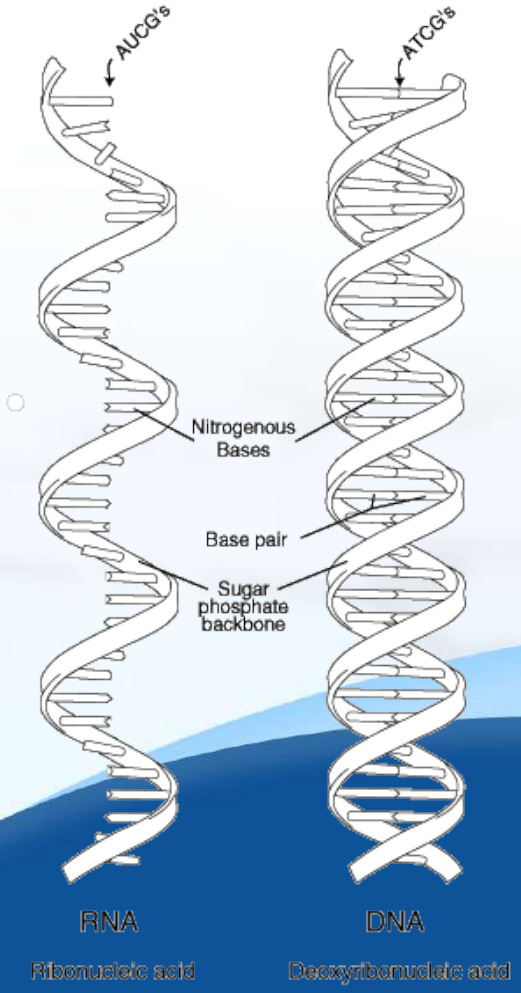
What are some functions of proteins?

- 4 Types of Proteins & their function in the body:
  - **Regulatory (ex: Enzymes)**
    - Controls the rate of reactions in your body
  - **Transport (ex: Hemoglobin transports O_2)**
    - Sending nutrients to different parts of the body
  - **Structural (ex: collagen, found in skin and bones)**
    - Forms/ makes up different parts of the body
  - **Protective (ex: antibodies protect against disease)**
    - Makes cells that act as fighters for the body

Finally…

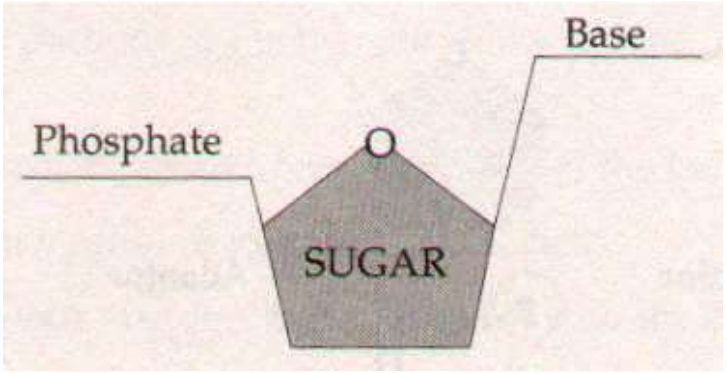
4. **Nucleic Acids**

- The function of nucleic acids is **to store and transmit genetic info**
- The elements that make up nucleic acids are… **C, H, O, N, & P**
- Two types:
  1. **DNA (Deoxyribonucleic Acid)**
  2. **RNA (Ribonucleic Acid)**

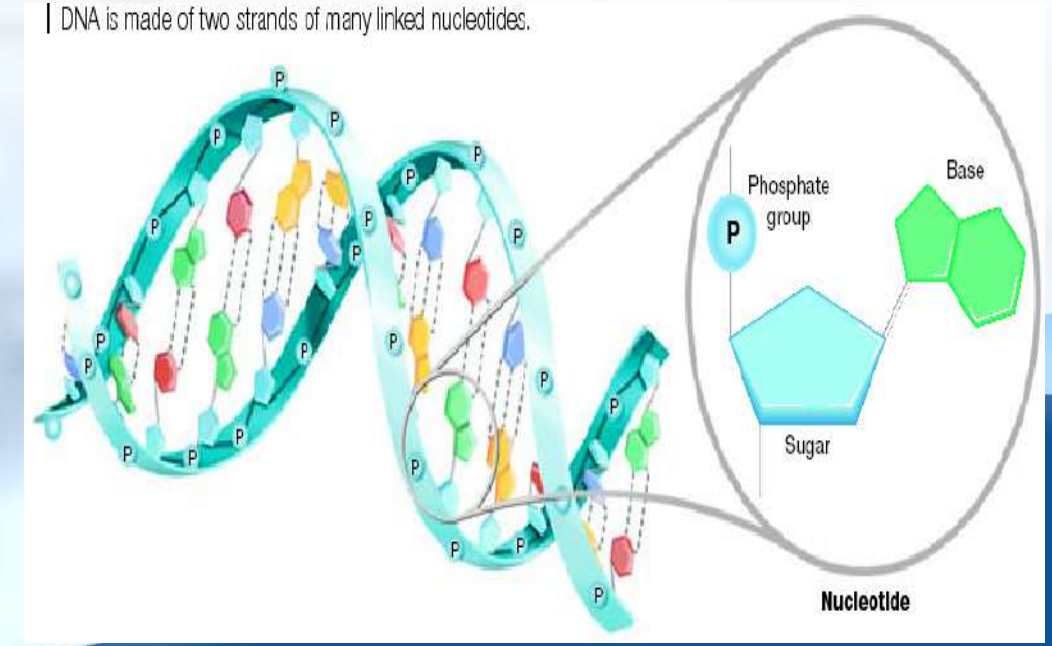


Organic Compounds: Nucleic Acids

- The monomers of **nucleic acids are nucleotides**

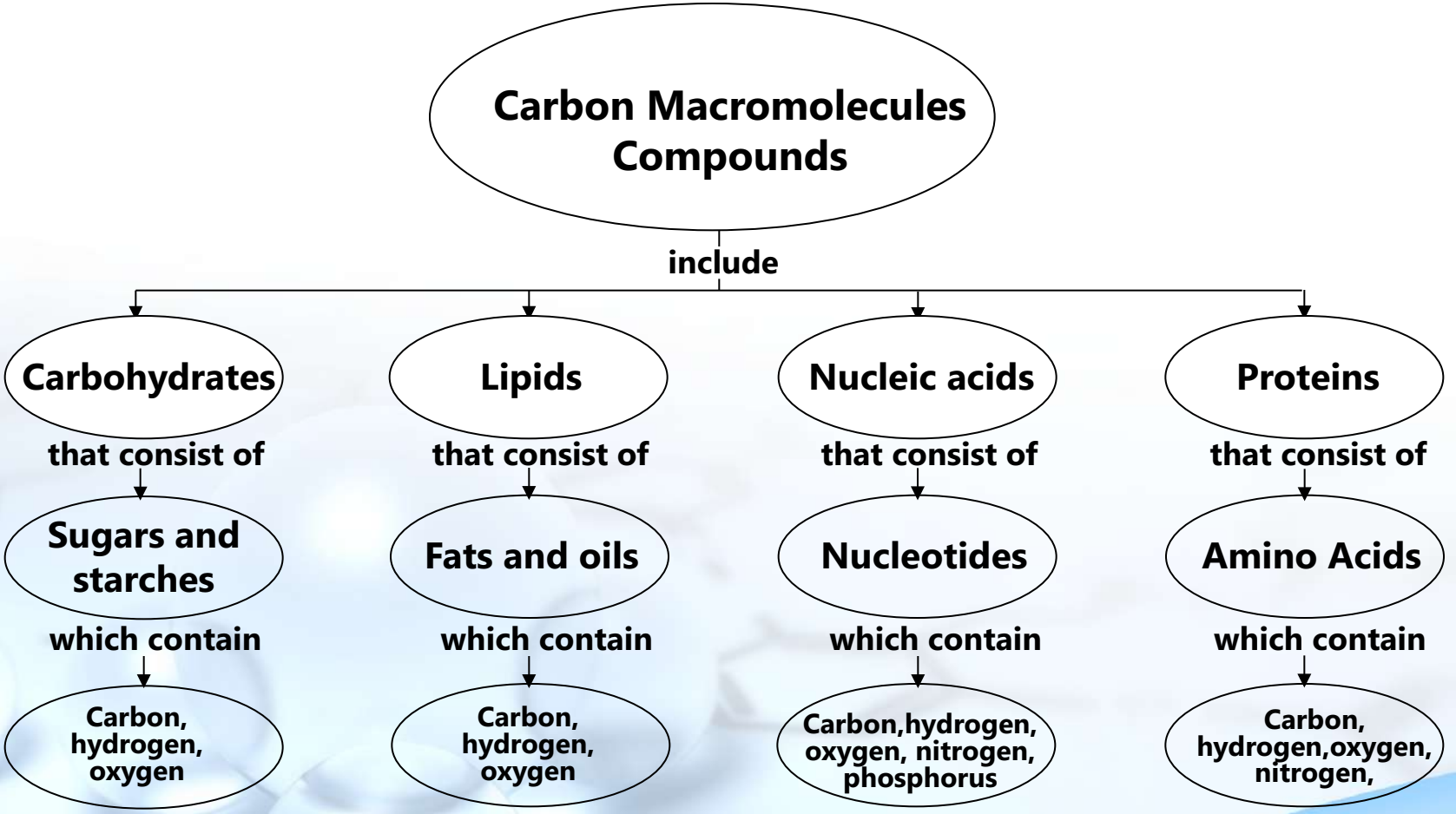


- Each nucleotide is made up of:
  - **A 5-carbon sugar**
  - **A phosphate group**
  - **A nitrogenous base**



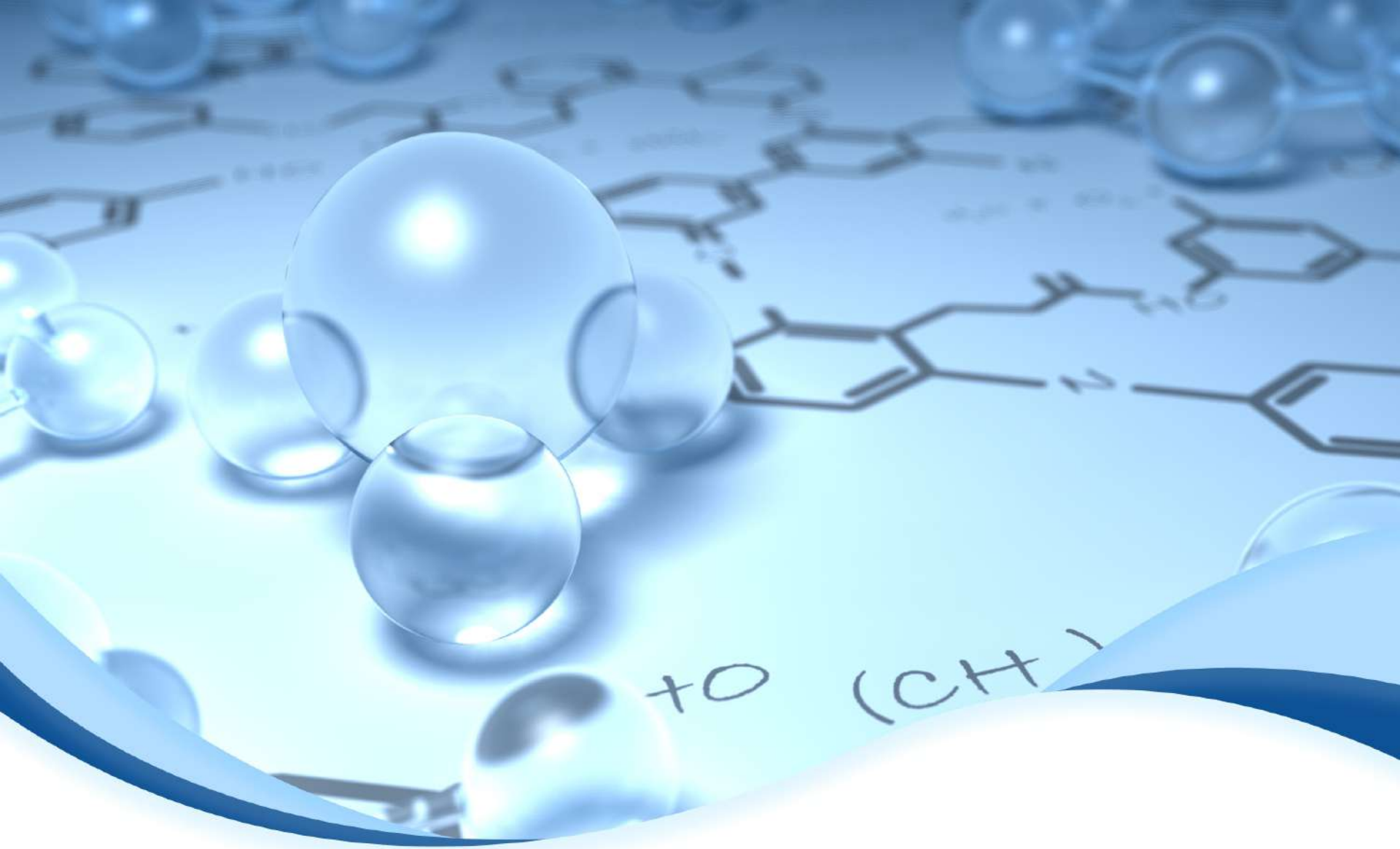
Monomer + Monomer, etc. = Polymer

MONOMERS (or building blocks)	POLYMERS
Monosaccharides	Carbohydrates (polysaccharides)
Glycerol and fatty acids (building block)	Lipids
Nucleotides	Nucleic Acids
Amino Acids	Proteins


Carbon Macromolecules Compounds
include
Carbohydrates
that consist of
Sugars and starches
which contain
Carbon, hydrogen, oxygen
Lipids
that consist of
Fats and oils
which contain
Carbon, hydrogen, oxygen
Nucleic acids
that consist of
Nucleotides
which contain
Carbon,hydrogen, oxygen, nitrogen, phosphorus
Proteins
that consist of
Amino Acids
which contain
Carbon, hydrogen,oxygen, nitrogen,

Ticket Out the Door

1. What are the monomers of (building blocks) of proteins?
2. What are the 3 basic parts of an amino acid?
3. What do proteins do for organisms?
4. What do nucleic acids do?
5. What are the 2 types of nucleic acids?
6. What are the monomers of nucleic acids?
7. What are the parts of a nucleotide?



The Chemistry of Life

Day 4

What is a Chemical Reaction?

•Everything that happens inside of an organism is based on **chemical reactions** – Examples:

- **Growth**
- **Its interaction with the environment**
- **Reproduction**
- **Movement**

•**Chemical reaction** – a process that changes one set of chemicals into another

•Chemical reactions always involve the **breaking of bonds and the formation** of new bonds!

Chemical Reaction Breakdown

- There are 2 parts to every chemical reaction:

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

Reactants **Products**

- Reactants represent what is **being used/what enters** into a reaction
  - Always found before the arrow!
- Products represent what is **made/what exits** a reaction
  - Always found after the arrow!

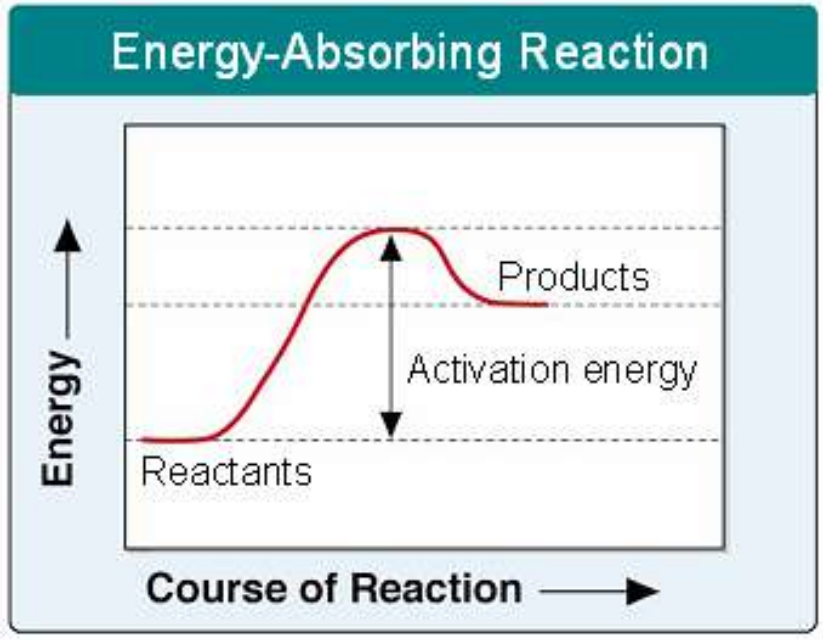
Do we need energy to complete all of these reactions?

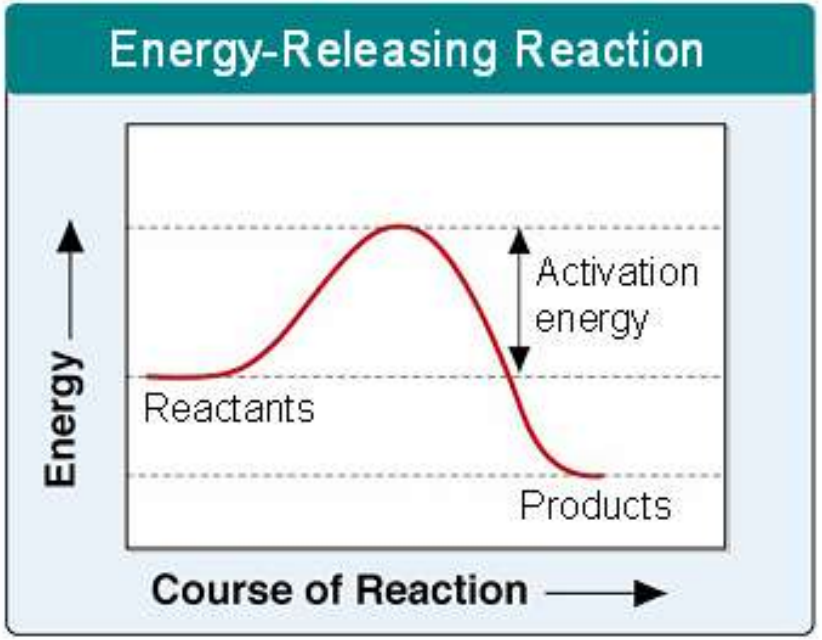
YES!!! Energy is a big factor in completing these reactions.

Some chemical reactions **release energy and some absorb energy**

- Chemical reactions that release energy are called **EXERGONIC REACTIONS**
  - These often occur spontaneously – such as Cellular Respiration
- Chemical reactions that absorb energy are called **ENDERGONIC REACTIONS**
  - These will not occur without a source of energy – such as Photosynthesis (the original energy comes from the sun!!!)

Chemical Reactions (cont'd)





Photosynthesis

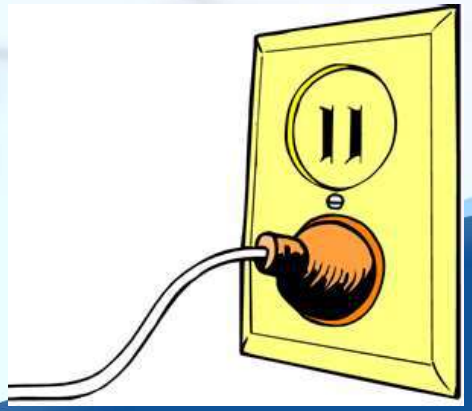
Cell Respiration

But not all reactions are spontaneous…some STILL require a little energy!

•Energy needed to get a reaction started is called **activation energy**.

•This "start energy" is important, because it can determine whether you **release or absorb** energy.

•It is important to every organism that they maintain a certain amount of energy…the amount of energy you use in the beginning can make a big difference on whether or not you complete an important reaction!



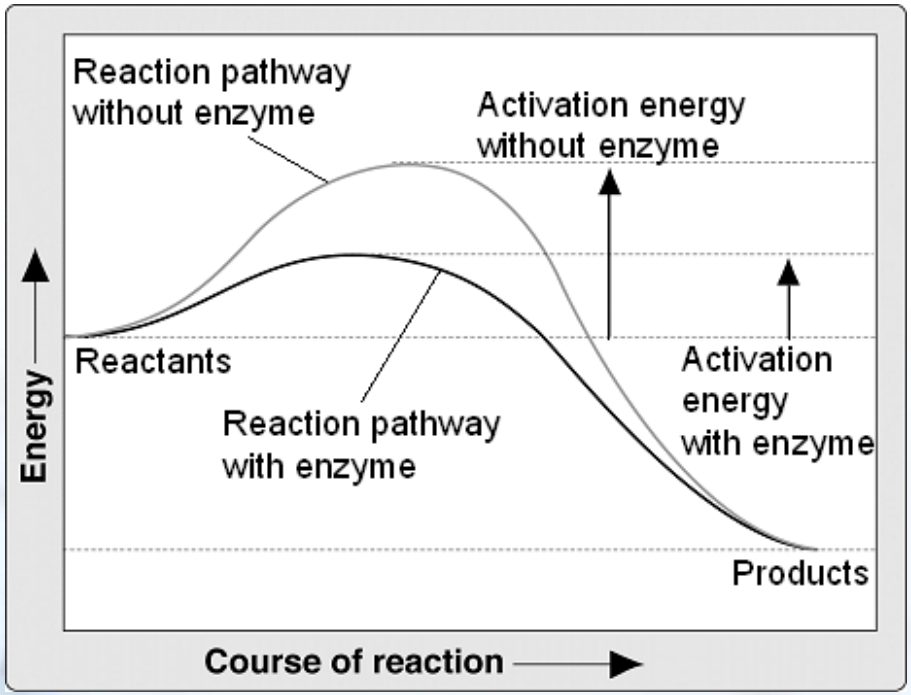
However… there is a PROBLEM!

•Some chemical reactions that make life possible are too slow or have activation energies that are too high to make them practical for living tissue…(*in other words they take TOO LONG*)

•Solution → Your body has a **protein** that lowers the amount of energy needed at the beginning of a reaction, so you have more energy to complete your metabolic processes needed to live your life!

These proteins are called… Enzymes!!!

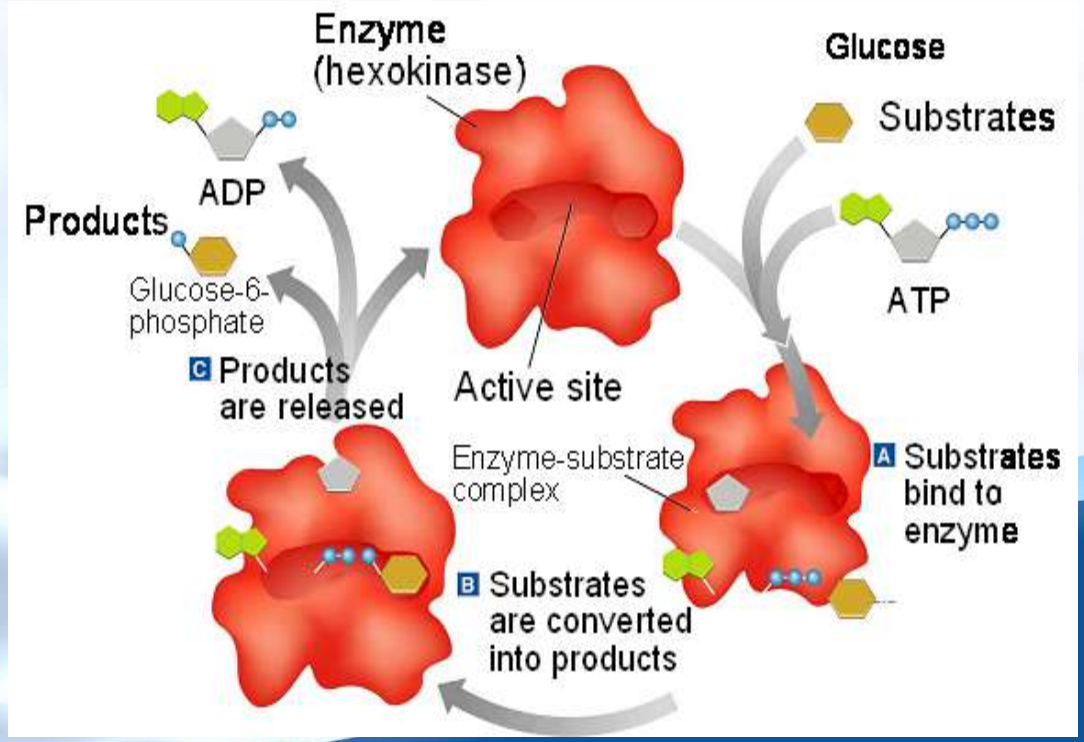
- Enzymes are proteins that act as **biological catalysts**
  - Catalysts:
    - Substance that **speed up the rate of a reaction**, without using a large amount of energy.



- Most enzymes end in the letters – ase.
  - Ex: your saliva/ spit is called AMYLASE

Enzymes

- Enzymes speed up a reaction by **lowering the activation energy** of a reaction
- Enzymes act as a **site of a reaction** and are not used up



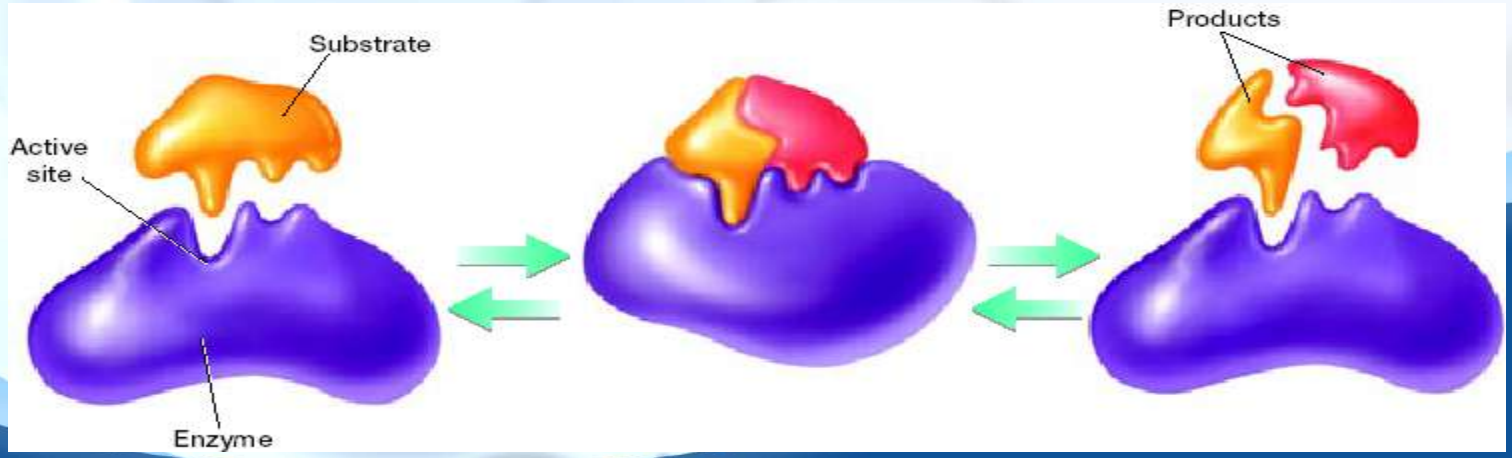
Scientists use a model to represent the way enzymes carry out chemical reactions

The Enzyme-Substrate Complex →
"Lock & Key" Model

Enzymes have very specific **Active Sites**, where only certain reactants can bind to reduce activation energy (E_A).

These reactants are called **"substrates."**

Enzymes release products after a reaction and can start the same process over again.



Remember…

- Enzymes are a type of **PROTEIN!!!**

- There job is to **regulate the body's activities** WITHOUT using too much energy.

- When you damage a protein, so it no longer works it becomes **DENATURED**.

Denaturation and Re-naturation of a Protein

There are many things that can affect the way an enzyme works:

- **Extreme Temperatures** → Both hot or cold can damage an enzyme
- **pH changes** → Mixing proteins with Strong Acids or Bases
- **Cell Activators** → Things that may turn on an enzyme
- **Cell Inhibitors** → Things that may turn off certain cell activities