❖ What is Biochemistry?

- It is the study of **chemistry** in the **living systems** (cells & organisms such as human)
  - ➢ Studying the **structure**, **interactions**, **organization**, **functions** & the **reactions** between **biological molecules**
  - ➢ Studying the **flow of energy** in the cells and its transformation from one type to another (which is called **bioenergetics**)

- **<u>We use biochemistry in medicine in:</u>**
  - ➢ **Diagnosing**, **monitoring** & **understanding** the molecular bases of diseases
  - ➢ **Designing drugs** (new antibiotics, chemotherapy agents)

- Living organisms on Earth are composed mainly of **31 elements,** classified into 4 tiers (groups):
  - ➢ **4 Primary elements** ➔ **Carbon**, **Hydrogen**, **Oxygen** & **Nitrogen**
    - ✓ They form 96.5% of an organism's weight (<u>the most abundant</u>)
  - ➢ **The second group** ➔ includes **Phosphorus** & **Sulfur**
    - ✓ <u>Less abundant</u> than the primary ones
  - ➢ 3rd and 4th groups ➔ they are called **Trace elements** & they are mostly metals
    - ✓ They are <u>minor</u> but also essential

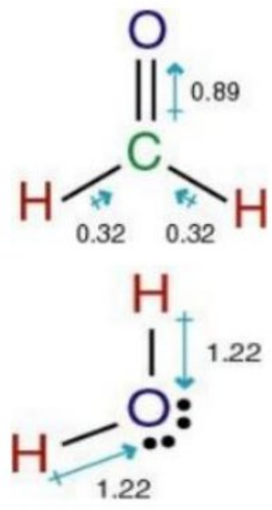
❖ Bonds (Covalent & Non-covalent):

- **Covalent bonds** ➔ bonds that involve **sharing electrons** between atoms formed during <u>chemical reactions</u>
- They have many properties, such as:
  - ➢ **Bond strength:** It is the <u>amount of energy</u> that must be supplied to break a bond and it is depends & affected by the bond length and orientation
  - ➢ **Bond length:** The <u>distance</u> between two nuclei
  - ➢ **Bond orientation:** Bond <u>angles</u> determining the overall <u>geometry</u> of molecules

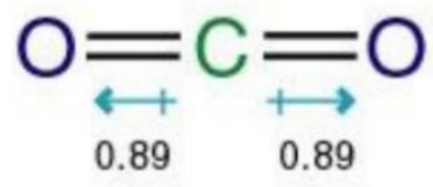
- The three-dimensional structures of molecules are specified by the bond angles (orientation) and bond lengths for each covalent linkage

- Covalent bonds can be either Polar or nonlpolar:
  - ▪ **Polar covalent bonds:**
  - ➢ Covalent bonds in which the **<u>electrons are shared unequally</u>** → called **dipoles**
  - ➢ It is due to the **difference in electronegativity** between the atoms forming the bond → so electrons are <u>closer</u> to the <u>more electronegative</u> atom making it <u>partially negative</u>, and the <u>less electronegative</u> atom will be <u>partially positive</u>
  - ➢ **Examples:** (O – N), (O – H), (N – H) and (H – <u>not</u> C)
  - ▪ **Non-polar covalent bonds:**
  - ➢ Covalent bonds in which the **<u>electrons are shared equally</u>** ➔ because <u>electronegativity is almost similar</u> between the atoms forming the bond
  - ➢ **Example:** (H – C)

- So according to the polarity of the bonds → the molecule can be polar or non-polar:
  - ✓ **Polar molecules** such as H_2O & H_2CO
    - ➢ Water molecule has **2 polar** (H – O) bonds with an angel between them that <u>doesn't equal 180°</u> (the molecule is bent) → so they <u>won't cancel each other pulling</u> the molecule toward O (more electronegative atom)



  - ✓ **Non-polar molecules** such as CO_2
    - ➢ CO_2 molecule has **2 polar** (H – C) bonds with an angel between them <u>equals 180°</u> so they <u>oppose & cancel each other</u>



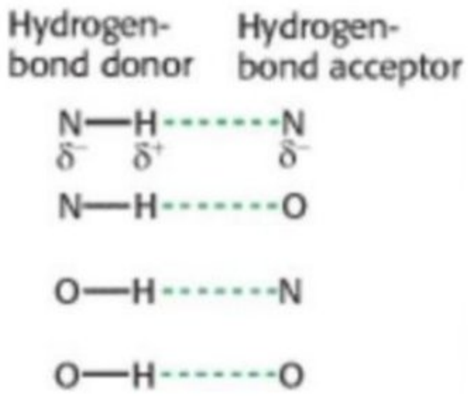
- **Non-covalent bonds** ➔ **no sharing** of electrons → they are <u>reversible</u> & <u>relatively weak</u>, so they can be broken and reformed during <u>physical or chemical reactions</u>, they have many types:

1) Electrostatic (ionic) interactions:

- **Charge – charge interactions** → similar charges = repulsion / opposite charges = attraction
- Occur between charged particles either **partially or fully** charged particles
- These forces are **quite strong** in the absence of water, and their strength depends on <u>amount of the charge</u> on the particle (directly) & the <u>distance</u> between the particles (inversely)

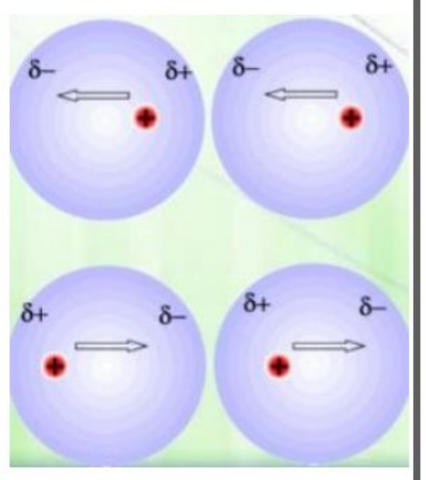
2) Hydrogen bond:

- It is considered a special type of electrostatic bonds (between charged particles)
- A **Hydrogen atom is partly shared** between 2 highly electronegative atoms:
  - ➢ **H-bond donor** ➔ <u>A highly electronegative atom with a partially positive H atom</u> (it is stronger when the donor is N, O or F)
  - ➢ **H-bond acceptor** ➔ <u>A high electronegative atom having a partial negative charge</u> (it is stronger when the acceptor is N, O or F)



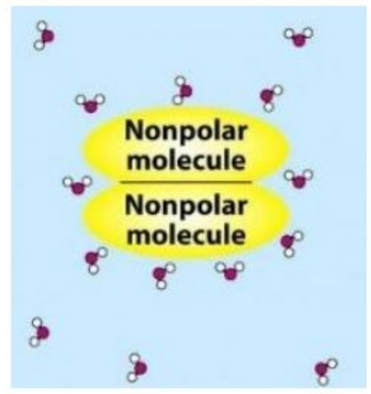
3) Van Der Waals interactions:

- They are instant interactions → caused by the **unequal distribution of electrons** around an atom → because electrons are <u>moving with time</u>
- The strength of these interaction highly affected **by distance**



4) Hydrophobic interactions:

- <u>Not true</u> interactions → They are the forces that cause the **self-association of nonpolar** compounds in an aqueous environment
- They **minimize the unfavorable** interactions between nonpolar groups and water (increase stability)
- Help in the formation of micelle

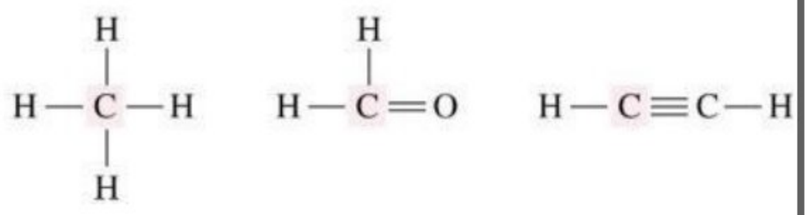


- **<u>Non-covalent interactions have many properties such as:</u>**
  - ➢ Weak and reversible interactions
    - ✓ The order of the strength of the bonds

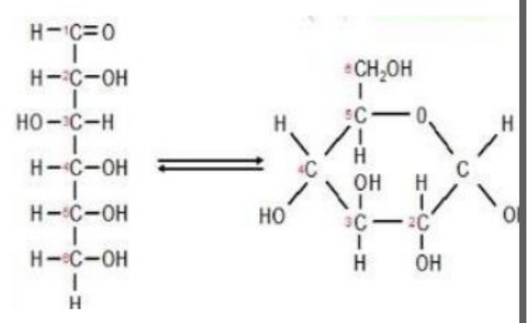
      Covalent >>>>> H-bonds & ionic > Van Der Waals > Hydrophobic
    - ✓ Although they are weak but important because the present in large numbers

- Can be either attractive or repulsive
- They significantly contribute to the **structure**, **stability**, and **functional** competence of macromolecules in living cells

❖ Carbon:



- It can form **4 bonds**, which can be single, double or triple bonds
- Each bond is very stable ➔ the strength of the bonds: **Triple > Double > Single**
- They link C atoms together in chains and rings (serve as a backbones)



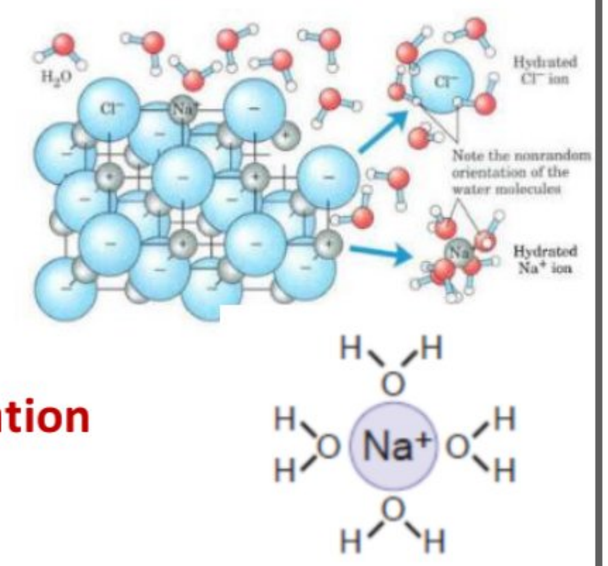
- Angels between Carbon bonds contribute to the 3D structure of molecules
- In a carbon backbone, some carbon atoms rotate around a single covalent bond producing molecules of different shapes

- Carbon can form **polar or nonpolar molecules** due to its intermediate electronegativity
- Pure carbon is **not water soluble**
- When carbon forms covalent bonds with **other elements** (O, N) → That makes it <u>water-soluble</u>

❖ Water:

- Water is a **polar molecule** (due to the <u>difference electronegativity</u> between H & O and it is <u>angular</u>)
- Water molecules produce a network (due to H-bonding) → making it **highly cohesive**

- **<u>Water is important to our bodies, because:</u>**
  - ➢ It forms about 60% of our bodies and 70-85% of the weight of a typical cell
  - ➢ It works as an **excellent solvent** of many substances in our body
    - ✓ Because it is a **small molecule** and due to **Electrostatic and Hydrogen bonds** → so they break and reform with other molecules and surrounding them forming the **Hydration shell**



  - ➢ Maintain a constant cellular environment (**homeostasis**) & it is an essential **buffer that maintain pH** by acting as a medium where acids and bases release their chemical reactions
    - ✓ When ionized it becomes a **positively charged hydronium** (or proton) & a **negatively charged hydroxide ion**
    - ✓ The equilibrium is toward forming water

$$H_2O + H_2O \rightleftharpoons H_3O^{\oplus} + OH^{\ominus}$$

  - ➢ It has a **High specific heat and heat of vaporization** → requires a large amount of heat to change its temperature by a small degree → **regulating temperature**
    - ✓ When body temperature increases ➔ sweating ➔ water absorb heat and regulate body temperature

- As the **temperature increases** → breaking hydrogen bonds → **less H-bonds**
- As the **temperature decreases** → forming hydrogen bonds → **more H-bonds**

- Participate in many biochemical reactions
  - ✓ Water molecule is a **nucleophile** so it is reactive
- **Nucleophile:** <u>Electron-rich</u> molecule → so attract electron-deficient molecules (Electrophiles or positively-charged molecules)