Introduction

Biochemistry is the chemistry of living organisms. It bridges the gap between the conventional chemistry and biology. Otherwise, biochemistry is the discipline that studies the molecules of living matter (Biomolecules). She seeks to determine their structures, their interactions, the chemical reactions from which they originate and in which they participate, which constitute metabolism. More broadly, she seeks to determine the roles that these molecules play within biological processes and, in doing so, to elucidate the foundations of how a cell or a living organism function.

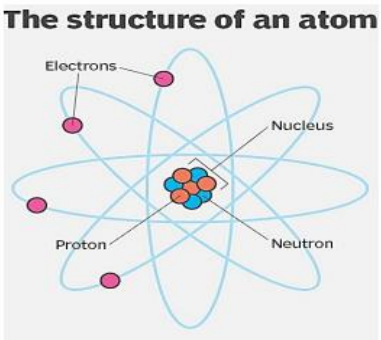
Living beings are particularly composed of water (65% for humans). This water plays a role in the solubilization of many ions and molecules. The remaining dry matter consists of two types of molecules: organic and inorganic (mineral). In a living organism, all molecules containing carbon are classified as organic, with the exception of CO_2 and its derived ions, HCO_3^- (bicarbonate) and CO_3^{2-} (carbonate). The other molecules therefore belong to the mineral kingdom.

Organic molecules include proteins, carbohydrates, lipids, nucleic acids, coenzymes, and vitamins. Mineral molecules are primarily ions involved in physiological processes, such as the establishment of transmembrane potentials (H^+, Na^+, K^+), or in certain enzymatic reactions.

Before understanding the classification and chemistry of carbon-containing biomolecules, it is important to understand the types of bonds that define the inter-and intra-biomolecular interactions. These include both covalent and non-covalent interactions.

1. Definitions

- **Atom**: is the smallest particle of an element, having the same chemical properties as the bulk element. It is called the fundamental unit of matter. It cannot be further divided into smaller parts and is made up of neutrons, electrons, and protons.



- **Molecule** is described as the merging of two or more same atoms or different atoms that are held together by various chemical bonds.

- **Electronegativity**, symbol χ, is a chemical property that describes the ability of an atom to attract electrons towards itself in a chemical bond. Higher values of electronegativity indicate a greater attraction for electrons.The highest value for electronegativity is 4.0
  - The attraction is between the positively charged protons in the nucleus of an atom and the valence electrons in the adjacent atom it is bonding with;
  - Electronegativity can be thought of as the strength of attraction between the protons of an atom and the valence electrons of an adjacent atom.

2. Chemical Bonding

Chemical bonding refers to the process of combining two or more atoms to form a molecule or compound. There are two types of electrostatic forces (or attractions) in compounds or molecules, intramolecular forces that exist between the bonded atoms of a compound or a molecule, and intermolecular forces that exist between molecules as described below.

2.1. Intramolecular forces

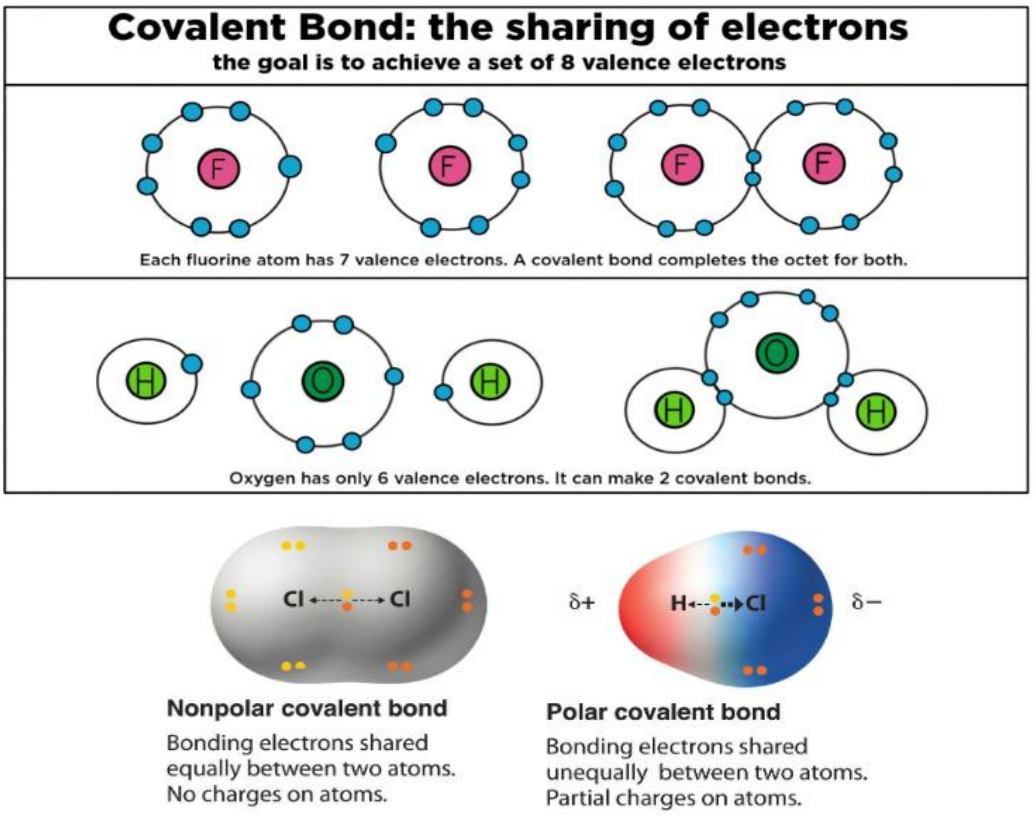
Intramolecular forces are the chemical bonds holding the atoms together in the molecules. The three major types of chemical bonds are covalent bond, the ionic bond, and the metallic.

2.2.1. Covalent bonds

Covalent bonds are formed by the sharing of electrons between non-metal atoms. The electrons involved are in the outer shells of the atoms. An atom that shares one or more of its electrons will complete its outer shell.

- If two bonded non-metal atoms have the same electronegativity, like H^g), the two nuclei of the atoms will attract the electrons with exactly the same strength, thus the electrons are shared equally between the two atoms. This is referred to as a nonpolar covalent bond;
- If two bonded non-metal atoms have different electronegativity, like HCI, the sharing of electrons is no longer equal. The element with the higher electronegativity pulls the electrons closer to itself. This results in one end of the bond having a slightly negative charge (δ-) and the other end of the bond having a slightly positive charge (δ+).

- Bonds that have unequal sharing of electrons are called polar covalent bonds. The word "polar" just means that there is an overall charge separation (ie. one end is positive and the other end is negative).

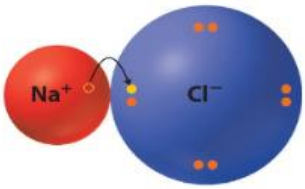


Nonpolar covalent bond
Bonding electrons shared equally between two atoms.
No charges on atoms.

Polar covalent bond
Bonding electrons shared unequally between two atoms.
Partial charges on atoms.

2.2.2. Ionic bonds

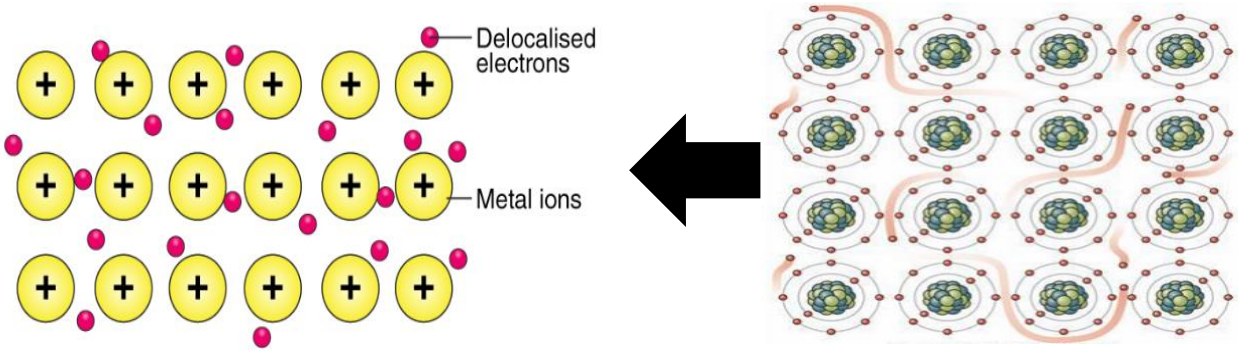
In ionic bonding, electrons are transferred from one atom to another resulting in the formation of positive and negative ions. The electrostatic attractions between the positive and negative ions hold the compound together. The predicted overall energy of the ionic bonding process, which includes the ionization energy of the metal and electron affinity of the nonmetal.



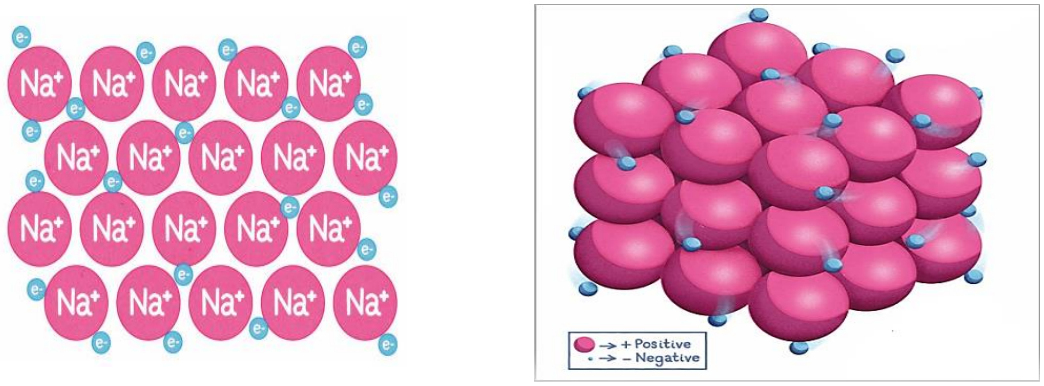
Ionic bond
Complete transfer of one or more valence electrons.
Full charges on resulting ions.

2.2.3. Metallic bonds

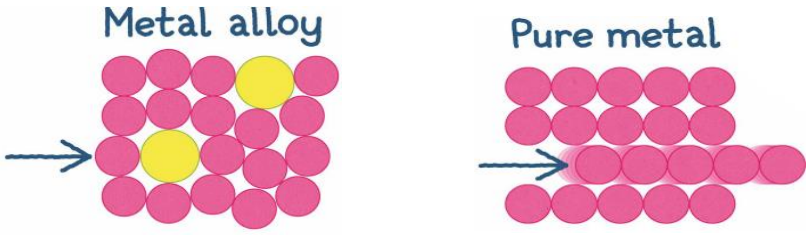
Metallic bonding results from a sea of delocalized electrons interacting with fixed positive ions in a lattice structure.



Otherwise, Metallic bonding is a type of strong chemical bond that occurs in **pure metals** and **alloys**. Metals are giant three-dimensional structures where layers of positive metal ions are surrounded by a sea of delocalised outer-shell electrons.

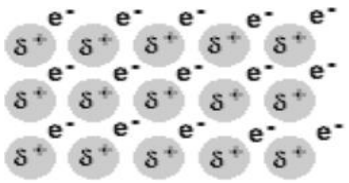


- **Alloys** are mixtures of two or more elements where at least one is a metal. In an alloy, the atoms are different sizes which distorts the layered structure. This means greater force is needed to make the layers slide over one another, which makes an alloy harder and stronger than the pure metal.
- **Pure metals** only contain one type of metal atom, so the atoms are arranged in layers which can slide over one another. This means they are malleable – can be hammered or pressed into shape without breaking or cracking – and ductile, so they can be drawn into wires.



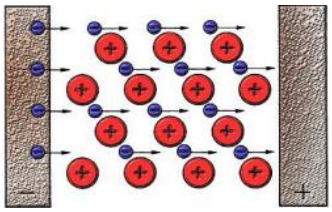
Metallic bonding is a type of chemical bonding and is responsible for several characteristic properties of metals such as their shiny lustre, their malleability, and their conductivities for heat and electricity.

a. **Malleable:** can be hammered into thin sheets

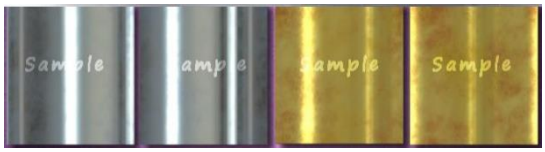


b. **Ductile**: Pulled into wire

c. Good conductors



d. Lustrous = shiny

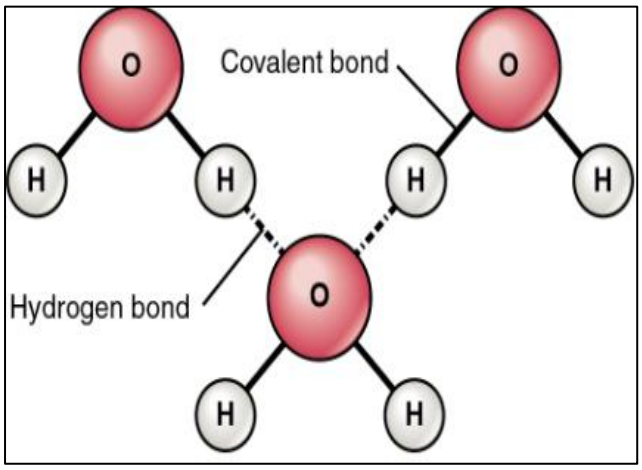


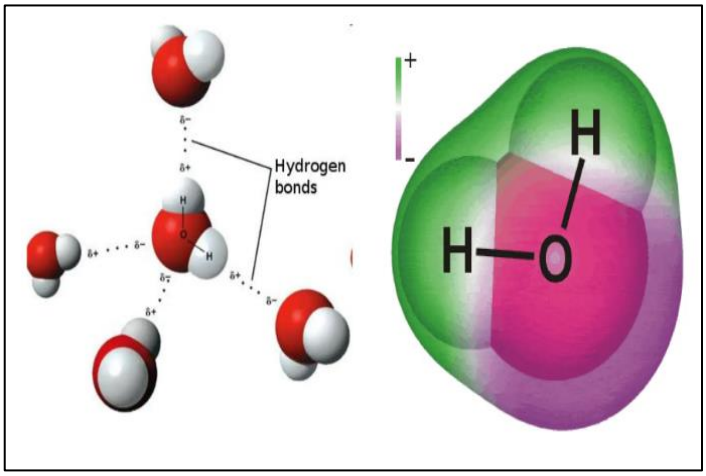
2.2. Intermolecular forces (attractions)

Intermolecular forces are the attractions between molecules. The intermolecular forces are usually much weaker than the intramolecular forces, but still, they play important role in determining the properties of the compounds.

2.2.1. Hydrogen Bonding

A hydrogen bond refers to the formation of hydrogen bonds, which are a special class of attractive intermolecular forces that arise due to the dipole-dipole interaction between a hydrogen atom that is bonded to a highly electronegative atom and another highly electronegative atom which lies in the vicinity of the hydrogen atom. For example, in water molecules (H2O), hydrogen is covalently bonded to the more electronegative oxygen atom. Therefore, hydrogen bonding arises in water molecules due to the dipole-dipole interactions between the hydrogen atom of one water molecule and the oxygen atom of another H2O molecule.

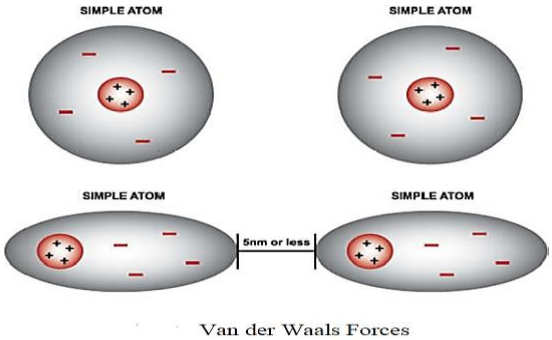




2.2.2. Van der Waals Forces

A Dutch scientist, J van der Waals in 1873 pointed out that particles (atoms, molecules or ions) of substances (similar or different) exert attractive forces on eachother, when they are brought near to each other. -These are physical forces (electrostatic in character) and much weaker than chemical forces i.e. ionic and "covalent bonds). These are named as van der Waals forces in honour of J. van der Waals.

Van der Waals forces are very short-lived inter-molecular attractive forces which are believed to exist between all kinds of atoms, molecules and ions when they are sufficiently close to each other.



Van der Waals Forces

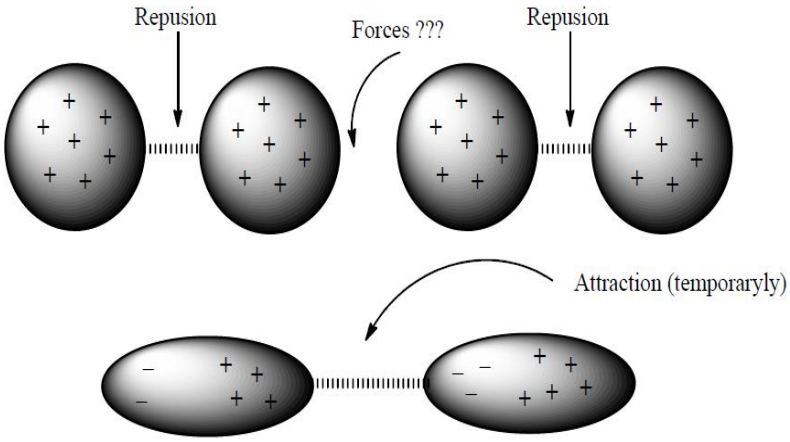


Fig X. Origin of van der Waals Forces

❖ Types of van der Waals Forces

There are four types of van der Waals forces. The origin of each one of these has been explained by a different scientist. The name of scientist has been associated with that type to commemorate his contribution. The four types are:

- **Dipole-dipole interactions:** These forces are found in polar molecules having permanent polarity in them. When polar molecules are brought nearer to each other, they orient themselves in such a way that the positive end of one dipole (polar molecule) attracts the negative end of another dipole and vice-versa as shown in Fig below.

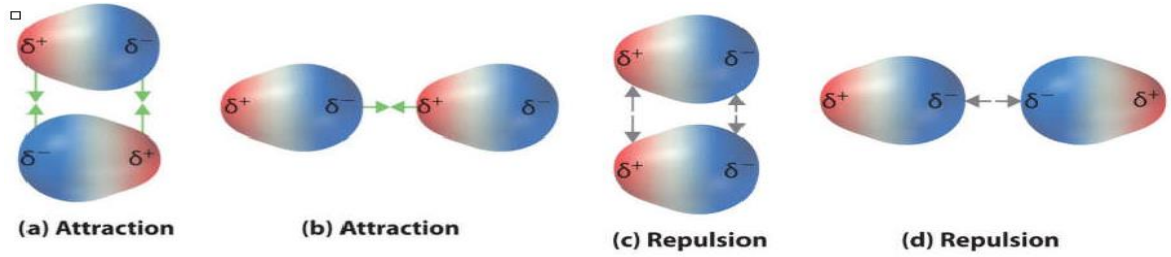
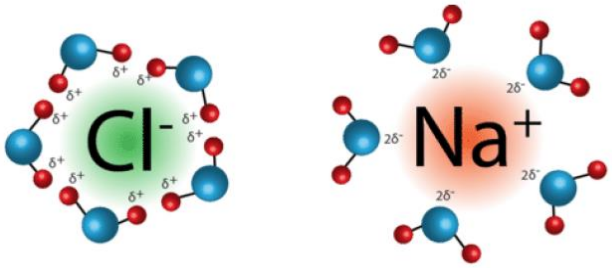


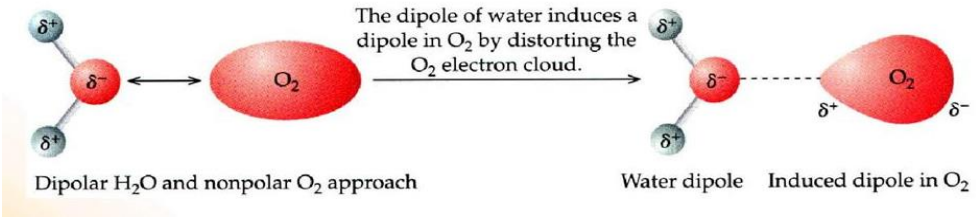
Fig . dipole-dipole interaction

- **Ion-dipole interactions:** Polar molecules are attracted towards ions. The negative end of dipoles is attracted towards the cation while the positive end towards the anion.



➢ **Dipole-induced dipole interactions**

This type of force is found in a mixture containing polar and non-polar molecules. When a non-polar molecule is brought near to a polar molecule, the positive end of the polar molecule attracts the mobile electrons of non-polar molecule and thus polarity is induced in non-polar molecule.



➢ **Instantaneous dipole-induced dipole interactions**

These forces are found in non-polar molecules such as di-atomic gases like H2, O2, C12 , N2 etc. as well as mono-atomic noble gases like He, Ne, Ar etc. A nonpolar atom or molecule may be visualised as a positive centre surrounded by asymmetrical negative electron colud.