بسم الله الرحمن الرحيم

BioChemistry | Lecture 1

Introduction to BioChem pt.1

Written by : Mousa Al-Neimat
Lana Alyaseen

Reviewed by : Shorouq Matalkah

Course information

Recommended textbooks

Marks' Basic Medical Biochemistry: A Clinical Approach 5th Edition, by Michael Lieberman (Author), Alisa Peet MD (Author), 2018

Biochemistry 8th edition by Mary Campbell (Author) and Shawn Farrell (Author)

Online:

https://themedicalbiochemistrypage.org/

Instructors

Prof. Nafez Abu Tarboush

Outline

- Introduction
- Acids and bases, pH, and buffers
- Macromolecules: Carbohydrates, lipids, amino acids, peptides, and proteins
- Protein structure-function relationship
- Part I: Fibrous proteins: collagen, elastin, and keratins

Part II: Globular proteins (plasma proteins, myoglobin, hemoglobin, and immunoglobulins)

Part III: Regulation of hemoglobin

Enzymes: structural features and classification, kinetics, mechanisms of regulation, cofactors

Protein purification and analysis

Biochemistry & chemical composition of living organisms

What is biochemistry?

Biochemistry = understanding life

Molecules that are found in human bodies

Know the chemical structures and address the function of biological molecules

How the structure is fitting the function

Understand the interaction and organization of different molecules within individual cells and whole biological systems

Reaction

Reactions that are catalyzed and being speeded up by enzymes (not all),This is why we need to study the biological molecules and their structure and interactions and this is why we study enzymes

Understand bioenergetics (the study of energy flow in cells)

Every reaction includes the flow of energy from one molecule to another or the usage of this energy for synthesising large molecules or to preform a specific cellular response

Biochemistry in medicine:

explains all disciplines
diagnose and monitor diseases
design drugs (new antibiotics, chemotherapy agents)
understand the molecular bases of diseases

You do not have to know biochemistry to be a physician, but it makes you an elite physician if you do

In order to study our bodies we need to know the chemical structures of the molecules that are inside it. And in order to know the chemical structure we need to know the atoms that form these molecules.

And this leads us to a question what are the atoms that are forming the molecules in our bodies. You are going to know them and their classification in the next slides

And what biological molecules these atoms are forming ?

- Water. (Which is the first one we are going to study since it is the most abundant).
- Acids, bases and buffers.
- Macromolecules.
  Macro = huge
  - Carbohydrates
  - Lipids
  - Nucleic acids (DNA/RNA)
  - Proteins

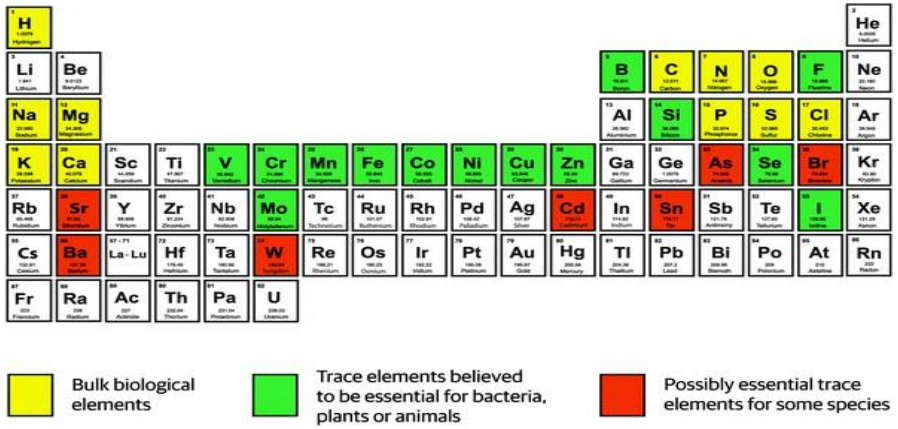
Note : These are not the only biological molecules in our bodies but these are some of them.

Chemical elements in living creatures

Four primary: carbon, hydrogen, oxygen, & nitrogen. They form 96.0%

Oxygen is the most abundant because of the presence of water molecules constituting most of our body.

Others exist in trace amounts but are essential, elements (mostly metals)

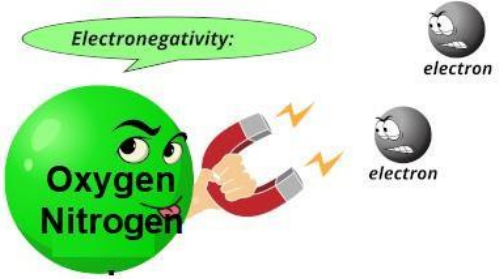


Now you may be thinking since H2O is the most abundant molecule in our bodies then why not hydrogen is the most abundant?
Actually hydrogen is more abundant than oxygen (in terms of number) but since here we are talking about mass.. oxygen has a molar mass that is more than the molar mass of two hydrogen atoms so it is more abundant in terms of mass.

TABLE 2.1 Elements of the Human Body

Name	Symbol	Percentage of Body Weight (Not quantity..not numbers)
Major Elements (Total 98.5%)		
Oxygen (Most abundant)	O	65.0
Carbon	C	18.0
Hydrogen	H	10.0
Nitrogen	N	3.0
Calcium	Ca	1.5
Phosphorus → 2.5%	P	1.0
Lesser Elements (Total 0.8%)		
Sulfur	S	0.25
Potassium	K	0.20
Sodium	Na	0.15
Chlorine	Cl	0.15
Magnesium	Mg	0.05
Iron	Fe	0.006
Trace Elements (Total 0.7%)		
Chromium	Cr	Molybdenum Mo
Cobalt	Co	Selenium Se
Copper	Cu	Silicon Si
Fluorine	F	Tin Sn
Iodine	I	Vanadium V
Manganese	Mn	Zinc Zn

Important terms



Electronegativity The atom's ability to withdraw (pull) the covalent bond's electrons toward itself.

Covalent bonds A bond that is formed by sharing of electrons between two atoms. Very strong bond (The Strongest)

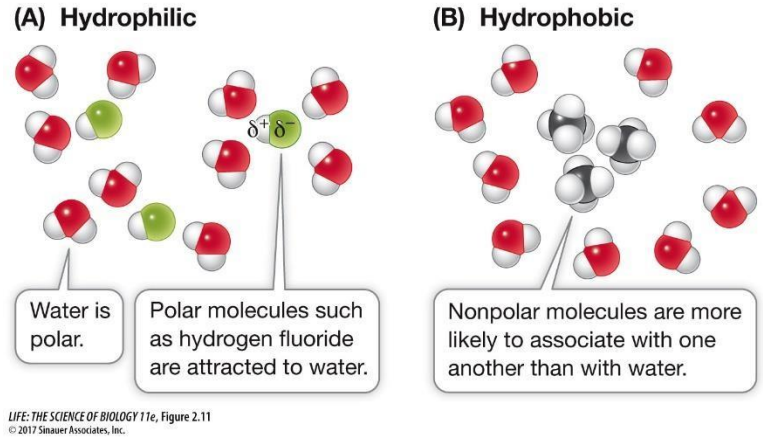
Polar vs. non-polar

Single vs. multiple

Atom—Atom

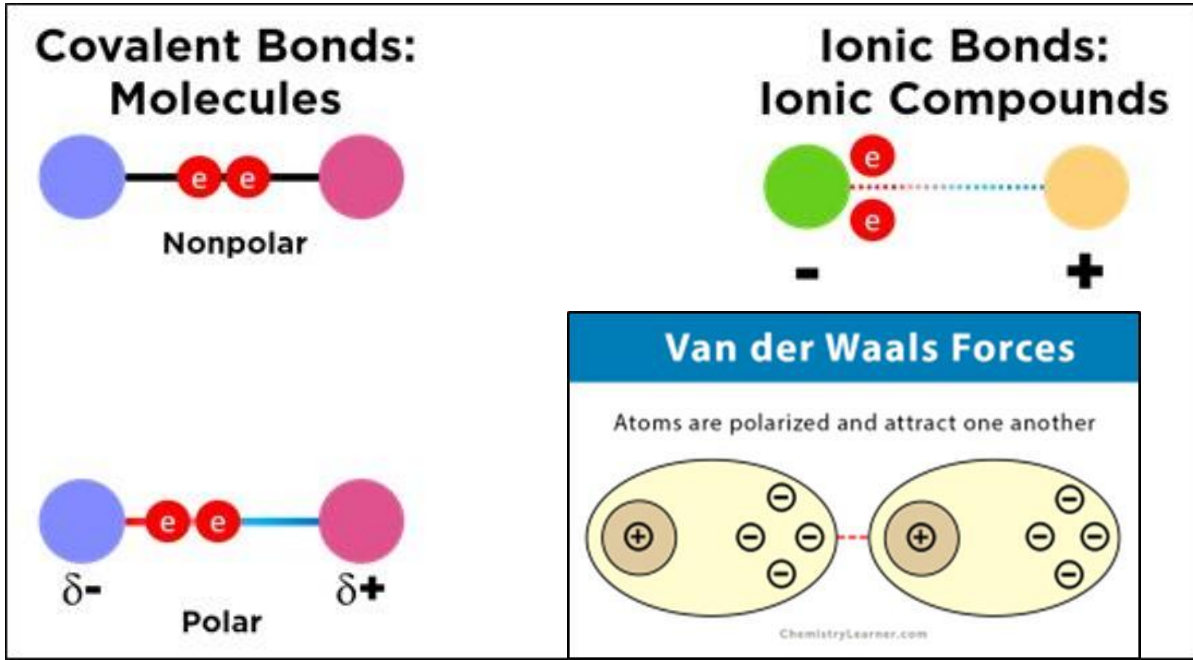
Atom=Atom ~> Double bond

Atom≡Atom ~> triple bond



Non-covalent interactions

Electrostatic interactions
Hydrogen bonds (donor and acceptor)
Van der Waals interactions
Hydrophobic interactions
Hydrophobic versus hydrophilic molecules
Nucleophile vs electrophile



Covalent bond, polarity and non-covalent interactions

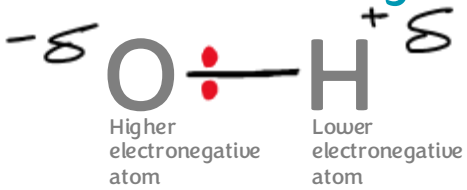
A bond that is formed by sharing of electrons between two atoms.

Since there is a sharing of electrons between two atoms, there can be two cases which are :

- There is a difference in electronegativity. ⟶ Polar covalent bond

The electrons are more closer to the more electronegative atom, this give it a partial negative charge.

The electrons are more away from the less electronegative atom, this give it a partial positive charge.



- There isn't a difference in electronegativity. ⟶ Non-Polar covalent bond

Some books consider if the difference in electronegativity is less than 0.4 it is not electronegative (Extra information)

No difference in electronegativity ~> non-polar

The concept of polarity opens up a new concept which are the non-covalent interactions

- Electrostatic interactions
- Hydrogen bonds
- Van der Waals interactions
- Hydroponic interactions

Covalent bond, polarity and non-covalent interactions

This what the doctor has said organized in to a small mind map

Covalent bond → Polarity → Polar → Positive and negative poles (partial positive and negative charges) → Inter-molecular interactions (especially with water and this leads to the concept of solubility)

Polarity → Non-Polar → Positive and negative poles (partial positive and negative charges) → Inter-molecular interactions (especially with water and this leads to the concept of solubility)

Solubility

Hydrophilic (polar) ~> water soluble. or any polar solvent

Hydrophobic (non-polar) ~> water non-soluble. Soluble in non-polar solvent

Important properties of bonds

Bond strength (amount of energy that must be supplied to break a bond)

And when the bond is broken it is going to give you that energy.

Bond length: the distance between two nuclei

Shape

Bond orientation: bond angles determining the overall geometry of atoms

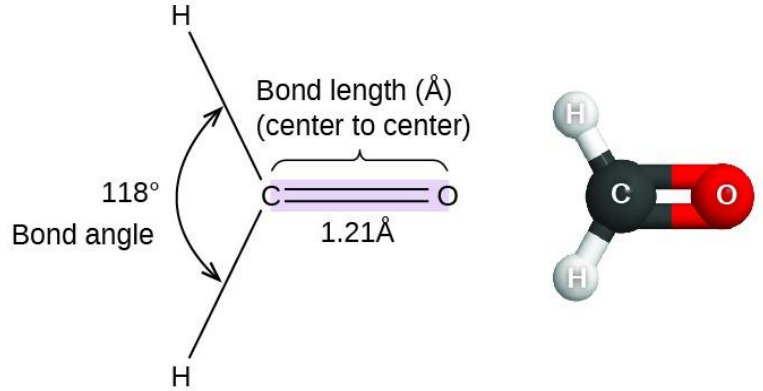
Why there is an angels between bonds ? Because of the repulsion.

Because of the repulsion between different covalent bond's electrons the bonds are away from each other to keep repulsion forces as small as possible.

The three-dimensional structures of molecules are specified by the bond angles

and bond lengths for each covalent linkage.

Shapes of molecules are always determined by two things : the atoms around any bond and the distribution of atoms around that specific bond.



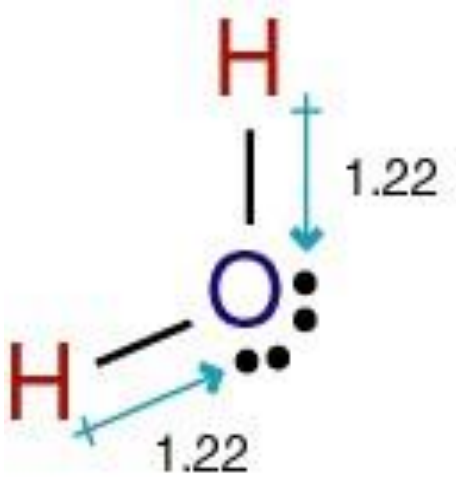
Polarity

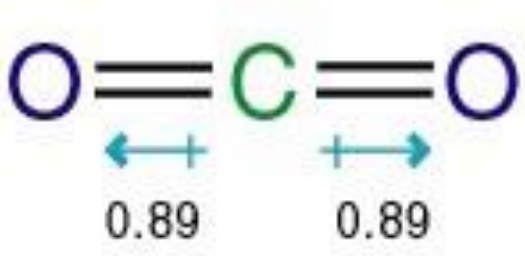
(Extra information)
How to determine if the molecule is polar or not ? Firs is it contains a polar bonds? If yes go to second can we divide it into two regions, with all partial negative charges on one side and all partial positive charge on the other side? If yes then it is angular and polar molecule.

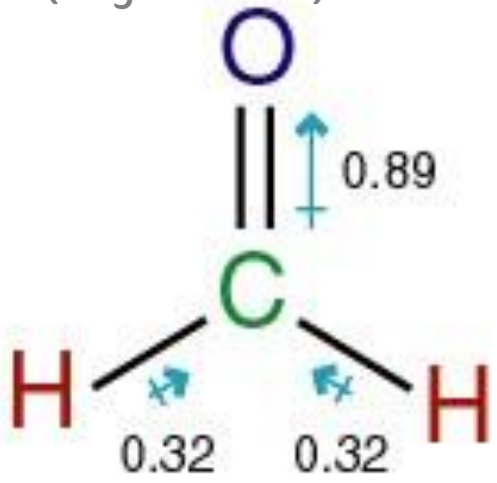
Electrons are shared unequally = "dipoles"

Both water and CO2 contain polar bonds, but only water is a polar molecule. Why?

Electronegativity doesn't always give me a polar molecules, it give us a polar bond but in order for the whole molecule to be polar it has to be angular. (Asymmetric) A means not.

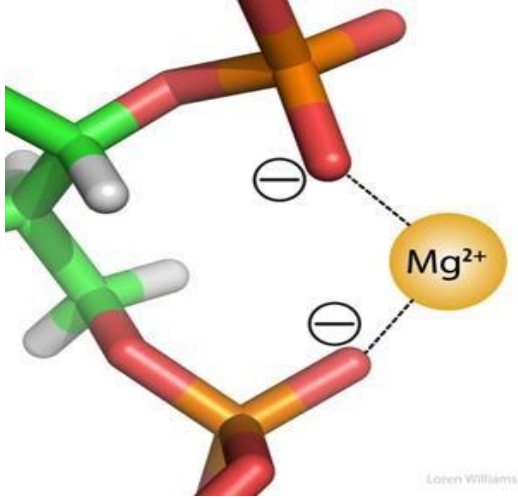






What are non-covalent interactions?

They are reversible and relatively weak

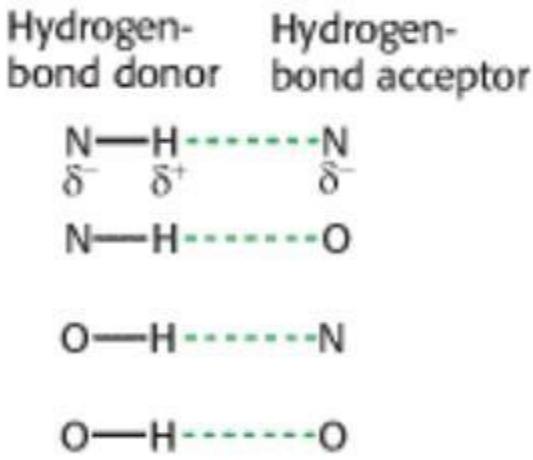


Electrostatic interactions (charge-charge interactions):

Quite strong in the absence of water

Hydrogen bonds

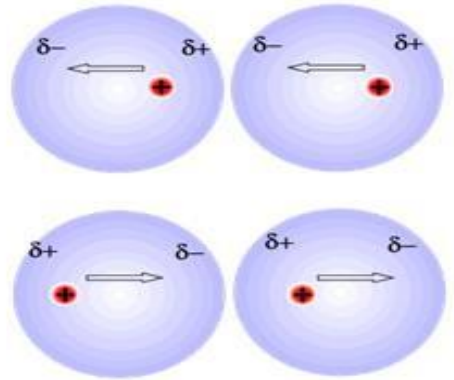
Shared between a donor and an acceptor



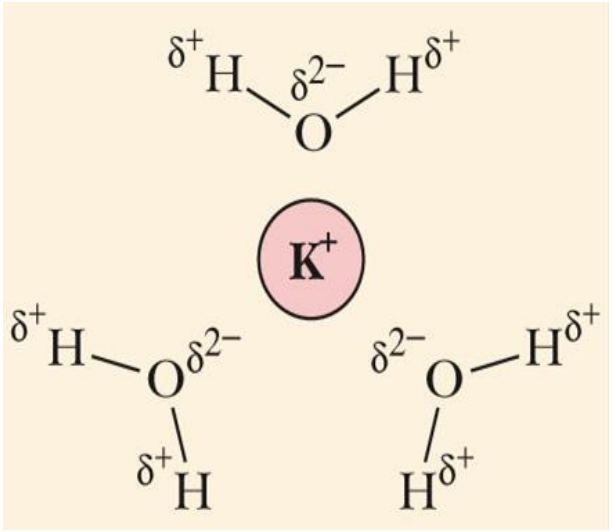
Van der Waals interactions

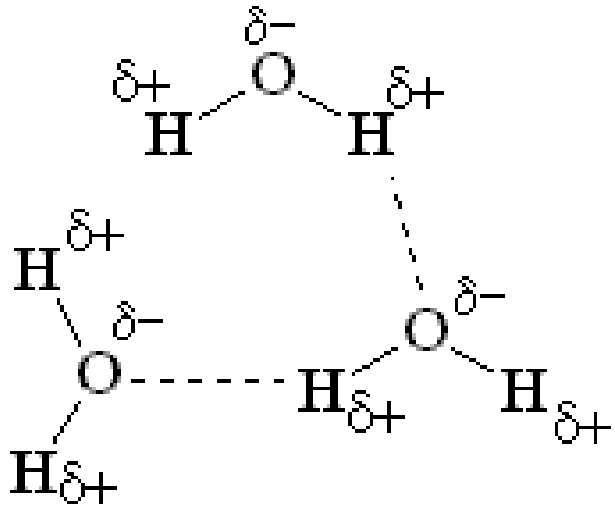
Unequal distribution of electronic charge around an atom changes with time

The strength of the attraction is affected by distance



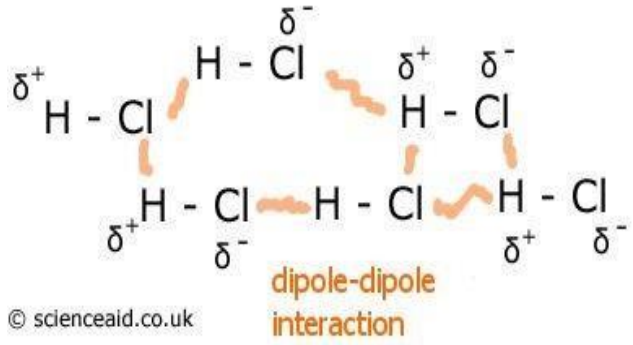
What are non-covalent interactions?





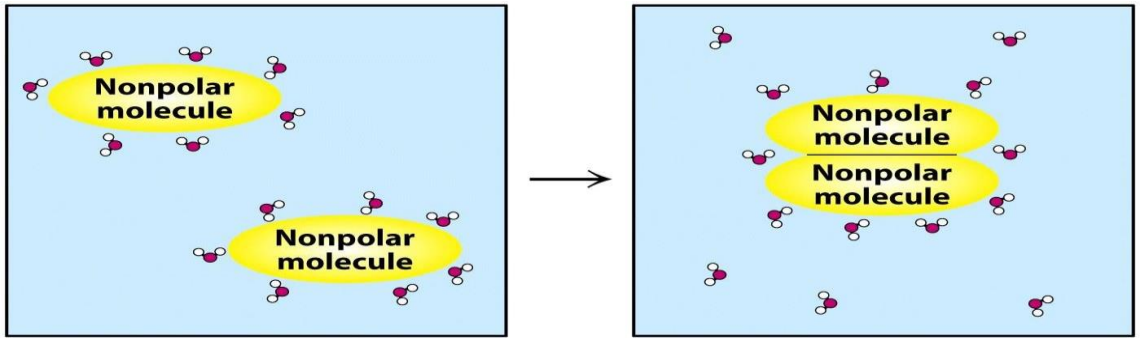
Dipole-dipole interaction

Dipole-charge interaction



Hydrophobic interactions

– Self-association of nonpolar compounds in an aqueous environment



- **Hydrophobic interactions are very important in biological molecules. Why?** They are the basis for the formation of the lipid bilayer in the plasma membrane.
- **Are hydrophobic interactions true interactions?** No, they are not. There are no actual bonds formed during these interactions.
- **So what happens exactly?** Nonpolar molecules appear to associate with each other, not because they are truly attracted to one another, but because they are avoiding water. In other words, their "goal" is not to gather together – they simply move away from water, which makes them cluster.
- **Why do they gather around each other? Why do hydrophobic interactions happen?** To minimize interaction with water (a polar molecule), which increases the system's overall stability.
- "Energy and stability have an inverse relationship: as energy decreases, stability increases."

Properties of noncovalent interactions

Reversible

Relatively weak

Molecules interact and bind specifically

Significantly contribute to the structure, stability, and functional competence of macromolecules in living cells

Can be either attractive or repulsive

Involve interactions both within the biomolecule and between it and the water of the surrounding environment

Carbon

Carbon and water are the main constituents of our body.

Properties of carbon (1)

It can form four bonds

Single, double, or triple bonds

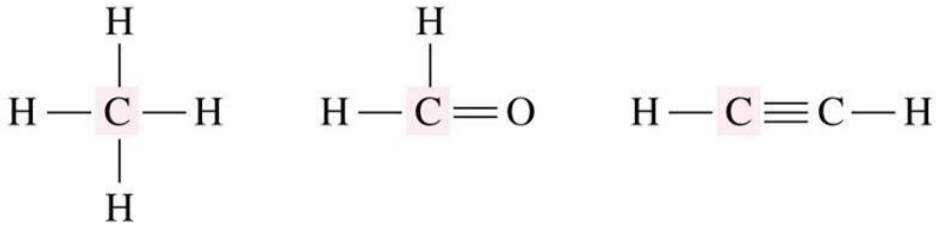
Bonds are very stable

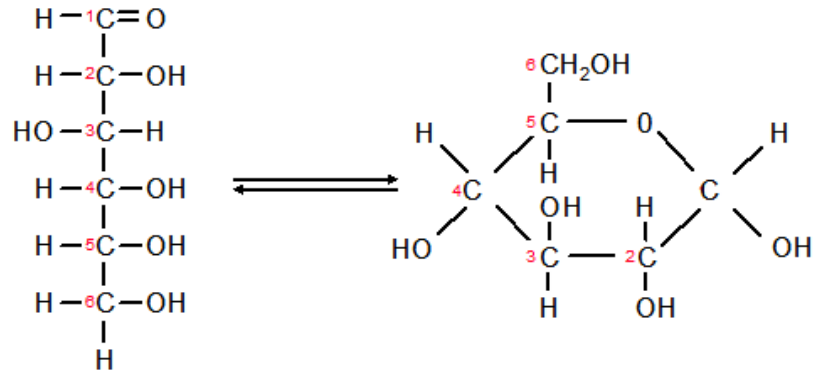
They link C atoms together in chains and rings

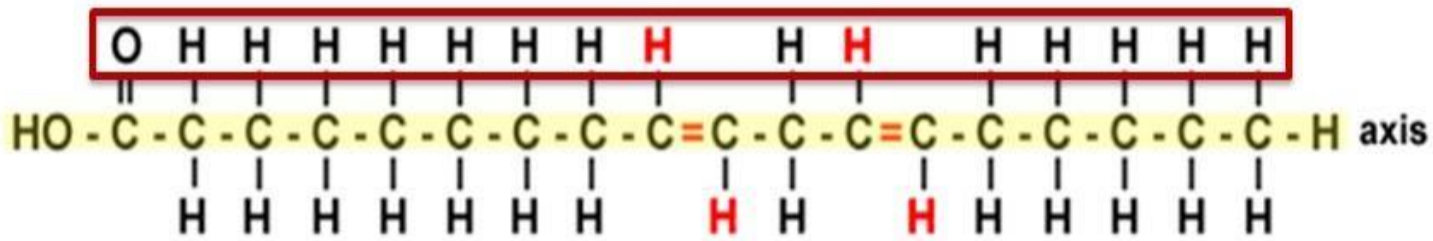
– These serve as backbones

It forms the basis of the molecular

Backbones in your body.

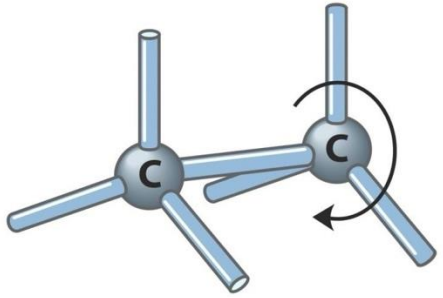


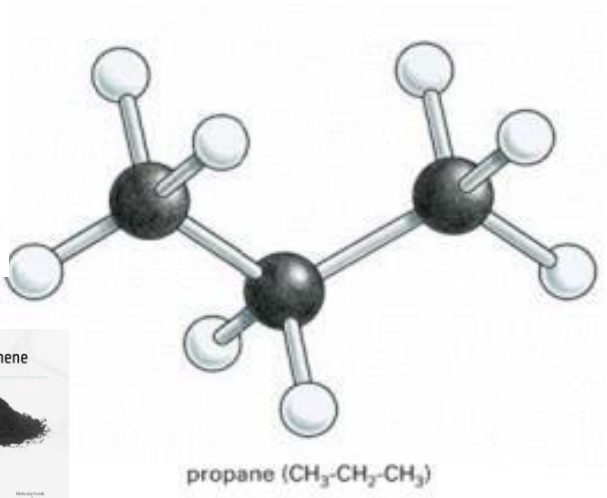




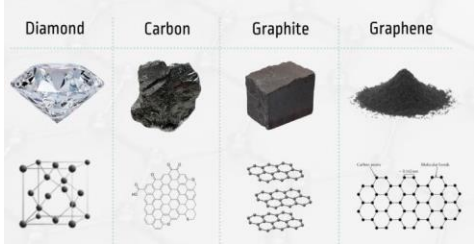
Properties of carbon (2)

- **Three-dimensional structures (angles)**





- **Rotation (molecules of different shapes)**

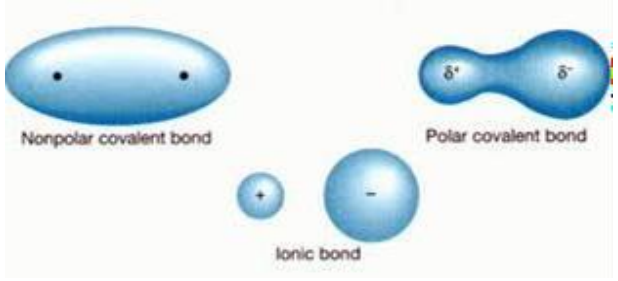


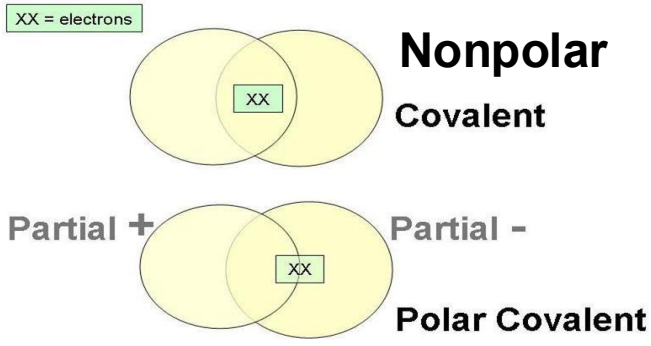
- **Electronegativity (between others):**

– It can form polar and non-polar molecules

- **Pure carbon is not water soluble (graphite, diamond)**

except when it is bonded to an electronegative atom such as oxygen, nitrogen, or sulfur.

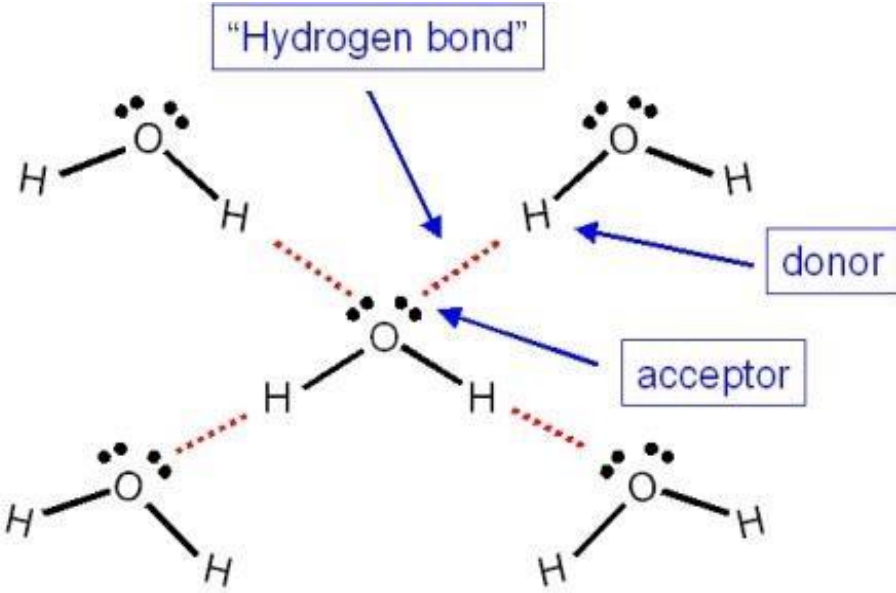




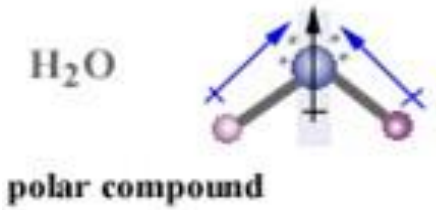
Water

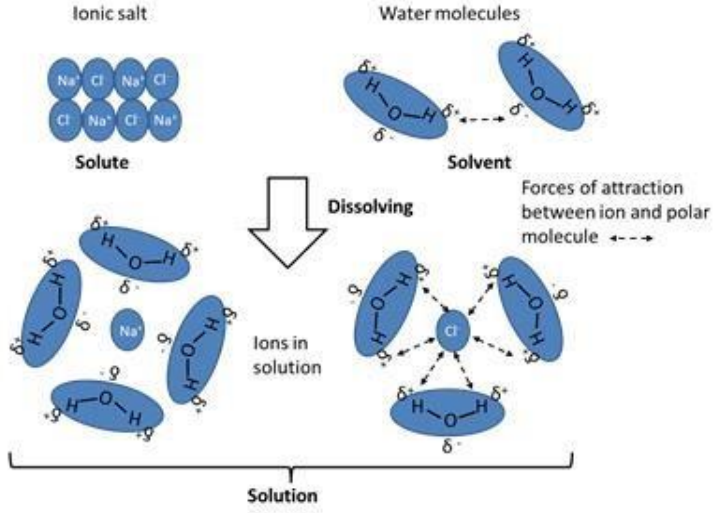
It is the first molecule we are going to study because it is the most abundant

Properties of water (1)



- **Polar**
- **Angular**
- **Dipole-dipole interactions and dipole-charge interactions**
- **Highly cohesive**
- **produces a network**
- **Water is an excellent solvent**





--Small this means that in 1 Liter of water there are a lot of molecules, and each has a partial charge. The solvent has to make bonds with the solute, so the more molecules I have, the better solvent it will be.

--Weakens electrostatic forces and hydrogen bonding between polar molecules

- **Why is it highly cohesive?** Because every water molecule can make up to four hydrogen bonds, forming a lattice. (Four hydrogen bonds: two from the lone pairs around the oxygen, and two from the hydrogen atoms.)
- Because water is a small and polar molecule, it can easily move between other molecules. It has a high capacity to pass through molecules and, at the same time, disrupt the forces between them. For example, if there are electrostatic interactions between two solute molecules, water can form hydrogen bonds from different sides, breaking the interaction between them.
- Water has a high heat capacity, so it needs a large amount of energy to increase its temperature. This is due to the large number of hydrogen bonds between its molecules. Because water is highly cohesive, any change in energy at any point in the liquid spreads quickly through the water molecules and dissipates among them.
- Water has the tendency to ionize. **Is it high or low?** Water has a very, very low tendency to ionize. Most molecules like water have a low tendency to ionize, except for strong acids and bases, which ionize completely.

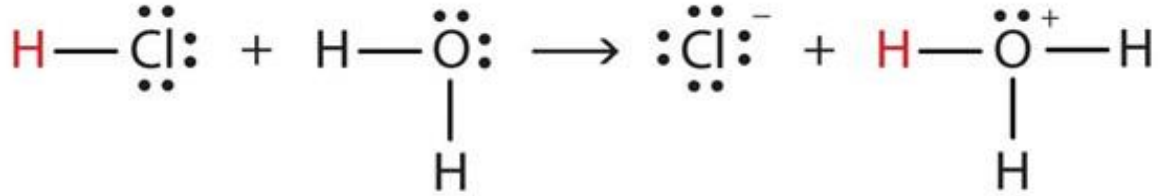
Properties of water (2)

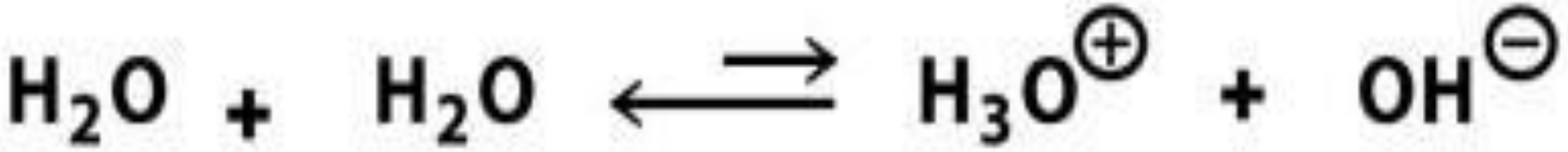
- **It is reactive because it is a nucleophile:**

– A nucleophile is an electron-rich molecule that is attracted to positively-charged or electron- deficient species (electrophiles).

- **It can be ionized**

Water molecules can react with each other which give you ions





Note: H3O+ = H +

رسالة من الفريق العلمي:

﴿ قُلْ يَا عِبَادِيَ الَّذِينَ أَسْرَفُوا عَلَىٰ أَنفُسِهِمْ لَا تَقْنَطُوا مِن رَّحْمَةِ اللَّهِ ۚ إِنَّ اللَّهَ يَغْفِرُ الذُّنُوبَ جَمِيعًا ۚ إِنَّهُ هُوَ الْغَفُورُ الرَّحِيمُ﴾

لا نَكُفُّ عنِ الأَمَلِ

For any feedback, scan the code or click on it.

Corrections from previous versions:

Versions	Slide # and Place of Error	Before Correction	After Correction
V0 → V1			
V1 → V2			