Intermolecular bonding: Noncovalent bonds

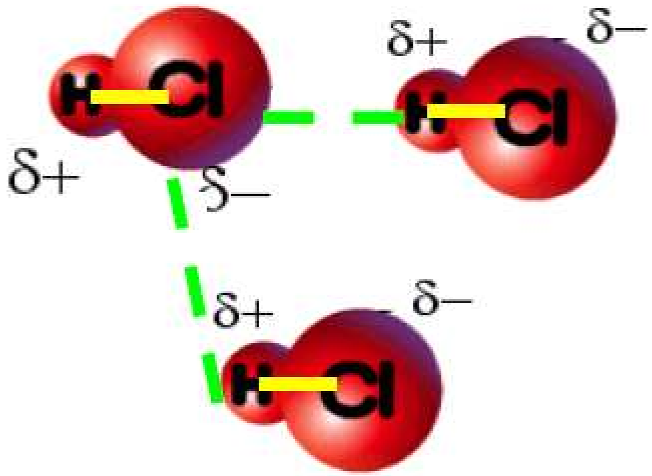
- Molecules often link together by weak interactions that do not require large amounts of energy and can be broken easily.
- These bonds are non-covalent in nature.
- There are four common non-covalent interactions:

– hydrogen bonds,
– ionic bonds,
– van der Waals forces, and
– hydrophobic interactions.

Inter and Intramolecular bonds

Intermolecular: between molecules (not a bond)

Intramolecular: bonds within molecules (stronger)



Types of Intermolecular Forces

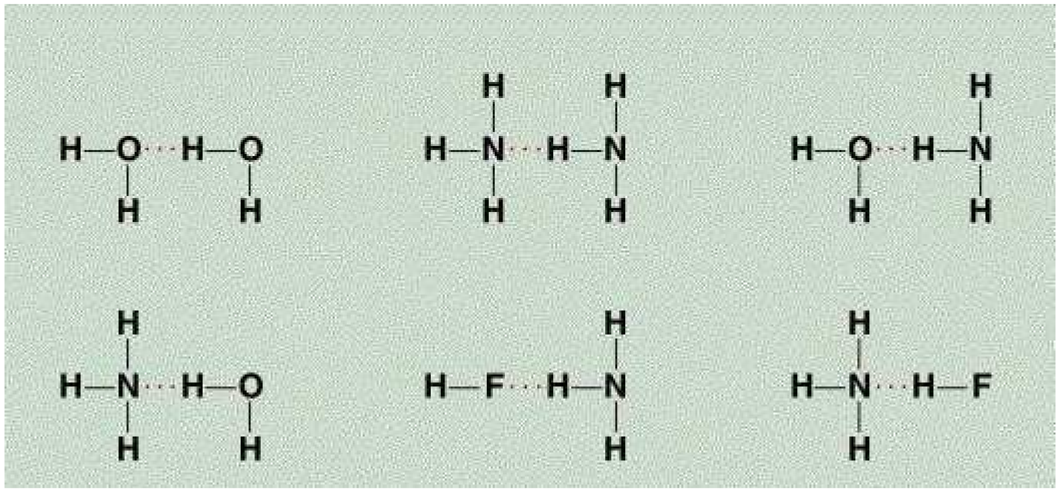
Hydrogen Bond (strongest)

*The hydrogen bond is a special dipole-dipole interaction between the hydrogen atom in a polar **N-H, O-H, or F-H** bond and an electronegative **O, N, or F** atom.

***IT IS NOT A BOND**.

A — H ··· B   or   A — H ··· A

A & B are N, O, or F



Non-Covalent Bonds
(Weak Bond)

- Weak bonds are those forces of attraction in biological systems, do not take a large amount of energy to break.
- For example, hydrogen bonds are broken by energies in the order of 4 - 5 kcal/mol.; van der Waals interactions have energies around Kcal/mol.
- Weak bonds may be easily broken but they are very important because they help to **determine and stabilize the shapes of biological molecules .**

Weak Bonds (conti..)

- For example they are important in :

  - Stabilizing the secondary structure (alpha helix and beta pleated sheet) of proteins.

  -Hydrogen bonds keep complementary strands of DNA together.

  - Hydrogen bonds participate in enzyme catalysis.

Hydrogen Bonds are weak bonds (3-5 kcal/mole)

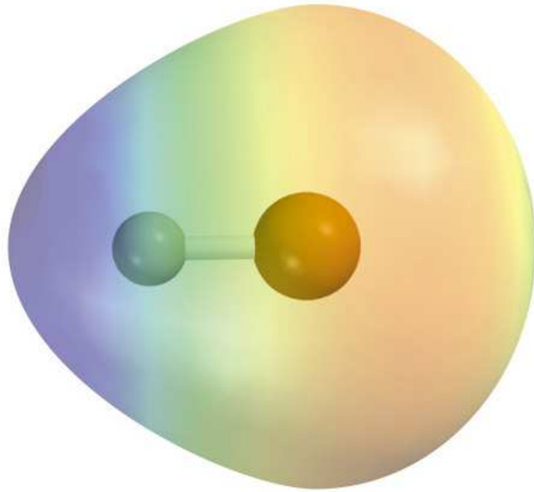
- Hydrogen bonds result from electrostatic attraction between electronegative atoms (such as O or N) and a hydrogen atom that is bonded covalently to a second electronegative atom.
- Examples:
  – N-H --- O=C -
  – -O-H----- O=C -
- Hydrogen bonds are weak bonds, typically about 3-5 kcal/mole.

$^{\delta+}H - Cl^{\delta-}$

[H :Cl]

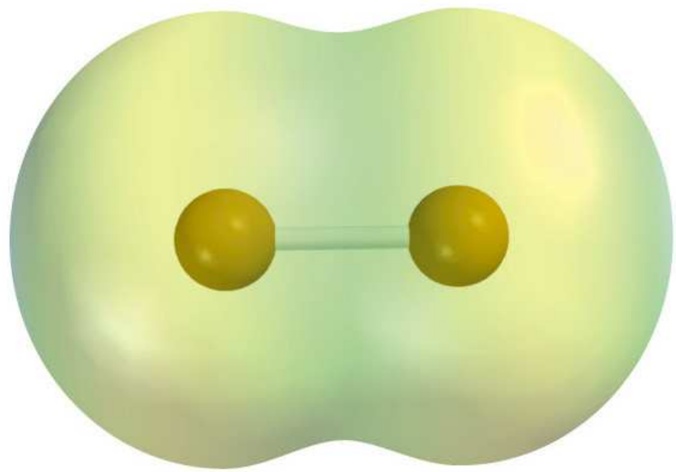
A polar covalent bond.

The bonding electrons are attracted more strongly by Cl than by H.



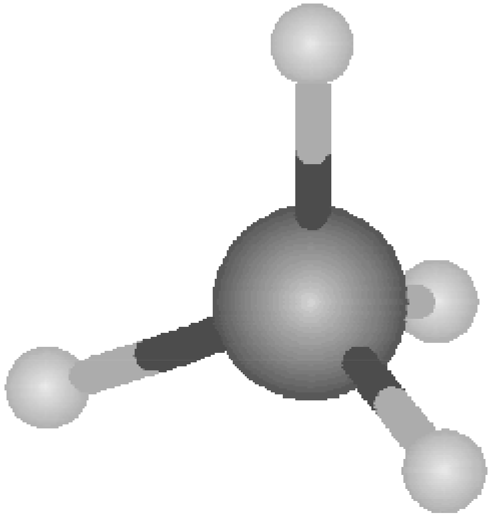
Cl:Cl

A nonpolar covalent bond



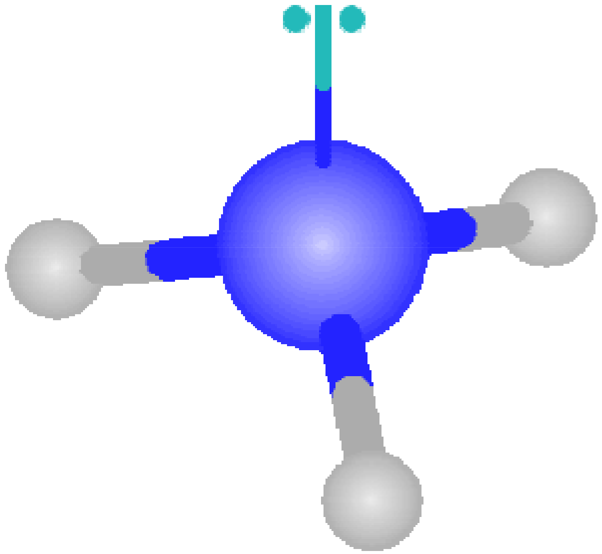
Hydrogen Bond

methane, CH_4



This does not have any hydrogen bonds.
Carbon is not very electronegative,
and it has no lone pairs of electrons in methane

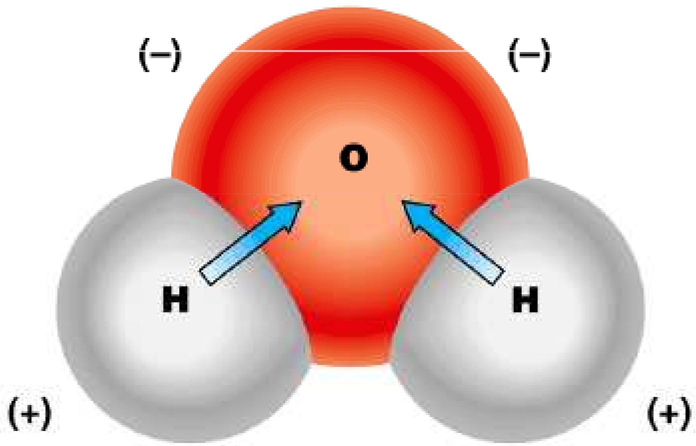
ammonia, NH_3

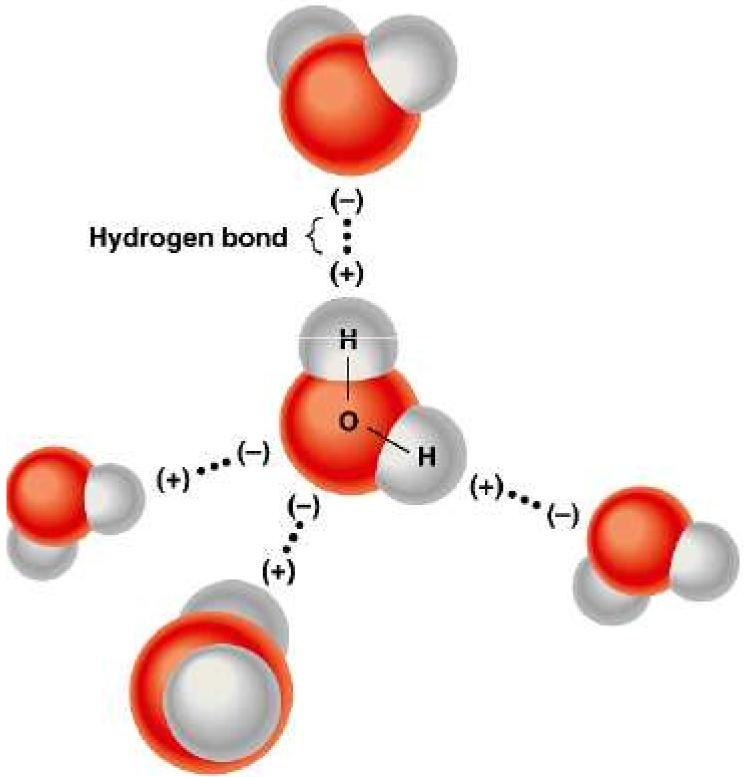


This does have hydrogen bonds.
Nitrogen is very electronegative,
and it has one lone pair of electrons in ammonia.

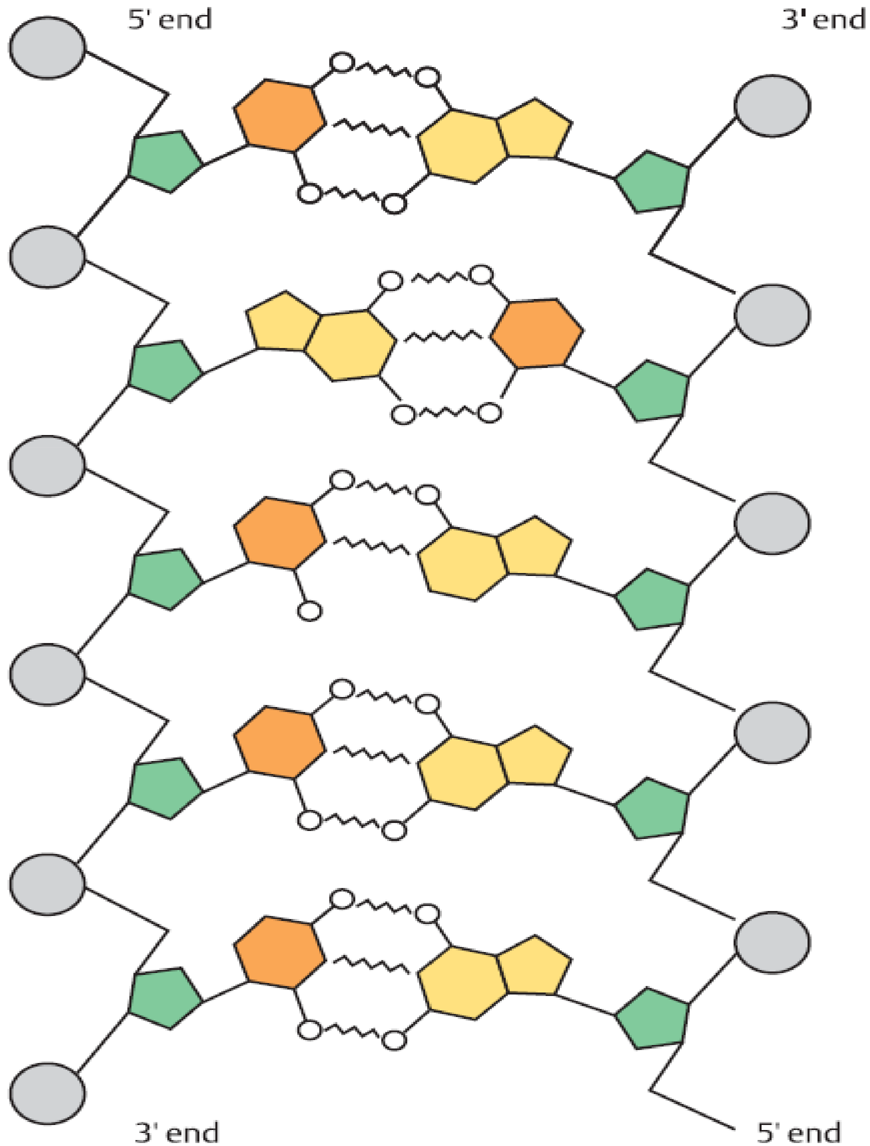
Hydrogen Bond in Water

(H_2O)





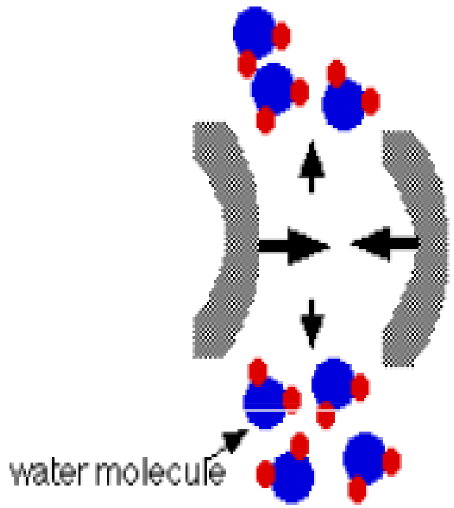
Hydrogen Bonds in DNA



Hydrophobic Bonds

• This type of **non-covalent bond** describes the interaction of nonpolar, hydrophobic molecules when they are put into water.
Hydrophobic (non-polar) molecules do not interact with polar water and cannot form H bonds.

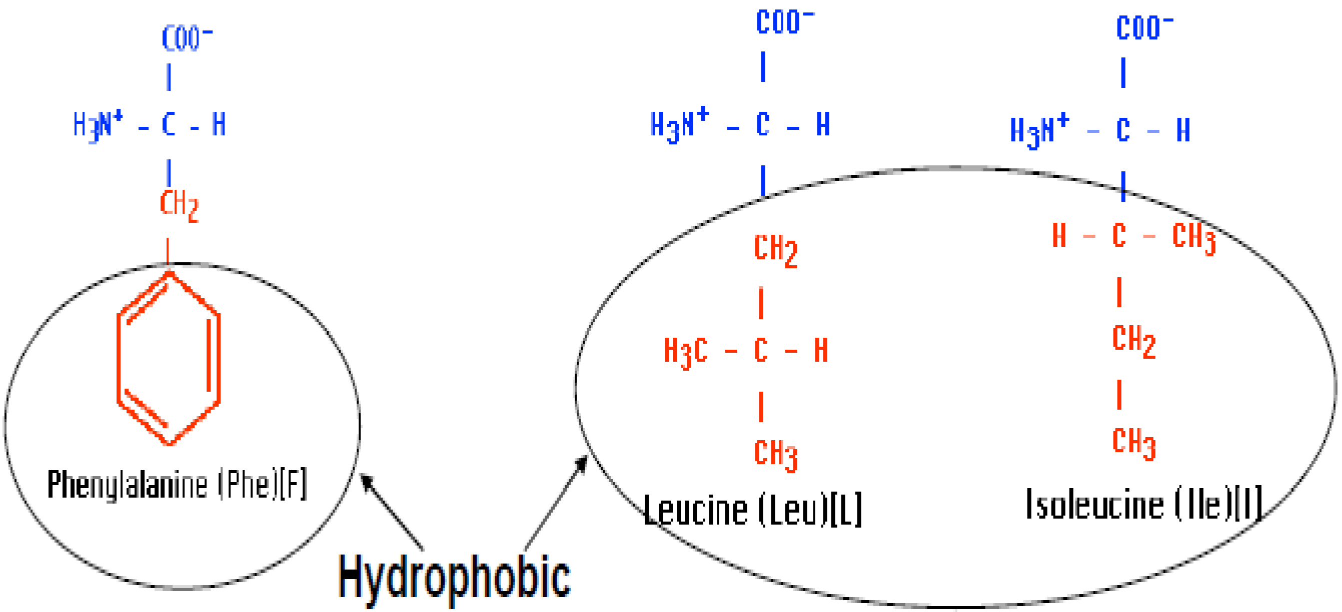
• So they interact with each other and repel the water (hydro=water; phobic= hating)



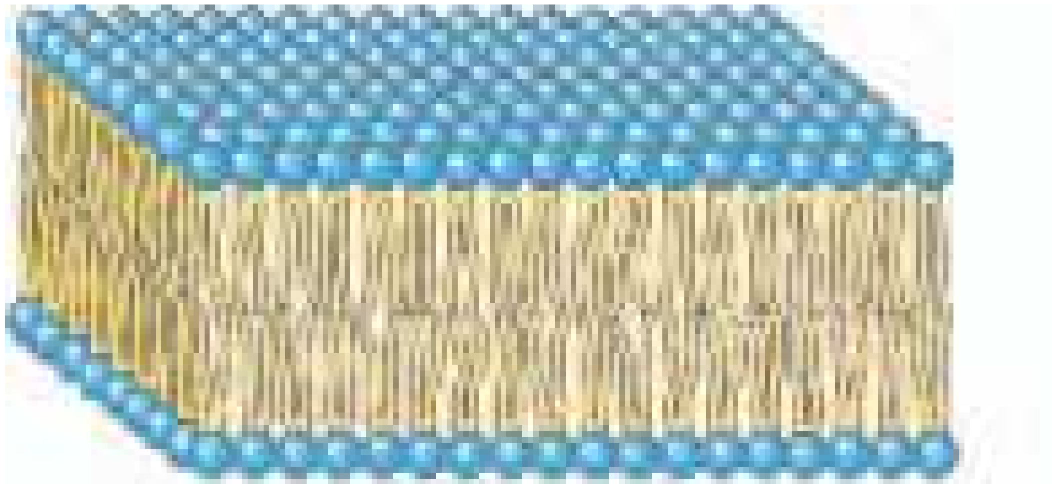
Hydrophobic Interactions

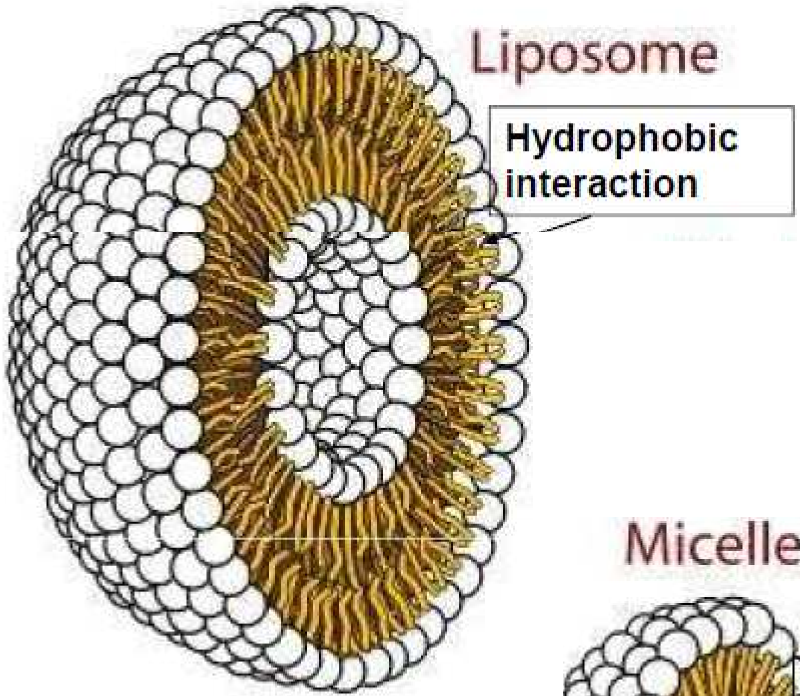
For example: in proteins

- The side chains (R groups) of hydrophobic amino acids, such as phenylalanine and leucine are nonpolar

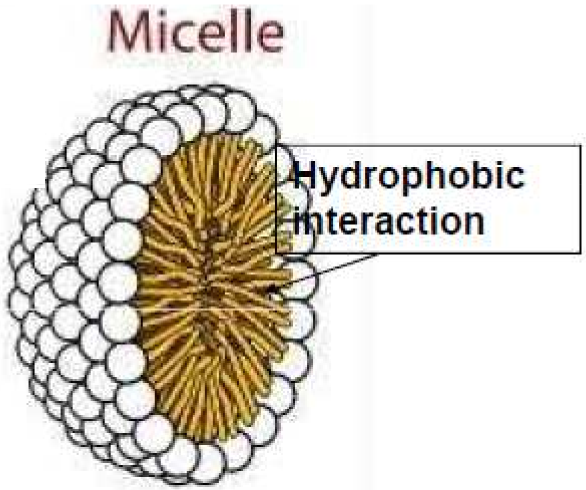


- **Hydrophobic bonds are very important in the formation of membranes**

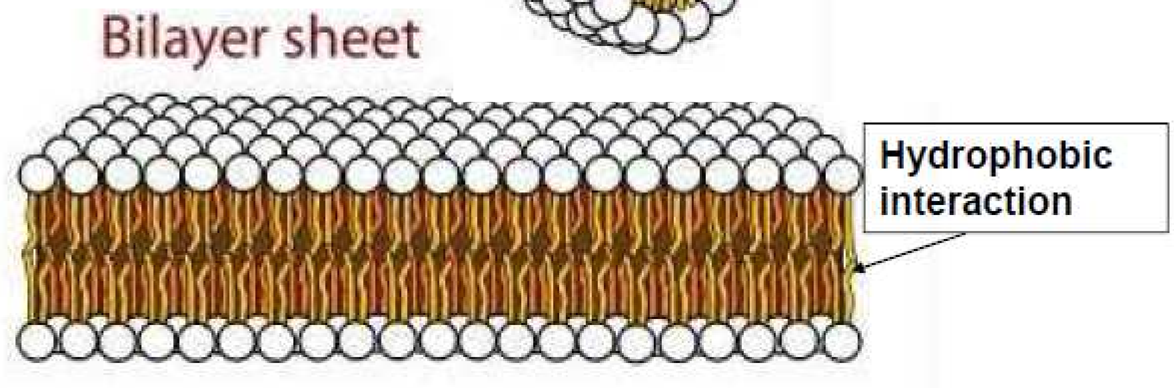




When a two-dimensional bilayer folds on itself, it forms a closed bilayer, a three-dimensional hollow vesicle (liposome) enclosing an aqueous cavity.



In micelles, the hydrophobic chains of the fatty acids are sequestered at the core of the sphere. There is virtually no water in the hydrophobic interior.

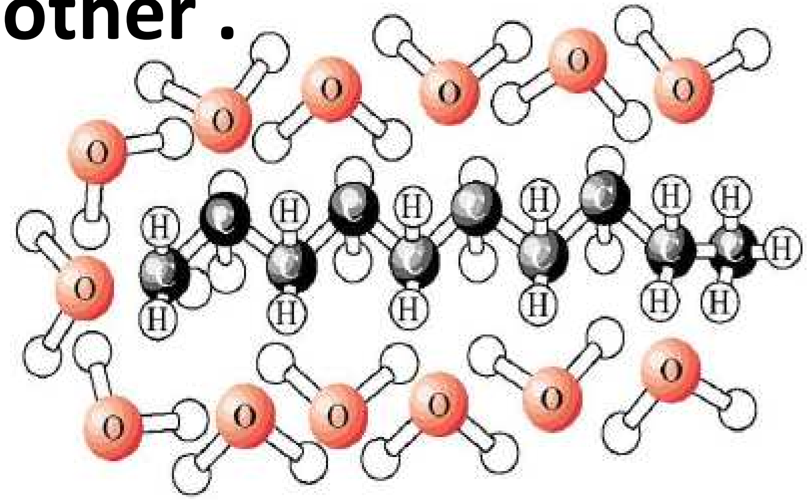


In an open bilayer, all acyl side chains except those at the the edges of the sheet are protected from interaction with water

Bond Polarity

- Why oil and water do not mix ?
  Oil is nonpolar, and water is polar.
- The two will repel each other, so one can not dissolve in the other .

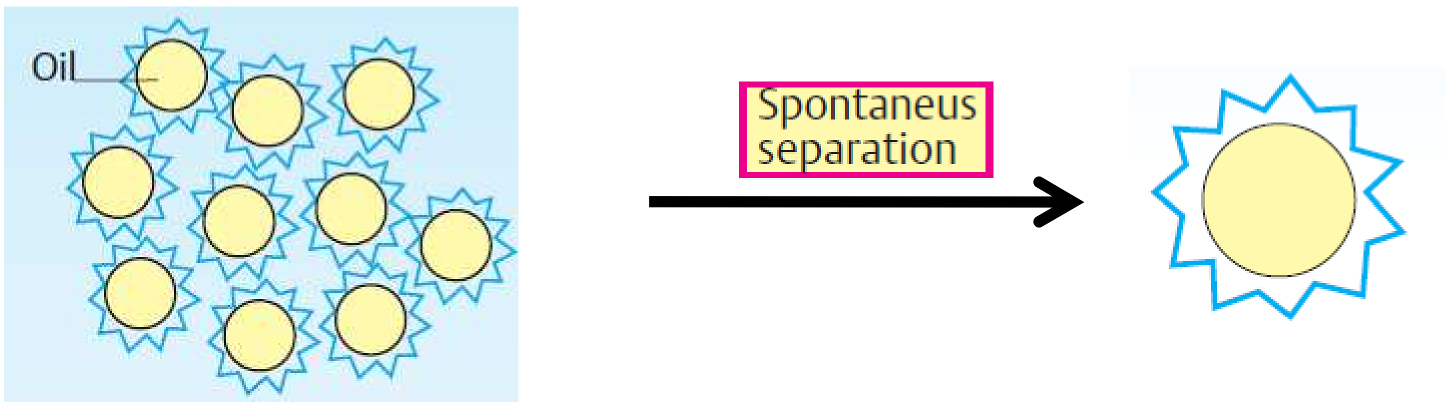
nonpolar molecules will aggregate to avoid water.
A similar situation occurs in parts of many proteins.



Water molecules
in cage around
hydrocarbon chain

The spontaneous separation of oil and water

When a mixture of water and oil is firmly shaken, lots of tiny oil drops form to begin with, but these quickly combine spontaneously to form larger drops and the two phases separate.
A larger drop has a smaller surface area than several small drops with the same volume.
Separation therefore reduces the area of surface contact between the water and the oil .



“Like Dissolves Like”

– **Polar dissolves Polar**

e.g.sugars dissolves in water; NaCl dissolves in water, but not in benzene.

– **Nonpolar dissolves in Nonpolar**

e.g. oil dissolves in benzene, but not in water.

Van der Waals Forces

* Small, weak interactions between molecules

3 Types of Van der Waals Forces

1) dipole-dipole
2) dipole-induced dipole
3) dispersion

Dipole – Dipole

between two polar molecules

Dipole – Induced Dipole

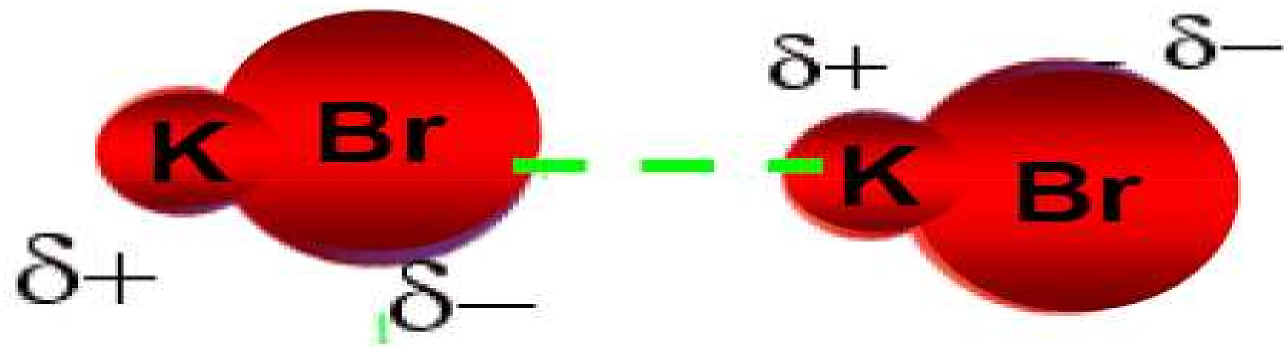
between a polar & a non-polar molecule

Dispersion

between two non-polar molecules

Dipole-Dipole

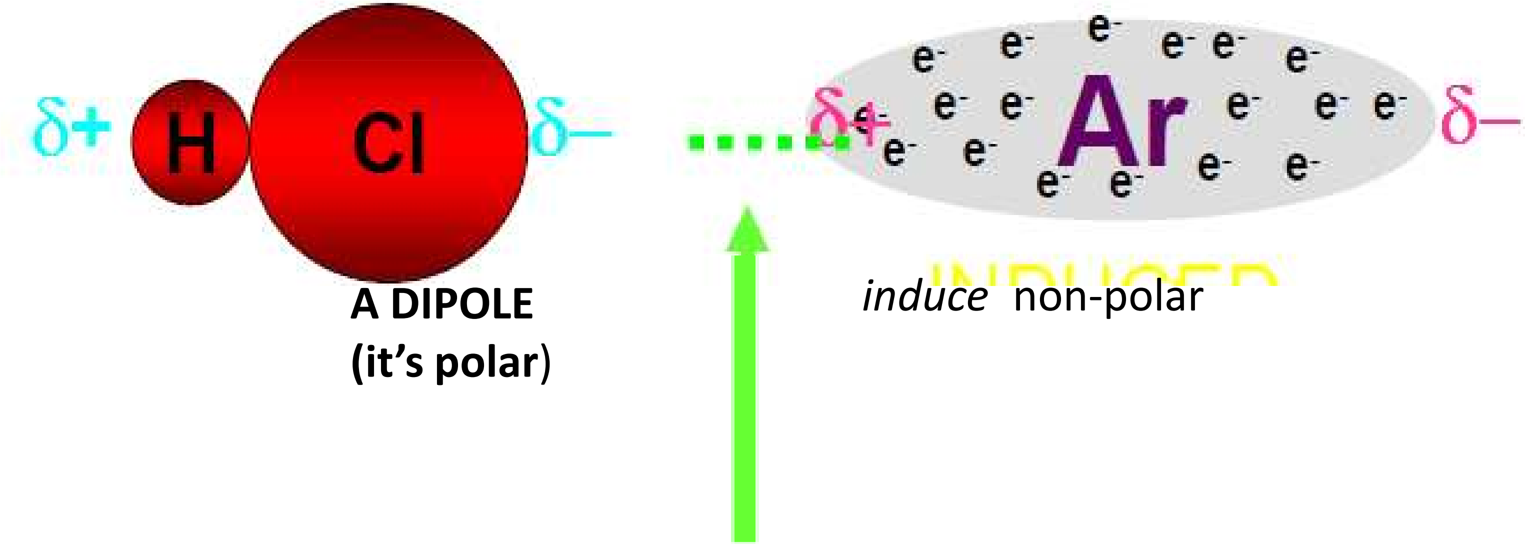
Two polar molecules align so that δ+ and δ- are matched (electrostatic attraction)



Two KBr molecules , their dipole-dipole interactions is shown with a dashed line

Dipole-Induced Dipole

* A dipole can *induce (cause)* a temporary dipole to form in a non-polar molecule
* The molecules then line up to match δ+ and δ- charges

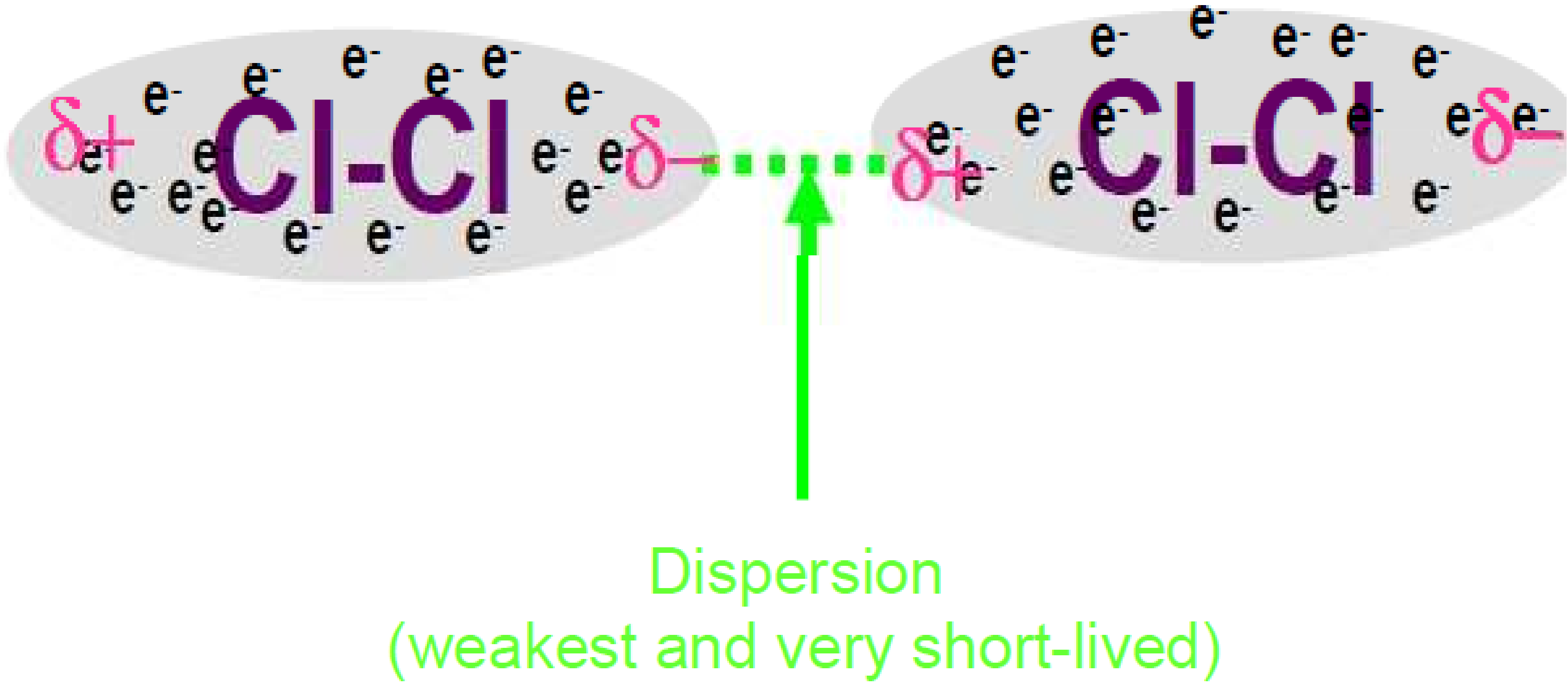


Dipole – Induced Dipole
(weak and short-lived)

Dispersion

* temporary dipole forms in a **non-polar** molecule which leads to… a temporary dipole to form in **ANOTHER non-polar molecule**

* Dispersion is the **ONLY** intermolecular attraction that occurs between non-polar molecules



Ionic Bonds

- Ionic bonds are forces of attraction between ions of opposite charge (+ and -)
- They are present in any kind of biological materials which that can form ions.

  eg. Carboxyl groups and Amino groups .

Bonds in proteins