Non-Covalent Bonds (Weak Bond)

- Weak bonds are those forces of attraction that, in biological situations, 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.
- In biological systems, ionic bonds, hydrogen bonds and van der Waals interactions are considered weak bonds

Weak Bonds (conti..)

- Weak bonds may be easily broken but they are very important because they help to **determine and stabilize the shapes of biological molecules**.
- 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.

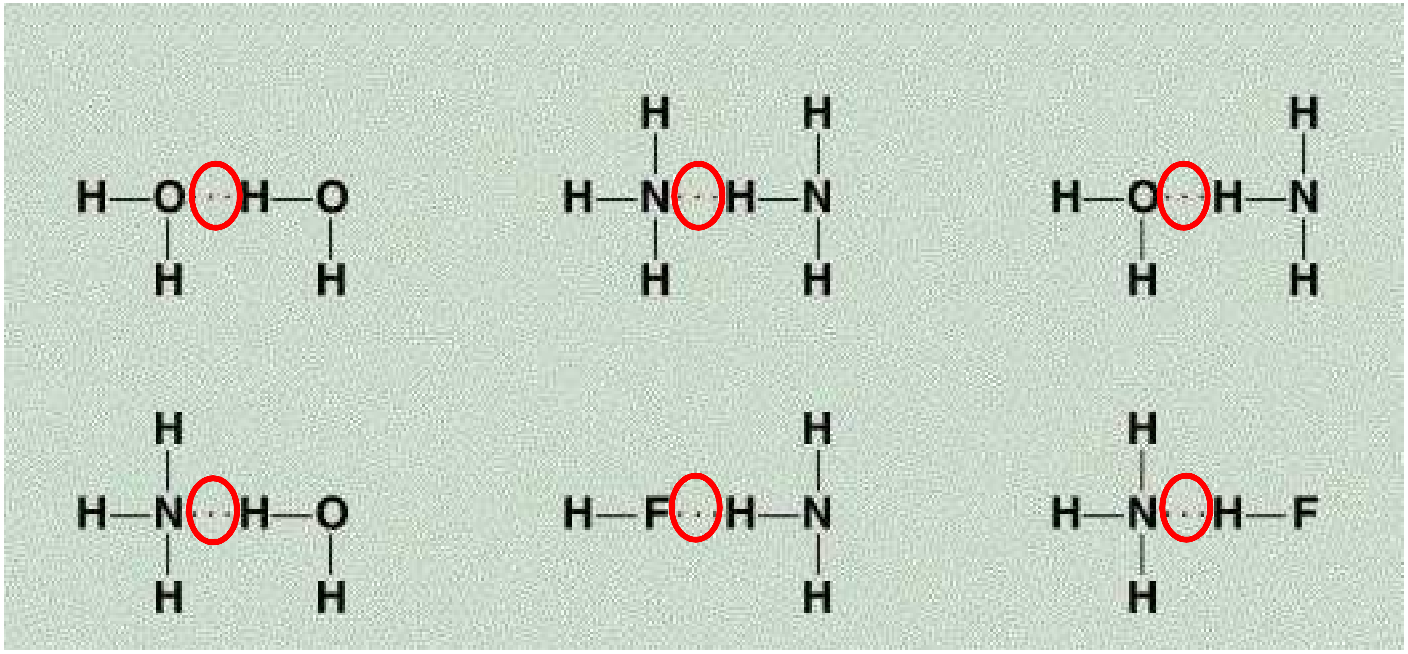
Types of Intermolecular Forces

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

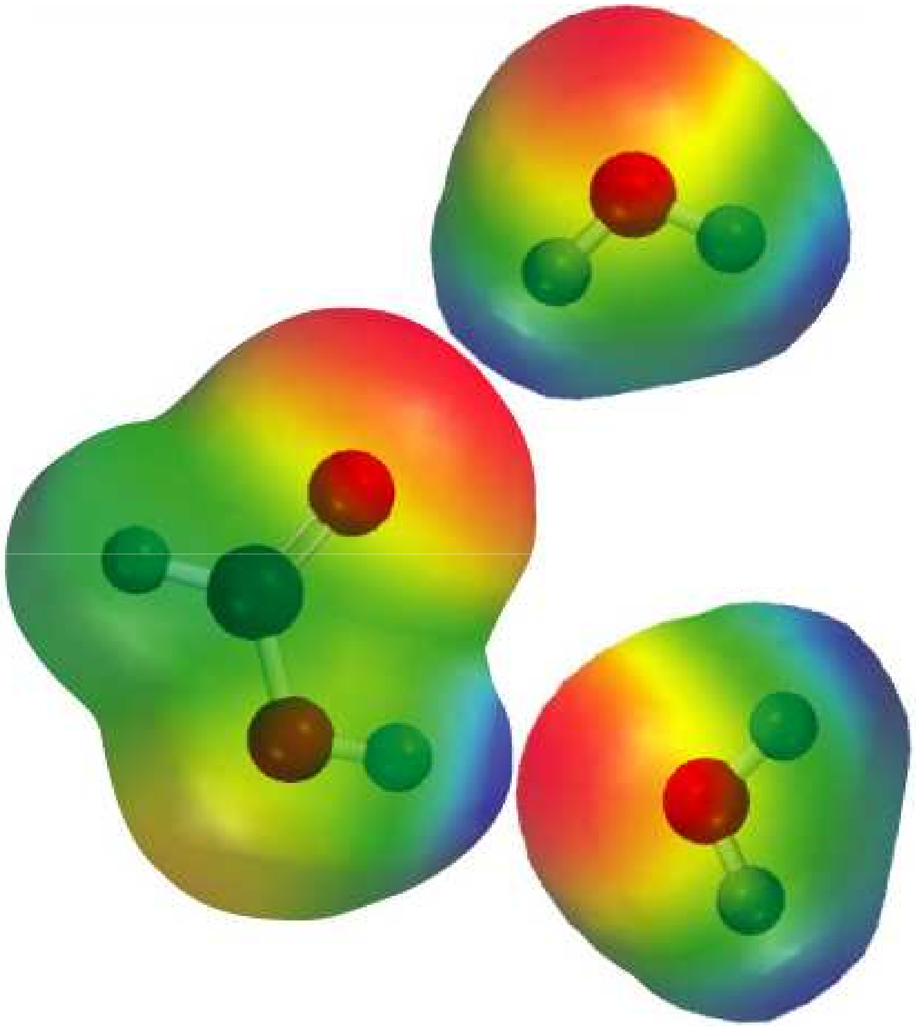
A & B are N, O, or F

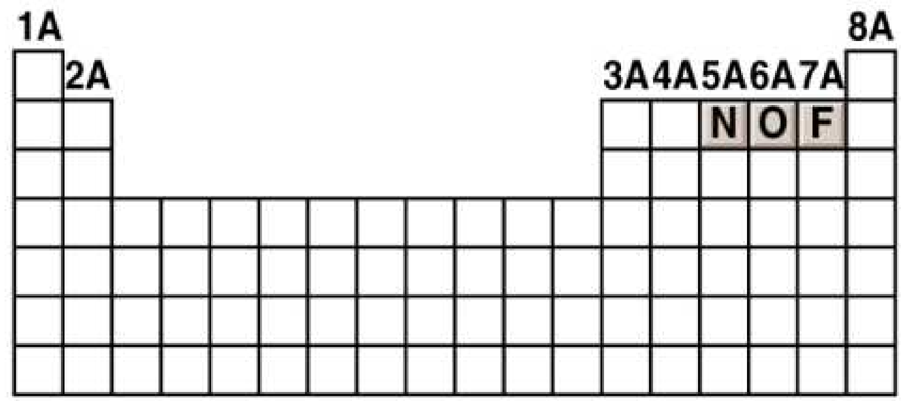


Hydrogen Bonds are weak bonds: 3-5 kcal/mole)

- 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

Hydrogen Bond

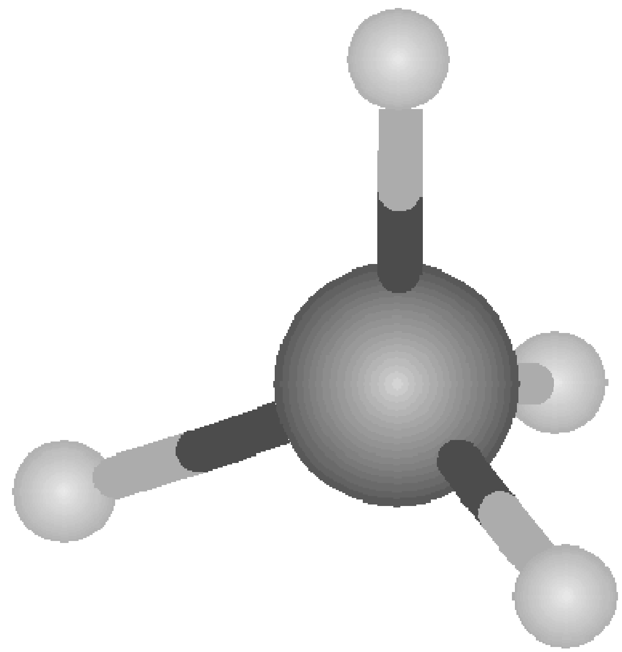




11.2

Hydrogen bonds

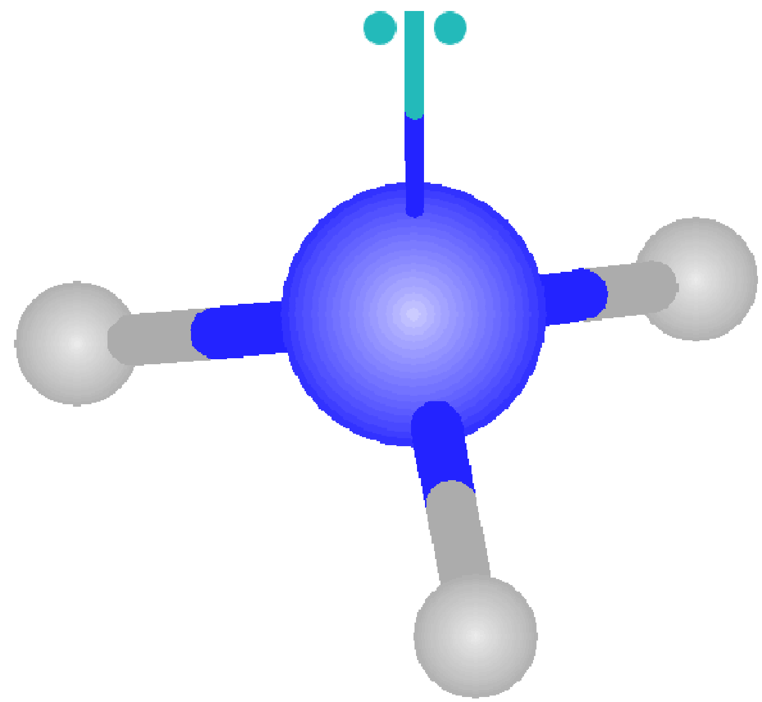
methane, CH_4 …



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

Hydrogen bonds

ammonia, NH_3 …



This <u>does</u> have hydrogen bonds.

Nitrogen is very electronegative, and it has one lone pair of electrons in ammonia.

Hydrogen Bond

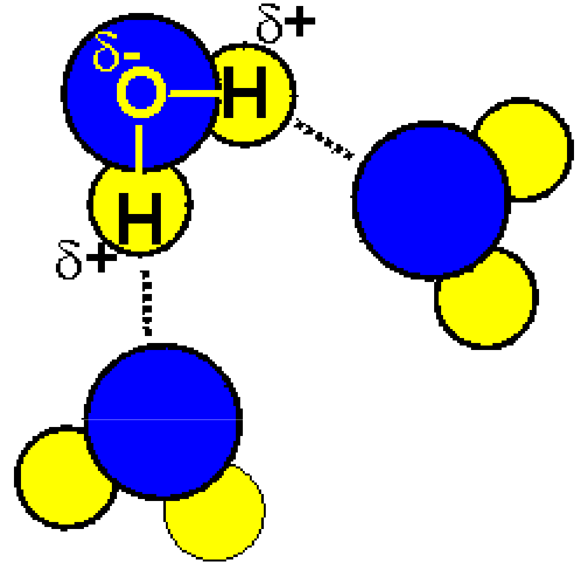
- Hydrogen bonds exist in water. Water molecules consist of one oxygen atoms and two hydrogen atom bonded using a covalent bond. Water molecules have a positive charge near the hydrogen because of a concentration of electrons. This causes a negative charge at the other side of the molecule, this distribution of charge causes a weak bond between water molecules so making the vaporising of water is not easy.

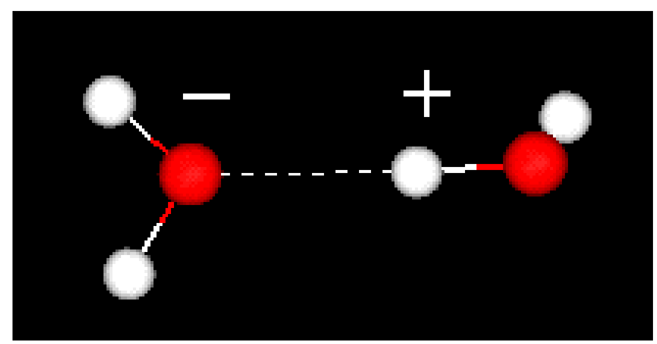
Hydrogen Bonding

- The polarity in a water molecule causes the HYDROGEN atoms of one water molecule to be attracted to the OXYGEN atoms of another water molecule.
- Very weak bonds, but there are so many! So, as a collective force, they can be quite strong.

Hydrogen Bonds

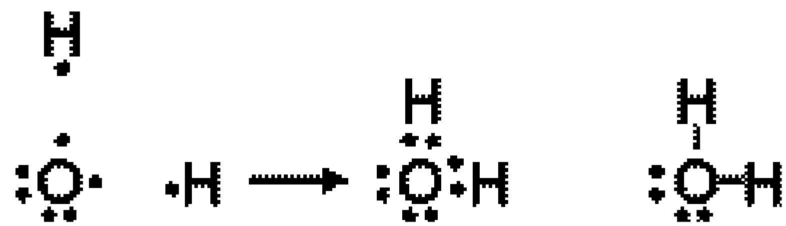
- Hydrogen bonds are attractive forces in which a hydrogen covalently bonded to a very electronegative atom is also weakly bonded to an unshared electron pair of another electronegative atom.



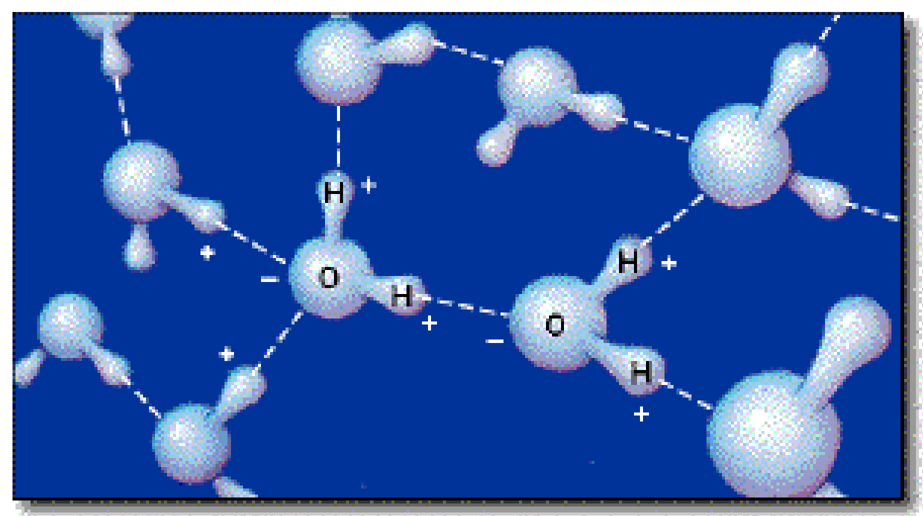


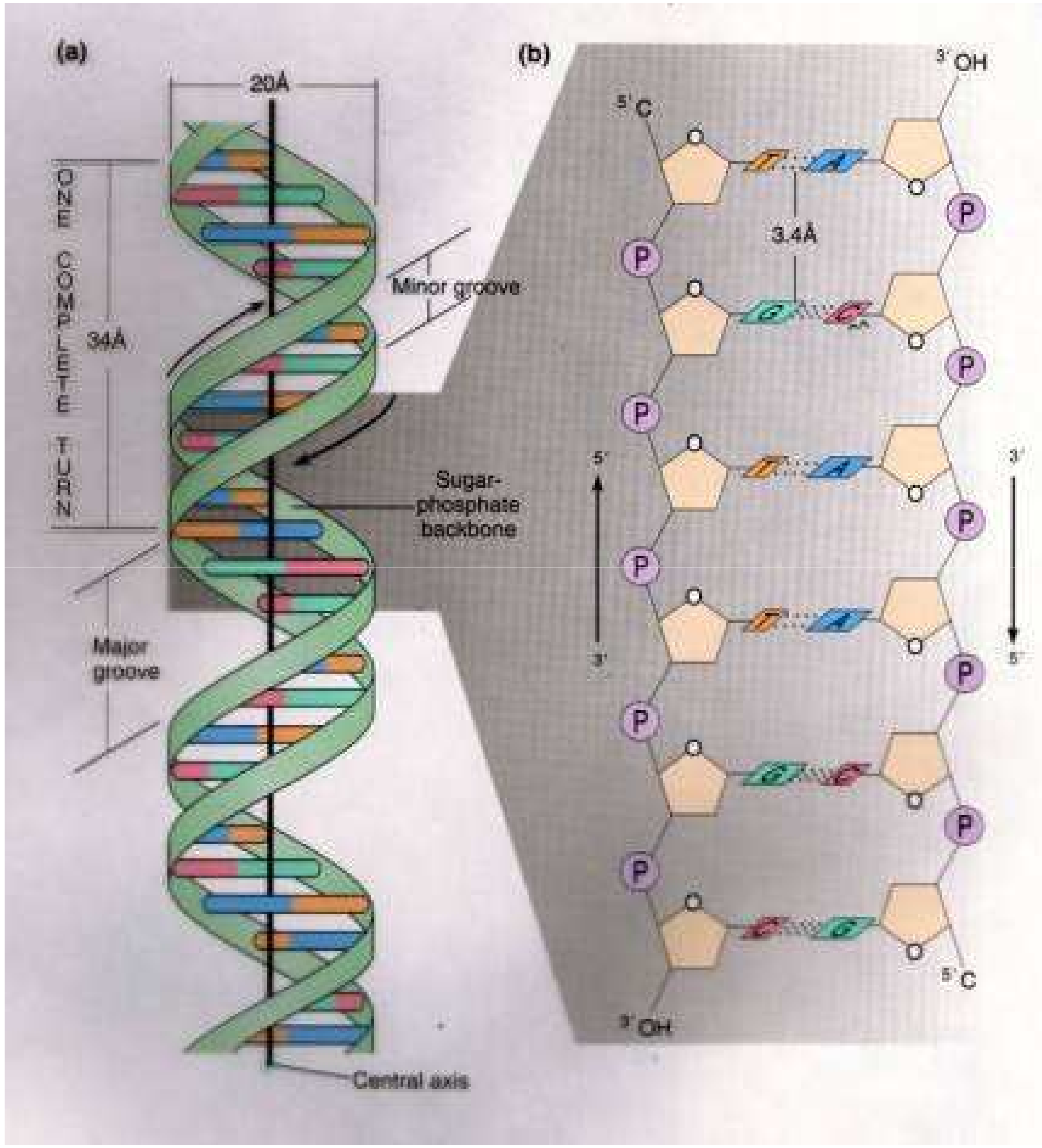
Hydrogen-Oxygen Bonding (H_2O)

- Covalent bonds can also have partial charges when the atoms involved have different electronegativities. Water is perhaps the most obvious example of a molecule with partial charges.



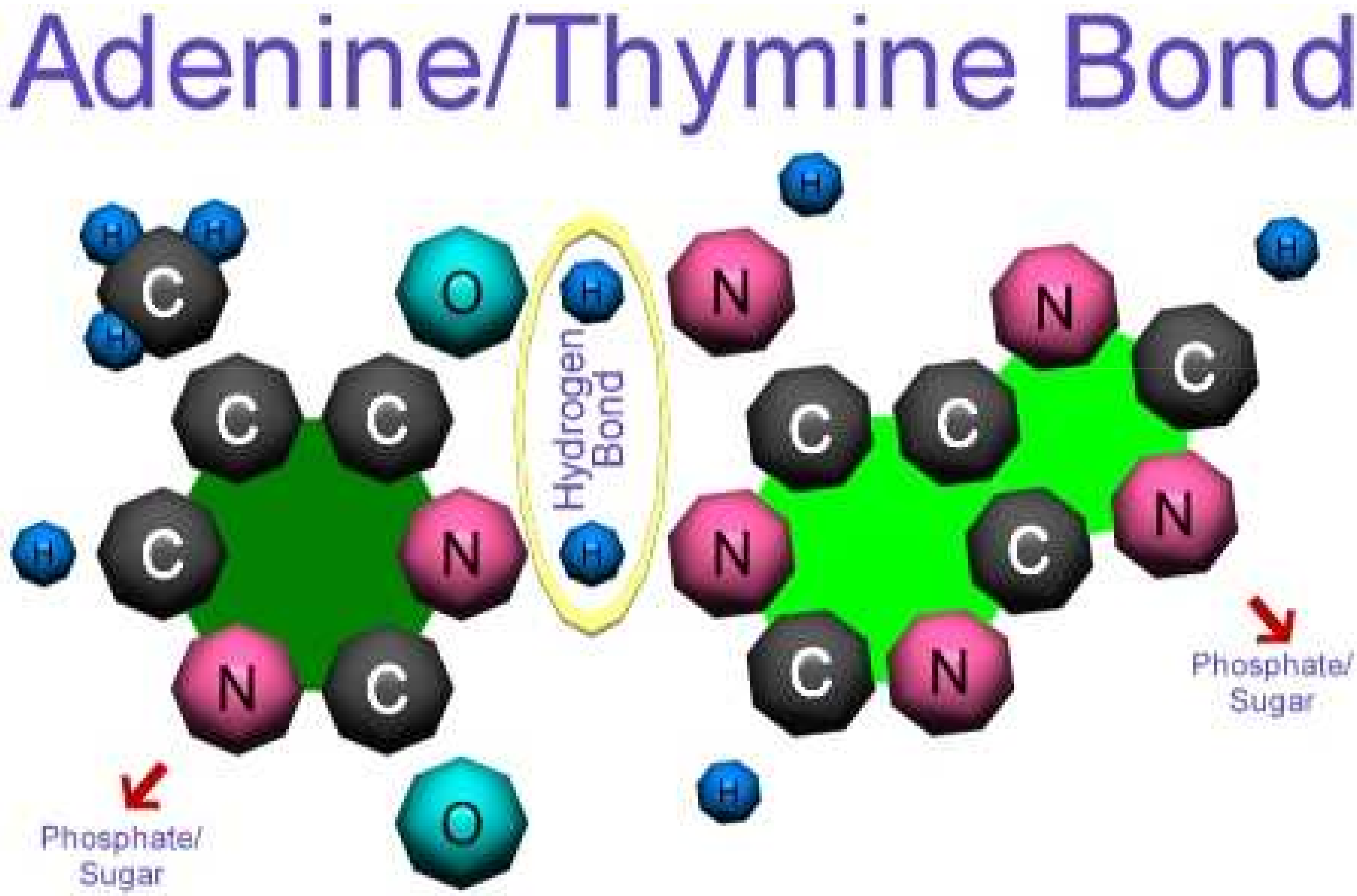
- The symbols delta+ and delta- are used to indicate partial charges. Oxygen, because of its high electronegativity, attracts the electrons away from the hydrogen atoms, resulting in a partial negative charge on the oxygen and a partial positive charge on each of the hydrogens. The possibility of hydrogen bonds (H-bonds) is a consequence of partial charges.





(a)
20Å
ONE COMPLETE TURN
34Å
Minor groove
Sugar-phosphate backbone
Major groove
Central axis
(b)
5' C
3' OH
3.4Å
P
5'
3'
3'
5'
5' C
3' OH

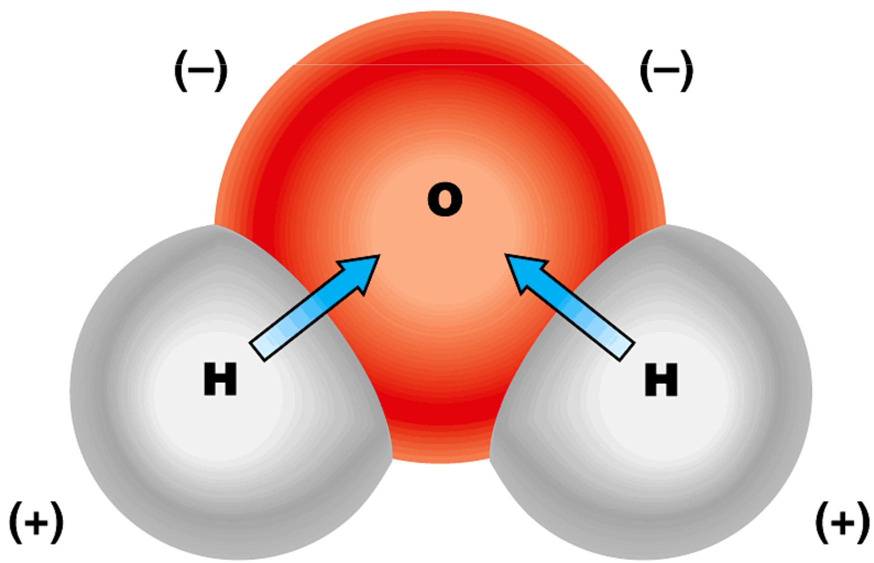
Hydrogen Bonds in DNA

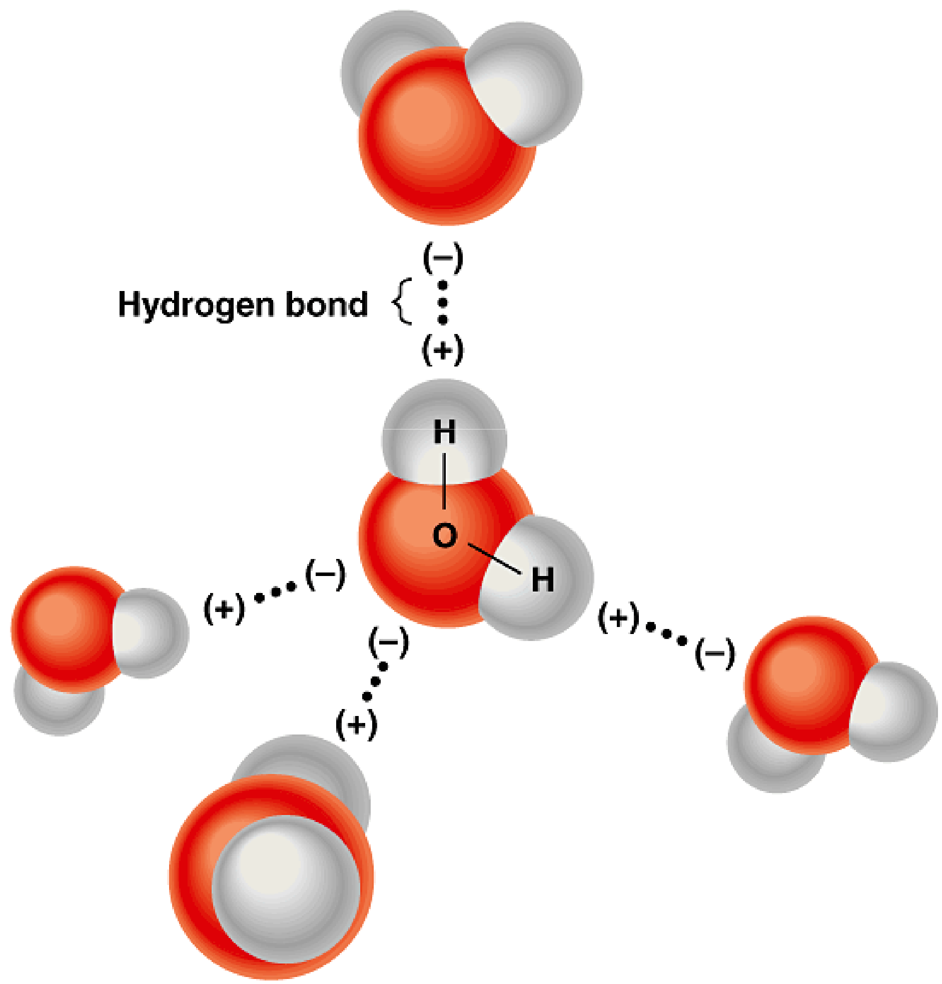


Bonding

Covalent bonding

Polar covalent bond





Van der Vaals Bond

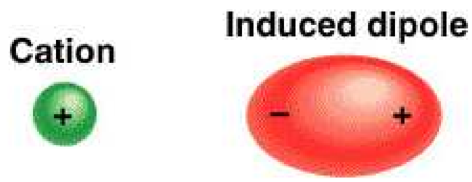
- Van der Vaals bonds are formed from an electrostatic charge in adjacent atoms. It is present between long-chained molecules in polymers bonding the chains together. When stretched the bonds break easily causing the material to deform.
- **Van der Waals bonds are the weakest bonds: 1-2 kcal/mole)**

- As any two atoms approach each other, electron clouds begin to overlap. Creates a situation known as "induced dipole". One electron "pushes" other to opposite side of its atom, so momentarily there is a slight electron deficit, therefore a slight + charge to attract the first electron's - charge. This situation oscillates back and forth between the two atoms, creating a very slight attractive force, ~ 1 kcal/mole = "Van der Waals" bond

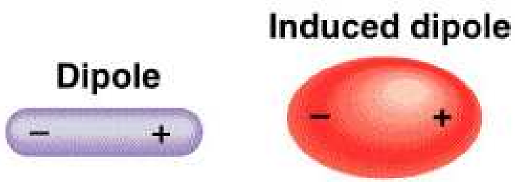
Types of Intermolecular Forces

4. Dispersion Forces – van der Walls forces/London forces (weakest)

Attractive forces that arise as a result of **temporary dipoles induced** in atoms or molecules



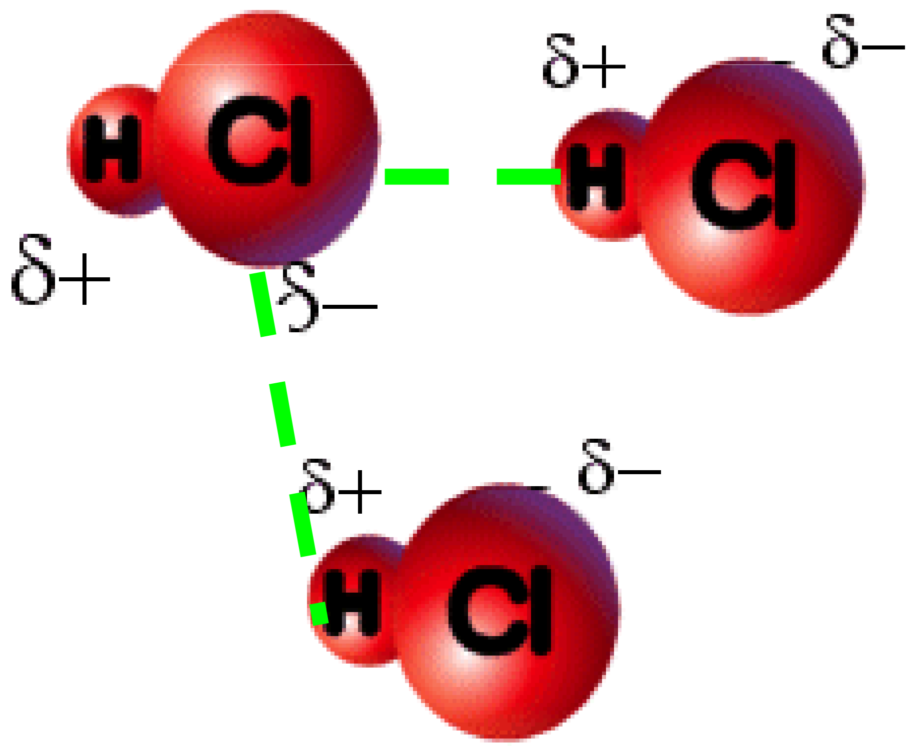
ion-induced dipole interaction



dipole-induced dipole interaction

Van der Waals Forces

Small, weak interactions <u>between</u> molecules

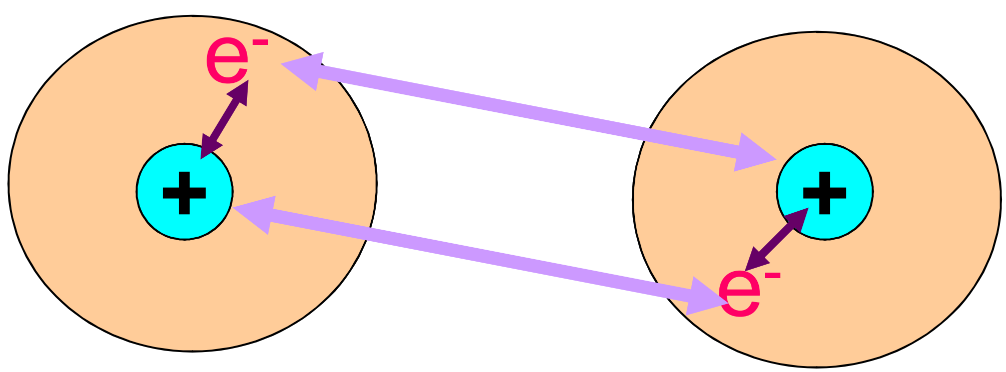


What is being attracted?

δ+ attracted to δ-

→ electrostatic attraction

e^- s of one atom to another atom's nucleus



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

b/w a polar & a non-polar molecule

Dispersion

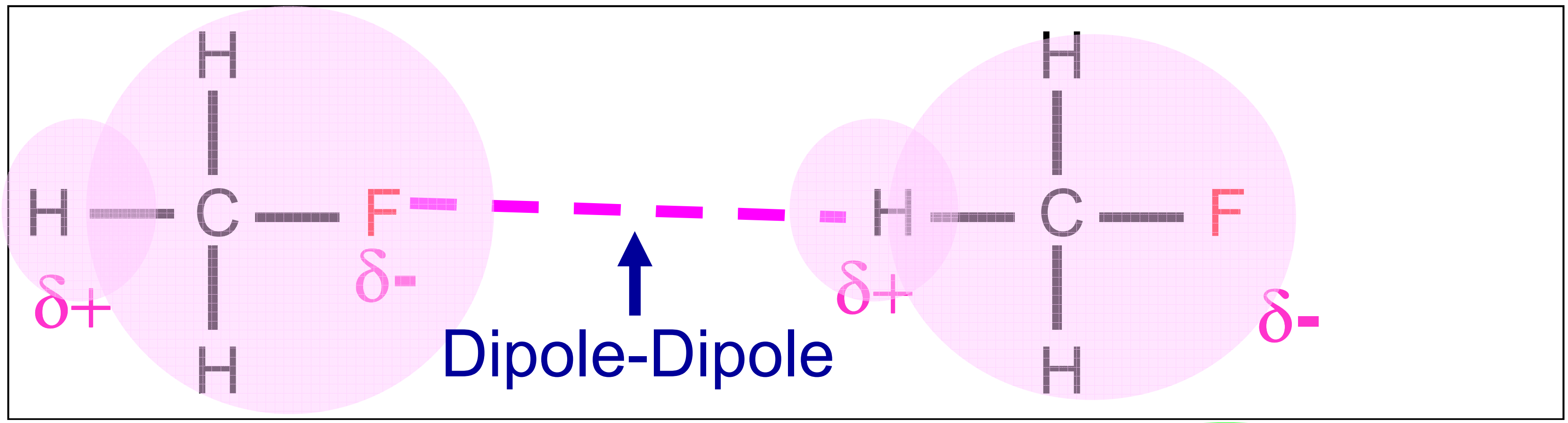
between two non-polar molecules

Dipole-Dipole

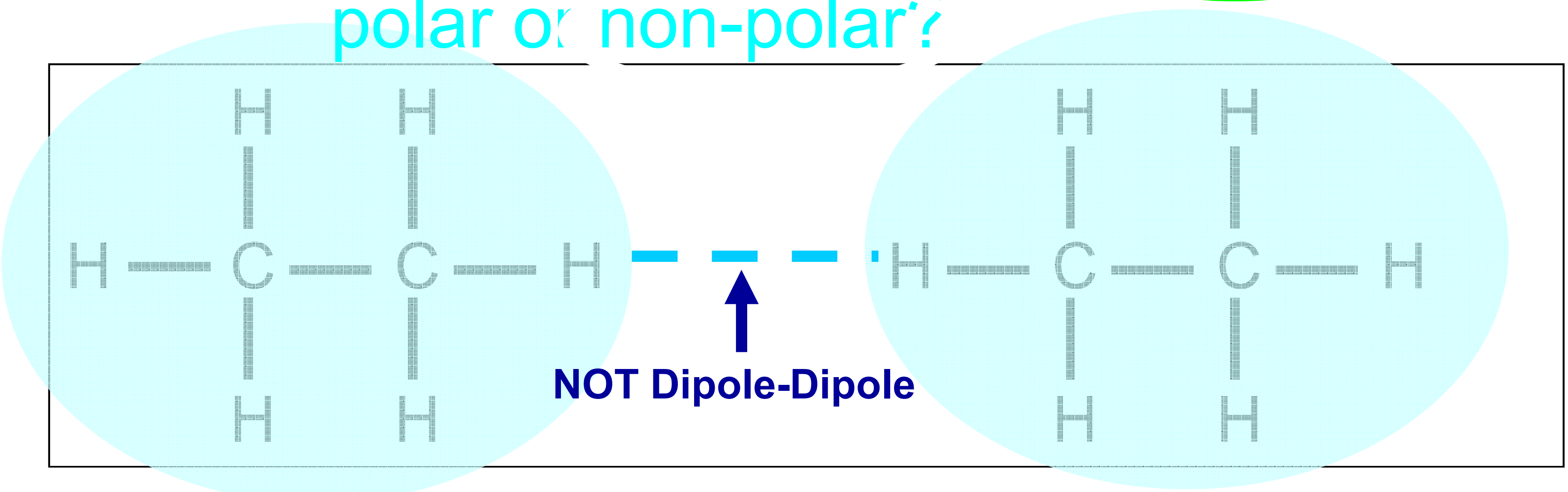
Two polar molecules align so that δ+ and δ- are matched (electrostatic attraction)

Ex: ethane (C_2H_6) vs. fluromethane (CH_3F)

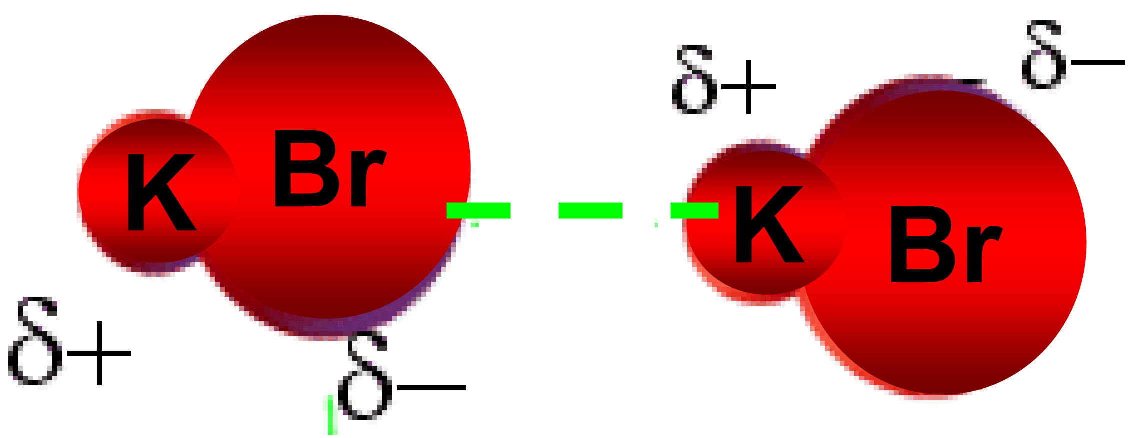
Fluoromethane (CH_3F) – boiling point = 194.7 K
polar or non-polar?



Ethane (C_2H_6) – boiling point = 184.5 K
polar or non-polar?



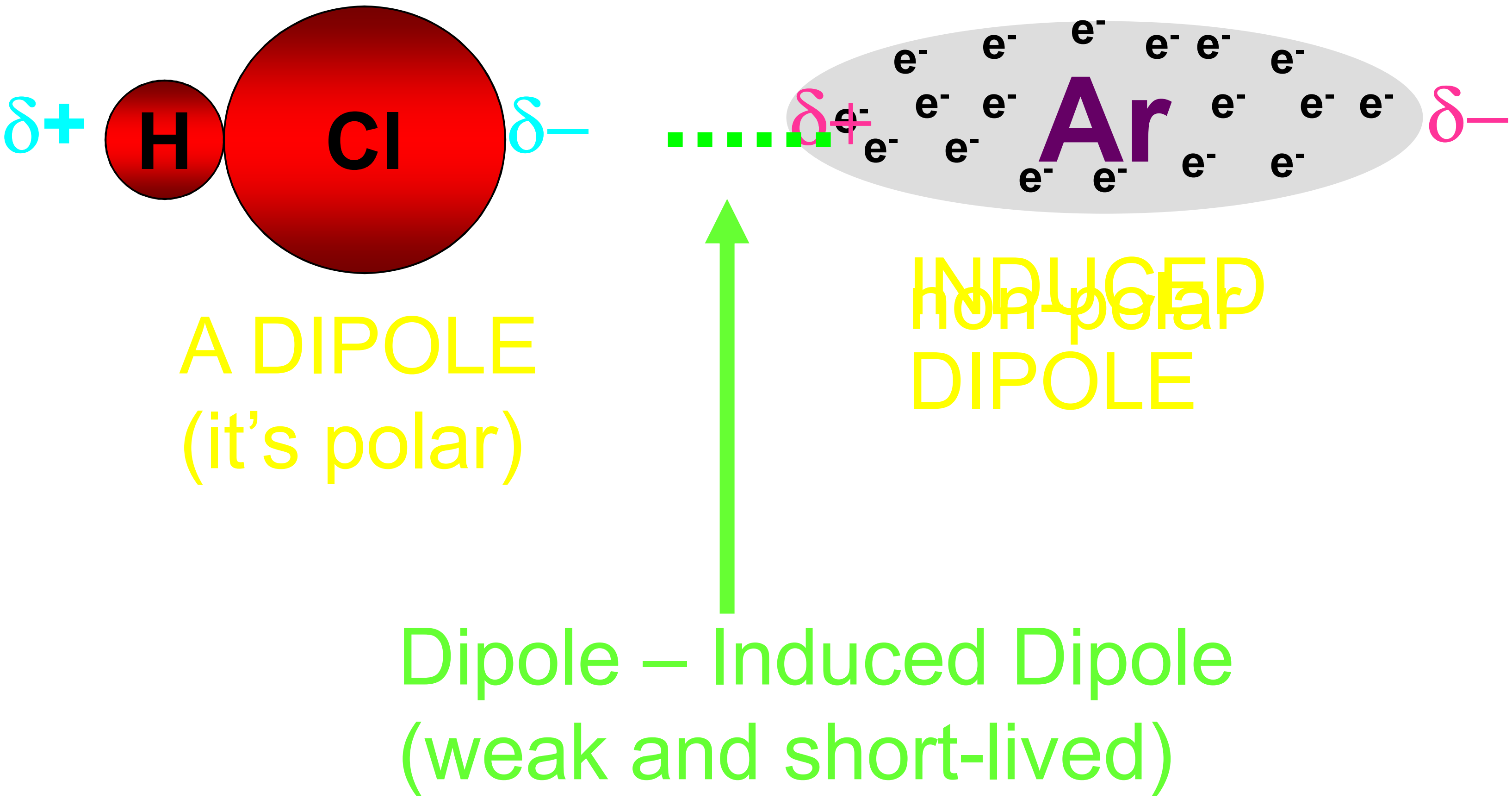
Two KBr molecules , their dipole-dipole interactions is shown with a dashed line.



Dipole-Induced Dipole

A dipole can
a temporary dipole to form in a
non-polar molecule

The molecules then line up
to match δ+ and δ- charges


δ+
H
Cl
δ–
A DIPOLE
(it's polar)
δ+
Ar
δ–
e-
INDUCED
non-polar
DIPOLE
Dipole – Induced Dipole
(weak and short-lived)

temporary dipole

non-polar molecule

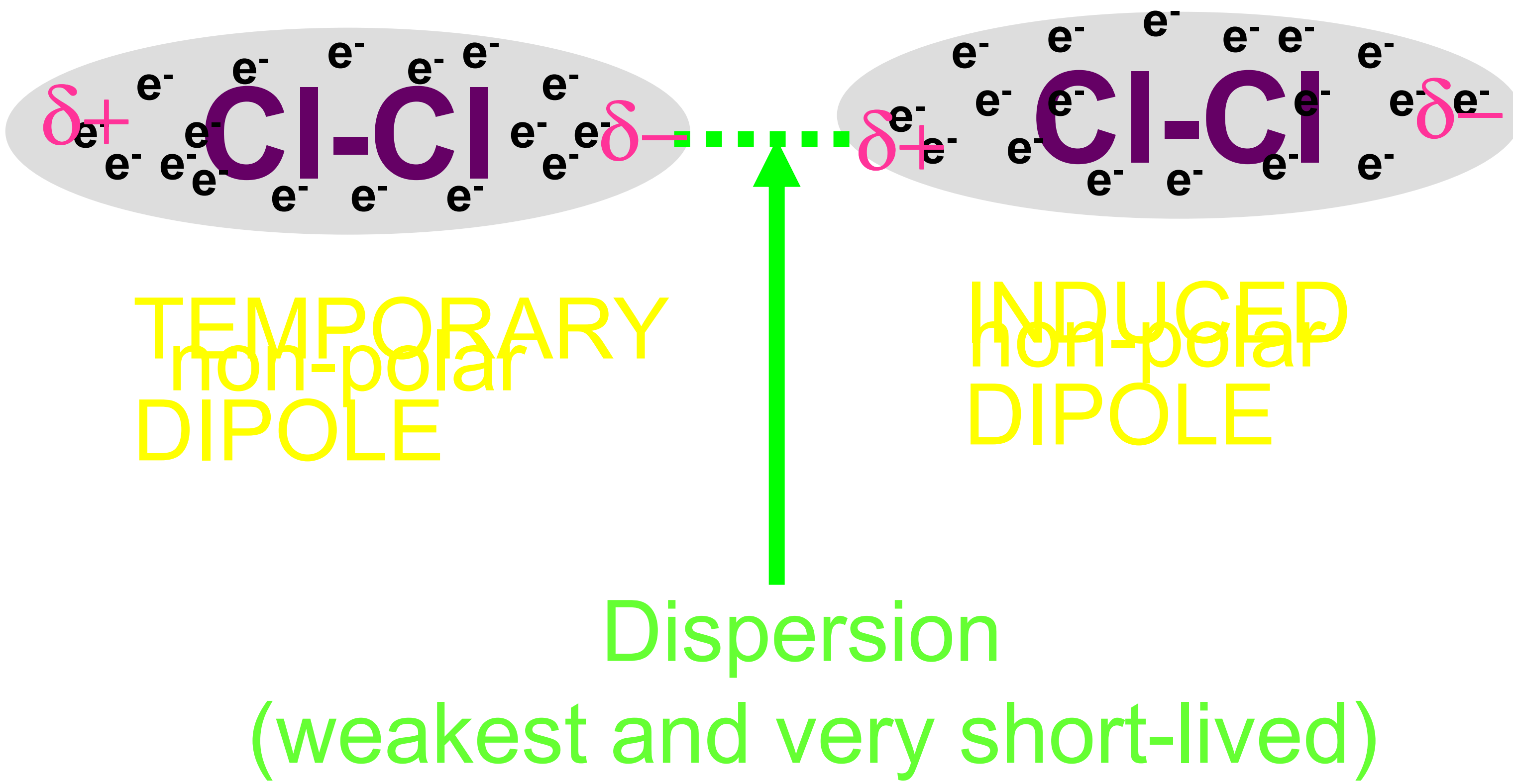
temporary dipole

ANOTHER

non-polar molecule

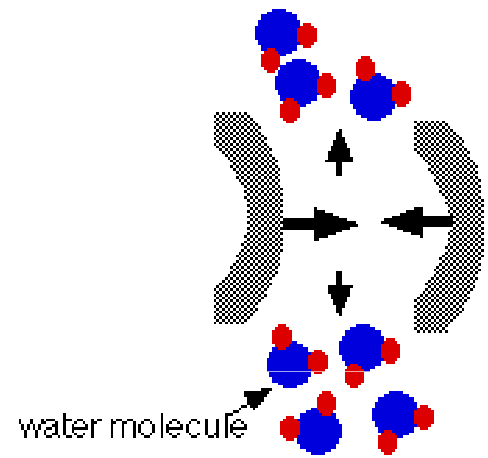
non-polar

molecules


Cl-Cl
δ+
δ−
e-
Cl-Cl
δ+
δ−
TEMPORARY
non-polar
DIPOLE
INDUCED
non-polar
DIPOLE
Dispersion
(weakest and very short-lived)

Hydrophobic Bonds

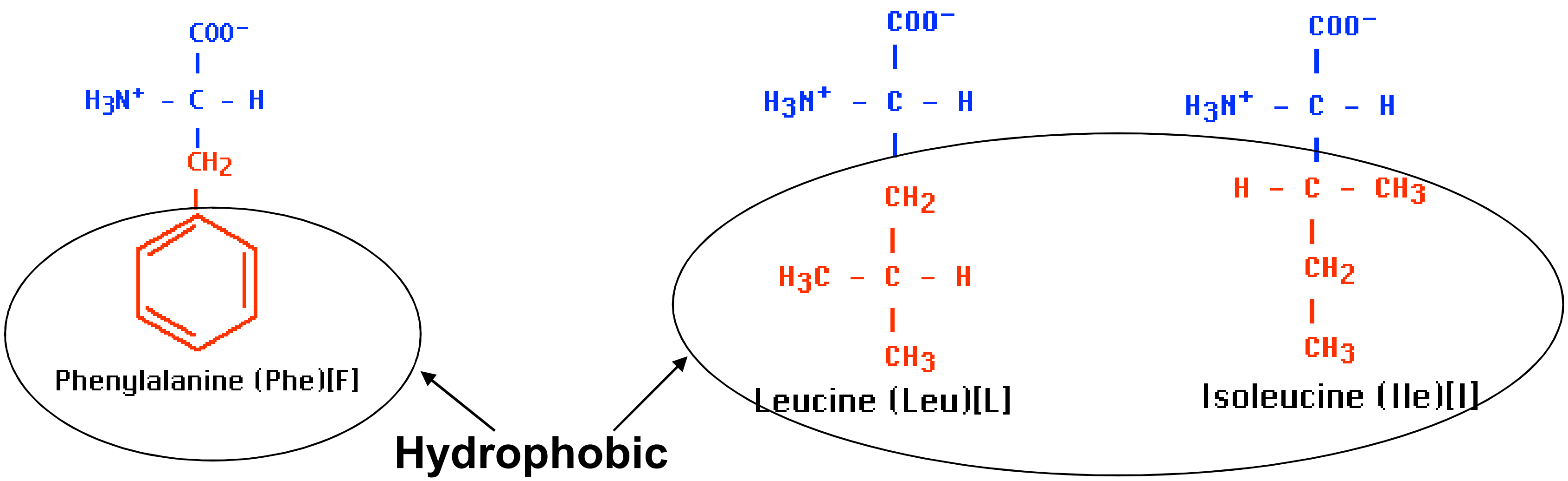
- This type of **non-covalent bond** describes the interaction of non-polar, hydrophobic molecules when they are put into water. Hydrophobic (non-polar) molecules do not interact with polar water and cannot form H-bonds.
- So they interact with each other and repel the water (hydro= water; phobic= hating)



Hydrophobic Interactions

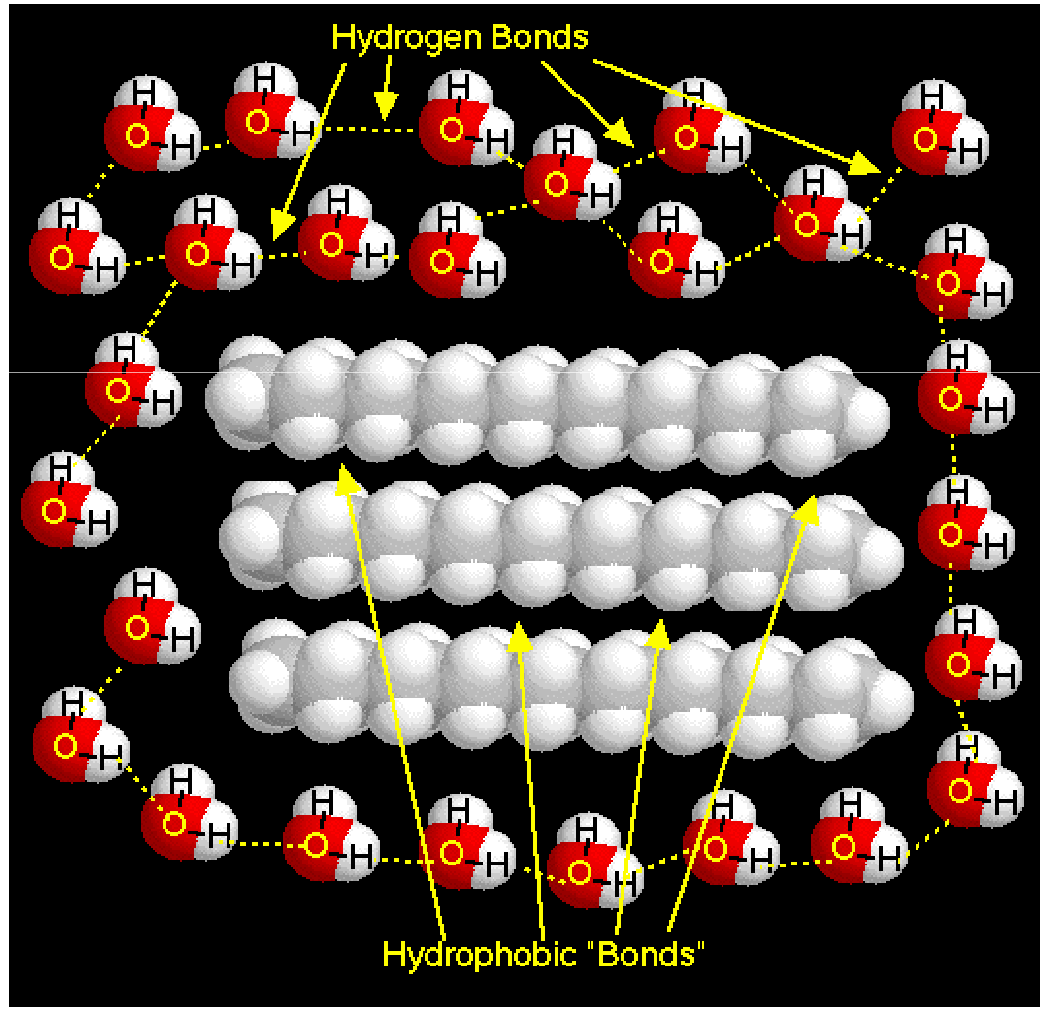
For example: in proteins

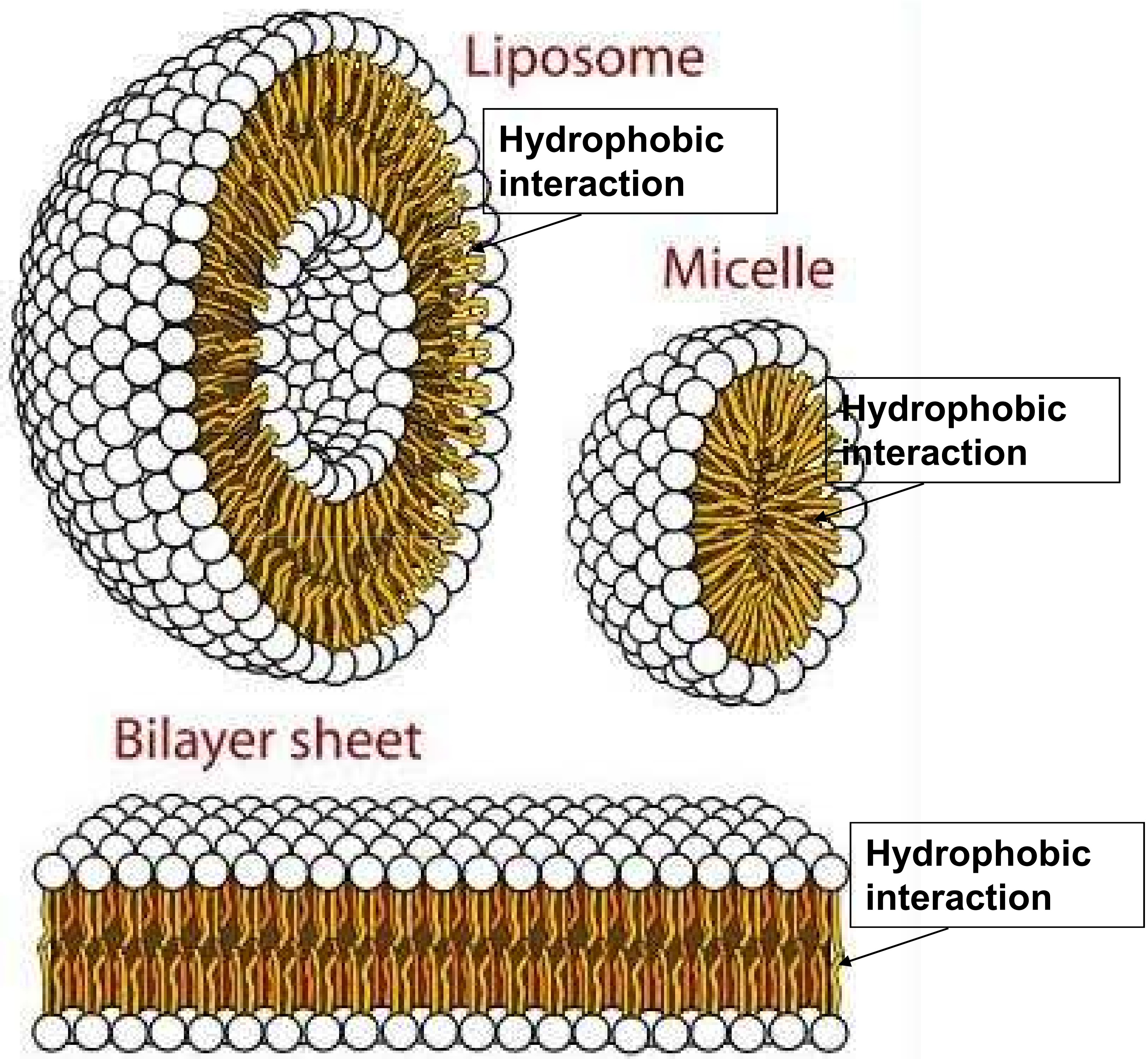
- The side chains (R groups) of hydrophobic amino acids, such as phenylalanine and leucine are nonpolar



For Example: in lipids and membranes

- **Hydrophobic bonds** are very important in the formation of **membranes** and in **enzyme-substrate binding.**




Liposome
Hydrophobic interaction
Micelle
Hydrophobic interaction
Bilayer sheet
Hydrophobic interaction

Strength of Bonds

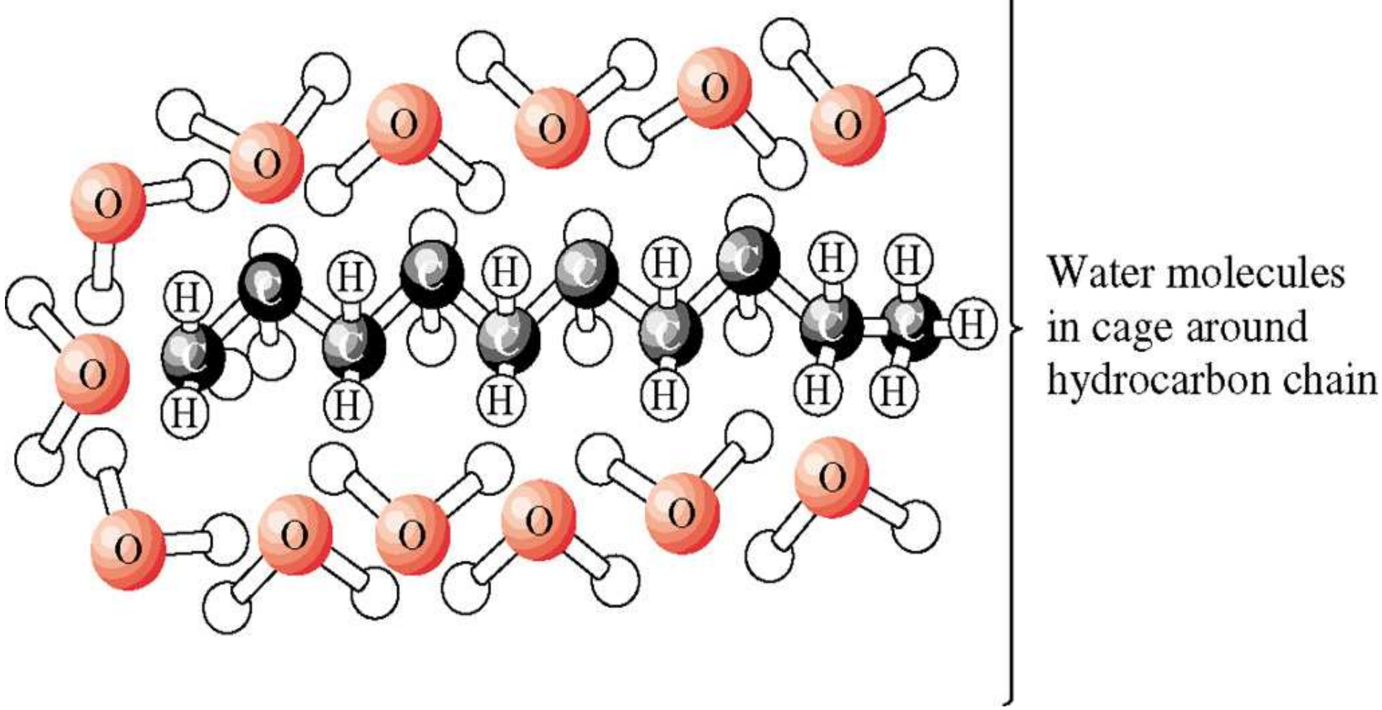
Bond	Energy (GPa)	Example of Bond
Covalent	1,000	Diamond
Ionic	30 - 100	Salt and Ceramics
Metallic	30 - 150	Metals
Hydrogen	8	Ice
Van der Vaals	2	Polythene

What are weak bonds?

- **Weak bonds are those forces of attraction that, in biological situations, 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. Compare this to the energy needed to break strong bonds**

Bond Polarity

- **This is why oil and water will not mix! Oil is nonpolar, and water is polar.**
- **The two will repel each other, and so you can not dissolve one in the other**

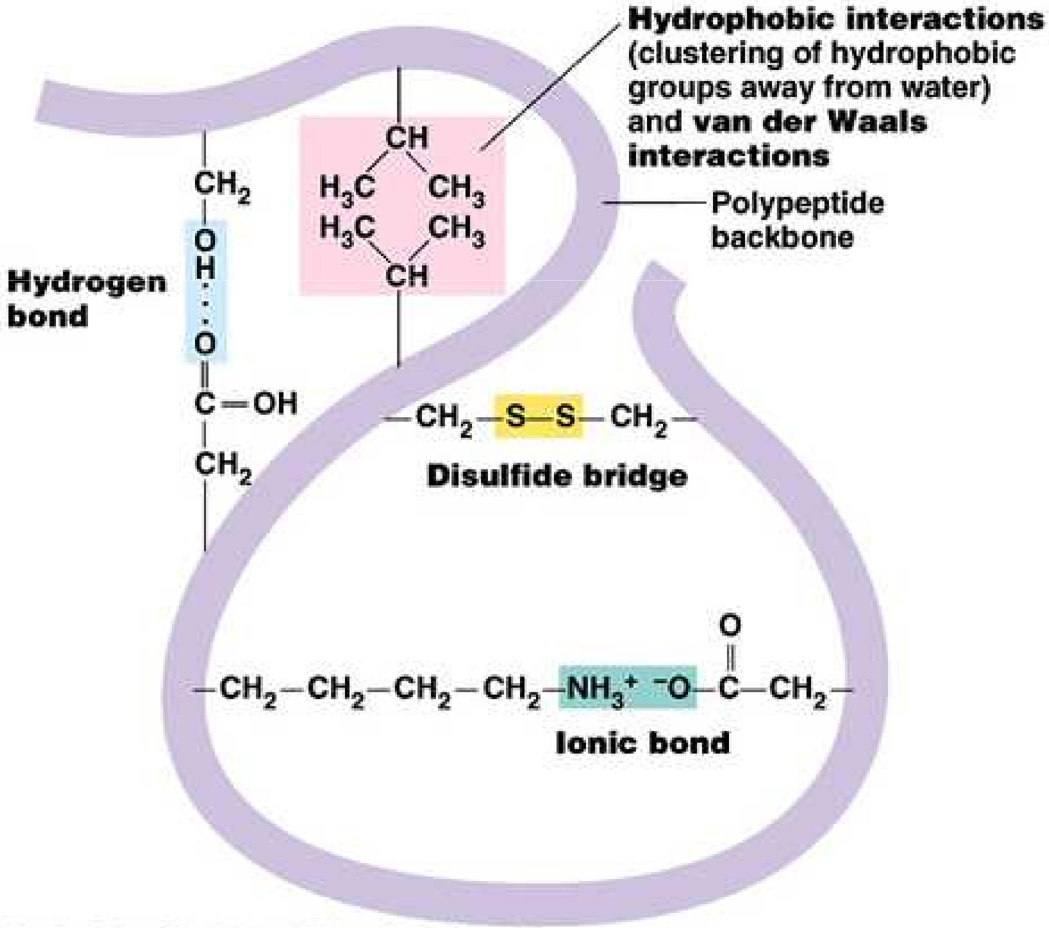


“Like Dissolves Like”

Shout dissolves all kind of oily spots on cloths, which cannot be removed by washing with water.

- 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.

Bonds in proteins

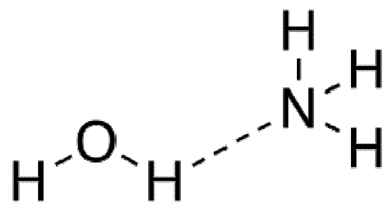


Ionic Bonds

- **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.**
- **E.g. in carboxyl group:**
-

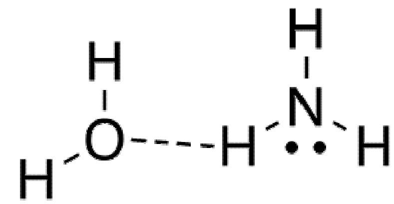
Function of ionic bonds

- **They are important in all biological processes. A few examples are:**
- They play an important role in determining the shapes (tertiary and quarternary structures) of proteins
- They are involved in the process of enzymic catalysis
- They are important in determining the shapes of chromosomes.
- They play a role in muscle contraction and cell shape
- They are important in establishing polarized membranes for neuron function and muscle contraction



hydrogen bond **donor**

hydrogen bond **acceptor**

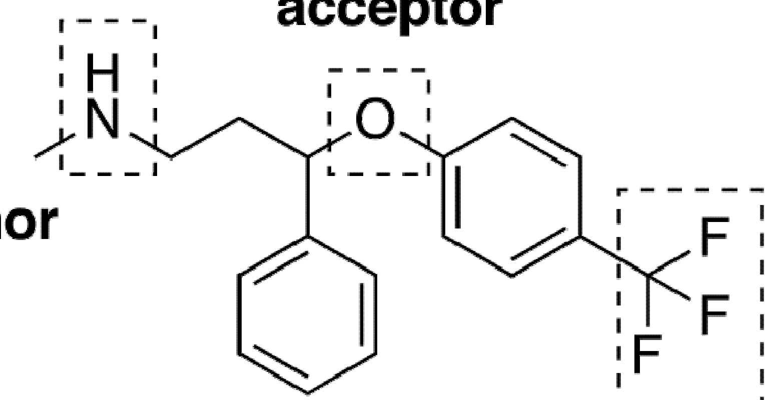


hydrogen bond **acceptor**

hydrogen bond **donor**

hydrogen bond **acceptor**

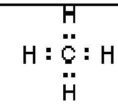
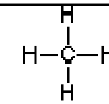
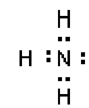
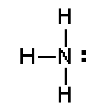
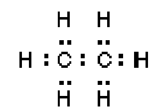
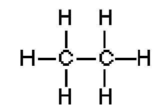
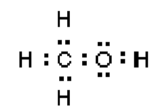
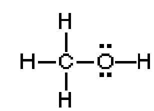
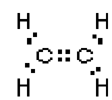
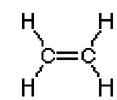
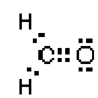
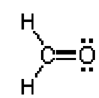
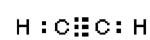
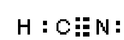
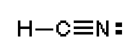
hydrogen bond **acceptor** and/or **donor**



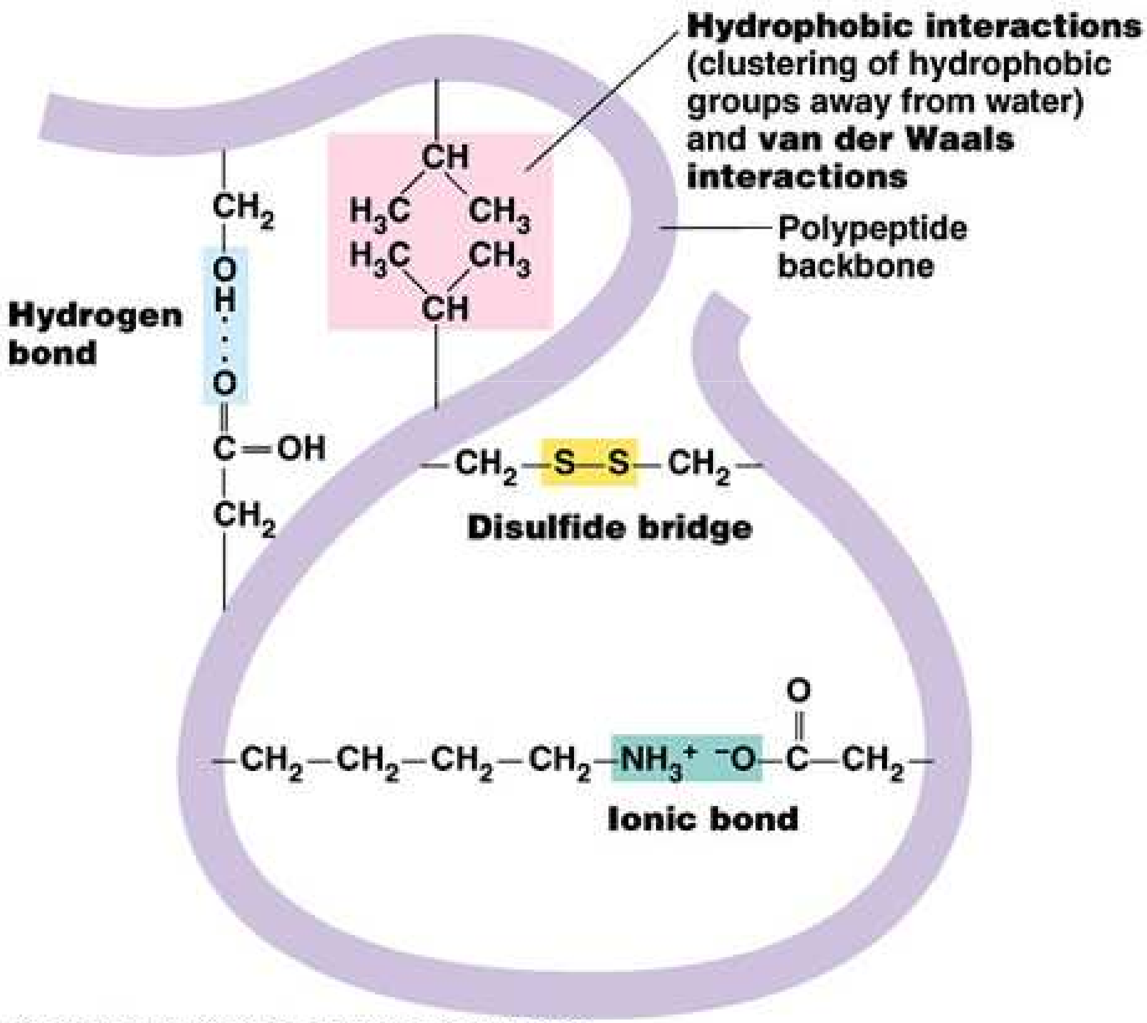
hydrogen bond **acceptor**

prozac

Some examples of such **structural formulas** are given in the following table

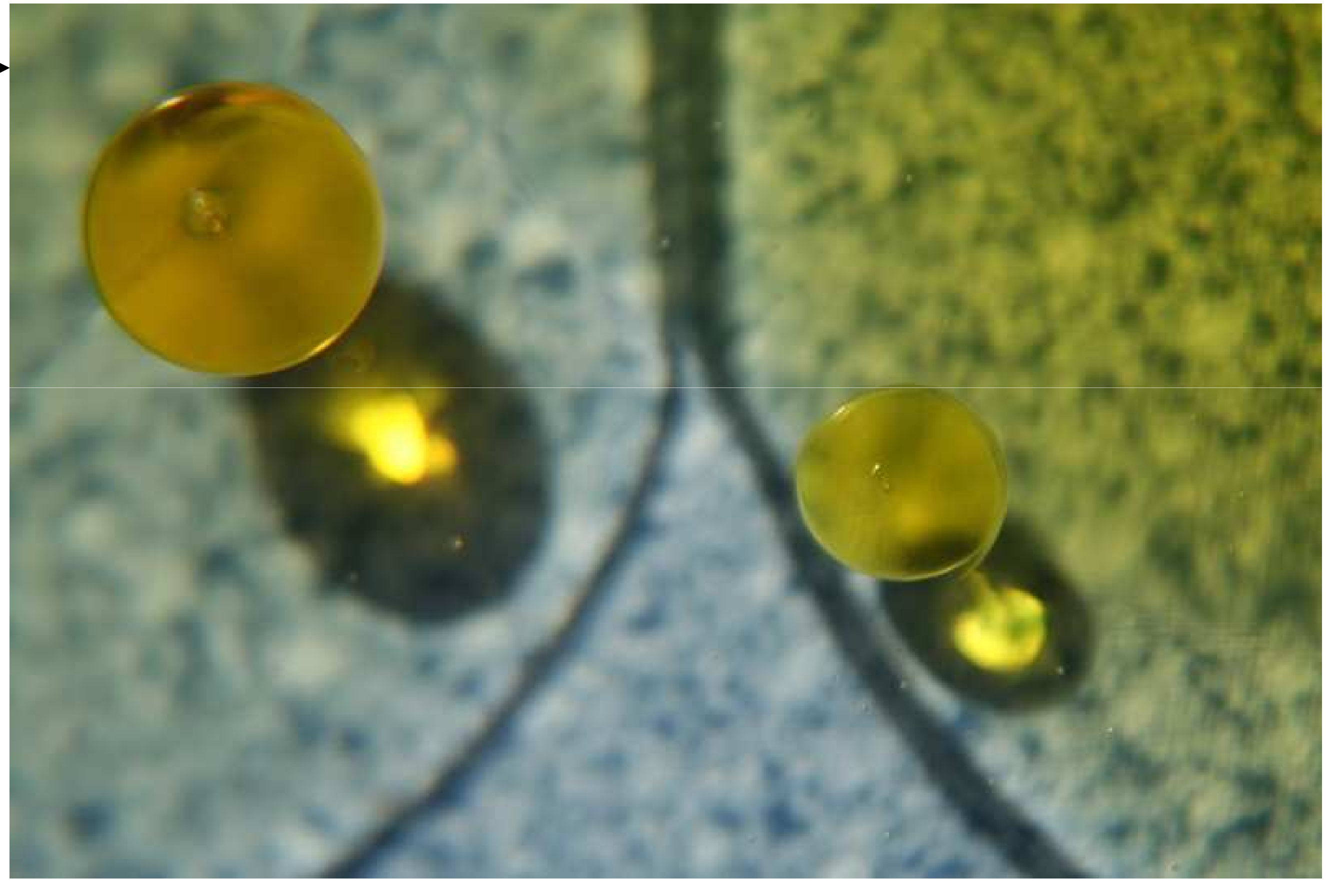
Common Name	Molecular Formula	Lewis Formula	Kekulé Formula
Methane	CH_4		
Ammonia	NH_3		
Ethane	C_2H_6		
Methyl Alcohol	CH_4O		
Ethylene	C_2H_4		
Formaldehyde	CH_2O		
Acetylene	C_2H_2		
Hydrogen Cyanide	CHN		

Hydrophobic interactions between hydrophobic amino acids in a protein molecule



What happens when you put oil drop in water? Does it dissolve?

No →



WHY?

Why do non-polar molecules mixed with water don't dissolve (e.g. oil slick on water)?

- Water is held together by hydrogen bonds.
- If nonpolar molecule is inserted into water, it would have to break the ordered lattice of water molecules held together by H bonds.
- But this would require energy, so it can't happen spontaneously.
- Instead, nonpolar molecules (or parts of molecules) will aggregate to avoid water. A similar situation occurs in parts of many proteins.