

II. Properties of Water

1. Ice and Liquid water structure
2. Cohesion / Surface Tension
3. High Heat Capacity
4. Solvent Properties
5. Dissociation: Acids & Bases / pH

II. Organic Chemistry

A. Hydrocarbons--nonpolar

1. alkanes-only single bonds
2. alkenes- C=C double bonds
3. aromatic-cyclic based on benzene

B. Functional Groups: *alcohol, aldehyde, ketone, carboxyl, amine, organophosphate, sulfhydryl*

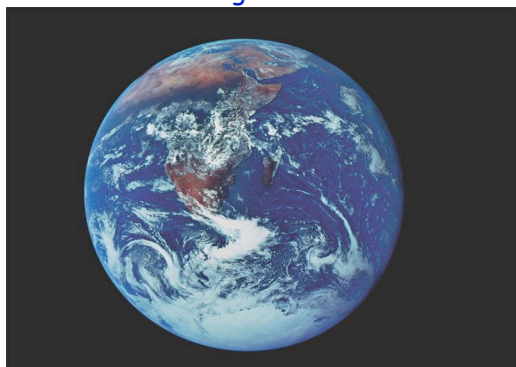
1. polar bonds between C and more electronegative atoms (O and N)
2. Combine two functional groups ester = alcohol + acid
3. amide = amine + acid

C. Isomers

1. Same chemical formula but differ in arrangement of atoms in space
2. Enantiomers (Optical Isomers): C can be bonded to 4 different groups in 2 ways producing molecules that are mirror images of one another that cannot be superimposed

Water As A Solvent For Life

Fig. 3.1

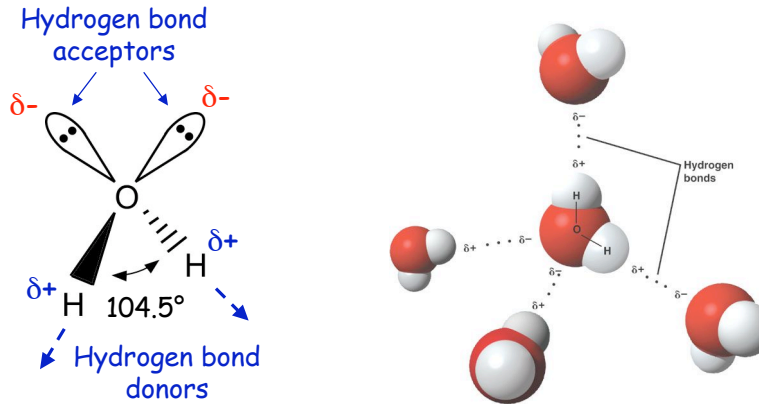


75% of the Earth's surface is covered with water

Water is essential for life on Earth

All living organisms require water more than any other substance

Fig. 3.2: Water: Structure and Properties



Water's **molecular structure** and **capacity to donate and accept hydrogen bonds** give it unusual **critical properties** that are significant for life

Fig. 3.5: Five Critical Properties of Water
1. Ice and liquid water structure

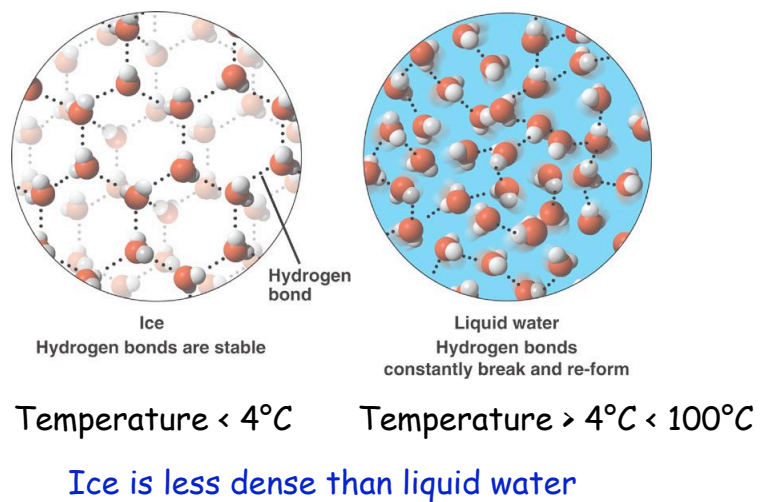
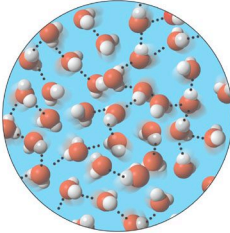


Fig. 3.3/3.4: Five Critical Properties of Water

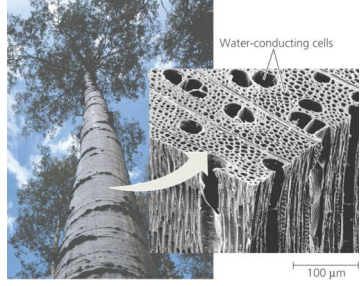
2. Cohesion



Liquid water
Hydrogen bonds
constantly break and re-form

Hydrogen bonds hold water molecules together in liquid

Water transport in plants



Water-conducting cells

100 μm

High surface tension

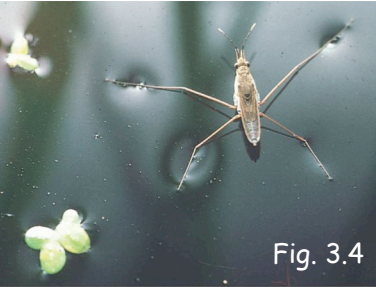
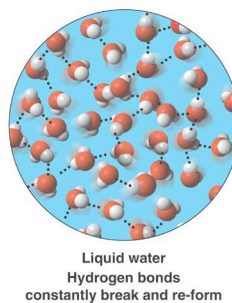
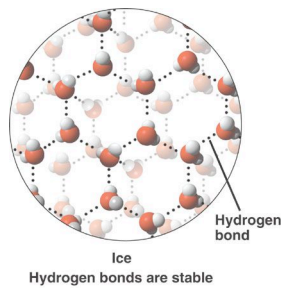


Fig. 3.4

The diagram illustrates the cohesion of water molecules in liquid form. It shows a cluster of water molecules (red and white spheres) with dashed lines representing hydrogen bonds between them. Text explains that these bonds constantly break and re-form, yet they collectively hold the molecules together. This property is linked to 'Water transport in plants', shown as a photograph of a tree trunk with a cross-section revealing 'Water-conducting cells'. A scale bar indicates 100 micrometers. Another property, 'High surface tension', is illustrated by a photograph of a water bug resting on the surface of a pond, which is supported by the cohesive forces of the water molecules.

Five Critical Properties of Water

3. Moderation of temperature



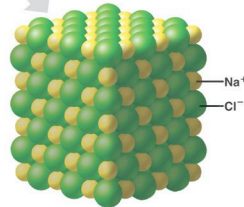
Heat energy can be absorbed by breaking hydrogen bonds

Water has a **high specific heat capacity**
specific heat capacity = amount of energy required to raise temperature of 1 g of water by 1°C (1 calorie, 1 cal)

Fig. 2.14/3.6: Five Critical Properties of Water
4. Water as a solvent



Fig. 2.14



A sphere of water molecules, called a hydration shell, surrounds each solute ion

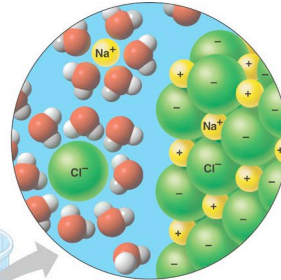


Fig. 3.6

Ionic substances tend to readily dissolve in water: **Hydrophilic**

Fig. 3.7: Five Critical Properties of Water
4. Water as a solvent (Cont'd)

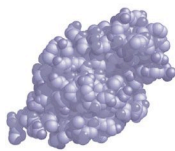
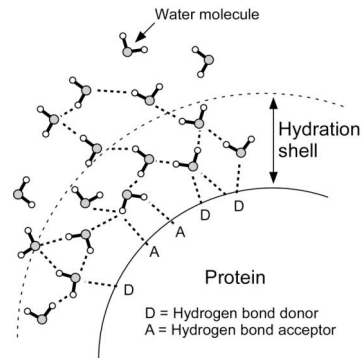
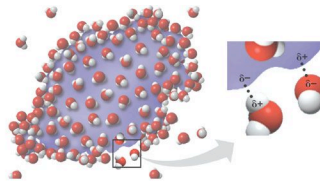


Fig. 3.7



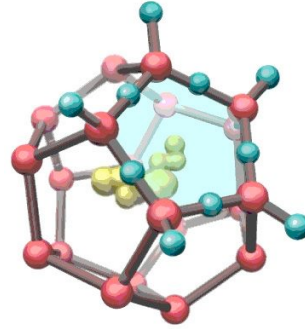
Molecules that contain **polar groups** that can hydrogen bond with water are also soluble in water ==> they are **Hydrophilic**

Review solute concentration in aqueous solutions (Molarity)
 (page 52-53 of text)

Five Critical Properties of Water

4. Water as a solvent (Cont'd)

Molecules that are **non-polar** (e.g. hydrocarbons such as oils) tend not to be soluble, or only slightly soluble in water: they are **Hydrophobic**

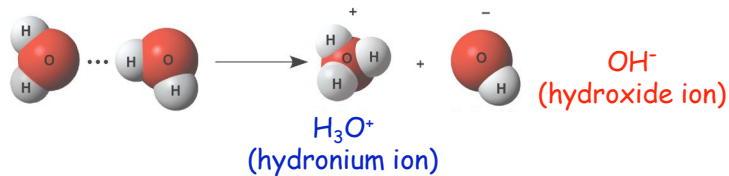


There are also **amphipathic** molecules that contain both hydrophilic parts and hydrophobic parts (e.g. lipids, proteins that we'll see later)

Five Critical Properties of Water

5. Dissociation of Water Molecules: Acids, Bases & pH

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This reaction is frequently abbreviated as:



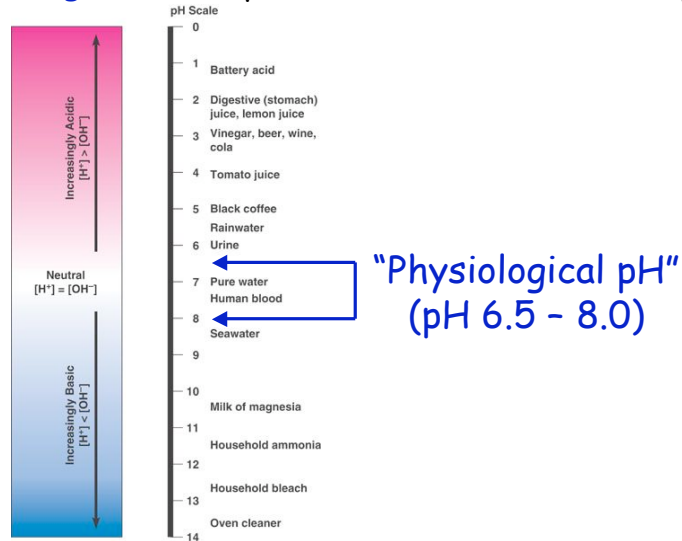
The **ion product** of water,

$$K_w = [\text{H}^+][\text{OH}^-] = 1.0 \times 10^{-14} \text{ M}^2 \text{ at } 25^\circ\text{C}$$

Thus, in pure water, $[\text{H}^+] = [\text{OH}^-] = 1.0 \times 10^{-7} \text{ M}$

Fig. 3.8: pH SCALE - $1.0 \times 10^{-7} \text{ M}$ is a very small number and can change by orders of magnitude (powers of 10x) ==> **pH**

$\text{pH} = -\log[\text{H}^+] = 7$ in pure water at 25°C = neutral pH



Acids and Bases

Acid: Increases the $[\text{H}^+]$ of a solution (**decreases the pH**)

Strong Acids dissociate completely to produce H^+



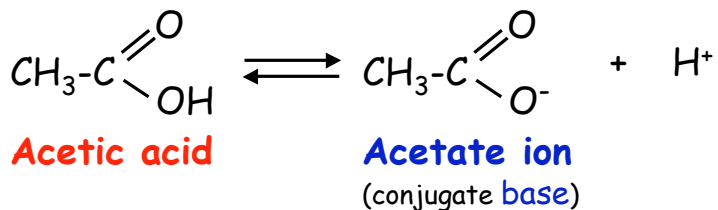
Base: Decreases the $[\text{H}^+]$ of a solution (**increases the pH**)

Strong Bases dissociate completely to produce OH^- this reduces the $[\text{H}^+]$ because $[\text{H}^+][\text{OH}^-] = 1 \times 10^{-14} \text{ M}^2$

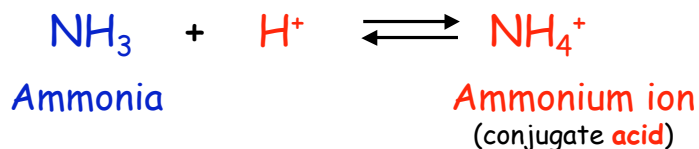


Weak **Acids** and weak **Bases**

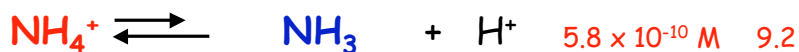
Weak acids partially dissociate to produce H^+
(they are **proton donors**):



Weak bases bind H^+ from H_2O
(they are **proton acceptors**):



Acid Dissociation Constant & pK_a



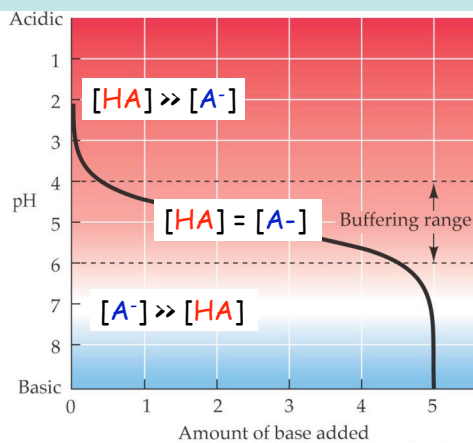
Acid ionization constant, $K_a = \frac{[H^+][A^-]}{[HA]}$ $pK_a = -\log K_a$

pK_a is a measure of propensity to dissociate:

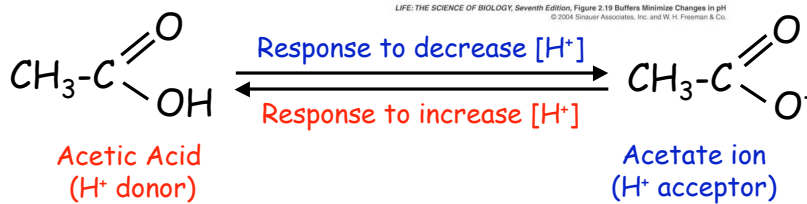
if $pH < pK_a$ the **HA** form predominates

if $pH > pK_a$ the **A⁻** form predominates

Buffers are solutions of weak Acid/Base pairs



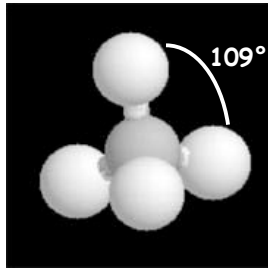
Buffers keep pH relatively constant in the range around pKa value by accepting or donating H^+ from solution



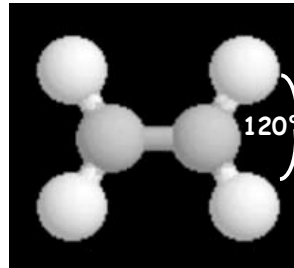
Organic Chemistry

The chemistry of molecules containing carbon bonded to other elements, principally: H, O, N, P, S ...

Hydrocarbons are **Nonpolar** (electrons are equally distributed) and do not mix freely with water
 ==> they are **Hydrophobic**.



Alkanes have only σ bonds
 methane: CH_4
 ethane: CH_3CH_3
 propane: $\text{CH}_3\text{CH}_2\text{CH}_3$
 butane: $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$



Alkenes have only σ bonds and π -bonds
 ethene: $\text{CH}_2=\text{CH}_2$

Hydrocarbons -- organic compounds containing only **carbon** and **hydrogen**. These are the most **reduced** organic compounds and react vigorously (*i.e.* burn) with **oxygen**.

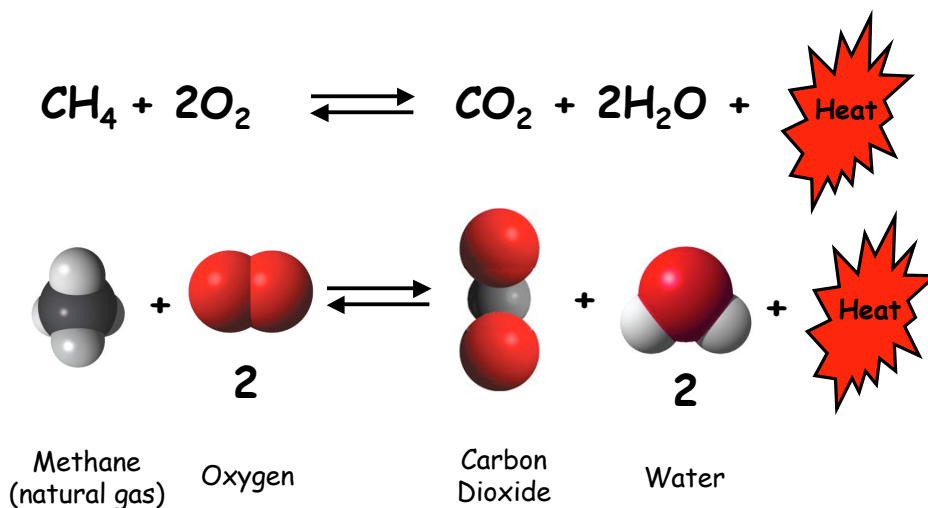
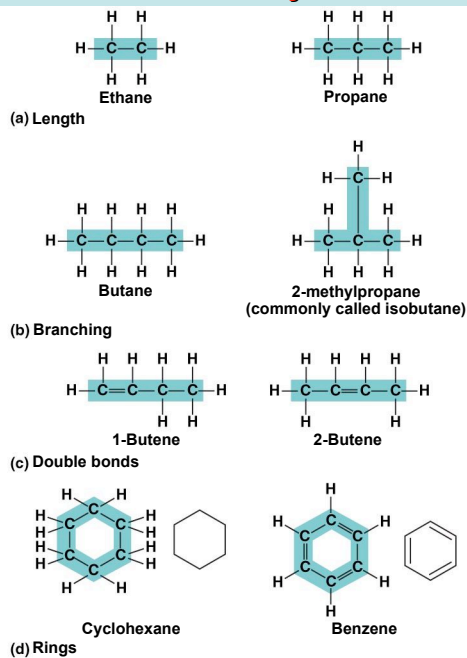


Fig. 4.5: Various Hydrocarbons



Aromatic Hydrocarbons -- are a special class of hydrocarbons in which atoms are arranged in a ring structure and are connected by σ -bonds and a system of π -bonds around the ring. The simplest example is **benzene**, C_6H_6 , and as shown below all atoms lie on a plane with bond angles of 120°

e.g. **Benzene**

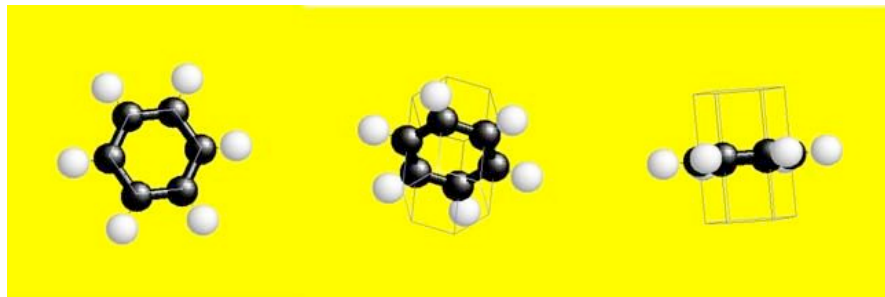
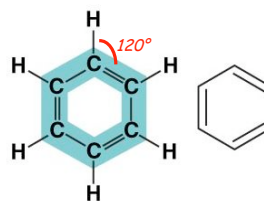
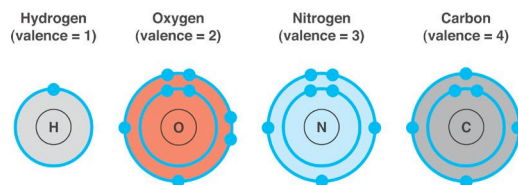


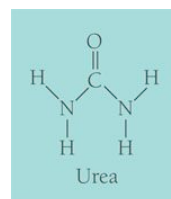
Fig. 4.5: Carbon also forms bonds with a variety of other Elements



Carbon dioxide
(CO₂)



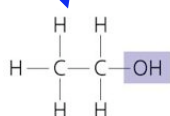
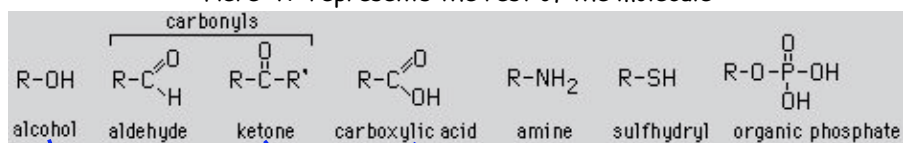
Urea
CO(NH₂)



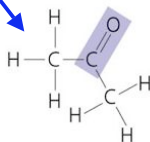
We will see more examples in other **functional groups**

Functional Groups

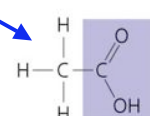
Here "R" represents the rest of the molecule



Ethanol



Acetone

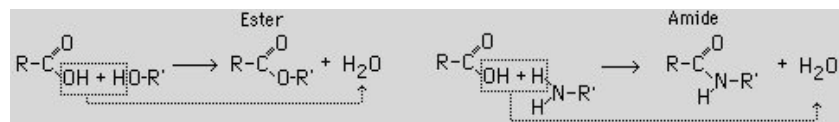


Acetic Acid

Organic compounds can contain atoms other than C and H; these form **"Functional Groups"** characterized by the types of atoms present and the way they are bonded giving these groups **special properties**.

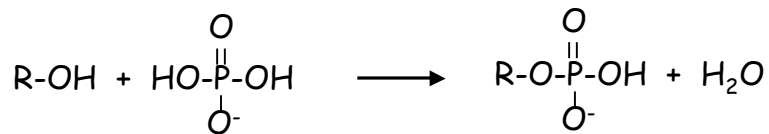
Linking Functional Groups → Polymers

Organic molecules with certain functional groups can be joined by a covalent bond formed when a molecule of water is removed; this allows the creation of new types of organic molecules.



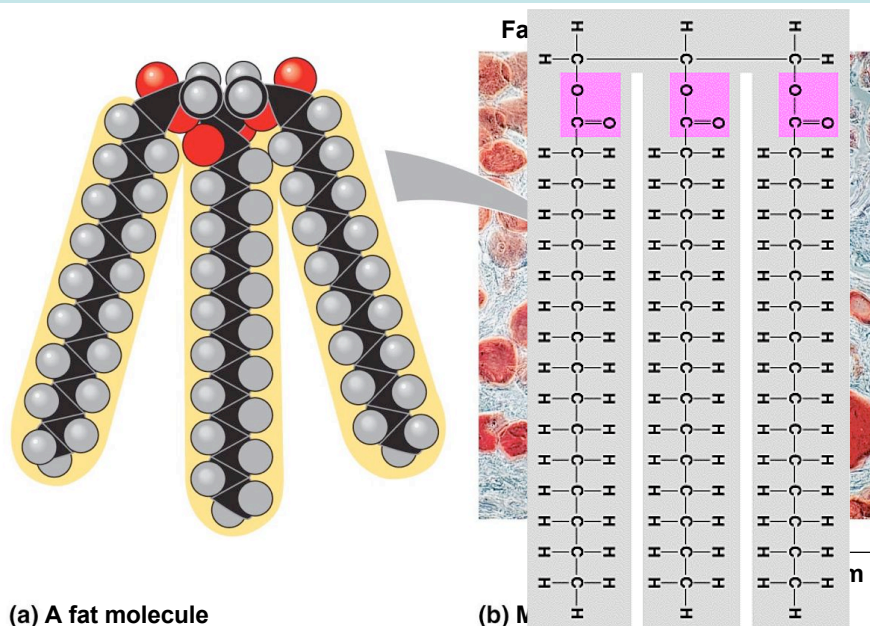
An **ester** is formed by combining an **alcohol** and a **carboxylic acid**.

An **amide** is formed by combining an **amine** and a **carboxylic acid**.



A **phosphoester** is formed from an alcohol and phosphoric acid

Fig. 4.6: Ester bonds link fatty acid carboxyl groups to OH-groups of Glycerol



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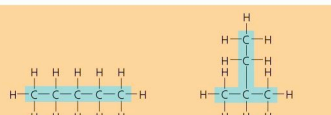
Isomers: Molecules that have the same chemical formula, *i.e.* the same number of each of the different kinds of atoms.

There are several different classes of Isomers depending upon how their structures are related to one another.

- **Structural**
- **Geometric**
- **Optical**

Fig. 4.7: There are different classes of Isomers

Structural Isomers



(a) Structural isomers differ in covalent partners, as shown in this example of two isomers of pentane.

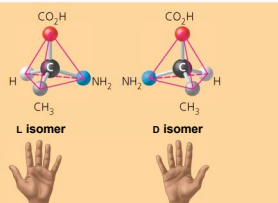
Geometric Isomers



cis isomer: The two Xs are on the same side. *trans* isomer: The two Xs are on opposite sides.

(b) Geometric isomers differ in arrangement about a double bond. In these diagrams, X represents an atom or group of atoms attached to a double-bonded carbon.

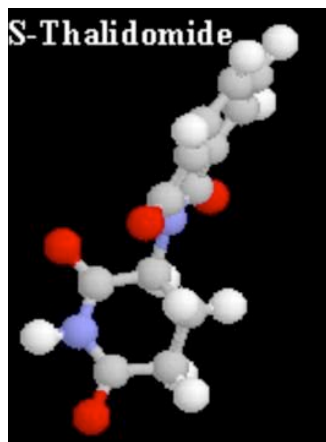
Optical Isomers
a.k.a. Enantiomers
which are said to be **Chiral**



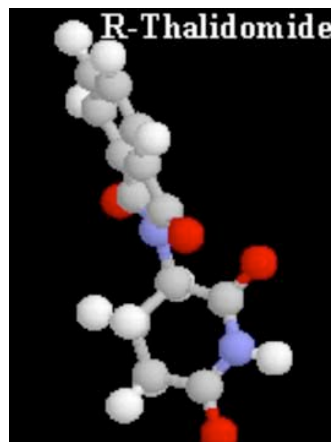
(c) Enantiomers differ in spatial arrangement around an asymmetric carbon, resulting in molecules that are mirror images, like left and right hands. The two isomers are designated the L and D isomers from the Latin for left and right (*levo* and *dextro*). Enantiomers cannot be superimposed on each other.

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Thalidomide was first used as a sedative and anti-nausea medication, but was found to cause serious birth defects when pregnant women take it during their first trimester.



S-Thalidomide was later found to be the form that causes birth defects.



R-Thalidomide does not cause birth defects and has therapeutic uses as a sedative and in treating Hansen's disease (Leprosy) and multiple myeloma.