Water And The Fitness Of The Environment.

Chapter 3

Objectives
Chapter 3 & 4

- Be familiar with the five properties of water
- Understand the relationship of kinetic energy and heat
- Understand the concept of pH and be able to calculate the pH of a solution
- Be able to explain the importance of Carbon
- Understand what an isomer is and be able to apply your understanding
- Be familiar with the various functional groups

Properties of Water That Emerge As a Result of Being a Polar Molecule

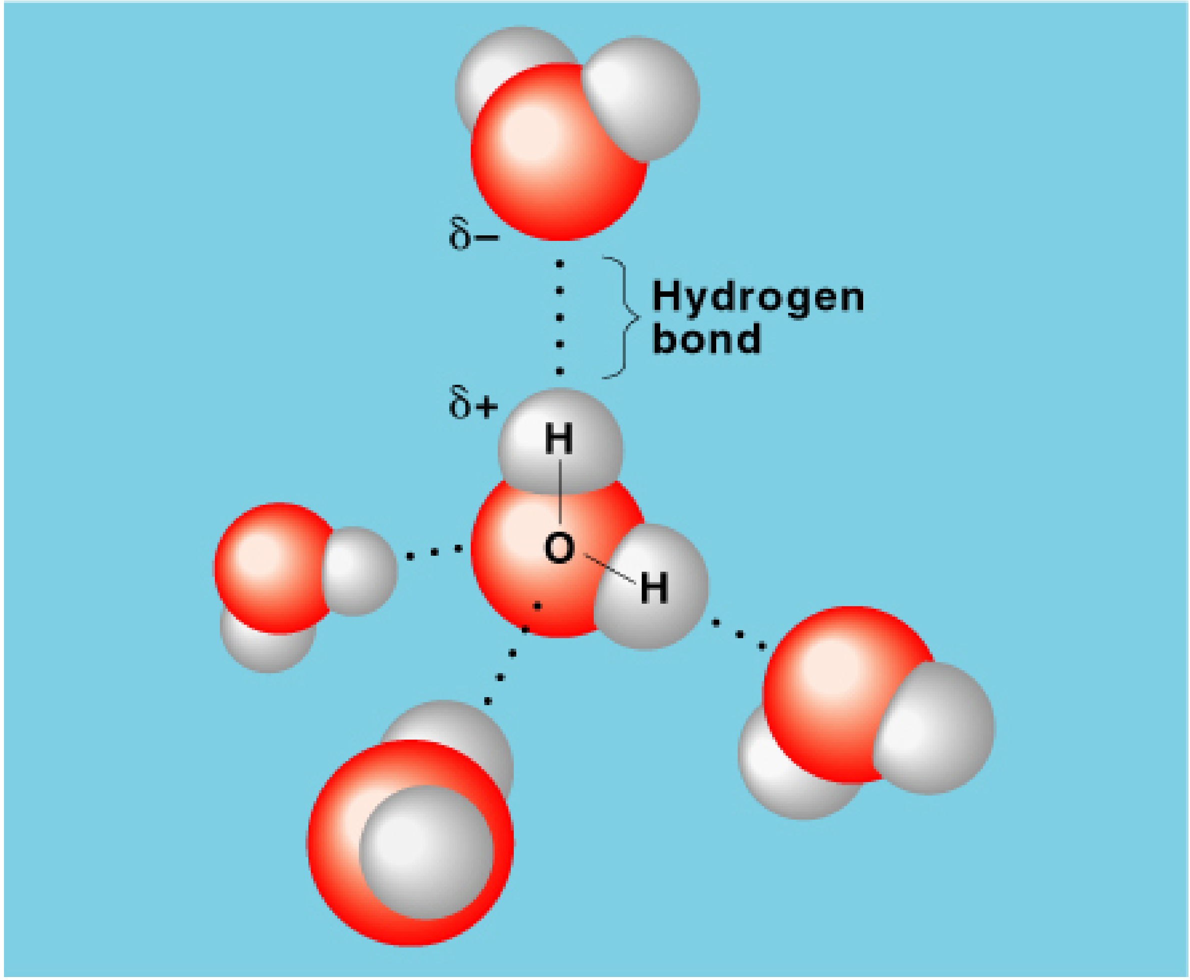
1) The polarity of water molecules enables Hydrogen bonding
2) Organisms depend on the cohesion of water molecules
3) Water moderates temperatures on Earth
4) Oceans and lakes don’t freeze solid because ice floats
5) Water is the solvent of life

The Polarity Of Water Molecules Results In Hydrogen Bonding

- Water is a polar molecule. Its polar bonds and asymmetrical "V" shape give water <u>molecules</u> partial units of opposite charge on opposite sides of the molecule.
- Hydrogen bonding orders water into a higher level of structural organization.
- Water has extraordinary properties that emerge as a consequence of its polarity and ability to form up to 4 Hydrogen bonds.

So what is a Hydrogen Bond?

- Remember we said that Hydrogen Bonds are caused by the slightly positive region of one polar molecule being weakly attracted to the slightly negative region of another polar molecule.
- Molecular distance and molecular energy (speed) determine the maximum length and duration of the attractions


δ−
Hydrogen bond
δ+
H
O
H

ORGANISMS DEPEND ON THE COHESION OF WATER MOLECULES.

- **Cohesion**: Phenomenon of a substance being held together by Hydrogen bonds.
  - **Adhesion**: Clinging of one substance to another substance
    - examples: water transport, capillary action
- **Surface tension**: Measure of how difficult it is to stretch or break the surface of a liquid.
    - Examples: water strider, overfill

WATER MODERATES TEMPERATURES ON EARTH.

- **Kinetic energy**: energy of motion; all atoms exhibit kinetic energy
- **Heat**: a measure of all kinetic energy in a system
- **Temperature**: measure of the average kinetic energy of molecules (^{0}C)

Units of Heat

- Calorie (cal): amount of heat energy needed to raise 1 g of water by 1 ^{0}C
- Kilocalorie (kcal): amount of heat energy needed to raise 1 kg of water by 1 ^{0}C
  - food measurements as Calories
- **Joule** (J): smaller than calorie.
  - 1J = 0.239 cal or 1 cal = 4.184 J
- **Specific heat**: Resistance to temperature change when absorbing or losing heat

Water Has High Specific Heat

- The specific heat of water is higher than most molecules
  - So what!
    - Enables living organisms to better resist changes in their body temperature
- **Heat of vaporization**: amount of heat that must be absorbed for 1 g of a substance to be converted from liquid to gaseous state
- **Evaporative cooling**: as liquid evaporates, the surface of the liquid that remains behind cools down
  - Sweat

In liquid water, no lattice forms, so liquid water is denser than ice.

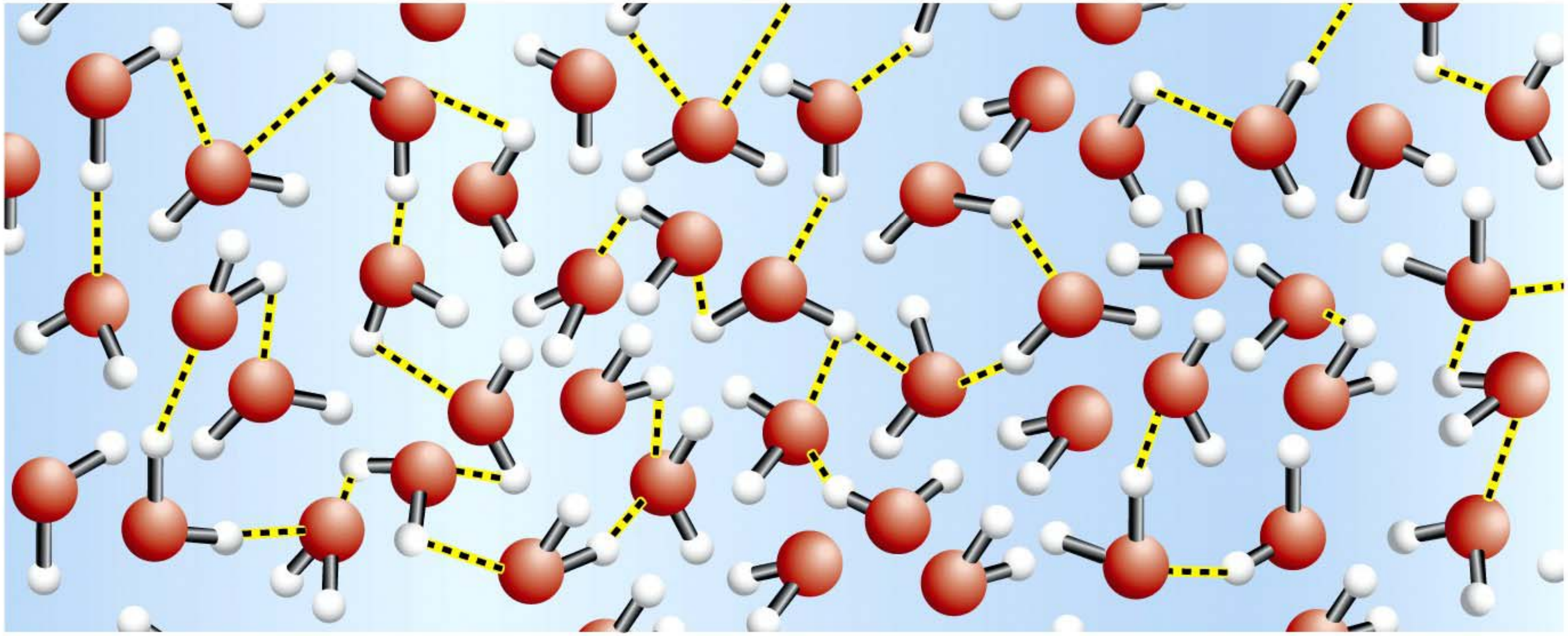


Figure 2-27b Biological Science, 2/e

Oceans And Lakes Don't Freeze Solid Because Ice Floats

- Because of Hydrogen bonding, water is less dense as a solid than it is as a liquid. Consequently, ice floats.
- So!
  - Expansion of water contributes to the fitness of the environment for life.
    - If ice sank then the remaining liquid would freeze until the whole thing was solid
    - Only a small amount would thaw when warmed

In ice, water molecules form a crystal lattice.

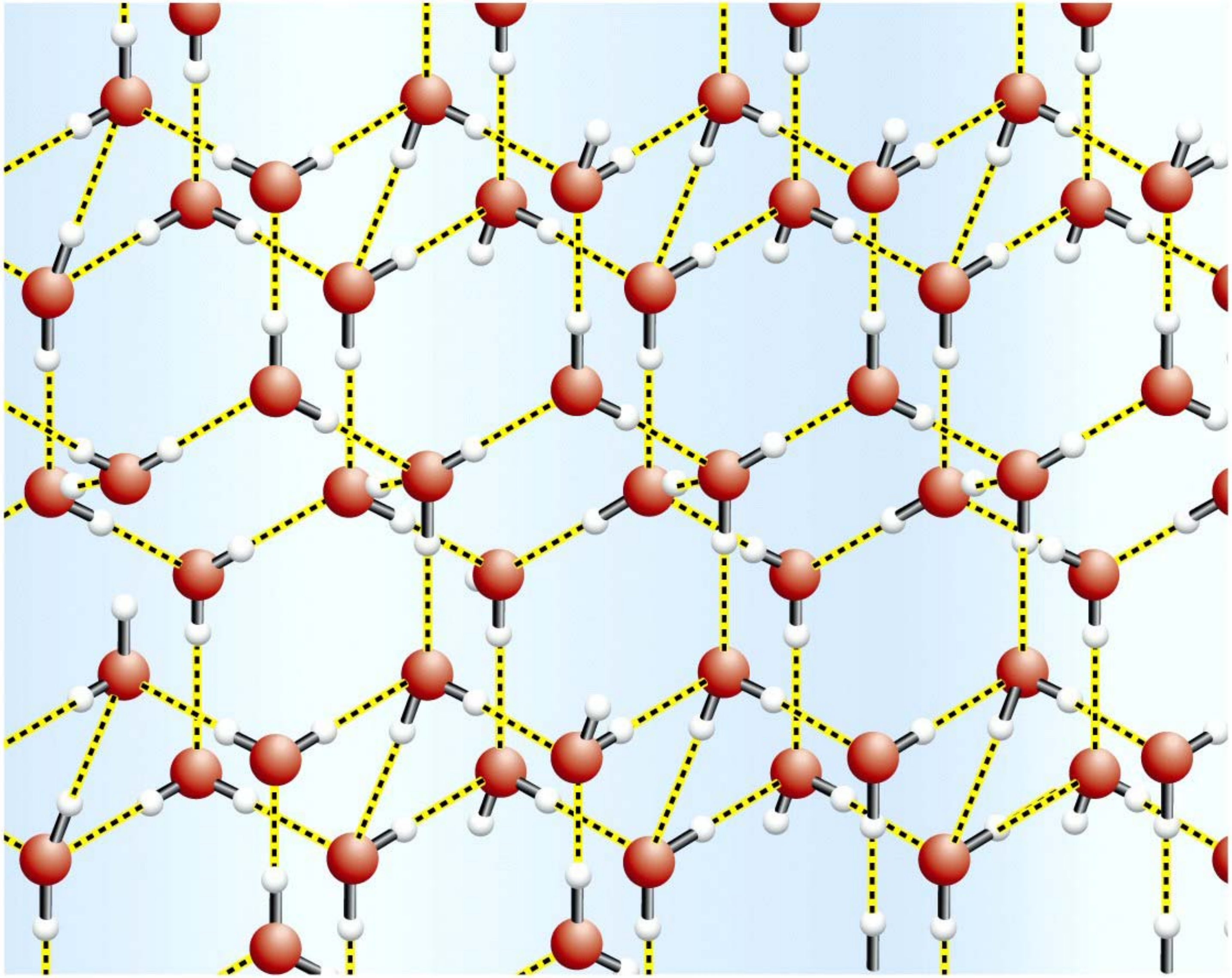


Figure 2-27a Biological Science, 2/e

Water Is The Solvent Of Life

- **Solution**: a homogenous mixture of two or more substances
  - **Solvent**: substance that dissolves another
  - **Solute**: substance that is dissolved
  - **Aqueous solution**: where water is the solvent
- Hydrophilic and hydrophobic substances
  - **Hydrophilic** (water loving): polar or ionic substances
  - **Hydrophobic** (water fearing): non-polar or non-ionic substances
- Solute concentration in aqueous solutions expressed as molarity (M)

Acid Base Reactions and pH: The Dissociation Of Water

$H_2O \Leftrightarrow H^+$ and OH^-

1M $[H_2O] \Leftrightarrow 10^{-7}$ M $[H^+]$ 10^{-7} M $[OH^-]$

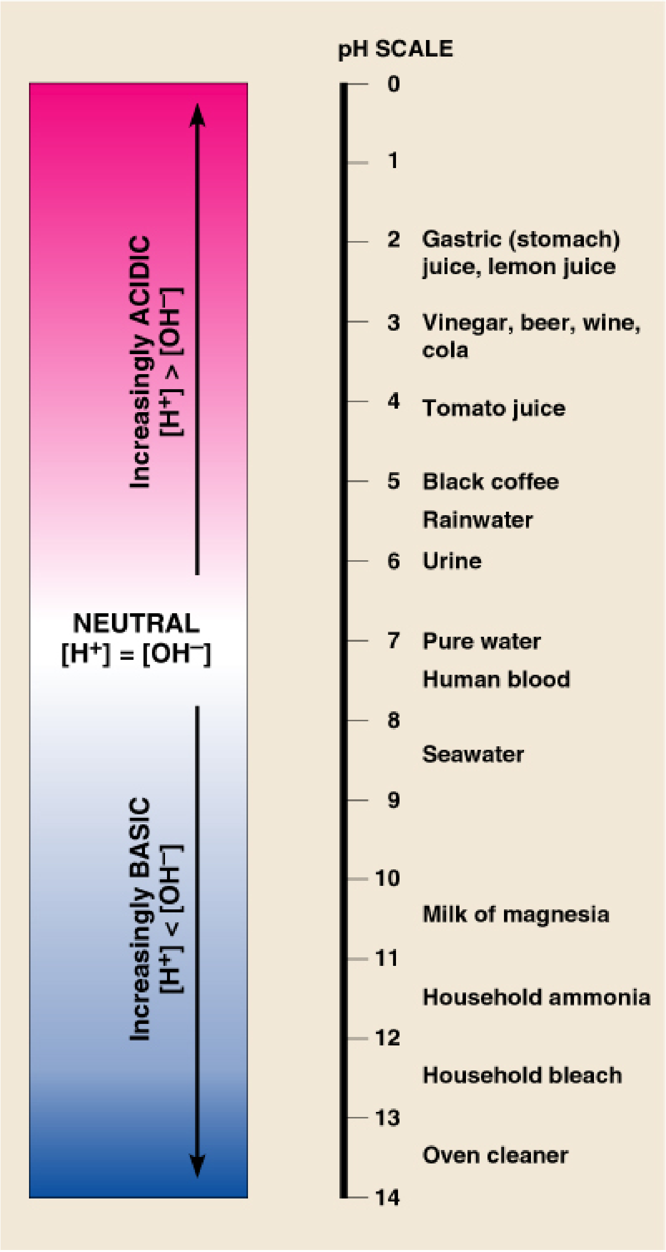
- **Acid**: a substance that results in an increase in $[H^+]$, generally adds H^+
- **Base**: a substance that results in an increase in $[OH^-]$, may directly or indirectly modify $[OH^-]$

M = molarity. Molarity is equal to 1 mole of substance (equal to 6.023×10^{23} molecules) dissolved into a liter of water.

pH

pH = -log $[H^+]$

- pH scale ranges from 0 to 14 (fig 3.9)
    - acidic range is <7
    - alkaline (basic) range is >7
    - neutral is =7
- **Buffer**: any substance that minimizes pH change by adding or removing H^+
- Acid precipitation threatens the fitness of the environment

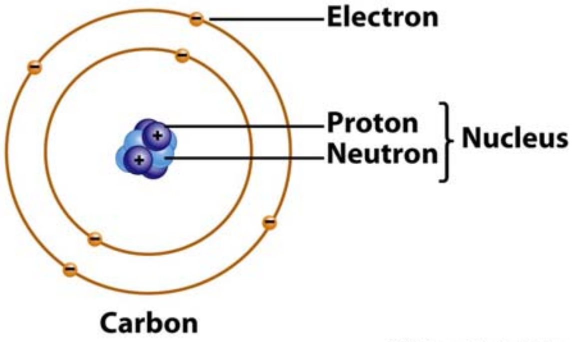

pH SCALE
0
1
2 Gastric (stomach) juice, lemon juice
3 Vinegar, beer, wine, cola
4 Tomato juice
5 Black coffee
Rainwater
6 Urine
7 Pure water
Human blood
8
Seawater
9
10
Milk of magnesia
11
Household ammonia
12
Household bleach
13
Oven cleaner
14
Increasingly ACIDIC
[H+] > [OH−]
NEUTRAL
[H+] = [OH−]
Increasingly BASIC
[H+] < [OH−]

Carbon and the Molecular Diversity of Life

Chapter 4

- Organic Chemistry is the study of Carbon compounds

What about Carbon?

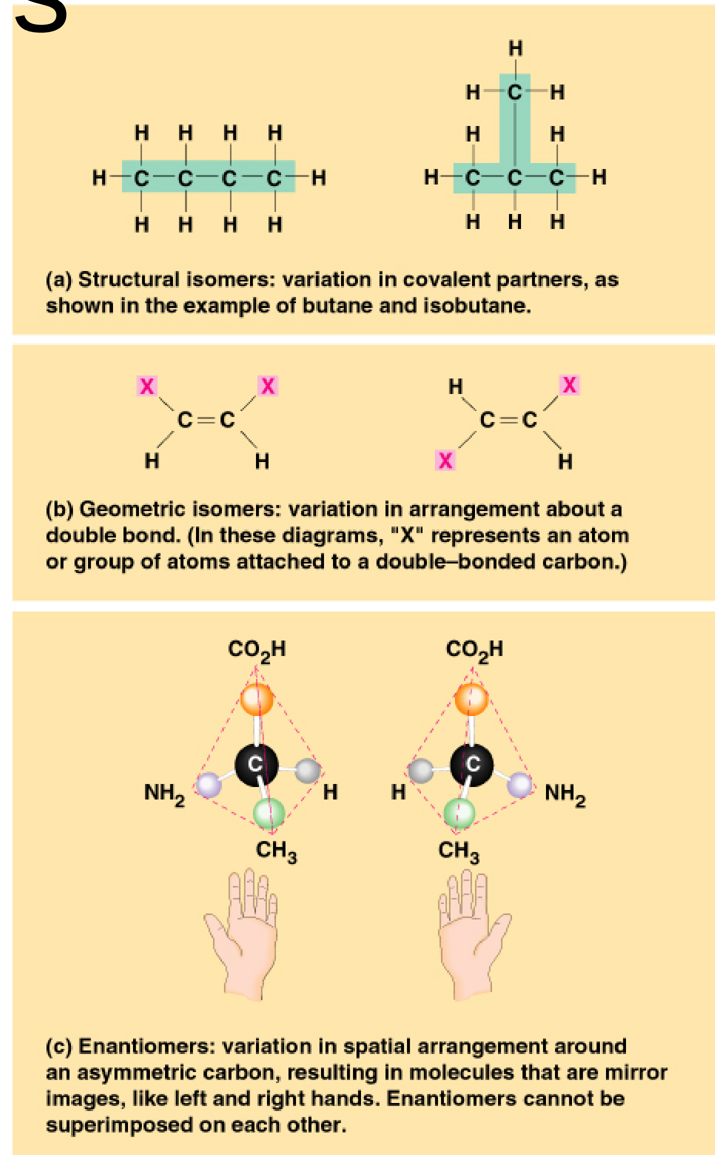


- Almost all molecules associated with life contain Carbon
- The structure of a Carbon atom allows it to form up to four atomic bonds
- The electronegativity of Carbon is such that carbon can form either polar or nonpolar atomic bonds

- Reduced forms of Carbon-based molecules are believed to have utilized energy to structurally undergo change to form the four types of organic molecules that living things make: proteins, nucleic acids, carbohydrates and lipids

Isomers

- **Isomers**: variation in the structure of organic molecules with the same molecular formula
  - **Structural isomers**: differ in the covalent arrangement of their atoms.
  - **Geometric isomers**: differ in their spatial arrangement around a C=C bond.
  - **Enantiomers**: structures that are mirror images of each other. Are built around an asymmetric (chiral) carbon atom.



(a) Structural isomers: variation in covalent partners, as shown in the example of butane and isobutane.

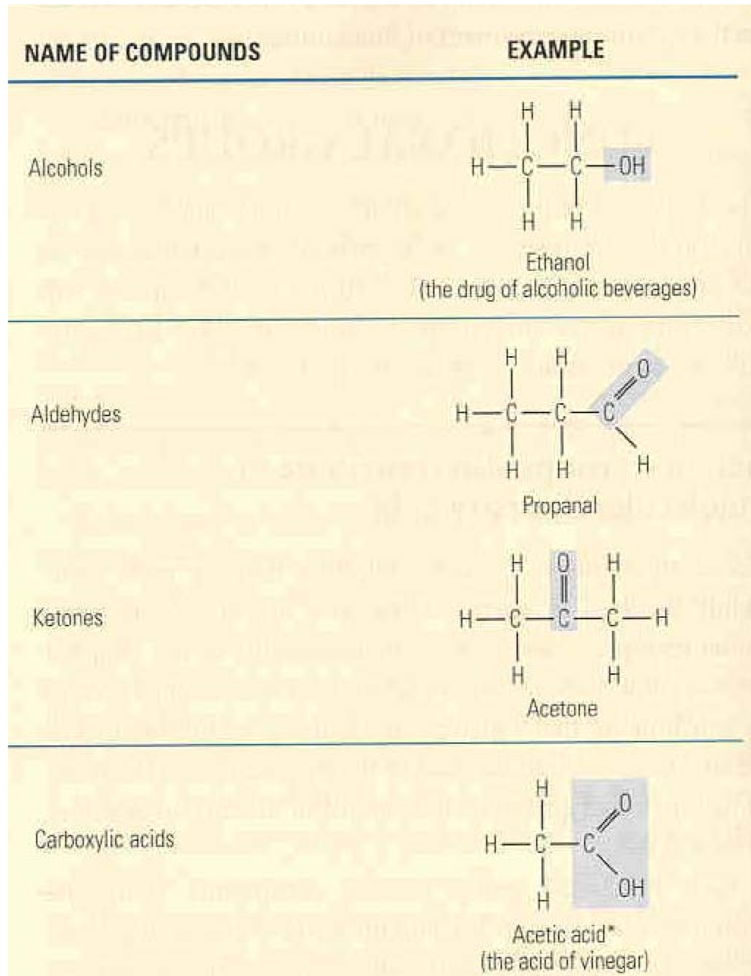
(b) Geometric isomers: variation in arrangement about a double bond. (In these diagrams, "X" represents an atom or group of atoms attached to a double–bonded carbon.)

(c) Enantiomers: variation in spatial arrangement around an asymmetric carbon, resulting in molecules that are mirror images, like left and right hands. Enantiomers cannot be superimposed on each other.

Functional Groups

Groups of Atoms Frequently Attached to the Skeletons of Organic Molecules

- Hydroxyl group -OH
  - Polar
  - Alcohols
- Carbonyl C=O
  - aldehyde: at end of carbon chain
  - ketone: nested inside carbon chain
- Carboxyl -COOH
  - form H+



Functional Groups

- Amino group $-NH_2$
  - Amines
  - Act as base
- Sulfhydryl -SH
  - Important for protein stabilization
  - Thiols
- Phosphate $-PO_4^{2-}$
  - Usually very reactive
  - ATP