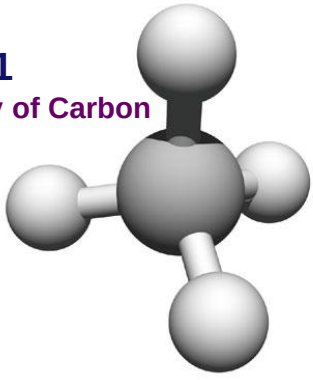
Chapter 3.1
The Chemistry of Carbon

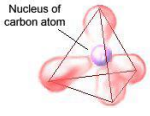


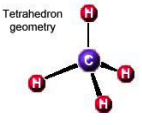
Why study Carbon?

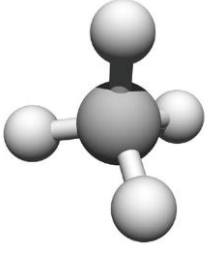
- All living things are made of cells
- Cells
  - ~72% H_2O
  - ~3% salts (Na, Cl, K…)
  - ~25% carbon compounds
    - carbohydrates
    - lipids
    - proteins
    - nucleic acids

Chemistry of Life

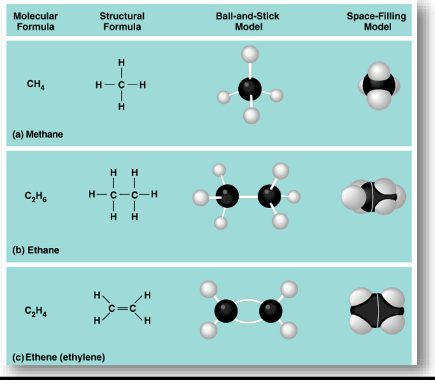
- Organic chemistry is the study of carbon compounds
- C atoms are versatile building blocks
  - bonding properties
  - 4 stable covalent bonds





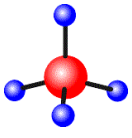


Complex molecules assembled like TinkerToys



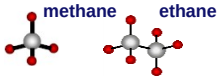
Hydrocarbons

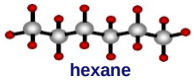
- Simplest C molecules = hydrocarbons
  - combinations of C & H
- Simplest HC molecule = methane
  - 1 carbon bound to 4 H atoms
  - non-polar
  - not soluble in H_2O
  - hydrophobic
  - stable
  - very little attraction between molecules
  - a gas at room temperature

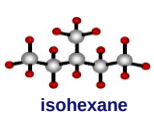


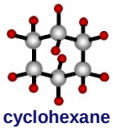
Hydrocarbons can grow…

- adding C-C bonds
  - straight line
    - ethane
    - hexane
  - branching
    - isohexane
  - ring
    - cyclohexane

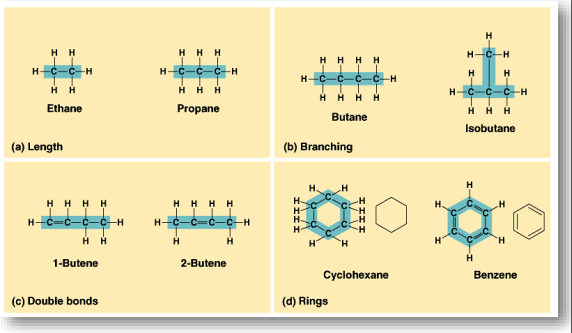






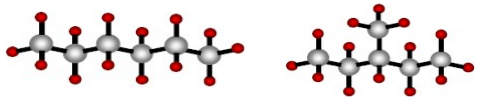


Diversity of Organic Molecules



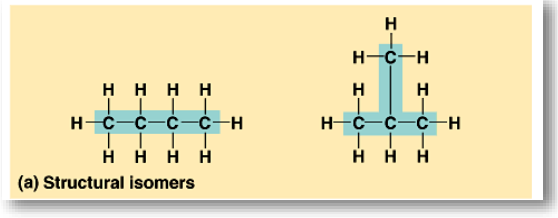
Isomers

- Molecules with same molecular formula but different structures
  - different chemical properties



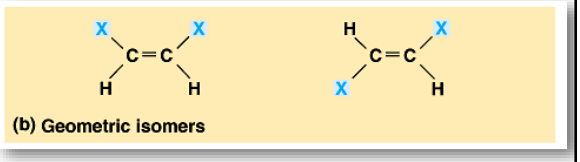
Structural Isomers

- Molecules differ in structural arrangement of atoms



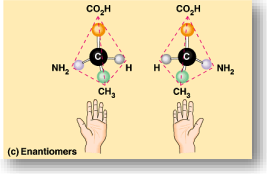
Geometric Isomers

- Molecules differ in arrangement around C=C double bond
  - same covalent partnerships



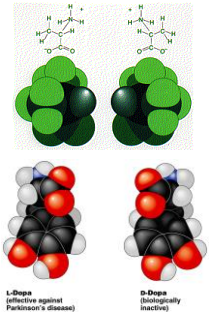
Enantiomer (stereo) Isomers

- Molecules which are mirror images of each other
  - C bonded to 4 different atoms or groups
    - assymetric
  - left-handed & right-handed versions
    - "L" versions are biologically active



Form Affects Function!

- Structural differences create important functional significance
  - amino acid alanine
    - L-alanine used in proteins
    - but not D-alanine
  - medicines
    - L-version active
    - but not D-version
  - sometimes with tragic results…



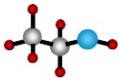
Form Affects Function!

- Thalidomide
  - prescribed to pregnant women in 50's & 60's
  - reduced morning sickness, but…
  - stereoisomer caused severe birth defects

Diversity of Molecules

- Substitute other atoms or groups around the C
  - ethane vs. ethanol
    - H replaced by an hydroxyl group (–OH)
    - nonpolar vs. polar
    - gas vs. liquid
    - biological effects!


ethane

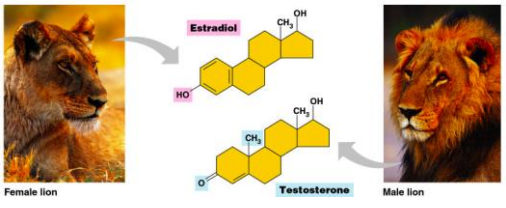

ethanol

Functional Groups

- Components of organic molecules that are involved in chemical reactions
  - give organic molecules distinctive properties
  - ex: male & female hormones…

Viva la difference!

- Basic structure of male & female hormones is identical
  - identical C skeleton
  - attachment of different functional groups
  - interact with different targets in the body



Types of functional groups

- 6 functional groups most important to chemistry of life:
  - hydroxyl
  - carbonyl
  - carboxyl
  - amino
  - sulfhydryl
  - phosphate
- Affect reactivity
  - hydrophilic
  - increase solubility in water

Hydroxyl

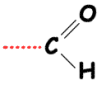
···· OH

- –OH
  - organic compounds with OH = alcohols
  - names typically end in *-ol*
    - ethanol

Table 4.1 Functional Groups of Organic Compounds

Functional Group	Formula	Name of Compounds	Example
Hydroxyl	—OH	Alcohols	H H H—C—C—OH H H Ethanol (the drug of alcoholic beverages)

Carbonyl

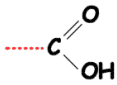


- C=O
  - O double bonded to C
    - if C=O at end molecule = aldelhyde
    - if C=O in middle of molecule = ketone

Table 4.1 Functional Groups of Organic Compounds

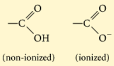
Functional Group	Formula	Name of Compounds	Example
Carbonyl		Aldehydes	 Propanal
		Ketones	 Acetone

Carboxyl

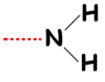


- –COOH
  - C double bonded to O & single bonded to OH group
    - compounds with COOH = acids
      - fatty acids
      - amino acids

Table 4.1 Functional Groups of Organic Compounds

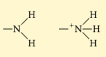
Functional Group	Formula	Name of Compounds	Example
Carboxyl	 (non-ionized) (ionized)	Carboxylic acids	 Acetic acid* (the acid of vinegar)

Amino



- $-NH_2$
  - N attached to 2 H
    - compounds with NH_2 = amines
      - amnio acids
    - NH_2 acts as base
      - ammonia picks up H^+ from solution

Table 4.1 Functional Groups of Organic Compounds

Functional Group	Formula	Name of Compounds	Example
Amino	 (non-ionized) (ionized)	Amines	 Glycine*

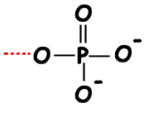
Sulfhydryl

- –SH
  - S bonded to H
    - compounds with SH = thiols
    - SH groups stabilize the structure of proteins

Table 4.1 Functional Groups of Organic Compounds

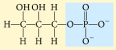
Functional Group	Formula	Name of Compounds	Example
Sulfhydryl	—SH	Thiols	 Ethanethiol

Phosphate



- $-PO_4$
  - P bound to 4 O
    - connects to C through an O
    - PO_4 are anions with 2 negative charges
    - one function of PO_4 is to transfer energy between organic molecules (ATP)

Table 4.1 Functional Groups of Organic Compounds

Functional Group	Formula	Name of Compounds	Example
Phosphate		Organic phosphates	 Glycerol phosphate

Why study Functional Groups?

- These help to make the building blocks for biological molecules

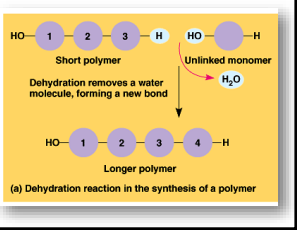
…and that comes next!

Macromolecules

- Smaller organic molecules join together to form larger molecules
  - macromolecules
- 4 major classes of macromolecules:
  - carbohydrates
  - lipids
  - proteins
  - nucleic acids

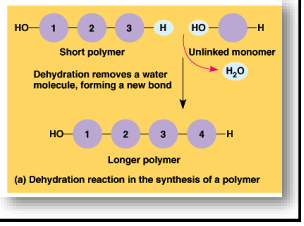
Polymers

- Long molecules built by linking chain of repeating smaller units
  - polymers
  - monomers = repeated small units
  - covalent bonds



How to build a polymer

- Condensation reaction
  - dehydration synthesis
  - joins monomers by "taking" H_2O out
    - 1 monomer provides OH
    - the other monomer provides H
    - together these form H_2O
  - requires energy & enzymes



How to break down a polymer

- Hydrolysis
  - use H_2O to break apart monomers
    - reverse of condensation reaction
    - H_2O is split into H and OH
    - H & OH group attach where the covalent bond used to be
  - ex: digestion is hydrolysis