Chapter 3.1
The Chemistry of Carbon

Why study Carbon?
- All living things are made of cells
- Cells
  - ~72% H₂O
  - ~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 H₂O
  - 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
    - asymmetric
    - 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
  - a sedative; 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!

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
  - amino
  - carbonyl
  - sulphydryl
  - carboxyl
  - phosphate

Affect reactivity
- hydrophilic
- increase solubility in water

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

<table>
<thead>
<tr>
<th>Table 4.1 Functional Groups of Organic Compounds</th>
</tr>
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<td>Functional Group</td>
</tr>
<tr>
<td>------------------</td>
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<td>Hydroxyl</td>
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Carbonyl
- C=O
  - O double bonded to C
  - if C=O at end molecule = aldehyde
  - if C=O in middle of molecule = ketone

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<td></td>
<td>Ketone</td>
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Carboxyl
- –COOH
  - C double bonded to O & single bonded to OH group
  - compounds with COOH = acids
    - fatty acids
    - amino acids

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Amino
- –NH₂
  - N attached to 2 H
  - compounds with NH₂ = amines
    - amnio acids
  - NH₂ acts as base
    - ammonia picks up H⁺ from solution

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

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<td>Thiol</td>
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Phosphate
- –PO₄³⁻
  - P bound to 4 O
  - connects to C through an O
  - PO₄ are anions with 2 negative charges
  - one function of PO₄ is to transfer energy between organic molecules (ATP)

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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$_2$O out
    - 1 monomer provides OH
    - the other monomer provides H
    - together these form H$_2$O
  - requires energy & enzymes

How to break down a polymer
- Hydrolysis
  - use H$_2$O to break apart monomers
    - reverse of condensation reaction
    - H$_2$O is split into H and OH
    - H & OH group attach where the covalent bond used to be
  - ex: digestion is hydrolysis