22.1 Organic Chemistry

- The study of the compounds of carbon, not classified as inorganic
  - Plastics, fibers, dyes, drugs, insecticides, perfumes, petroleum products, etc…
- Carbon atoms
  - Form 4 covalent bonds
  - Bond with each other
  - Are able to make long chains

Functional Groups

- **Functional groups** – small structural units within a molecule at which most of the compound’s reactions occur
- Define organic families
- Functional groups are only a part of an organic molecule.
- \( R \) (and \( R' \)) – represents the unimportant part of the molecule that does not react,
  - Can be organic fragment containing carbon atoms
  - Sometimes, a hydrogen atom
Functional Groups and Solubility

- The functional groups and size determine if a molecule is soluble in water.
- “likes dissolve likes”
- Hydrocarbons are nonpolar and tend to be insoluble in water (a polar solvent).
- These include alkanes, alkenes, and alkynes.
- Molecules can have a mixture of polar and nonpolar structures.

Solubility and Forces

- Molecules with polar functional groups tend to be soluble in water.
- Alcohols, carboxylic acids, amines, and amides
- How?
- Hydrogen bonding!
Solubility and Size

• Large molecules, even if they contain polar functional groups, tend to be insoluble.

22.6 Most biochemicals are organic compounds

• Biochemistry is the systematic study of the chemicals of living things.
• Living things are composed mostly of organic compounds.
• Living systems require:
  – Materials (lipids)
  – Energy (lipids and carbohydrates)
  – Information or “blueprints” (proteins and nucleic acids)

22.7 Carbohydrates

• Carbohydrates are monomers and macromolecules with empirical formulas of $C_n(H_2O)_m$ where $x$ and $y$ are integers.
• “hydrated carbon”
• Important food source for most organisms

• Monosaccharides: small molecules that when broken down provide quick energy for cells (sugar high)
  – Glucose, sucrose, fructose

• Polysaccharides – macromolecular carbohydrates that store large amounts of energy
  – Starch, glyogen and cellulose
Polysaccharides

- Starch: polymers of glucose (Glu)
  - where plants store energy
  - two types: Amylose (20%) and Amylopectin (80%)

\[
\begin{align*}
\text{Glu} + O & \rightarrow \text{Glu-}O \\
\text{amylose, } n \text{ is very large} & \\
\text{Glu} + O & \rightarrow \text{Glu-}O \\
\text{Glu} + O & \rightarrow \text{Glu-}O \\
\text{etc.} & \\
\text{amylopectin (m, n, and } n \text{ are large numbers)} &
\end{align*}
\]

Lipids comprise a family of water-insoluble compounds

- Very large group of molecules.
- Only requirement is that hydrocarbons compose a large portion of the molecule
- Triacylglycerols are one type of lipid.
  - Esters between glycerol and three long chain fatty acids
  - Edible fats and oils like olive oil, butterfat, and lard

\[
\begin{align*}
\text{CH}_2\text{OOCR} & \\
\text{CH}_2\text{OOCR} & \\
\text{CH}_2\text{OOCR} & \\
\text{triaclylglycerol—typical molecule present in many edible oils} &
\end{align*}
\]

Lipids and Cell Membranes

- **Glycerophospholipids** - lipids involved in animal cell membrane
- Composed of (a) glycerol, (b) 2 fatty acids and (c) a phosphate unit attached to an amino-alcohol unit
- It is missing the extra fatty acid.
• Large molecules that have a polar end and a nonpolar end.
• The nonpolar end (tail) is **hydrophobic**.
• The polar end (head) is **hydrophilic**.

**Will they dissolve in water?**

- Proteins are polymers of amino acids.
  - The most important biochemicals in cells are proteins (enzymes, antibodies, hormones, transport molecules, and structural materials):
    - Protect organisms from disease
    - Extract energy from food
    - Move essential cellular components
    - Responsible for vision, taste and smell
    - Etc...
    - Proteins are the molecular machinery of the cell.
  - Macromolecules called **polypeptides**.
  - Monomer components are from a set of 20 **amino acids**.
Amino Acids

- Building blocks of polypeptides
- All have 2 functional groups: amine and carboxylic acid.
- They are identified by their “R” group.

<table>
<thead>
<tr>
<th>Position</th>
<th>R Group</th>
<th>Functional Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>α</td>
<td>H₂, glycine (Gly)</td>
<td>R = CH₂, alanine (Ala)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R = CH₃, phenylalanine (Phe)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R = CH₂CH₂CO₂H, glutamic acid (Glu)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R = CH₂CH₂CH₂NH₂, lysine (Lys)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R = CH₂S₂, cysteine (Cys)</td>
</tr>
</tbody>
</table>

- Amino acids condense to create a peptide bond.
- Use three letter abbreviation for the amino acids.
- The terminal amine group in a polypeptide is always written on the left and the terminal carboxylic acid is always written on the right.
Circle the amine terminus and put a square around the carboxylic acid terminus.

Gly – Ser – Glu – Phe – Phe – Lys – Lys – Lys

Proteins

• Some proteins consist of a single polypeptide chain (a long molecule).
• MOST proteins are mixtures of two or more polypeptides (two or more long molecules).
• And in some proteins the polypeptides are identical.
• Proteins may also include small organic molecules and metal ions in their structure.

• Hemoglobin – example of a protein with 4 polypeptide chains and the Heme molecule that imparts the red color of blood.
• Notice the iron(II) in the middle of Heme molecule.
Protein Shape

- The final shape of a protein, called its **native form**, is critical to its ability to function.
- Physical agents such as heat, poisons, and certain solvents can alter a protein's native form.
  - When this happens, the protein is said to have been **denatured**.
  - It loses its shape.
- A change in pH can radically alter the ability of a protein to function.
- Therefore, it is very important that body pH be stable.

22.8 Nucleic Acids

- The instructions for self-replication in biological organisms is stored and transmitted by macromolecules called **nucleic acids**.
- Genetic information is stored in molecules of **DNA** (deoxyribonucleic acid), located in the cell nuclei. (MM > 10^9 g/mol)
- The information stored in DNA is transmitted by **RNA** (ribonucleic acid). (MM = 20,000 – 40,000 g/mol)

Nucleotides

**Nucleotides**: the building blocks of nucleic acids, require 3 components

1. A nitrogen containing organic base
   - **Purines**: two-ring structures, adenine and guanine
   - **Pyrimidines**: one-ring structures, thymine (in DNA), cytosine and uracil (RNA)

![Nucleotides Diagram]
2. A pentose sugar
   - RNA - ribose
   - DNA – deoxyribose

3. A phosphate linkage derived from phosphoric acid

Structure of Nucleic Acids

- A nucleic acid polymer contains nucleotide chains in which the phosphate group of one nucleotide links to the sugar ring of a second.
  - The primary structure: the sequence of bases

```
A  C  G  T

G  C  A  T

A  T  G  C

T  G  C  A
```

- ACGT
• Watson and Crick (1953)
• X-ray data actually taken by Rosalind Franklin.
• 2 strands of sugar-phosphate backbones wound around in a double helix.
• Held together by hydrogen bonds between bases.
• Complimentary base pairs – the matching of bases
  – Adenine pairs with thymine
  – Guanine pairs with cytosine
  – WHY!

Is this going to happen????

Or this?

Hydrogen bonding!
Structure of RNA

• Similar to DNA, but…
  – Sugar is ribose (not deoxyribose).
  – RNA uses uracil instead of thymine.
  – RNA is much smaller.
  – RNA is usually single stranded, not double-stranded.
• Complimentary base pairing (G w/C and A w/ U) creates loops and kinks
• The principle job of RNA is to provide information to synthesize proteins.