Carbon and the Molecular Diversity of Life

Chapter 4
CARBON

• Carbon is has ability to form large and complex, molecules

Aspirin molecular formula? A triglyceride
Organic chemistry is the study of carbon compounds.

- Ethanol
- Hemoglobin
• (Wohler 1828) → organic molecules can be synthesized from inorganic

• Don’t need a kidney to make urea!
Stanley Miller 1953

Organic molecules can arise spontaneously (abiotic synthesis)

Water vapor

Condenser

Cooled water containing organic molecules

Sample contains amino acids, hydrocarbons

primitive sea conditions

Stanley Miller 1953

Organic molecules can arise spontaneously (abiotic synthesis)
Miller

• Evidence for evolution

• Physical/natural laws govern all natural phenomena

• [New Scientist – Stanley Miller’s exp](#)
Carbon forms diverse molecules by bonding to 4 other atoms

- usually H, O, N

<table>
<thead>
<tr>
<th>Name</th>
<th>Molecular Formula</th>
<th>Structural Formula</th>
<th>Ball-and-Stick Model</th>
<th>Space-Filling Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Methane</td>
<td>CH₄</td>
<td>H–C–H</td>
<td><img src="image1" alt="Ball-and-Stick Model" /></td>
<td><img src="image2" alt="Space-Filling Model" /></td>
</tr>
<tr>
<td>(b) Ethane</td>
<td>C₂H₆</td>
<td>H–C–C–H</td>
<td><img src="image3" alt="Ball-and-Stick Model" /></td>
<td><img src="image4" alt="Space-Filling Model" /></td>
</tr>
<tr>
<td>(c) Ethene (ethylene)</td>
<td>C₂H₄</td>
<td>H–C=CH</td>
<td><img src="image5" alt="Ball-and-Stick Model" /></td>
<td><img src="image6" alt="Space-Filling Model" /></td>
</tr>
</tbody>
</table>
Molecular Diversity Arises from Carbon Chains

- Carbon chains form organic molecules
  - Why are these called “hydrocarbons”?

(a) Length

- Ethane
- Propane

(b) Branching

- Butane
- 2-Methylpropane (commonly called isobutane)

(c) Double bonds

- 1-Butene
- 2-Butene

(d) Rings

- Cyclohexane
- Benzene
Hydrocarbons

- hydrophobic
- undergo reactions that release large amount of energy (ex. Fossil fuels)
- Ex. fats

\[
C_3H_8 + 5 O_2 \rightarrow 4 H_2O + 3 CO_2 + \text{Energy}
\]

Common name: Propane
IUPAC name: Propane
Hydrocarbon: Fat is a fuel reserve in animals

A triglyceride = why?
Isomers
• same molecular formula, but different atom bonding

![Structural isomers](image)

- **glucose**
- **fructose**
• Stereoisomers are “handed”

• Thalidomide, given for morning sickness in Europe in late 1950s. Sedative. Found to be teratogen. Was found in some animals that only the S stereoisomer is teratogenic – but turns out they both are.
Functional groups are key to function of biological molecules

Both steroids, both have 4 fused rings, note functional groups
The 7 functional groups most important in life:

1. Hydroxyl group —OH

**STRUCTURE**
- (may be written HO—)

**EXAMPLE**
- Ethanol, the alcohol present in alcoholic beverages

**NAME OF COMPOUND**
- Alcohols (their specific names usually end in -ol)

**FUNCTIONAL PROPERTIES**
- Is polar as a result of the electrons spending more time near the electronegative oxygen atom.
- Can form hydrogen bonds with water molecules, helping dissolve organic compounds such as sugars.
2. Carbonyl group \( \text{C}=\text{O} \)

**Structure**
- Ketones if the carbonyl group is within a carbon skeleton
- Aldehydes if the carbonyl group is at the end of the carbon skeleton

**Example**
- Acetone, the simplest ketone
- Propanal, an aldehyde

**Name of Compound**
- Ketones if the carbonyl group is within a carbon skeleton
- Aldehydes if the carbonyl group is at the end of the carbon skeleton

**Functional Properties**
- A ketone and an aldehyde may be structural isomers with different properties, as is the case for acetone and propanal.
- These two groups are also found in sugars, giving rise to two major groups of sugars: aldoses (containing an aldehyde) and ketoses (containing a ketone).
3. Carboxyl group \(-\text{COOH}\)

- Acetic acid
  - $\text{H} - \text{C} - \text{O} - \text{H}$
  - $\text{H} - \text{C} - \text{C} - \text{O} - \text{H}$

- Acetic acid → Acetate ion + H⁺
4. Amino group -NH₂

**Example**

Because it also has a carboxyl group, glycine is both an amine and a carboxylic acid; compounds with both groups are called amino acids.

**Amines**

- Acts as a base; can pick up an H⁺ from the surrounding solution (water, in living organisms).
- Ionized, with a charge of 1+, under cellular conditions.
5. Sulfhydryl group \(-\text{SH}\)

Cysteine is an important sulfur-containing amino acid.

Thiols

- Two sulfhydryl groups can react, forming a covalent bond. This “cross-linking” helps stabilize protein structure.
- Cross-linking of cysteines in hair proteins maintains the curliness or straightness of hair. Straight hair can be “permanently” curled by shaping it around curlers, then breaking and re-forming the cross-linking bonds.
6. Phosphate group $-\text{PO}_4$

In addition to taking part in many important chemical reactions in cells, glycerol phosphate provides the backbone for phospholipids, the most prevalent molecules in cell membranes.

Organic phosphates

- Contributes negative charge to the molecule of which it is a part (2− when at the end of a molecule; 1− when located internally in a chain of phosphates).

Glycerol phosphate

- Has the potential to react with water, releasing energy.
7. Methyl group \(-\text{CH}_3\)

**STRUCTURE**

**EXAMPLE**

5-Methyl cytidine is a component of DNA that has been modified by addition of the methyl group.

- Addition of a methyl group to DNA, or to molecules bound to DNA, affects expression of genes.
- Arrangement of methyl groups in male and female sex hormones affects their shape and function.
ATP: Energy for Cellular Processes

adenosine attached to a string of 3 phosphates
1 phosphate split off to form ADP + energy