Chapter 4
Carbon and the Molecular Diversity of Life
Organic Chemistry

- The study of carbon compounds.

Urea
Carbon’s versatility

- Forms 4 covalent bonds.
- Molecular shape is tetrahedral.
- Bonds easily to itself.
Major Elements Of Organic Molecules

- Carbon: +4 or −4
- Hydrogen: +1
- Oxygen: −2
- Nitrogen: −3

The valences are the “rules” for building organic molecules.
Hydrocarbons

- Organic molecules made of only carbon and hydrogen.
### Examples

<table>
<thead>
<tr>
<th>Molecular Formula</th>
<th>Structural Formula</th>
<th>Ball-and-Stick Model</th>
<th>Space-Filling Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄</td>
<td>H — C — H — H</td>
<td><img src="#" alt="Ball-and-Stick Model of Methane" /></td>
<td><img src="#" alt="Space-Filling Model of Methane" /></td>
</tr>
<tr>
<td>(a) Methane</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C₂H₆</td>
<td>H — C = C — H</td>
<td><img src="#" alt="Ball-and-Stick Model of Ethane" /></td>
<td><img src="#" alt="Space-Filling Model of Ethane" /></td>
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<tr>
<td>(b) Ethane</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C₂H₄</td>
<td>H — C = C — H</td>
<td><img src="#" alt="Ball-and-Stick Model of Ethene (ethylene)" /></td>
<td><img src="#" alt="Space-Filling Model of Ethene (ethylene)" /></td>
</tr>
<tr>
<td>(c) Ethene (ethylene)</td>
<td></td>
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</tbody>
</table>
Isomers

- Compounds with the same molecular formula but have different structures.
- Result: Different molecular and chemical properties.
Types Of Isomers

1. Structural
2. Geometric
3. Enantiomers
Structural Isomers

- Different in covalent arrangements of their atoms.

Butane

Isobutane
Geometric Isomers

- Same covalent partnership but differ in spatial arrangements.
- Arise from the inflexibility of double bonds.
(a) Structural isomers

(b) Geometric isomers

(c) Enantiomers
Enantiomers

- Molecules that are mirror images of each other.
- Usually involve an asymmetric carbon.
(a) Structural isomers

(b) Geometric isomers

(c) Enantiomers
Organisms are sensitive to even the most subtle variations in molecular architecture.
Example – Thalidomide

- Cells can distinguish between two isomers.
- One is an effective drug.
- The other causes birth defects.
A group of atoms attached to a carbon skeleton.
Have consistent properties.
Their number and kind give properties to the molecule.
Importance of Functional Groups

Female lion

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What to focus on:

- Structure of the functional group
- Properties of the functional group
- Examples of molecules with the functional group
Hydroxyl

**STRUCTURE**

- OH
- (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.
**Ketones if the carbonyl group is within a carbon skeleton**

**Aldehydes if the carbonyl group is at the end of the carbon skeleton**

- 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).
Aldehydes

- A carbonyl group at the end of a carbon skeleton.
  Ex. – C=O
  \[ \text{H} \]
- Sometimes written as
  – CHO
Ketones

- A carbonyl group in the middle of a carbon chain.

Ex. \(-\text{C–C–C–}\)
Carboxyl

**STRUCTURE**

[Diagram of a carboxyl group]

**EXAMPLE**

Acetic acid, which gives vinegar its sour taste

**NAME OF COMPOUND**

Carboxylic acids, or organic acids

**FUNCTIONAL PROPERTIES**

- Has acidic properties because the covalent bond between oxygen and hydrogen is so polar; for example,

  ![Acetic acid](image)

  ![Acetate ion](image)

- Found in cells in the ionized form with a charge of 1− and called a carboxylate ion (here, specifically, the acetate ion).
Carboxylic Acids

- Donate $H^+$ (acid).
- Form many weak organic acids.
Amino

STRUCTURE

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.

FUNCTIONAL PROPERTIES

- Acts as a base; can pick up an H⁺ from the surrounding solution (water, in living organisms).

  (nonionized) (ionized)

- Ionized, with a charge of 1⁺, under cellular conditions.

NAME OF COMPOUND

Amines
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.
Phosphate

**STRUCTURE**

[Image of phosphate structure]

**EXAMPLE**

Glycerol phosphate

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.

**NAME OF COMPOUND**

Organic phosphates

**FUNCTIONAL PROPERTIES**

- 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).
- Has the potential to react with water, releasing energy.
**Methyl**

**STRUCTURE**

- Molecular structure of methyl.

**EXAMPLE**

- 5-Methyl cytidine

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

**NAME OF COMPOUND**

Methylated compounds

**FUNCTIONAL PROPERTIES**

- 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.
Summary

- Recognize that carbon is a versatile atom in terms of bonding and forming molecules.
- Be able to recognize isomers.
- Know the seven functional groups and what properties they give to molecules.