Chapter 4

Carbon and the Molecular Diversity of Life

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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Overview: Carbon: The Backbone of Life

- Although cells are 70–95% water, the rest consists mostly of carbon-based compounds
- Carbon is unparalleled in its ability to form large, complex, and diverse molecules
- Proteins, DNA, carbohydrates, and other molecules that distinguish living matter are all composed of carbon compounds

Concept 4.1: Organic chemistry is the study of carbon compounds

- **Organic chemistry** is the study of compounds that contain carbon
- Organic compounds range from simple molecules to colossal ones
- Most organic compounds contain hydrogen atoms in addition to carbon atoms

- *Vitalism*, the idea that organic compounds arise only in organisms, was disproved when chemists synthesized these compounds
- *Mechanism* is the view that all natural phenomena are governed by physical and chemical laws

Concept 4.2: Carbon atoms can form diverse molecules by bonding to four other atoms

- Electron configuration is the key to an atom's characteristics
- Electron configuration determines the kinds and number of bonds an atom will form with other atoms

The Formation of Bonds with Carbon

- With four valence electrons, carbon can form four covalent bonds with a variety of atoms
- This *tetravalence* makes large, complex molecules possible
- In molecules with multiple carbons, each carbon bonded to four other atoms has a tetrahedral shape
- However, when two carbon atoms are joined by a double bond, the molecule has a flat shape

- The electron configuration of carbon gives it covalent compatibility with many different elements
- The valences of carbon and its most frequent partners (hydrogen, oxygen, and nitrogen) are the “building code” that governs the architecture of living molecules

- Carbon atoms can partner with atoms other than hydrogen; for example:
  - Carbon dioxide: CO_2

$$O = C = O$$

  - Urea: $CO(NH_2)_2$

Molecular Diversity Arising from Carbon Skeleton Variation

- Carbon chains form the skeletons of most organic molecules
- Carbon chains vary in length and shape

PLAY Animation: Carbon Skeletons

Hydrocarbons

- **Hydrocarbons** are organic molecules consisting of only carbon and hydrogen
- Many organic molecules, such as fats, have hydrocarbon components
- Hydrocarbons can undergo reactions that release a large amount of energy

Isomers

- **Isomers** are compounds with the same molecular formula but different structures and properties:
  - **Structural isomers** have different covalent arrangements of their atoms
  - **Geometric isomers** have the same covalent arrangements but differ in spatial arrangements
  - **Enantiomers** are isomers that are mirror images of each other

PLAY Animation: Isomers

- Enantiomers are important in the pharmaceutical industry
- Two enantiomers of a drug may have different effects
- Differing effects of enantiomers demonstrate that organisms are sensitive to even subtle variations in molecules

PLAY Animation: L-Dopa

Concept 4.3: A small number of chemical groups are key to the functioning of biological molecules

- Distinctive properties of organic molecules depend not only on the carbon skeleton but also on the molecular components attached to it
- A number of characteristic groups are often attached to skeletons of organic molecules

The Chemical Groups Most Important in the Processes of Life

- **Functional groups** are the components of organic molecules that are most commonly involved in chemical reactions
- The number and arrangement of functional groups give each molecule its unique properties

- The seven functional groups that are most important in the chemistry of life:
  - Hydroxyl group
  - Carbonyl group
  - Carboxyl group
  - Amino group
  - Sulfhydryl group
  - Phosphate group
  - Methyl group

ATP: An Important Source of Energy for Cellular Processes

- One phosphate molecule, **adenosine triphosphate** (**ATP**), is the primary energy-transferring molecule in the cell
- ATP consists of an organic molecule called adenosine attached to a string of three phosphate groups

The Chemical Elements of Life: *A Review*

- The versatility of carbon makes possible the great diversity of organic molecules
- Variation at the molecular level lies at the foundation of all biological diversity

You should now be able to:

1. Explain how carbon's electron configuration explains its ability to form large, complex, diverse organic molecules
2. Describe how carbon skeletons may vary and explain how this variation contributes to the diversity and complexity of organic molecules
3. Distinguish among the three types of isomers: structural, geometric, and enantiomer

4. Name the major functional groups found in organic molecules; describe the basic structure of each functional group and outline the chemical properties of the organic molecules in which they occur

5. Explain how ATP functions as the primary energy transfer molecule in living cells