

Chapter 4

Overview: Carbon: The Backbone of Life

- Living organisms consist 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

Organic Molecules and the Origin of Life on Earth

- Stanley Miller's classic experiment demonstrated the abiotic synthesis of organic compounds
- Experiments support the idea that abiotic synthesis of organic compounds, perhaps near volcanoes, could have been a stage in the origin of life

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 ability 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 atoms joined to the carbons are in the same plane as the carbons
- 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
 - Urea: $\text{CO}(\text{NH}_2)_2$

Molecular Diversity Arising from Carbon Skeleton Variation

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

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

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Isomers

- **Isomers** are compounds with the same molecular formula but different structures and properties
 - **Structural isomers** have different covalent arrangements of their atoms
 - **Cis-trans isomers** have the same covalent bonds but differ in spatial arrangements
 - **Enantiomers** are isomers that are mirror images of each other
- Enantiomers are important in the pharmaceutical industry
- Two enantiomers of a drug may have different effects
- Usually only one isomer is biologically active
- Differing effects of enantiomers demonstrate that organisms are sensitive to even subtle variations in molecules

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

- Distinctive properties of organic molecules depend on the carbon skeleton and on the molecular components attached to it
- A number of characteristic groups can replace the hydrogens 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