

Campbell Biology

Chapter 4: Carbon and the Molecular Diversity of Life

A1: Carbon: The Backbone of Life

- Living organisms are made up of chemicals made mostly out of carbon
- Carbon enters the biosphere through photosynthetic organisms that convert the atoms into the molecules of life
- Carbon has an unparalleled ability to form large, complex, and varied molecules, like proteins, DNA, carbohydrates, etc.
- In organic compounds, carbon is usually bonded to hydrogen, oxygen, nitrogen, phosphorus, or sulfur

A1: Organic Chemistry is the Study of Carbon Compounds

- Organic chemistry is the study of compounds containing carbon
- Chemists had learned to artificially synthesize inorganic compounds, but it was believed it would be impossible to synthesize organic compounds in a laboratory setting
- Frederick Wöhler accidentally created urea from NH_4^+ (ammonium) ions and CNO^- (cyanate) ions
- Chemists soon learned that compounds that originate in living beings could be reproduced in a laboratory setting
- Organic compounds range from CH_4 to huge molecules

A2: Organic Molecules and the Origin of Life on Earth

- Stanley Miller deduced that complex organic molecules could arise spontaneously under the conditions of early Earth
- Some suggest that spontaneous synthesis of organic compounds created life near a volcano
- The percentages of CHNOPS in each organism are about the same, showing the common ancestry of all species on Earth
- Carbon's versatility in its ability to bond to four different atoms allows an inexhaustible variety of organic molecules to be built
- Species and individuals are differentiated in the types of organic molecules they synthesize, and carbon's versatility contributes to the great biodiversity on Earth

A1: Carbon Atoms can form Diverse Molecules by Bonding to Four Other Atoms

- The key to an atom's chemical characteristics is its electron configuration, as it determines how many kinds and number of bonds the atom will form
- The valence shell determines how many electrons are available for bonding

A2: The Formation of Bonds with Carbon

- Carbon has six electrons, with two in the first shell and four in the valence shell
- Carbon follows the octet rule of bonding, so it will usually share its four electrons with other atoms
 - A covalent bond is made up of two shared atoms
- Carbon usually forms single or double covalent bond
- Each carbon atom serves as an intersection where a molecule can branch off into four different locations, allowing large and complex molecules to be built
- The hybridization of carbon's four orbitals allows it to form a tetrahedral shape with a 109.5° bond angle
- Any molecule where carbon forms four single bonds has the same tetrahedral shape
- When two carbons are joined via a double bond, each grouping of a carbon to four other atoms has a tetrahedral shape, thus C_2H_4 (ethene) is shaped like two overlapping tetrahedrons
- The electron shape and valence electron number of H₂NOPS is what serves as the basis for covalent bonding in organic chemistry
- Each line in a structural formula represents one shared pair of electrons

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