Carbon, Carbon in the Sky—Are You Swinging Low and High?

A. Coniferous trees are the premier producers of the great northern forests.

1. They take in large amounts of carbon dioxide during photosynthesis.

2. Carbon dioxide levels in the atmosphere decline during the warm months.

3. An indication that the earth may be getting warmer, earlier is the shift toward breaking dormancy earlier in the growing season.

B. Carbon in its many forms permeates the entire world of life.

I. Properties of Organic Compounds

A. The Molecules of Life

1. Only living cells can synthesize carbohydrates, lipids, proteins, and nucleic acids.

2. These molecules are organic compounds consisting of carbon and one or more additional elements, covalently bonded to one another.

B. Carbon's Bonding Behavior

1. Oxygen, hydrogen, and carbon are the most abundant elements in living matter.

2. Much of the H and O are linked as water.

3. Carbon can share pairs of electrons with as many as four other atoms to form organic molecules of several configurations.

4. A carbon atom can rotate freely around a single covalent bond.

5. A double covalent bond restricts rotation.

6. Such interactions help give rise to the three-dimensional shapes and functions of biological molecules.

C. Functional Groups

1. In hydrocarbons, only hydrogen atoms are attached to the carbon backbone; these molecules are quite stable.

2. Functional groups are atoms or groups of atoms covalently bonded to a carbon backbone; they convey distinct properties, such as solubility and chemical reactivity, to the complete molecule.

D. How Do Cells Build Organic Compounds?

1. Enzymes are a special class of proteins that mediate five categories of reactions:

a. functional-group transfer from one molecule to another,

b. electron transfer –stripped from one molecule and given to another,

c. rearrangement of internal bonds converts one type of organic molecule to another,

d. condensation of two molecules into one,

2. In a condensation reaction, one molecule is stripped of its H^+, another is stripped of its OH—; then the two molecule fragments join to form a new compound and the H^+ and OH— form water.

3. Hydrolysis is the reverse: one molecule is split by the addition of H^+ and OH— (from water) to the components.

II. Carbohydrates

A. The Simple Sugars

1. Monosaccharides–one sugar unit–are the simplest carbohydrates.

2. They are characterized by solubility in water, sweet taste, and several –OH groups.

3. Ribose and deoxyribose (five-carbon backbones) are building blocks for nucleic acids.

4. Glucose and fructose (six-carbon backbones) are used in assembling larger carbohydrates.

5. Other important molecules derived from sugar monomers include glycerol and vitamin C.

B. Short-Chain Carbohydrates

1. An oligosaccharide is a short chain of two or more sugar monomers.

2. Disaccharides–two sugar units–are the simplest.

a. Lactose (glucose + galactose) is present in milk.

b. Sucrose (glucose + fructose) is a transport form of sugar used by plants and harvested by humans for use in food.

c. Maltose (two glucose units) is present in germinating seeds.

3. Oligosaccharides with three or more sugar monomers are attached as short side chains to proteins where they participate in membrane function.

C. Complex Carbohydrates

1. A polysaccharide is a straight or branched chain of hundreds or thousands of sugar monomers.

2. Starch is a plant storage form of energy, arranged as unbranched coiled chains, easily hydrolyzed to glucose units.

3. Cellulose is a fiberlike structural material–tough, insoluble–used in plant cell walls.

4. Glycogen is a highly-branched chain used by animals to store energy in muscles and liver.

5. Chitin is a specialized polysaccharide with nitrogen attached to the glucose units; it is used as a structural material in arthropod exoskeletons and fungal cell walls.

e. cleavage of one molecule into two.

III. Lipids

A. Lipids are greasy or oily compounds with little tendency to dissolve in water.

1. They can be broken down by hydrolysis reactions.

2. They function in energy storage, membrane structure, and coatings.

B. Fats and Fatty Acids

1. A fatty acid is a long chain of mostly carbon and hydrogen atoms with a –COOH group at one end.

2. When they are part of complex lipids, the fatty acids resemble long, flexible tails.

a. Unsaturated fats are liquids (oils) at room temperature because one or more double bonds between the carbons in the fatty acids permits "kinks" in the tails.

b. Saturated fats (triglycerides) have only single C–C bonds in their fatty acid tails and are solids at room temperature.

3. Fats are formed by the attachment of one (mono-), two (di-), or three (tri-) fatty acids to a glycerol.

a. They are a rich source of energy, yielding more than twice the energy per weight basis as carbohydrates.

b. They are also provide an insulation blanket for animals that must endure cold, harsh temperatures.

C. Phospholipids

1. These are formed by attachment of two fatty acids plus a phosphate group to a glycerol.

2. They are the main structural material of membranes where they arrange in bilayers.

D. Sterols and Their Derivatives

1. Sterols have a backbone of four carbon rings but no fatty acid tails.

2. Cholesterol is a component of cell membranes in animals and can be modified to form sex hormones (testosterone and estrogen) and vitamin D.

E. Waxes

1. They are formed by attachment of long-chain fatty acids to long-chain alcohols or carbon rings.

2. They serve as coatings for plant parts and as animal coverings.

IV. Amino Acids and the Primary Structure of Proteins

A. Proteins function as enzymes, in cell movements, as storage and transport agents, as hormones, as antibodies, and as structural material.

B. Structure of Amino Acids

1. Amino acids are small organic molecules with an amino group, a carboxyl group, and one of twenty varying R groups.

2. All of the parts of an amino acid molecule are covalently bonded to a central carbon atom.

C. Primary Structure of Proteins

1. Primary structure is defined as ordered sequences of amino acids each linked together by peptide bonds to form polypeptide chains.

2. There are 20 kinds of amino acids available in nature.

3. The sequence of the amino acids is determined by DNA and is unique for each kind of protein.

a. Fibrous proteins have polypeptide chains organized as strands or sheets; they contribute to the shape, internal organization, and movement of cells.

b. Globular proteins, including most enzymes, have their chains folded into compact, rounded shapes.

V. How Does a Protein's Three-Dimensional Structure Emerge?

A. Three-dimensional structure is determined by how amino acid sequences present their atoms for hydrogen bonding.

B. Second Level of Protein Structure

1. Secondary structure refers to the helical coil (as in hemoglobin) or sheetlike array (as in silk) that results from hydrogen bonding of side groups on the amino acid chains.

2. The peptide bonds between the amino acids of primary structure allow slight bending to permit secondary structure.

C. Third Level of Protein Structure

1. Tertiary structure is the result of folding due to interactions among R groups along the polypeptide chain.

2. The result is a more compact, globular shape in complex proteins.

D. Fourth Level of Protein Structure

1. Quaternary structure describes the complexing of two of more polypeptide chains.

2. Hemoglobin is a good example of four interacting chains that form a globular proteins; keratin and collagen are complex fibrous proteins.

E. Glycoproteins and Lipoproteins

1. Lipoproteins have both lipid and protein components; they transport fats and cholesterol in the blood.

2. Glycoproteins consist of oligosaccharides covalently bonded to proteins; they are abundant on the exterior of animal cells, as cell products, and in the blood.

F. Structural Changes by Denaturation

1. High temperatures or changes in pH can cause a loss of a protein's normal three-dimensional shape (denaturation).

2. Normal functioning is lost upon denaturation, which is often irreversible (for example, a cooked egg).

VI. Focus on the Environment: Food Production and a Chemical Arms Race

VII. Nucleotides

A. Nucleotides are small organic molecules with roles in metabolism.

B. Each nucleotide consists of a five-carbon sugar (ribose or deoxyribose), a nitrogen-containing base, and a phosphate group.

1. Adenosine phosphates are chemical messengers (cAMP) or energy carriers (ATP).

2. Nucleotide coenzymes transport hydrogen atoms and electrons (examples: NAD^+ and FAD).

VIII. Nucleic Acids

A. Nucleic acids are polymers of nucleotides.

1. Four different kinds of nucleotides are strung together to form large single or double-stranded molecules.

2. Each strand's backbone consists of joined sugars and phosphates with nucleotide bases projecting toward the interior.

B. The two most important nucleic acids are DNA and RNA.

1. DNA is a double-stranded helix carrying encoded hereditary instructions.

2. RNA is single stranded and functions in translating the code to build proteins.