

Biomolecules, Classification, Significance, Composition, Structure

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The organic molecules which are essential for the existence of life such as carbohydrates, proteins, lipids and nucleic acids are called Biomolecules. They are essential for life as they form the basis of cellular structure, store energy, regulate metabolic processes, and carry genetic information. Made primarily of carbon, hydrogen, oxygen, and other elements, they serve as the fundamental building blocks that sustain biological functions and processes in all living organisms.

Biomolecules

The sustainability of life and biological processes determined by the organic molecules are referred to as Biomolecules. These are classified into four categories including carbohydrates, proteins, lipids and nucleic acids. Carbohydrates are the primary energy source, fuel for cellular activities. Proteins which are made of amino acids; functions include catalysis, structural support, and cell communication.

Lipids include fats and oils; serve as energy reserves, provide insulation, and form cell membranes. Nucleic acids (**DNA & RNA**) store and transmit genetic information essential for growth, reproduction, and cellular functions.

Biomolecules are made of main elements including carbon, hydrogen, oxygen, nitrogen, and phosphorus, formed through covalent bonds into complex structures. Synthesized and broken down via metabolic pathways, showing their dynamic role.

Biomolecules Classification

Biomolecules can be better understood by looking at their categories, building blocks, and functions side by side. The table below provides a clear comparison of the four major biomolecules.

Biomolecules Classification			
Biomolecule	Composition	Function	Examples
Carbohydrates	Carbon, Hydrogen, Oxygen (1:2:1 ratio)	Primary energy source, structural components	Glucose, Starch, Cellulose, Glycogen
Proteins	Chains of amino acids (C, H, O, N, sometimes S)	Enzymatic activity, structural support, transport, defense, signaling	Enzymes, Hemoglobin, Keratin, Antibodies
Lipids	C, H, O (less O than carbs)	Energy storage, insulation, membrane structure, signaling	Fats, Oils, Phospholipids, Steroids
Nucleic Acids	C, H, O, N, P	Storage and transmission of genetic information	DNA, RNA
Others (supportive categories)	Varies (depends on type)	Regulation, co-factors, metabolic roles	Vitamins, Minerals, Secondary Metabolites

Biomolecules Significance

Biomolecules are the foundation of life, performing vital roles in the structure, function, and regulation of living organisms. Their significance can be understood through the following aspects:

- Proteins such as collagen and keratin, along with carbohydrates like cellulose, provide strength and stability to cells, tissues, and entire organisms.
- Carbohydrates and lipids act as the main energy sources. While carbohydrates provide quick energy, lipids serve as long-term storage reserves.
- Many proteins act as enzymes, catalyzing biochemical reactions that drive metabolism and sustain life processes.
- DNA and RNA store, transmit, and regulate genetic information, ensuring accurate development, growth, and reproduction.

- Molecules like hormones and neurotransmitters, often proteins or lipids, enable communication between cells, tissues, and organs, coordinating vital body functions.
- Antibodies (proteins) and certain lipids form part of the immune system, defending the body against pathogens.
- Proteins like hemoglobin transport oxygen, while molecules such as glycogen (a carbohydrate) store energy for later use.

Biomolecules New Developments

- Tools like AlphaFold 2 (AF2) have revolutionized protein structure prediction which helps in drug discovery and understanding complex biomolecular interactions. Streamlining target identification for diseases like cancer.
- Proteins, peptides, and nucleic acids are being used to build multifunctional nanomedicines. Applications include drug delivery, cancer therapy, and theranostics (therapy + diagnostics). Molecular dynamics simulations improve their design and performance.
- Advanced infrared techniques allow imaging biomolecules in living cells. Overcomes water interference challenges in traditional imaging. Enables real-time monitoring of biomolecular dynamics in natural environments.
- Advances in biomolecule research are driving progress in medicine, biotechnology, and materials science. These innovations support global health solutions and personalized medicine.

Biomolecules Composition

Biomolecules Composition has primarily elements including carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), and sulfur (S) which combines to the four main types of biomolecules with unique compositions and structures:

- Carbohydrates
 - Composition: Carbon, hydrogen, and oxygen (in a 1:2:1 ratio).
 - Examples: Glucose ($C_6H_{12}O_6$), sucrose, cellulose.
- Proteins
 - Composition: Chains of amino acids containing carbon, hydrogen, oxygen, nitrogen, and sometimes sulfur.
 - Examples: Enzymes, hemoglobin, keratin.
- Lipids
 - Composition: Carbon, hydrogen, and oxygen (less oxygen than carbohydrates). Some also contain phosphorus (e.g., phospholipids).
 - Examples: Fats, oils, cholesterol.
- Nucleic Acids
 - Composition: Carbon, hydrogen, oxygen, nitrogen, and phosphorus.
 - Examples: DNA and RNA, which are polymers of nucleotides (comprising a sugar, phosphate group, and nitrogenous base).

Biomolecules Structure

Living organisms are made up of specific chemical compounds that provide structure, energy, and the ability to carry out life processes. These compounds, called biomolecules, are built mainly from six key elements, carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur. Depending on how these elements combine, they form four major classes of biomolecules, each with distinct structures and roles essential for sustaining life.

• Carbohydrates

- Built from monosaccharides (simple sugars) of C, H, and O.
- Can form linear chains or ring-shaped cyclic structures.
- Polysaccharides (e.g., starch, cellulose) = long chains of monosaccharides linked by glycosidic bonds.
- Example: Glucose has a hexagonal ring structure.

• Proteins

- Made of amino acids linked by peptide bonds.
- Four levels of structure:
 - Primary – amino acid sequence.
 - Secondary – α -helices or β -sheets (hydrogen bonding).
 - Tertiary – 3D folding (hydrogen bonds, ionic bonds, disulfide bridges).
 - Quaternary – multiple polypeptide subunits.
- Example: Hemoglobin has four subunits (quaternary structure).

• Lipids

- Composed of glycerol + fatty acids.
- Types:
 - Simple lipids: triglycerides.
 - Complex lipids: phospholipids (hydrophilic head + hydrophobic tail).
- Example: Phospholipids arrange into bilayers in cell membranes.

• Nucleic Acids

- Polymers of nucleotides (sugar + phosphate + nitrogen base).
- DNA: double helix, complementary base pairing (A-T, G-C).
- RNA: usually single-stranded, with uracil instead of thymine.
- Example: DNA double helix stabilized by hydrogen bonds between base pairs.

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