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Class 12
Chemistry

Chapter 15
Biochemistry
Handwritten Notes

BIOCHEMISTRY

Carbohydrates

Carbohydrates are macromolecules composed of elements carbon, hydrogen, and oxygen. Each carbon is bonded to at least one oxygen atom. All carbohydrates contain an aldehyde or keto group and a hydroxyl group. They have the general formula $C_x(H_2O)_y$. This formula suggest that they are hydrates of carbon with few exceptions.

Functions of Carbohydrates: Carbohydrates act as the primary source of energy, especially glucose. They also serve as energy storage in the form of starch (plants) and glycogen (animals). Some carbohydrates provide structural support, such as cellulose in plant cell walls. They are also involved in cell recognition and act as precursors of other biomolecules.

Callasification of Carbohydrates: Carbohydrates are classified into monosacchrides (Single sugar unit, cannot be hydrolyzed), Oligosachrides (2-10 units) and (Polysachrids (long chains of many units).

- **Monosacchrides:** Monosacchrides are the simplest carbohydrates containing 3-6 carbon atoms. They are classified as aldoses (–CHO) and ketoses (>C=O). General formula $[(CH_2O)_n]$. Classification is based on the number of carbon atoms tetroses, pentoses, hexoses etc. Examples include glucose and fuctose. They show optical isomerism due to chiral carbons and exist in open-chain and cyclic forms. Glucose commonly forms a six-membered ring (pyranose). They also show α and β forms (anomers). Most monosacchrides are reducing sugars. They are white crystalline solid, soluble in water and sweet taste. Cannot be hydrolyzed. Some monosachride molecules can rotate the plane of plane-polarized light to the right (clockwise). They are called dextro-rotatory or dextrose sugars.
- **Oligosacchorides:** Oligosacchrides contain 2-10 monosacchrides units linked by glycosidic bonds. The most common are disacchrides such as sucrose, lactose, and maltose. They can be reducing or non-reducing sugars depending on the presence of a free functional group. For example, maltose is reducing, while sucrose is non-reducing. They are white crystalline solids, have a sweet taste and are soluble in water.
- **Polysacchrides:** Polysacchrides are complex carbohydrates made of any monosacchride units. They are generally insoluble and non-sweet. Starch (plants) and glycogen (animals) are used for energy storage, while cellulose provides structural support. Starch contain amylose and amylopectin, while glycogen is highly branched. The difference between starch and cellulose is due to α and β glycosidic linkages.

Proteins

Proteins are nitrogeneous high molecular weight polymers. The building blocks of all proteins are the amino acids, therefore, all proteins produce amino acids on hydrolysis. Proteins are complex nitrogeneous substances that produce amino acids on complete hydrolysis. Proteins are large complex molecules that play an important role in various biological processes.

Structure-Based Classification: The structure of a protein depends upon the spatial arrangement of polypeptide chains present in proteins. Since three spatial arrangements are possible, proteins have the following four structures.

- **Primary Structure of Proteins:** The primary structure is the linear sequence of amino acids in a polypeptide chain joined by peptide bonds. This sequence is genetically controlled and determines all higher levels of structure.
- **Secondary Structure of Proteins:** The secondary structure is the regular folding of the polypeptide chain due to hydrogen bonding. The main forms α-helix and β-~~helix~~ pleated sheet. Example, collagen.
- **Tertiary Structure of Proteins:** The twisting or folding of polypeptide chains represents a tertiary structure of proteins. For example, myoglobin.
- **Quaternary Structure of Proteins:** The quaternary structure exists when two or more polypeptide chains combine to form a functional protein, such as hemoglobin.

Classification of Proteins Based on Constitution: On the basis of composition, proteins are classified into:

- Simple Proteins: Simple proteins consist of only amino acids and yeild only amino acids on hydrolysis, e.g. albumin
- Composite or Conjugated Proteins: These proteins contain a non-protein part (prosthetic group) along with amino acids. such as glycoproteins, lipoproteins, phosphoproteins, hemoproteins etc.
- Derived proteins: Derived proteins are formed by partial hydrolysis of denaturation of simple or conjugated proteins. For example, peptones, peptides etc.

Classification of Proteins based on Shapes: Based on shape, proteins are classified into:

- Fibrous Proteins: Fibrous proteins are long, thread-like, insoluble, polypeptide chains. They mainly provide structural support, e.g. keratin, collagen, mayosin, elastin.
- Globular Proteins: Globular proteins are compact, spherical, and soluble. They perform functional roles such as enzymes and hormones. These proteins are usually soluble in acids, water, alcohol and bases. Example albumin of eggs and heamoglobin.

Classification of Proteins on the Basis of Functions: Proteins perform different roles and are classified into several functional types.

- Enzymes: Enzymes are biological catalysts that speed up reactions by lowering activation energy and are highly specific.
- Structural Proteins: These provide support and strength to cells and tissues, e.g. collagen and keratin.
- Transport Proteins: They transport substances in the body, e.g. hemoglobin carries oxygen.
- Storage Proteins: These store essential substances e.g. ferritin stores iron.
- Hormonal Proteins: These act as chemical messengers, e.g. insulin.
- Defensive Proteins: These protect the body e.g. antibiotics.
- Receptor Proteins: These receptor proteins are present on cell membranes and help in signal reception and transmission.
- G-Protein-Coupled Receptors (GPCRs): These are special membrane proteins that transmit signals into the cell through G-proteins, playing an important role in cell communication.
- Contractile Proteins: These proteins are responsible for movement, e.g. actin and myosin in muscles.
- Regulatory Proteins: They control gene expression and cellular processes.

Structure-Function Relationship of Proteins: The function of a protein depends on its structure. Any change in structure, such as denaturation (due to heat, pH, or chemicals), leads to loss of function, while the primary structure remains unchanged.

Enzymes

Enzymes are biocatalysts that alter the speed of metabolic activities in living bodies. Enzymes are complex protein molecules that are quite specific in action and sensitive to temperature and pH.

Role of Enzymes as a Biocatalyst: As biocatalysts, enzymes speed up biochemical reactions in living organisms, making life processes possible under normal conditions. They do this by providing an alternative pathway with lower activition energy. Enzymes are not used up in the reaction and can be reused. Their specificity and efficiency make them essential for processes like digestion, respiration, and synthesis of biomolecules.

When an enzyme attaches to a substrate, a temporary Enzyme-Substrate Complex (ES) is formed. The ES complex then breaks down the enzyme product.

Factors Affecting Enzyme Activity: Enzymes are very sensitive to the environment in which they work. Here are some factors that can affect:

1894, Lock and Key model by chemist Emil Fischer.
1958, Daniel Koshland, american biologist introduced induced-fit model.

- Temperature: Enzymes work at their maximum speed at a specific temperature called optimum temperature. For example, an animal enzyme works at 37°C, a plant enzyme acts at 60°C etc. Enzyme activity increases with temperature due to increased kinetic energy and more frequent collisions between enzyme and substrate. However, beyond optimum temperature, the enzyme structure gets denatured, causing a rapid decrease in activity.

- Substrate Concentration: As substrate concentration increases, the rate of reaction also increases because more enzyme-substrate complexes are formed. However, after a certain point, all active sites become saturated, and the reaction rate reaches a maximum (Vmax).
- pH: Each enzyme has an optimum pH at which it shows maximum activity. A change in pH can affect the structure of the enzyme and its active site, reducing its activity or causing denaturation. For instance, the enzyme pepsin works in the stomach and is active in acidic environments (pH = 2) while the enzyme trypsin works in the small instestine and is active in alkaline conditions (pH = 8 to 9).

Role of Inhibitors in Enzyme Catalyzed Reactions: Inhibitors are substances that decrease or stop enzyme activity by interfering with the formation of the enzyme-substrate complex. They affect the rate of reaction and are important in controlling biochemical processes.

- Competitive Inhibitors: Competitive Inhibitors are substances that compete with the substrate for the active site of the enzyme because they have a similar structure to the substrate. When the inhibitor binds, it prevents the substrate from attaching, thus reducing enzyme activity. For example, Sarin (nerve gas), acts as a competitive inbibitor to Acetylcholine (neurotransmitter). Sarin mimics acetylylcholine's structure and competes for its active site, causing acetylcholine to build up in the synapses.
- Non-Competitive Inbibitors: Non-competitive inhibitors bind to site other than the active site (called an allosteric site). This changes the shape of the enzyme, making the site less effective or inactive. For example, mercury ions bind to the enzyme's thiol groups and change the shape and activity of the enzyme.

Lipids

Lipids are non-polar, hydrophobic organic compounds that are insoluble in water but soluble in organic solvents. They mainly consist of fatty acids and glycerol and are important for energy storage, insulation, and cell structure.

Classification of Lipids: Lipids can be classified into:

- Triglycerides: Triglycerides are the most common lipids, formed by the esterfication of glycerol with three fatty acids. Fatty acids contain long hydrocarbon chains containing 12 to 22 carbon atoms and a carboxylic acid group at one end. They are building blocks of most lipids. Examples, palmitic acid, oleic acid and linoliec acid. They are found in oils, butter and adipose tissue. If fatty acids are saturated, they form fats that are solid at rom temperature. If they are unsaturated, they form oils, which are liquid at rom temperature.
- Phospholipids: They are esters of glycerol, two fatty acids, and a phosphate group. (PO_4^{3-}). They have a hydrophilic (polar) head and hydrophobic (non-polar) tail, making them esssential components of cell membranes.
- Steriods: Steriods are organic compounds with a typical molecular structure containing four fused rings of carbon atom. They are important for hormone production and maintaing cell-membrane structure. Example, chlosterol, testosterone, estrogen.
- Waxes: Waxes are esters of long-chain fatty acids and long-chain alchols. They provide protection and waterproofing in plants and animals. Examples, lanoline, beeswax, whale oil etc.
- Isoprenoids or Terpenes: These are lipids made from isoprene units and include compounds like vitamins and essential oils. They play roles in biological functions and plant metabolism. Example: menthol, Chlorophyll etc.

Classification of lipids based on chemical structure: Lipids are classified as simple, phosphdipids, and deravitive lipids based on their chemical composition.

- Simple lipids: These are composed of fatty acids and glycerol molecules. For example, tryglyceriads, waxes, compound lipids.
- Phospholipids: Phospholipids are complex lipids containing a phosphate group and are important for membrane formation. For example, glycolipids.
- Derivative lipids: They are formed by hydrolysis of simple, or complex lipids. For example, steriods, prostaglandins.

Classification of lipids on the bases of function: Based on function, lipids are grouped into energy-storing, structural, signaling, and protective lipids

- **Energy-storing lipids:** Lipids like triglycerides store large amounts of energy for later use.
- **Structural lipids:** lipids such as phospholipids and chloestrol form the structure of cell membrane.
- **Signaling lipids:** Some lipids act as hormones or signaling molecules, helping in communication between cells. For example; Eicosanoids.
- **Protective lipids:** Lipids provide insulation and protection to organs and help maintain body temperature.

Classification of lipids on the basis of Physical Characteristics: Lipids can be classified based on their degree of saturation and physical properties.

- **Saturated Glycerides:** Fatty acids that contain only single bonds between carbon atoms are called saturated glycerides. They exit as solids at room temperature. Example; butter, cheese, lard etc.
- **Unstaturated Glycerides:** Fatty acids that contain at least one carbon-carbon double bond are called unsaturated glycerides. They exist in liquid state at room temperature. Oils are an example.

Essential Lipids: Lipids that are not produced by the body and enter the body through food are known as essential lipids. Polyunsaturated fatty acids (PFA) are the most important lipids and are found in the form of Polyunsaturated fats (Omega-6 and Omeg-3 fats). These fats are essential for hormone synthesis, cell membrane structure, brain and vision health, and can help lower blood chloestrol levels.

Non-Essential Lipids: Monounsaturated fats are not required in the diet because the body can synthesize them from amino acids. However, they reduce the risk of cardiovascular disease. Non-essential lipids are present in olive oil, peanuts and avocado.

Nucleic Acids

Nucleic acids are naturally occuring biomolecules that acts as the primary information-carrying molecules in cells. They store, transmit, and help express genetic information required for growth and functioning of living organisms.

Types of nucleic acids: There are two types of nucleic acids: Deoxyribonucleic acid and Ribonucleic acid. DNA mainly stores genetic information, while RNA helps in protein synthesis.

Structural Components of DNA and RNA: DNA and RNA are polymeric molecules made up of repeating units called nucleotides. The nucleotides differ mainly in the nitrogeneous bases attached to carbon 1 of the pentose sugar.

- **Components of Nucleotide:** Each nucleotide consits of three components.
  1. **Pentose Sugar:** A five-carbon sugar. In RNA, it is ribose, while in DNA it is deoxyribose, the $-OH$ at carbon 2 is replaced by hydrogen.
  2. **Nitrogeneous Base:** DNA contains four bases, Adnine (A), Thymine (T), Cytosine (C), and Guanine (G). In RNA, thymine is replaced by uracil (U). Adnine, and Guanine are purines (doubl-ring base), while cytosine, Thymine, and Uracil are pyrimidines (single-ring bases).
  3. **Phosphate Unit:** Attached to carbon-5 of the sugar in both RNA and DNA.

Difference between RNA and DNA: RNA contains ribose sugar, while DNA contains deoxyribose sugar. DNA contains thymine, where as RNA contains uracil instead of thymine. DNA is double stranded, while RNA is generally single-stranded, although it may fold back on itself. DNA is mainly found in the nucleus, while RNA is found in both nucleus and cytoplasm.

Structure of DNA: DNA has a double helix structure, discovered by J. Watson and Francis Crick in 1953, for which they received the 1962 Nobel Prize. It consits of two antiparallel strands twisted around each other. The strands are held together by hydrogen bonds between complementary bases pairs (A pairs with T, and C pairs with G) The sequence of these base pairs forms the genetic code, which contains instructions for building proteins and controlling body functions. The specific part of DNA that carries hereditary information is called a gene. DNA is also self-replicating meaning it copies itself before cell division so that each daughter cell

recieves the same genetic information.
Structure of RNA: RNA is usually single-stranded and is formed from DNA to carry genetic information for protein synthesis. The DNA first copies its code into messenger RNA (mRNA). This mRNA carries the information to the cytoplasm, where proteins are synthesized. Other types of RNA include, transfer RNA (brings amino acids) and Ribosomal RNA (helps form ribosomes). Together, they help convert genetic code into a polypeptide chain, which is later processesd into a protein.