Biomolecules:short notes for revision

Biomolecules

The branch of chemistry that deals with the molecules involved in living system, is called **Biochemistry**. Carbohydrates, proteins, vitamins and nucleic acids are some of the major components of our body. These are collectively called **Biomolecules**.

[TOPIC 1] Carbohydrates

Carbohydrates are optically active polyhydroxy aldehydes or polyhydroxy ketones or substances that will yield these types of compounds on hydrolysis.

1.1 Classification of Carbohydrates

Carbohydrates are classified as monosaccharides, oligosaccharides and polysaccharides on the basis of their behaviour on hydrolysis.

(*i*) **Monosaccharides** These cannot be hydrolysed further to give simpler unit of polyhydroxy aldehyde or ketone, e.g. glucose, fructose.

(*ii*) **Oligosaccharides** These yield two to ten monosaccharide units on hydrolysis. They are further classified as di, tri, tetra saccharides etc., depending upon the number of monosaccharides they provide on hydrolysis.

(*iii*) **Polysaccharides** They yield a large number of monosaccharide units on hydrolysis, e.g. starch, cellulose, glycogen.

All the monosaccharides and disaccharides are sweet in taste, so called sugars. All monosaccharides and disaccharides (except sucrose) reduces Fehling's solution or Tollen's reagent hence, are called reducing sugars. In these sugars, aldehydic and ketonic groups are free. If the reducing groups, i.e. aldehydic or ketonic groups are bonded, these are called non-reducing sugars, e.g. sucrose. These sugars do not reduces Tollen's or Fehling's solution.

All carbohydrates are optically active as they contain one or more asymmetric (i.e. chiral) carbon atom.

1.2 Monosaccharides

The two important monosaccharides are glucose and fructose.

Glucose

Glucose occurs freely as well as in the combined form in nature. It can be prepared

(*i*) From sucrose (cane sugar)

$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{H^+} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Fructose}}{C_6H_{12}O_6}$$

(*ii*) From starch

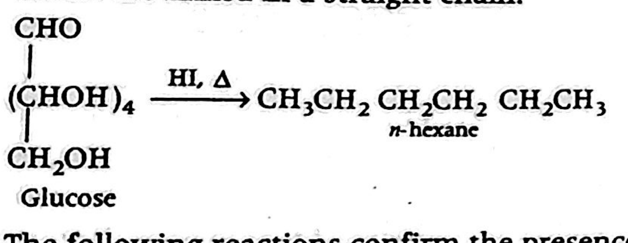
$$\underset{\text{Starch or cellulose}}{(C_6H_{10}O_5)_n} + nH_2O \xrightarrow[393K;\ 2\text{-}3\ atm]{H^+} \underset{\text{Glucose}}{nC_6H_{12}O_6}$$

Linear Structure of Glucose

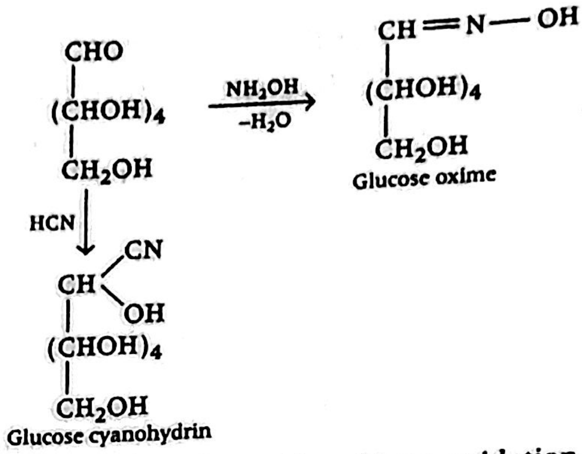
Glucose was assigned the structure $\left(\begin{array}{l} CHO \\ | \\ (CHOH)_4 \\ | \\ CH_2OH \end{array}\right)$ on the basis of following evidences:

(*i*) Its molecular formula was found to be $C_6H_{12}O_6$.

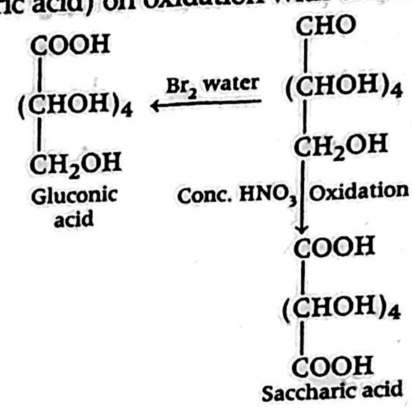
(*ii*) On prolonged heating with HI, it forms *n*-hexane, suggesting that all the six carbon atoms are linked in a straight chain.



(*iii*) The following reactions confirm the presence of carbonyl group $\left(>C=O\right)$ in glucose.

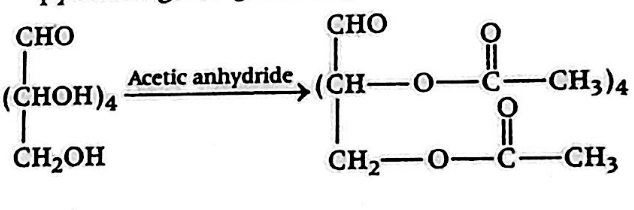


(*iv*) Glucose forms gluconic acid on oxidation with bromine water and saccharic acid (or glucaric acid) on oxidation with conc. HNO_3.



Formation of gluconic acid indicates that carbonyl group is an aldehydic group. Similarly, formation of saccharic acid indicates the presence of a primary alcoholic (—OH) group in glucose.

(*v*) Glucose on acetylation with acetic anhydride $(CH_3CO_2)O$ in the presence of pyridine gives glucose pentaacetate.



Facts that cannot be explained by open chain structure of glucose

Open structure of glucose can explain most of the properties of glucose but cannot explain the following properties.

(*i*) Glucose does not

(*a*) form additive products with $NaHSO_3$.

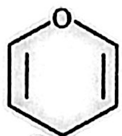
(*b*) form oxime of glucose pentaacetate.

(*c*) react with Schiff's reagent.

(*ii*) Glucose exists in two stereoisomeric forms, i.e. α-D-glucose and β -D-glucose. Both differs in the orientation of —OH group at C_1-atom.

Cyclic Structure of Glucose

Glucose exists as a cyclic hemiacetal structure in which —OH groups may add to —CHO group and forms a six-membered ring in which —OH at C-5 is involved in ring formation.

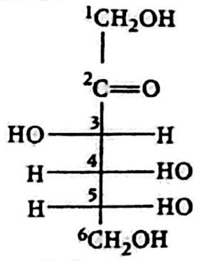


Pyran

The six membered cyclic structure of glucose is called **pyranose** structure in anology with pyran, a cyclic compound with one oxygen atom and five carbon atoms in ring.

Fructose

Fructose is an important ketohexose which is obtained along with glucose by the hydrolysis of disaccharides like sucrose. It is also known as fruit sugar. It is a laevorotatory compound and is appropriately written as



D-fructose

It exist as five membered ring and named as furanose.

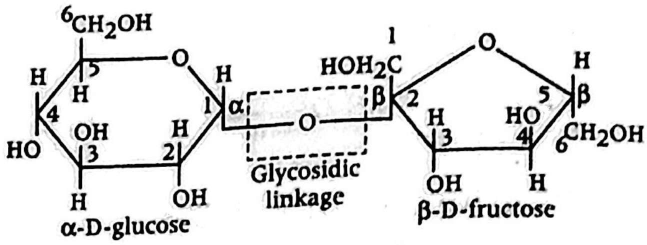
Sucrose on hydrolysis with acids or enzyme gives equimolar mixture of D (+) - glucose and D (−) - fructose.

$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{HCl} \underset{\text{D (+) -glucose}}{C_6H_{12}O_6} + \underset{\text{D (−) -fructose}}{C_6H_{12}O_6}$$

1.3 Disaccharides

Disaccharides on hydrolysis with dilute acids or enzymes give two molecules of monosaccharides. These molecules may be either same or different monosaccharides.

The two monosaccharide units are joined together by an oxide linkage formed by the loss of a water molecule. Such a linkage between two monosaccharide units through oxygen atom is called **glycosidic linkage**. e.g.



Haworth structure of sucrose

Hydrolysis of sucrose brings about a change in the sign of rotation from dextro (+) to laevo (−) and the product is named as **invert sugar**.

Maltose is composed of two α-D-glucose units and it is a reducing sugar.

Lactose is known as milk sugar because it is found in milk and composed of β-D-galactose and β-D-glucose. It is known as reducing sugar.

1.4 Polysaccharides

Polysaccharides are formed when large number of monosaccharides molecules join together with elimination of water molecules.

Starch is the main storage of polysaccharide of plants, it is a polymer of α-glucose. It consists of two components: **amylose** (water soluble) and **amylopectin** (water insoluble). Amylose is a long unbranched chain with 200-1000 α-D (+) - glucose units held by C_1 - C_4 glycosidic linkage. Amylopectin is a branched chain polymer of α-D-glucose units in which chain is formed by C_1 - C_4 glycosidic linkage whereas branching occurs by C_1 - C_6 glycosidic linkage.

Cellulose is a straight chain polysaccharide polymer of β-D-glucose units and found in cell wall of plant cells.

Glycogen is a polysaccharide carbohydrate which is stored in animal body. It is also called **animal starch** as its structure is similar to amylopectin and is rather more highly branched.

[TOPIC 2] Proteins, Vitamins and Nucleic Acids

2.1 Amino Acids

Amino acids contains amino (—NH_2) and carboxyl (—COOH) functional groups.

Classification of Amino Acids

(*i*) Depending upon the relative position of amino group with respect to carboxyl group, the amino acid can be classified as α, β, γ and δ and so on.

(*ii*) Amino acids are classified as acidic, basic or neutral depending upon the relative number of amino and carboxyl groups in their molecule. Equal number of amino and carboxyl groups makes it neutral, more number of amino than carboxyl groups makes it basic and more carboxyl groups as compared to amino groups makes it acidic.

(*iii*) Amino acids that can be synthesised in the body are known as **non-essential amino acids**. e.g. Glycine, alanine. On the other hand, those which cannot be synthesised in the body and must be obtained through diet are called **essential amino acids**, e.g. valine, leucine.

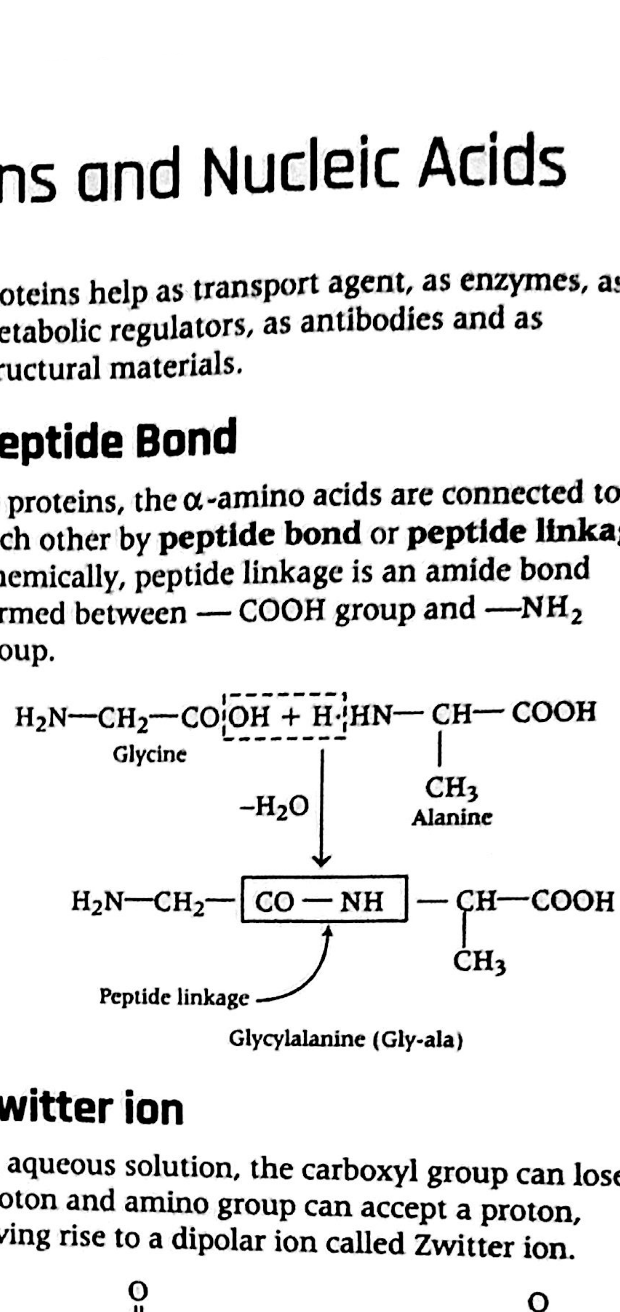
2.2 Proteins

Proteins are essential for the growth of our body. Chemically, **proteins** are condensation polymers in which the monomeric units are α-amino acids. These are the building blocks of proteins.

Proteins help as transport agent, as enzymes, as metabolic regulators, as antibodies and as structural materials.

Peptide Bond

In proteins, the α-amino acids are connected to each other by **peptide bond** or **peptide linkage**. Chemically, peptide linkage is an amide bond formed between — COOH group and —NH_2 group.



Glycylalanine (Gly-ala)

Zwitter ion

In aqueous solution, the carboxyl group can lose a proton and amino group can accept a proton, giving rise to a dipolar ion called Zwitter ion.

Structure of Proteins

Structure of proteins can be studied at four levels. Primary, secondary, tertiary and quaternary.

(i) The sequence in which the various amino acids are linked to one another in a protein molecule is called its **primary structure.**

(ii) **Secondary structure** refers to the shape in which a long polypeptide chain exist. They are found to exist in two different types of structures which are α-helix and β-pleated sheet.

(iii) The **tertiary structure** of proteins represents overall folding of the polypeptide chains. The main forces which stabilises 2° and 3° structure of proteins are hydrogen bonds, disulphide linkages, van der Waals' forces and electrostatic forces of attraction.

(iv) Although many proteins exist as a single polypeptide chain, but some of the proteins are composed of two or more polypeptide chains called subunits. The spatial arrangement of these subunits with respect to each other is known as **quaternary structure.**

(v) On the basis of molecular structure, proteins are classified as fibrous and globular proteins.

(a) **Fibrous proteins** When the polypeptide chains run parallel and are held together by hydrogen and disulphide bonds, a fibre like structure is formed. Such proteins are insoluble in water. e.g. keratin, myosin.

(b) **Globular proteins** When the chains of polypeptides coil around to give a spherical shape, the protein is called a globular protein. Such proteins are usually soluble in water. e.g. albumin, insulin.

Denaturation of Proteins

Due to temperature or pH change, secondary and tertiary structures are destroyed but primary structure remains intact. This process is called **denaturation of proteins.**

2.3 Enzymes

Enzymes are the biocatalysts which are needed to catalyse biochemical reactions. Almost all the enzymes are globular proteins. Enzymes are very specific for a particular substrate and reaction.

2.4 Vitamins

- **Vitamins** are required in small amounts for the growth, life and health of human beings and animals.
- Vitamins can be water soluble (vitamin B and C) or fat soluble (Vitamin A, D, E and K), depending upon their solubility. Water soluble vitamins must be supplied regularly in diet because they are readily excreted in urine and cannot be stored (except B_{12}) in our body.
- Deficiency of vitamins in diet may cause various types of deficiency diseases.

Table 1.1 Some important vitamins, their sources and their deficiency diseases

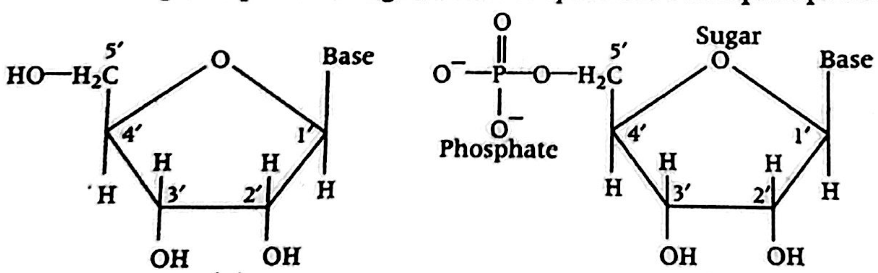
Name of vitamins	Sources	Deficiency diseases
Vitamin A	Fish liver oil, carrots, butter and milk	Xerophthalmia, night blindness
Vitamin B_1	Milk, yeast, green vegetables and cereals	Beri-beri (loss of appetite)
Vitamin B_2	Milk, egg white, liver	Cheilosis, digestive disorders
Vitamin B_6	Yeast, milk, cereals	Convulsions
Vitamin B_{12}	Meat, fish, egg and curd	Pernicious anaemia
Vitamin C	Citrus fruits, amla and green leafy vegetables	Scurvy
Vitamin D	Exposure to sunlight, fish	Rickets and osteomalacia
Vitamin E	Vegetable oils	Muscular weakness and increased fragility of RBCs
Vitamin K	Green leafy vegetables	Delayed blood clotting

2.5 Hormones

Hormones are the chemical substances, produced by endocrine glands in the body and are released directly in blood stream. On the basis of chemical constitution hormones can be divided into two classes, i.e. steroid and non-steroid hormones.

2.6 Nucleic Acids

1. Constituents of nucleus of a cell are responsible for heredity or inherent characters. The proteins and nucleic acids are the main components of the nucleus.
   Nucleic acids are biomolecules which are found in nuclei of all living cells. DNA (Deoxyribonucleic acid) and RNA (Ribonucleic acid) are two main types of nucleic acids. These are polynucleotides as they are long chain polymers of nucleotides.
2. Complete hydrolysis of DNA (or RNA) yields a pentose sugar, phosphoric acid and nitrogen containing heterocyclic compounds called bases.
3. DNA has four bases: adenine (A), guanine (G), cytosine (C) and thymine (T), RNA has adenine, guanine, cytosine and uracil (U).
4. A unit formed by the attachment of a base to 1′ position of sugar is called **nucleoside** (fig. (a)). When nucleoside is linked to phosphoric acid at 5′ position of sugar moeity, we get a **nucleotide** (fig. (b)). Thus, nucleotide is made up of a pentose sugar, a heterocyclic base and phosphoric acid unit.



(a) (b)

5. James Watson and Francis Crick gave a double strand helix structure of DNA. Two nucleic acids chains are bound about each other and held together by hydrogen bonds between pair of bases. The two strands are complementary to each other.

6. RNA has a single stranded helical structure. RNA molecules are of three types and they perform different functions. They are named as messenger RNA (*m*-RNA), ribosomal RNA (*r*-RNA) and transfer RNA (*t*-RNA).
7. DNA (Deoxyribonucleic acid) transmits the hereditary characters from one generation to another.
8. RNA (Ribonucleic acid) synthesises protein in the cell.