Chapter_14

Biomolecules

1. **Carbohydrates** may be defined as optically active polyhydroxy aldehydes or ketones or the compounds which produce such units on hydrolysis.

2. **Classification of Carbohydrates**
   - Simple carbohydrates which cannot be hydrolysed further to simpler carbohydrates are called **monosaccharides**. e.g. glucose, fructose, ribose, etc.
   - Carbohydrates which give 2-10 monosaccharide units on hydrolysis are called **oligosaccharides** (e.g. maltose, lactose) and that give a large number of monosaccharide units are called **polysaccharides** e.g. starch, cellulose, etc.
   - Carbohydrates in which ketonic or aldehydic groups are free and are capable of reducing Fehling's solution or Tollen's reagent are known as **reducing sugars**. e.g. all monosaccharides and disaccharides except sucrose.
   - Carbohydrates in which aldehydic or ketonic group are bonded and do not reduce Fehling's solution or Tollen's reagent are called **non-reducing sugars**, e.g. sucrose.

3. **Glucose** It occurs freely in nature as well as in the combined form. It can be prepared as follows :
   - From sucrose,

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

   - From starch,

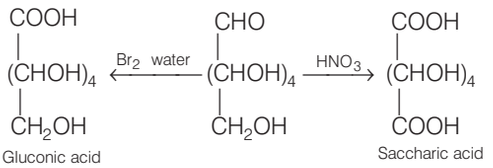
$$(C_6H_{10}O_5)_n + nH_2O \xrightarrow[393K,\ 2\text{-}3\ atm]{H^+} n\,\underset{\text{Glucose}}{C_6H_{12}O_6}$$

4. **Structures of Glucose**

   On the basis of following evidences, the structure of glucose is assigned :
   - On prolonged heating with HI, glucose gives *n*-hexane which suggest that all the six carbon atoms in glucose are linked linearly.

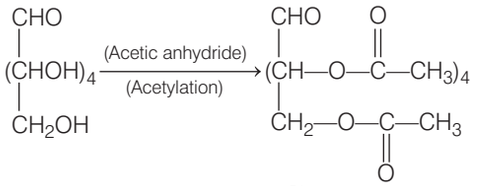
$$HOCH_2(CHOH)_4CHO + HI \xrightarrow{\Delta} \underset{n\text{-hexane}}{CH_3(CH_2)_4CH_3}$$

   - When oxidised with bromine water, glucose gives gluconic acid and with HNO_3, it gives saccharic acid.



Gluconic acid — Saccharic acid

   Acetylation of glucose with acetic anhydride gives glucose penta-acetate which confirms the presence of five —OH groups. Since, it exists as a stable compound, five —OH groups should be attached to different carbon atoms.



Glucose penta-acetate
(Stable compound)

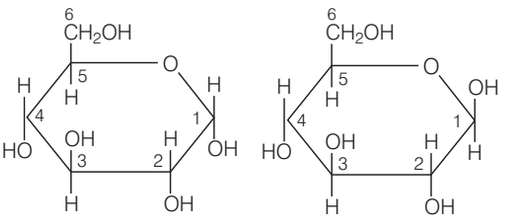
5. Open chain structure of D-glucose could not explain the following reactions.
   (i) Despite having the aldehyde group, glucose does not give Schiff's test and 2,4-DNP test.
   (ii) It does not form the hydrogen sulphite addition product with $NaHSO_4$.
   (iii) The penta-acetate of glucose does not react with hydroxyl amine showing the absence of free —CHO group.

6. The two monosaccharides are joined together by [—O—] linkage formed by loss of a water molecule. Such a linkage is known as **glycosidic linkage**.

7. **Mutarotation** is the spontaneous change in the specific rotation of an optically active compound towards an equilibrium value.

8. When two cyclic forms of a carbohydrate differ in configuration of hydroxyl groups at C-1, they are called **anomers** and represented as α and β-form.

9. The six membered cyclic structure of glucose is known as pyranose structure (α or β).



10. Although, sucrose is *dextro*-rotatory but after hydrolysis it gives *dextro*-rotatory glucose and *laevo*-rotatory fructose (the mixture is *laevo*-rotatory because *laevo*-rotation is more than *dextro*-rotation). Since, hydrolysis of sucrose brings about a change in the sign of rotation i.e. from *dextro* (+) to *laevo* (–) hence, the product is known as **invert sugar**.

11. **Maltose** is composed of two α-D-glucose units in which C-1 of one glucose unit (I) is linked to C-4 of another glucose unit (II). The free aldehyde group can be produced at C-1 of second glucose solution and it shows reducing properties.

12. **Lactose** is composed of β-D-galactose and β -D-glucose.

13. **Starch** consists of two components namely **amylose** and **amylopectin**.
   - Amylose is soluble in water and constitutes 15-20% of starch while, amylopectin is insoluble in water and constitutes about 80-85% of starch. In both amylose and amylopectin, the D-glucose units are linked through α-glycosidic linkages.
   - Chemically, amylose is a long unbranched chain with 200-1000 α-D(+)-glucose units that are held together by C_1—C_4 glycosidic linkage. While amylopectin is a highly branched chain polymer of α-D-glucose units in which glycosidic linkage is present between C_1—C_4 atoms, whereas branching occurs through C_1—C_6 glycosidic linkage.

14. The compounds containing both amino ($—NH_2$) and carboxyl ($—COOH$) functional groups in the same molecule are called **amino acids**,
e.g. $R—\underset{\underset{COOH}{|}}{CH}—NH_2$.

- **Amino acids** which are synthesised by the body are called **non-essential**. On the other hand, those which cannot be synthesised in the human body and are supplied in the form of diet because they are required for proper health and growth are called **essential amino acids**.
- Amino acids in which carboxyl group in aqueous solution loses a proton while, amino group accepts a proton results formation of ***Zwitter* ion**.

$$H_2N—\underset{\underset{R}{|}}{CH}—COOH \rightleftharpoons H_3\overset{+}{N}—\underset{\underset{R}{|}}{CH}—COO^-$$

Zwitter ion

- In *Zwitter* ionic form, α-amino acids show amphoteric behaviour, as they react with acids and bases both.

15. The word **protein** is derived from Greek word, 'proteios' meaning 'primary' or of prime importance. Chemically, protiens are the polymers in which the monomeric units are the α-amino acids.

They are connected to each other by —CO —NH— bond which is called the **peptide bond** or peptide linkage.

- *On the basis of molecular shape, proteins are classified into following two types :*

(a) **Fibrous proteins** have thread or fibre, like structures in which polypeptide chains run parallel and held together by hydrogen and disulphide bonds e.g. keratin, myosin etc.

(b) **Globular proteins** have spherical shape in which the chains of polypeptide coil around, e.g. insulin, albumins etc.

- On the basis of structure and shape, proteins can be studied on the following four different levels.

(a) **Primary structure** is the specific sequence in which various amino acids are linked with each other to form a polypeptide.

(b) **Secondary structure** is the conformation which the polypeptide chains assume as a result of hydrogen bonding between $—\overset{\overset{O}{||}}{C}—$ and —NH— groups of the peptide bond. They exist in two different structures *which are as follows:*

(i) In α-**helix**, polypeptide chain forms all possible hydrogen bonds between —NH group of each amino acid and $>C{=}O$ of an adjacent turn leading to twisting of polypeptide chain into a right handed helix.

(ii) In β-**structure** or β-**pleated sheet** all peptide chains are stretched out to maximum extension and they laid side by side which are held together by intermolecular hydrogen bonds.

(c) **Tertiary structure** is the further folding of the secondary structure of proteins :

(d) **Quaternary structure** some proteins are composed of two or more polypeptide chains called subunits. The spactial arrangement arrangement of these subunits with respect to each other is known as quaternary structure.

16. When there is a physical change (like change in temperature) or chemical change (like change in pH) in the native form of protein, the hydrogen bond gets disturbed. As a result, globules unfold and helices get uncoiled and protein loses its biological activity, known as **denaturation of protein**.

During denaturation 2° and 3° structures destroyed but 1° structure remains intact,
e.g. coagulation of egg white on boiling and curdling of milk.

17. **Biological catalysts** are known as enzymes. They are made up of proteins. Enzymes are highly specific for a particular reaction and for a particular substrate, e.g. invertase, zymase etc.

18. **Vitamins** are organic compounds required in the diet in small amounts to perform specific biological functions for normal maintenance of growth and health.

- These are classified as **fat soluble** (A, D, E and K) and **water soluble** (B and C).
- Deficiency diseases of vitamin A, B_6, B_{12}, C, D and E are xerophthalmia, convulsion, pernicious anaemia, scurvy, rickets and infertility, respectively.
- Because vitamin B and C are soluble in water, they are excreted readily in urine and hence, cannot be stored in the body.

19. **Nucleic acids** are of two types: deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).

- **DNA** is composed of deoxyribose sugar; adenine and guanine (i.e purine base) thymine and cytosine (i.e pyrimidine base) and phosphoric acid. Its structural unit is called **nucleotide**.
  Nucleoside = sugar + base
  Nucleotide = phosphate + sugar + base
  ∴ Nucleotide = nucleoside + phosphate
- **James Watson** and **Francis Crick** proposed a double stranded helical structure of DNA.
- The process by which a DNA molecule produces two identical molecules of itself in the nucleus of the cell is called **replication**.
- **RNA** is composed of ribose sugar, adenine and guanine (purine base) uracil and cytosine (pyrimidine base) and phosphoric acid. There are three types of RNA.
  (i) Ribosomal RNA (*r*-RNA)
  (ii) Messenger RNA (*m*-RNA)
  (iii) Transfer RNA (*t*-RNA).

20. **Hormones** are the chemical substances, produced by the endocrine glands in the body and are release directly in blood stream. On the basis of constitution, they are of two types (steroid and non-steroid).