Chapter: Biomolecules

Top Concepts:

1. **Definition of carbohydrates:** Polyhydroxy aldehydes or polyhydroxy ketones or compounds which give these on hydrolysis.

2. **Classification of carbohydrates:**
   a. Monosaccharides
      - Simplest carbohydrates
      - Cannot be hydrolysed into simpler compounds
      - E.g. Glucose, mannose
   b. Oligosaccharides
      - Carbohydrates which give 2 to 10 monosaccharide units on hydrolysis
      - E.g. Sucrose, Lactose, Maltose
   c. Polysaccharides
      - Carbohydrates which on hydrolysis give large number of monosaccharide units.
      - E.g. Cellulose, starch

3. **Anomers:** Such pairs of optical isomers which differ in configuration only around C₁ atom are called anomers. E.g. α-D-glucopyranose and β-D-glucopyranose

4. **Epimers:** Such pairs of optical isomers which differ in configuration around any other C atom other than C₁ atom are called epimers. E.g. D-glucose and D-mannose are C₂ epimers.

\[ \text{CHO} \quad \text{CHO} \\
\text{HO} \quad \text{HO} \\
\text{H} \quad \text{H} \\
\text{CH}_2\text{OH} \quad \text{CH}_2\text{OH} \]

D - Glucose  \hspace{1cm}  D - Mannose
5. Preparation of glucose (also called dextrose, grape sugar):

a. From sucrose:

\[ C_{12}H_{22}O_{11} + H_2O \xrightarrow{H^+} C_6H_{12}O_6 + C_6H_{12}O_6 \]

Sucrose → Glucose + Fructose

b. From starch:

\[ \left( C_{6\times10^{n}} \right)_n + nH_2O \xrightarrow{H^+} 393K;2-3\text{ atm} \rightarrow nC_6H_{12}O_6 \]

Sucrose or cellulose → Glucose

6. Structure elucidation of glucose:

- Shows the presence of 6 carbons linked linearly

- Shows the presence of –CHO group (open chain structure)

- Shows the presence of –CHO group (open chain structure)
HNO$_3$ + Glucose (CHOH)$\rightarrow$ (COOH)$_4$ + Cu$_2$O + 3H$_2$O

shows that glucose is a reducing sugar
(Open chain structure)

HNO$_3$ + Glucose (CHOH)$\rightarrow$ COONa + (CHOH)$_4$ + Cu$_2$O + 3H$_2$O

shows that glucose is a reducing sugar
(Open chain structure)

Glucose $\xrightarrow{\text{HNO}_3}$ (CHOH)$_4$

This indicates the presence of primary alcoholic group in glucose
Saccharic acid

Glucose $\xrightarrow{5\text{CH}_2\text{COCH}_3}$ $\xrightarrow{\text{ZnCl}_2}$ (CHOH)$_4$ + 5 CH$_3$COOH

Shows the presence of 5 – OH groups
Penta acetyl glucose

Unusual reactions of glucose: (Presence of ring structure)
Glucose does not give Schiff’s test and does not react with sodium bisulphite and NH$_3$.

Pentaacetyl glucose does not react with hydroxyl amine. This shows the absence of –CHO group and hence the presence of ring structure.

7. Cyclic structure of glucose:
8. Cyclic structure of fructose:

\[
\begin{align*}
\text{HO} & - \text{C}^2\text{CH}_2\text{OH} \\
\text{HO} & - \text{C}^3\text{H} \\
\text{H} & - \text{C}^4\text{OH} \\
\text{H} & - \text{C}^5\text{OH} \\
\text{C}^6\text{H}_2\text{OH} \\
\end{align*}
\]

\[\beta - D - (-) - \text{Fructofuranose}\]

\[
\begin{align*}
\text{HOH}_2 & - \text{C}^2\text{OH} \\
\text{HO} & - \text{C}^3\text{H} \\
\text{H} & - \text{C}^4\text{OH} \\
\text{H} & - \text{C}^5\text{OH} \\
\text{C}^6\text{H}_2\text{OH} \\
\end{align*}
\]

\[\alpha - D - (-) - \text{Fructofuranose}\]

9. Reaction of Glucose with Phenyl hydrazine: Formation of Osazone:

\[
\begin{align*}
\text{CHO} & \xrightarrow{\text{C}_6\text{H}_5\text{NNH}_2} \text{C}_6\text{H}_5\text{NHNH}_2 \\
\text{(CHOH)}_4 & \xrightarrow{\text{H}_2\text{O}} \text{(CHOH)}_3\text{CH}_2\text{OH} \\
\text{(CHOH)}_3\text{CH}_2\text{OH} & \xrightarrow{\text{C}_6\text{H}_5\text{NNH}_2} \text{C}_6\text{H}_5\text{NHNH}_2
\end{align*}
\]

Glucose and fructose gives the same osazone because the reaction takes place at C_1 and C_2 only.
10. **Lobry De Bruyn Van Ekenstein Rearrangement:**

\[
\begin{array}{c}
\text{CHO} \\
H - C - OH \\
(CHOH)_3 \\
CH_2OH \\
D-Glucose
\end{array}
\quad
\begin{array}{c}
\text{CH}_2\text{OH} \\
\text{CHO} \\
\text{NaOH} \\
\text{CHO} \\
\text{D-Fructose}
\end{array}
\quad
\begin{array}{c}
\text{CHO} \\
\text{NaOH} \\
\text{CHO} \\
\text{CHO} \\
\text{D-Mannose}
\end{array}
\quad
\begin{array}{c}
\text{H - C - OH} \\
\text{C - OH} \\
\text{CHO} \\
\text{CH}_2\text{OH}
\end{array}
\]

- Same results are obtained when fructose or mannose is reacted with an alkali.
- It is because of form of ene-diol intermediate.
- It explains why fructose acts as a reducing sugar.

11. **Mutarotation:** The spontaneous change in specific rotation of an optically active compound is called mutarotation. E.g. \(\alpha\)-D-glucose (m.p. = 146°C) with specific rotation \([\alpha]_D = +111^\circ\) and \(\beta\)-D-glucose (m.p. = 150°C) with specific rotation \([\alpha]_D = +19.2^\circ\) When either form is dissolved in water & allowed to stand, the specific rotation of the solution changes slowly and reaches or constant value of +52.5°.

\[
\begin{align*}
\alpha\text{-D-glucose} & \quad \text{open chain form} & \quad \beta\text{-D-glucose} \\
\text{sp. rot}^n = 111^\circ & \quad \text{sp. rot}^n = +52.5^\circ & \quad \text{sp. rot}^n = +19^\circ
\end{align*}
\]

12. **Haworth projection:** Representation for ring structure:

6 membered ring is called pyranose ring.

5 membered ring is called furanose ring.

How to write the projection: Groups projected to the right in the Fischer projection are written below the plane and those to the left are written above the plane.

Haworth projection of Glucose:
Haworth projection for Fructose:

α - D - (−) - Fructofuranose

β - D - (−) - Fructofuranose
13. Glycosidic linkage: The oxide linkage formed by the loss of a water molecule when two monosaccharides are joined together through oxygen atom is called glycosidic linkage.

14. Sucrose (invert sugar): Sucrose is dextrorotatory but on hydrolysis it gives dextrorotatory & laevorotatory and the mixture is laevorotatory.

\[
\text{Sucrose} + \text{H}_2\text{O} \xrightarrow{\text{H}^+} \text{D-glucose} + \text{D-fructose}
\]

Sucrose is a non-reducing sugar because the two monosaccharide units are held together by a glycosidic linkage between C1 of α-glucose and C2 of β-fructose. Since the reducing groups of glucose and fructose are involved in glycosidic bond formation, sucrose is a non-reducing sugar.

Haworth Projection of Sucrose:
Maltose: Maltose $\xrightarrow{H_2O} \text{Glucose} + \text{Glucose}$

Haworth projection of maltose:
16. Lactose (Milk sugar): It is composed of β-D-galactose and β-D-glucose. The linkage is between C1 of galactose and C4 of glucose. Hence it is also a reducing sugar.

\[
\text{Lactose } \xrightarrow{\text{H}_2\text{O}} \text{ Glucose } + \text{ Glucose}
\]

\[
\begin{array}{c}
\text{C}4 \beta \\
\text{C}1 \beta
\end{array}
\]

Haworth projection of lactose:
17. **Starch:** It is a polymer of $\alpha$-glucose and consists of two components — Amylose and Amylopectin.

<table>
<thead>
<tr>
<th>Amylose</th>
<th>Amylopectin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water soluble component</td>
<td>Water insoluble component</td>
</tr>
<tr>
<td>It is a long unbranched chain polymer</td>
<td>It is a branched chain polymer</td>
</tr>
<tr>
<td>Contains 200 – 1000 $\alpha$-D-(+)-glucose units held by $\alpha$ - glycosidic linkages involving C1 – C4 glycosidic linkage</td>
<td>It is a branched chain polymer of $\alpha$-D-glucose units in which chain is formed by C1–C4 glycosidic linkage whereas branching occurs by C1–C6 glycosidic linkage.</td>
</tr>
<tr>
<td>Constitutes about 15-20% of starch</td>
<td>Constitutes about 80- 85% of starch</td>
</tr>
</tbody>
</table>

18. **Amino acids:**

$$\text{R} - \text{CH} - \text{COOH} \quad \text{NH}_2$$

Where R – Any side chain

Most naturally occurring amino acids have L – Config.

19. **Essential amino acids:** Those amino acids which cannot be synthesised in the body and must be obtained through diet, are known as essential amino acids. Example: Valine, Leucine

20. **Non-essential amino acids:** The amino acids, which can be synthesised in the body, are known as non-essential amino acids. Example: Glycine, Alanine
21. Zwitter ion form of amino acids: Amino acids behave like salts rather than simple amines or carboxylic acids. This behaviour is due to the presence of both acidic (carboxyl group) and basic (amino group) groups in the same molecule. In aqueous solution, the carboxyl group can lose a proton and amino group can accept a proton, giving rise to a dipolar ion known as zwitter ion. This is neutral but contains both positive and negative charges. In zwitter ionic form, amino acids show amphoteric behaviour as they react both with acids and bases.

\[ \text{R} - \text{CH} - \text{COOH} + \text{OH}^- \rightarrow \text{R} - \text{CH} - \text{COO}^- + \text{H}_2\text{O} \]

zwitterion

22. Isoelectronic point: The pH at which the dipolar ion exists as neutral ion and does not migrate to either electrode cathode or anode is called isoelectronic point.

23. Proteins: Proteins are the polymers of \( \alpha \)-amino acids and they are connected to each other by peptide bond or peptide linkage. A polypeptide with more than hundred amino acid residues, having molecular mass higher than 10,000u is called a protein.

24. Peptide linkage: Peptide linkage is an amide linkage formed by condensation reaction between \(-\text{COOH}\) group of one amino acid and \(-\text{NH}_2\) group of another amino acid.

\[ \text{H}_2\text{N} - \text{CH} - \text{COOH} + \text{H}_2\text{N} - \text{CH} - \text{COOH} \rightarrow \text{H}_2\text{N} - \text{CH} - \text{C} - \text{NH} - \text{CH} - \text{COOH} \]

25. Primary structure of proteins: The sequence of amino acids is said to be the primary structure of a protein.

26. Secondary structure of proteins: It refers to the shape in which long polypeptide chain can exist. Two different types of structures:

a. \( \alpha \) – Helix:
   
   - Given by Linus Pauling in 1951
   - It exists when R- group is large.
   - Right handed screw with the NH group of each amino acid residue H – bonded to – C = O of adjacent turn of the helix.
• Also known as 3.6,13 helix since each turn of the helix has approximately 3.6 amino acids and a 13 – membered ring is formed by H – bonding.
• C = O and N – H group of the peptide bonds are trans to each other.
• Ramachandran angles (Φ and Ψ) - Φ angle which Cα makes with N – H and Ψ angle which Cα makes with C = O.

b. β – pleated sheet:
• Exists when R group is small.
• In this conformation all peptide chains are stretched out to nearly maximum extension and then laid side by side which are held together by hydrogen bonds.

27. Tertiary structure of proteins: It represents the overall folding of the polypeptide chain i.e., further folding of the 2° structure.

Types of bonding which stabilise the 3° structure –

i. Disulphide bridge (-S – S-)
ii. H – bonding – (C = O ... H – N)
iii. Salt bridge (COO⁻ ... +NH₃)
iv. Hydrophobic interactions
v. van der Waals forces

Two shapes are possible:

<table>
<thead>
<tr>
<th>Fibrous proteins</th>
<th>Globular proteins</th>
</tr>
</thead>
<tbody>
<tr>
<td>When the polypeptide chains run parallel and are held together by hydrogen and disulphide bonds, then fibre– like structure is formed.</td>
<td>This structure results when the chains of polypeptides coil around to give a spherical shape.</td>
</tr>
<tr>
<td>Such proteins are generally insoluble in water</td>
<td>These are usually soluble in water.</td>
</tr>
<tr>
<td>Examples: keratin (present in hair, wool, silk) and myosin (present in muscles), etc</td>
<td>Examples: Insulin and albumins</td>
</tr>
</tbody>
</table>
28. Quaternary structure of proteins: Some of the proteins are composed of two or more polypeptide chains referred to as sub-units. The spatial arrangement of these subunits with respect to each other is known as quaternary structure of proteins.

29. Denaturation of proteins: The loss of biological activity of proteins when a protein in its native form, is subjected to physical change like change in temperature or chemical change like change in pH. This is called denaturation of protein. Example: coagulation of egg white on boiling, curdling of milk

30. Nucleoside: Base + sugar

31. Nucleotide: Base + sugar + phosphate group

32. Nucleic acids (or polynucleotides): Long chain polymers of nucleotides. Nucleotides are joined by phosphodiester linkage between 5’ and 3’ C atoms of a pentose sugar.

33. Two types of nucleic acids:

<table>
<thead>
<tr>
<th>Deoxyribonucleic Acid (DNA)</th>
<th>Ribonucleic Acid (RNA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>It has a double stranded α-helix structure in which two strands are coiled spirally in opposite directions.</td>
<td>It has a single stranded α-helix structure.</td>
</tr>
<tr>
<td>Sugar present is β–D–2-deoxyribose</td>
<td>Sugar present is β–D–ribose</td>
</tr>
<tr>
<td>Bases: Purine bases: Adenine (A) and Guanine (G)</td>
<td>Bases: Purine bases: Adenine (A) and Guanine (G)</td>
</tr>
<tr>
<td>Pyrimidine bases: Thymine (T) and</td>
<td>Pyrimidine bases: Uracil (U) and</td>
</tr>
</tbody>
</table>
cytosine (C)           cytosine (C)
It occurs mainly in the nucleus of the cell.    It occurs mainly in the cytoplasm of the cell.
It is responsible for transmission for heredity character.   It helps in protein synthesis.

34. Double helix structure of DNA:

- It is composed of 2 right handed helical polynucleotide chains coiled spirally in opposite directions around the same central axis.
- Two strands are anti-parallel i.e. their phosphodiester linkage runs in opposite directions.
- Bases are stacked inside the helix in planes ⊥ to the helical axis.
- Two strands are held together by H – bonds (A = T, G = C).
- The two strands are complementary to each other because the hydrogen bonds are formed between specific pairs of bases. Adenine forms hydrogen bonds with thymine whereas cytosine forms hydrogen bonds with guanine.
- Diameter of double helix is 2 nm.
- Double helix repeats at intervals of 3.4 nm. (One complete turn)
- Total amount of purine (A + G) = Total amount of pyrimidine (C + T)

35. Vitamins: Vitamins are organic compounds required in the diet in small amounts to perform specific biological functions for normal maintenance of optimum growth and health of the organism.

36. Classification of vitamins: Vitamins are classified into two groups depending upon their solubility in water or fat.

<table>
<thead>
<tr>
<th>Fat soluble vitamins</th>
<th>Water soluble vitamins</th>
</tr>
</thead>
<tbody>
<tr>
<td>These vitamins are soluble in fat and oils but insoluble in water.</td>
<td>These vitamins are soluble in water.</td>
</tr>
<tr>
<td>They are stored in liver and adipose (fat storing) tissues</td>
<td>Water soluble vitamins must be supplied regularly in diet because they are readily excreted in urine and cannot be stored (except vitamin B12) in our body.</td>
</tr>
<tr>
<td>Example: Vitamin A, D, E and K</td>
<td>Example: Vitamin C, B group vitamins</td>
</tr>
</tbody>
</table>
37. Important vitamins, their sources and their deficiency diseases:

<table>
<thead>
<tr>
<th>Name of vitamin</th>
<th>Source</th>
<th>Deficiency diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin A</td>
<td>Fish liver oil, carrots, butter and milk</td>
<td>e r o p h t h a l m i a (hardening of cornea of eye)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Night blindness</td>
</tr>
<tr>
<td>Vitamin B₁</td>
<td>Yeast, milk, green vegetables and cereals</td>
<td>Beri beri (loss of appetite, retarded growth)</td>
</tr>
<tr>
<td>(Thiamine)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin B₂</td>
<td>Milk, egg white, liver, kidney</td>
<td>Cheilosis (fissuring at corners of mouth and lips), digestive disorders and burning sensation of the skin.</td>
</tr>
<tr>
<td>(Riboflavin)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin B₆</td>
<td>Yeast, milk, egg yolk, cereals and grams</td>
<td>Convulsions</td>
</tr>
<tr>
<td>(Pyridoxine)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin B₁₂</td>
<td>Meat, fish, egg and curd</td>
<td>Pernicious anaemia (RBC deficient in haemoglobin)</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>Citrus fruits, amla and green leafy vegetables</td>
<td>Scurvy (bleeding gums)</td>
</tr>
<tr>
<td>(Ascorbic acid)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin D</td>
<td>Exposure to sunlight, fish and egg yolk</td>
<td>Rickets (bone deformities in children) and osteomalacia (soft bones and joint pain in adults)</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>Vegetable oils like wheat germ oil, sunflower oil, etc.</td>
<td>Increased fragility of RBCs and muscular weakness</td>
</tr>
<tr>
<td>Vitamin K</td>
<td>Green leafy vegetables</td>
<td>Increased blood clotting time</td>
</tr>
</tbody>
</table>