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,

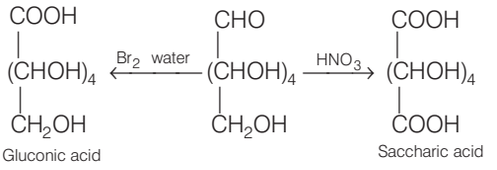
$$(C_6H_{10}O_5)_n + nH_2O \xrightarrow[393K,\ 2\text{-}3\ atm]{H^+} n\,\underset{\text{Glucose}}{C_6H_{12}O_6}$$

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.

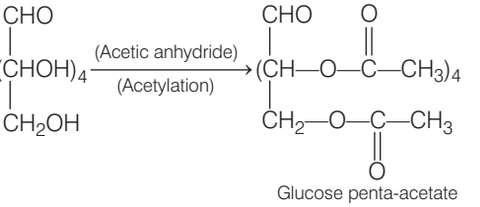
$$HOCH_2(CHOH)_4CHO + HI \xrightarrow{\Delta} \underset{n\text{-hexane}}{CH_3(CH_2)_4CH_3}$$

   - 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)

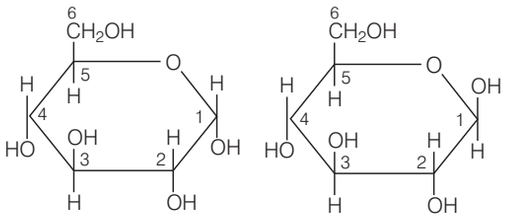
5. Open chain structure of D-glucose could not explain the following reactions.
   (i) Despite having the aldehyde group, glucose does not give Schiff's test and 2,4-DNP test.
   (ii) It does not form the hydrogen sulphite addition product with $NaHSO_4$.
   (iii) The penta-acetate of glucose does not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

$$H_2N—\underset{\displaystyle R}{\underset{|}{CH}}—COOH \rightleftharpoons \underset{\text{Zwitter ion}}{H_3^+N—\underset{\displaystyle R}{\underset{|}{CH}}—COO^-}$$

- 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
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—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 $\rangle C{=}O$ 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).

Practice Questions

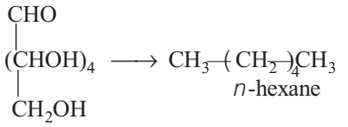
1. Carbohydrate that cannot be hydrolysed further to give simpler unit of polyhydroxy aldehyde or ketone is called

(a) monosaccharide *(b)* oligosaccharide
(c) polysaccharide *(d)* sucrose

2. Which of the following is not an example of polysaccharide?

(a) Starch *(b)* Cellulose
(c) Glycogen *(d)* Maltose

3. Name the reagent and condition required for carrying out the following reaction.



(a) HF, Δ *(b)* HCl, Δ
(c) HBr, Δ *(d)* HI, Δ

4. Name the product which is formed by the oxidation of glucose and gluconic acid with nitric acid.

(a) Rhamnose
(b) Saccharic acid
(c) Citric acid
(d) Oxalic acid

5. Which of the following act as epimeric pair?

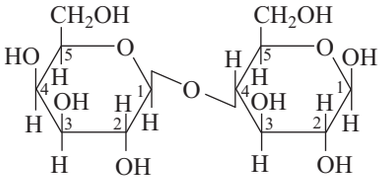
(a) Glucose and fructose
(b) Fructose and mannose
(c) Glucose and mannose
(d) Glucose and sucrose

6. In sucrose, the two monosaccharides are held together by a glycosidic linkage. The linkage is between

(a) C_1 of α-D-glucose and C_2 of β-D-fructose
(b) C_2 of α-D-glucose and C_1 of β-D-fructose
(c) C_1 of β-D-glucose and C_2 of β-D-fructose
(d) C_1 of β-D-glucose and C_2 of α-D-fructose

7. Invert sugar is a mixture of
(a) D-glucose + D-fructose
(b) L-glucose + D-fructose
(c) L-glucose + D-glucose
(d) L-glucose + L-glucose

8.



Study the structure carefully and then mark the correct option of followed question.

What is the name of above disaccharide?
(a) Sucrose *(b)* Maltose
(c) Lactose *(d)* Talose

9. Which of the following is known as animal starch?
(a) Amylose *(b)* Amylopectin
(c) Glycogen *(d)* Cellulose

10. The total number of amino acids to form protein in human body is
(a) 25 *(b)* 100
(c) 20 *(d)* 10

11. Which of the following amino acids can be synthesised in the body?
(a) Valine *(b)* Leucine
(c) Lysine *(d)* Glycine

12. Which of the following structure of protein is formed when polypeptide in a protein has amino acids linked with each other in a specific sequence?
(a) primary structure
(b) secondary structure
(c) tertiary structure
(d) quaternary structure

13. The spatial arrangement of the two or more polypeptide chains with respect to each other is known as
(a) primary structure
(b) secondary structure
(c) tertiary structure
(d) quaternary structure

14. Which of the following is/are example(s) of denaturation of protein?
(a) Coagulation of egg white
(b) Clotting of blood
(c) Curdling of milk
(d) Both (a) and (c)

15. What is the common name given to the enzyme which catalyse the oxidation of one substrate with simultaneous reduction of another substrate?
(a) Reductioxidase
(b) Oxidonductase
(c) Oxidoreductase
(d) Reductoxides

16. Which of the following is a fat soluble vitamin?
(a) Vitamin A *(b)* Vitamin B_6
(c) Vitamin C *(d)* Vitamin B_2

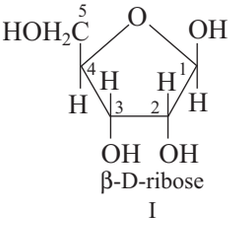
17. Water soluble vitamin is
(a) vitamin C *(b)* vitamin D
(c) vitamin E *(d)* vitamin K

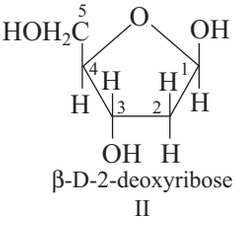
18. Pyridoxine is also known as
(a) vitamin B_2 *(b)* vitamin B_6
(c) vitamin B_{12} *(d)* vitamin B_1

19. Which of the following disease is caused by the deficiency of vitamin E?
(a) *Beri-beri* *(b)* Rickets
(c) Scurvy *(d)* Muscular weakness

20. Which of the following combination is correct between nucleic acid and its respective sugar base?
(a) DNA $\rightarrow$ β-D-3-deoxyribose
(b) DNA $\rightarrow$ β-D-1-deoxyribose
(c) RNA $\rightarrow$ β-D-ribose
(d) RNA $\rightarrow$ β-D-3-deoxyribose

21. Consider the following structures.


β-D-ribose
I


β-D-2-deoxyribose
II

Identify structure I and II and choose the correct option.

	I	II
(a)	β-D-ribose	β-D-2-deoxyribose
(b)	α-D-ribose	β-D-3-deoxyribose
(c)	β-D-deoxyribose	β-D-ribose
(d)	β-D-deoxyribose	α-D-ribose

22. Which one of the following does not constitute the nucleic acid?
(a) Uracil
(b) Ribose sugar
(c) Phosphoric acid
(d) Guanidine

23. Which of the following is a type of RNA?
(a) *m*-RNA *(b)* *t*-RNA
(c) *r*-RNA *(d)* All of these

24. Which of the following is not a hormone?
(a) Insulin
(b) Endorphins
(c) Norepinephrine
(d) Thymine

25. The major role of insulin is
(a) to decrease the glucose level in human body
(b) to keep the blood glucose level within the narrow limit
(c) to regulate growth
(d) to transport minerals

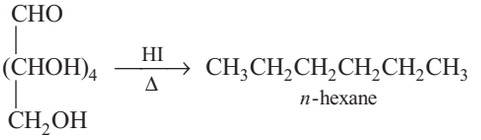
ANSWERS

1.	(a)	**2.**	(d)	**3.**	(d)	**4.**	(b)	**5.**	(c)	**6.**	(a)	**7.**	(a)	**8.**	(c)	**9.**	(c)	**10.**	(c)
11.	(d)	**12.**	(a)	**13.**	(d)	**14.**	(d)	**15.**	(c)	**16.**	(a)	**17.**	(a)	**18.**	(b)	**19.**	(d)	**20.**	(c)
21.	(a)	**22.**	(d)	**23.**	(d)	**24.**	(d)	**25.**	(b)										

Hints & Solutions

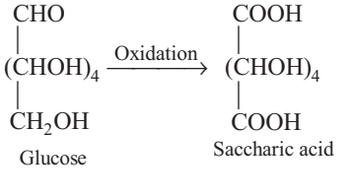
2. (*d*) Maltose is not an example of polysaccharide. Starch, cellulose and glycogen are examples of polysaccharide as they yield a large number of monosaccharides on hydrolysis.

3. (*d*) The reagent for the given reaction is HI. On prolonged heating with HI, glucose forms hexane, suggesting that all 6C-atoms are linked in a straight chain.

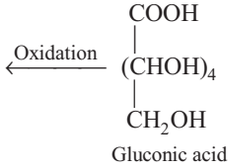


Glucose — *n*-hexane

4. (*b*) Glucose and gluconic acid, both on oxidation yields a dicarboxylic acid, saccharic acid. This indicates the presence of primary alcohol (OH) group in glucose. Reaction involved is as follows :

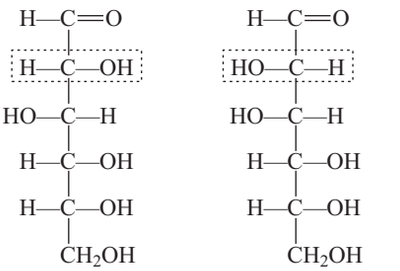


Glucose — Saccharic acid



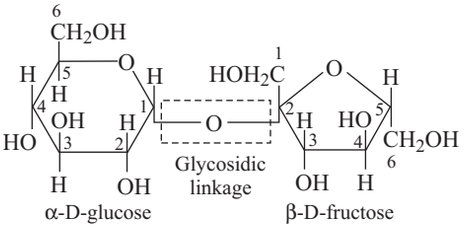
Gluconic acid

5. (*c*) Glucose and mannose are epimers because they differ in configuration at only one chiral carbon.



D - (+) - glucose — D - (+) - mannose

6. (*a*) In sucrose, the two monosaccharides are held together by a glycosidic linkage.
The linkage is between C_1 of α-D-glucose and C_2 of β-D-fructose.



Sucrose

7. (*a*) Invert sugar is a mixture of D-glucose and D-fructose. Sucrose is also known as invert sugar. Solution of sucrose is dextrorotatory. When sucrose is hydrolysed it forms equimolar quantity of D-glucose and D-fructose. The solution of formed products is found to be laevorotatory. This change in optical properties of sucrose is called inversion of cane sugar. The equimolar product is formed, i.e. D-glucose and D-fructose is called invert sugar.

8. (*c*) The given disaccharide is lactose. In this structure, the linkage is between C1 of galactose and C4 of glucose.

9. (*c*) Glycogen is also known as animal starch because its structure is similar to amylopectin and is rather more highly branched. The carbohydrates get stored in animal body as glycogen.

10. (*c*) The total number of amino acids to form protein in human body is 20. These amino acids are necessary to build protein in body.

11. (*d*) Valine, leucine and lysine are among the amino acids that cannot be synthesised in body, whereas glycine can be synthesised in the body.

12. (*a*) In primary structure of protein, each polypeptide in a protein has amino acids linked with each other in a specific sequence.

14. (*d*) Coagulation of egg white and curdling of milk are examples of denaturation of protein.
During denaturation, secondary and tertiary structures are destroyed but primary structure remain intact. Clotting of blood is not a kind of denaturation of protein.

15. (*c*) Enzyme which catalyse the oxidation of one substrate with simultaneous reduction of another substrate are named as oxidoreductase enzyme.
The ending of the name of an enzyme is -ase.

16. (*a*) Vitamin A is a fat soluble vitamin because it is soluble in fat and oils but insoluble in water.

17. (*a*) Vitamin C is water soluble, while vitamin A,D,E and K are fat soluble.

19. (*d*) Muscular weakness is caused by the deficiency of vitamin E. To remove deficiency, vegetable oil like wheat germ oil, sunflower oil etc. should be included in the diet.

20. (*c*) Option (c) is the correct combination. In DNA molecule, the sugar moiety is β-D-2-deoxyribose whereas in RNA molecule, it is β-D-ribose.

22. (*d*) Guanidine does not constitute the nucleic acid. Uracil is a base present in RNA. Ribose sugar and phosphoric acid are a part of DNA or RNA.

23. (*d*) 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).

24. (*d*) Thymine is not a hormone. It is a nitrogenous base. All other three options are hormone. Insulin and endorphins are polypeptides, whereas norepinephrine is an amino acid derivatives.