Revision Notes

Class 12 Chemistry

Chapter 10 Biomolecules

1. Introduction

Biomolecules are complex organic compounds that govern the common activities of living organisms. Carbohydrates, proteins, nucleic acids, lipids, and other complex biomolecules make up living systems. Furthermore, simple molecules such as vitamins and mineral salts play an important role in the functions of organisms.

2. CARBOHYDRATES

Plants are the primary producers of carbohydrates, which comprise a large group of naturally occurring organic compounds. Cane sugar, glucose, starch, and other common examples The majority of them have the general formula $C_xH_{2y}O_y$ and were thought to be carbon hydrates, hence the name carbohydrate. The molecular formula of glucose $(C_6H_{12}O_6)$, for example, fits into this general formula, $C_6(H_2O)6$. However, not all of the compounds that fit into this formula are carbohydrates. Rhamnose, $C_6H_{12}O_5$, is a carbohydrate, but it does not fall under this definition. Carbohydrates can be defined chemically as optically active polyhydroxy aldehydes or ketones, or compounds that produce such units upon hydrolysis. Some carbohydrates with a sweet taste are also known as sugars. Sucrose is the most common sugar found in our homes, whereas lactose is the sugar found in milk.

2.1 Classification of Carbohydrates

Carbohydrates are classified based on how they react to hydrolysis. They have been broadly classified into the three groups listed below:

2.1.1 Monosaccharides

A monosaccharide is a carbohydrate that cannot be hydrolyzed further to produce simpler units of polyhydroxy aldehyde or ketone. Examples include glucose, fructose, ribose, and others.

Monosaccharides are further classified based on the number of carbon atoms and the functional group they contain. When a monosaccharide contains an aldehyde group, it is referred to as an aldose, and when it contains a keto group, it is referred to as a ketose. As shown by the examples, the number of carbon atoms constituting the monosaccharide is also introduced in the name.

Different types of monosaccharides

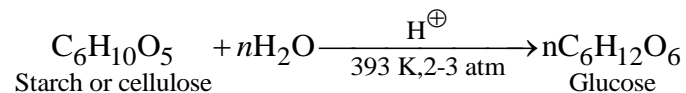| Carbon atoms	General Term	Aldehyde	Ketone
3	Triose	Aldotriose	Ketotriose
4	Tetrose	Aldotetrose	Ketotetrose
5	Pentose	Aldopentose	Ketopentose
6	Hexose	Aldohexose	Ketohexose
7	Heptose	Aldoheptose	Ketoheptose

2.1.2 Oligosaccharides

Oligosaccharides are carbohydrates that, when hydrolyzed, yield two to ten monosaccharide units. They are further classified as disaccharides, trisaccharides, tetrasaccharides, and so on, based on the number of monosaccharides produced during hydrolysis. Disaccharides are the most common of these. The two monosaccharide units formed by hydrolysis of a disaccharide may be identical or
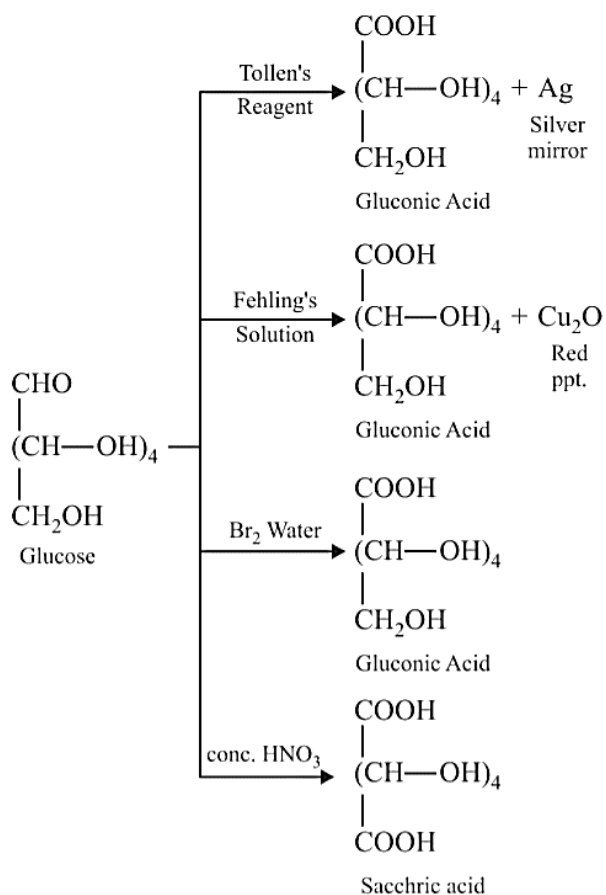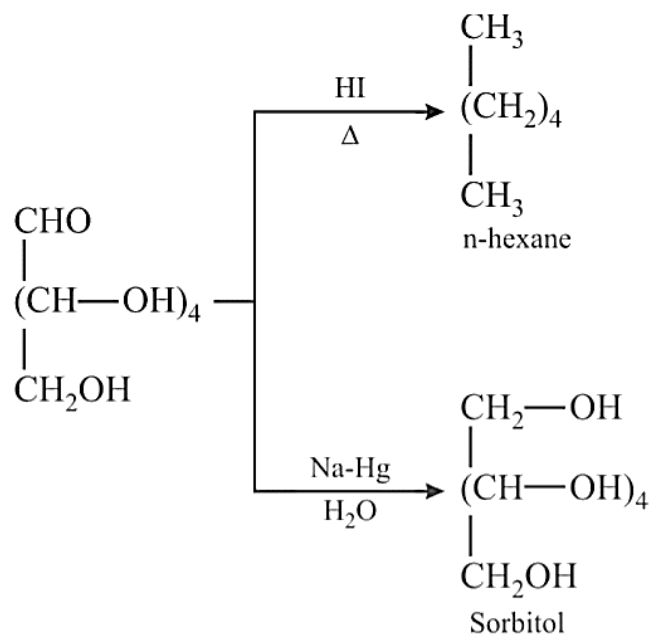
dissimilar. Sucrose, for example, yields one molecule of glucose and one molecule of fructose when hydrolyzed, whereas maltose yields only two molecules of glucose.

2.1.3 Polysaccharides

Polysaccharides are carbohydrates that when hydrolyzed yield a large number of monosaccharide units. Starch, cellulose, glycogen, gums, and other common examples Polysaccharides do not have a sweet taste, so they are also known as non-sugars.

2.1.4 Reducing and Non-Reducing Sugars

Carbohydrates are also classified as reducing or non-reducing sugars. Reducing sugars are all carbohydrates that reduce Fehling's solution and Tollens' reagent. Sugars are reduced by all monosaccharides, whether aldose or ketose.

Nonreducing sugars, such as sucrose, are formed when the reducing groups of monosaccharides, such as aldehydic or ketonic groups, are bonded in disaccharides. Reducing sugars, on the other hand, are sugars that have these functional groups free, such as maltose and lactose.

3. GLUCOSE (ALDOHEXOSE)

3.1 Preparation of Glucose

(A) From Sucrose (Cane Sugar):

When sucrose is boiled in alcoholic solution with dilute HCl or H_2SO_4, glucose and fructose are obtained in equal amounts.

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

(B) From Starch

Glucose is commercially obtained by hydrolyzing starch with dilute H_2SO_4 at 393 K under pressure.

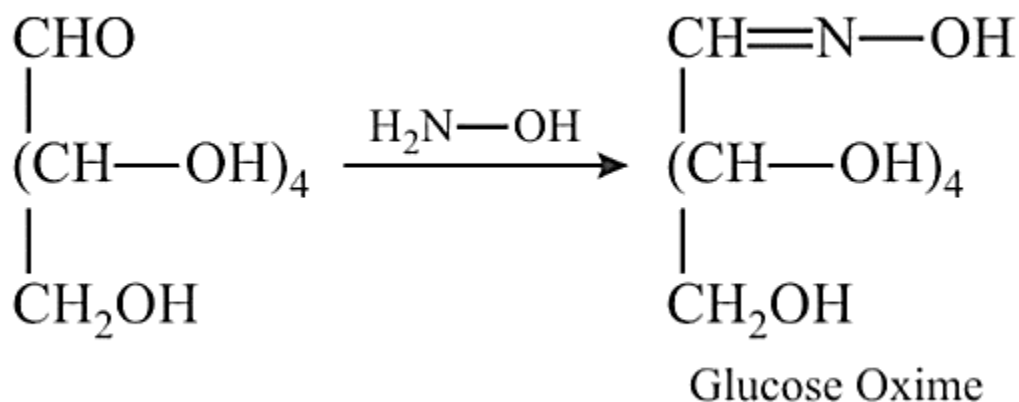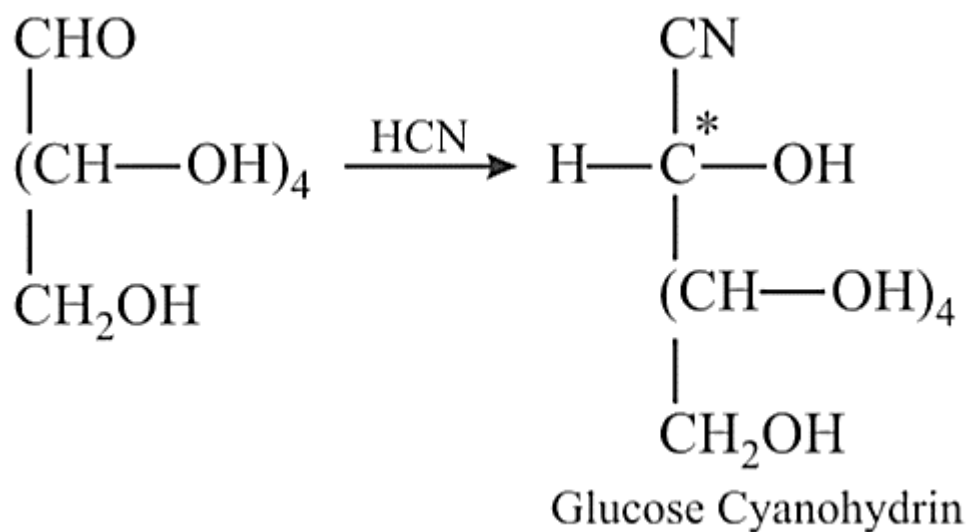$$\underset{\text{Starch or cellulose}}{C_6H_{10}O_5} + nH_2O \xrightarrow[\text{393 K,2-3 atm}]{H^{\oplus}} \underset{\text{Glucose}}{nC_6H_{12}O_6}$$

3.2 Reactions

(A) Oxidation

(B) Reduction

$$CHO - (CH-OH)_4 - CH_2OH$$

$\xrightarrow[\Delta]{HI}$

$$CH_3 - (CH_2)_4 - CH_3$$
n-hexane

$\xrightarrow[H_2O]{Na-Hg}$

$$CH_2-OH - (CH-OH)_4 - CH_2OH$$
Sorbitol

Note: Reduction with HI yields n-hexane, demonstrating that all six carbons of glucose are arranged in a straight chain.

(C) Oxime Formation

$$CHO - (CH-OH)_4 - CH_2OH$$

$\xrightarrow{H_2N-OH}$

$$CH=N-OH - (CH-OH)_4 - CH_2OH$$
Glucose Oxime

(D) Cyanohydrin Formation

$$\text{CHO} \atop \underset{\text{CH}_2\text{OH}}{\overset{|}{(\text{CH}-\text{OH})_4}} \xrightarrow{\text{HCN}} \text{H}-\overset{\text{CN}}{\underset{\underset{\text{CH}_2\text{OH}}{\overset{|}{(\text{CH}-\text{OH})_4}}}{\overset{|}{\underset{|}{\text{C}^*}}}}-\text{OH}$$

Glucose Cyanohydrin

Note: Since carbonyl C has become chiral, two diastereomers are formed.

(E) Acetylation

$$\text{CHO} \atop \underset{\text{CH}_2\text{OH}}{\overset{|}{(\text{CH}-\text{OH})_4}} \xrightarrow{5\text{CH}_3\text{COCl}} \text{CHO} \atop (\text{CH}-\text{O}-\overset{\text{O}}{\overset{||}{\text{C}}}-\text{CH}_3)_4 \atop \text{CH}_2-\text{O}-\overset{\text{O}}{\overset{||}{\text{C}}}-\text{CH}_3$$

Glucose Pentaacetate
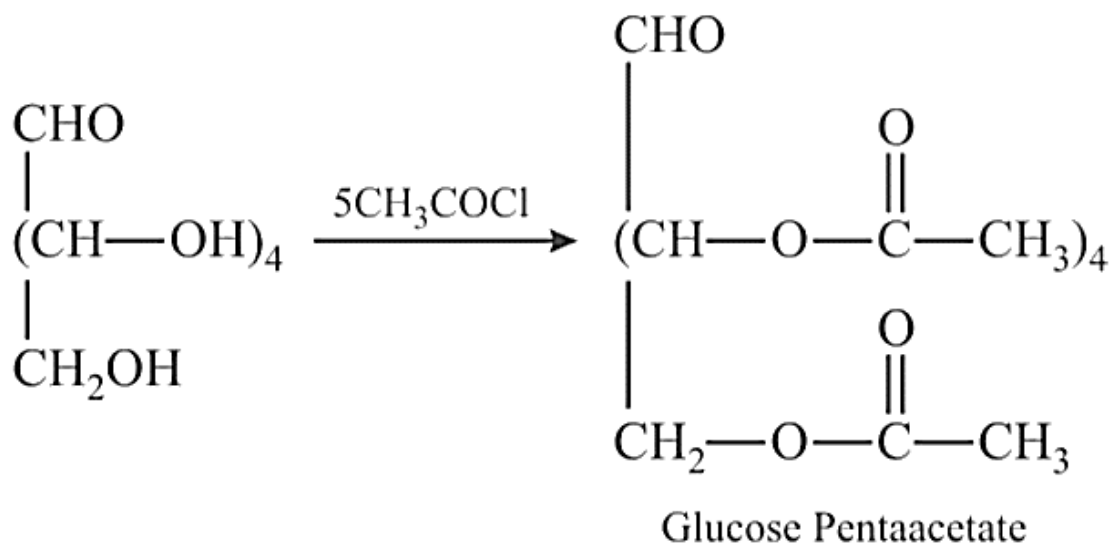
(F) Reaction with phenylhydrazine (formation of osazone)

$$
\begin{array}{c}
\text{CHO} \\
| \\
\text{CH—OH} \\
| \\
\text{(CH—OH)}_3 \\
| \\
\text{CH}_2\text{OH}
\end{array}
\xrightarrow{\text{3Ph—NH—NH}_2}
\begin{array}{c}
\text{CH}=\text{N—NH—Ph} \\
| \\
\text{C}=\text{N—NH—Ph} \\
| \\
\text{(CH—OH)}_3 \\
| \\
\text{CH}_2\text{OH}
\end{array}
$$
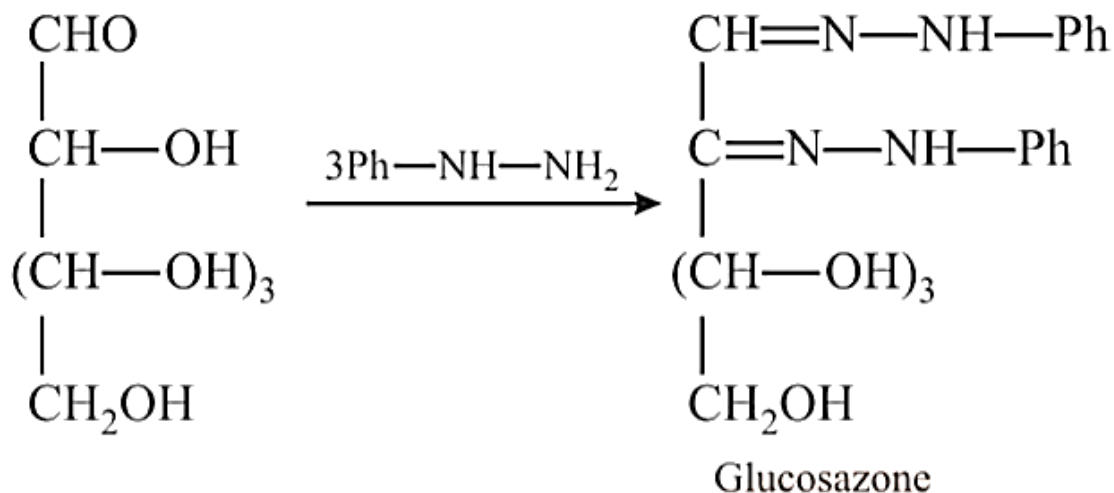
Glucosazone

Note: To produce osazone, one mole consumes three moles of PhNHNH2. Two moles produce hydrazone, and one is used to convert a CHOH group to a carbonyl group.

3.3 Configuration in Monosaccharides

D(+)-glucose is the correct name for glucose. The letter 'D' before the name of glucose represents the configuration, whereas the letter '(+)' represents the molecule's dextrorotatory nature. It should be noted that the letters 'D' and 'L' have no bearing on the compound's optical activity. The following is a definition of D– and L– notations. The letters 'D' or 'L' before the name of any compound indicate the stereoisomer's relative configuration. This refers to their affinity for a specific isomer of glyceraldehyde. Glyceraldehyde has one asymmetric carbon atom and comes in two enantiomeric forms, as shown.

CHO

H —|— OH

CH$_2$OH

(+) – Glyceraldehyde

CHO

HO —|— H
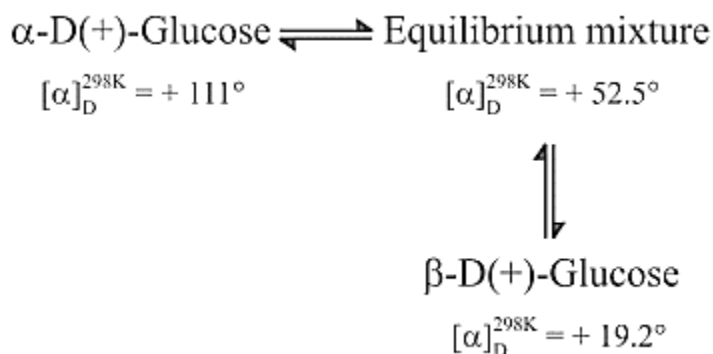
CH$_2$OH
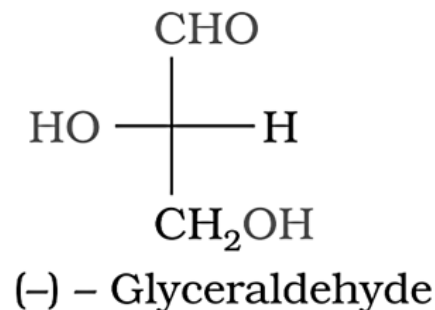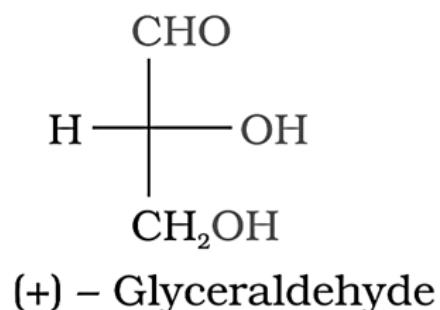
(–) – Glyceraldehyde

All compounds that can be chemically correlated to the (+) isomer of glyceraldehyde have D-configuration, whereas those that can be correlated to the (–) isomer of glyceraldehyde have L-configuration. The lowest asymmetric carbon atom (as shown below) is compared when assigning the configuration of monosaccharides. As with (+) glucose, –OH on the lowest asymmetric carbon is on the right side, similar to (+) glyceraldehyde, so it is assigned D-configuration. The structure is written in such a way that the most oxidised carbon is at the top for this comparison.

CHO

H —|— OH

CH$_2$OH

D– (+) – Glyceraldehyde

CHO

H —|— OH

HO —|— H

H —|— OH

H —|— OH

CH$_2$OH
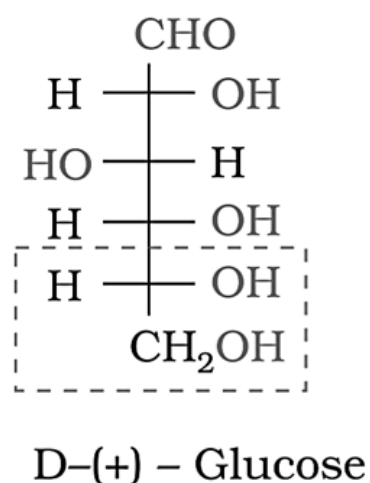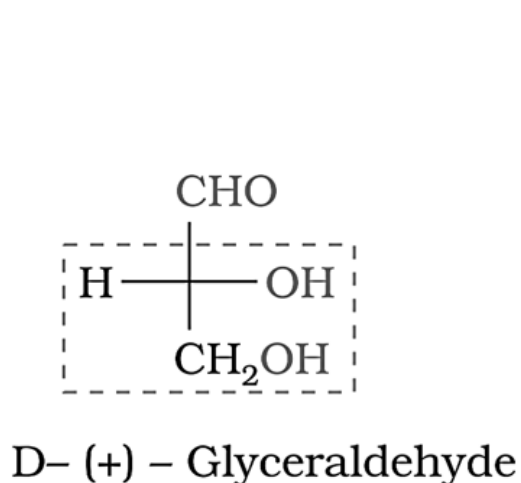
D–(+) – Glucose

3.4 Cyclic Structure of Glucose

Glucose has been discovered to exist in two different crystalline forms, which are known as α and β. The α-form of glucose (m.p. 419 K) is obtained by crystallisation from a concentrated glucose solution at 303 K, whereas the β.-form (m.p. 423) is obtained by crystallisation from a hot and saturated aqueous solution at 371 K. In aqueous solution, both α-D-glucose and β-D-glucose undergo mutarotation. Although the crystalline forms of α- and β-D (+)-glucose are quite stable in aqueous solution, each form gradually transforms into an equilibrium mixture of the two.

α-D(+)-Glucose $\rightleftharpoons$ Equilibrium mixture

$[\alpha]_D^{298K} = +111°$ $[\alpha]_D^{298K} = +52.5°$

β-D(+)-Glucose

$[\alpha]_D^{298K} = +19.2°$

This is demonstrated by the fact that the specific rotation of a freshly prepared aqueous solution of α-D(+)-glucose decreases with time from +111° to +52.5°, whereas that of β-D(+)-glucose increases from +19.2° to 52.5°. Thus, mutarotation refers to the spontaneous change in specific rotation of an optically active compound with time to an equilibrium value. It was discovered that glucose forms a six-membered ring, with –OH at C-5 playing a role in ring formation. This explains the lack of a –CHO group as well as the presence of glucose in two forms, as shown below. These two cyclic forms coexist with an open chain structure.
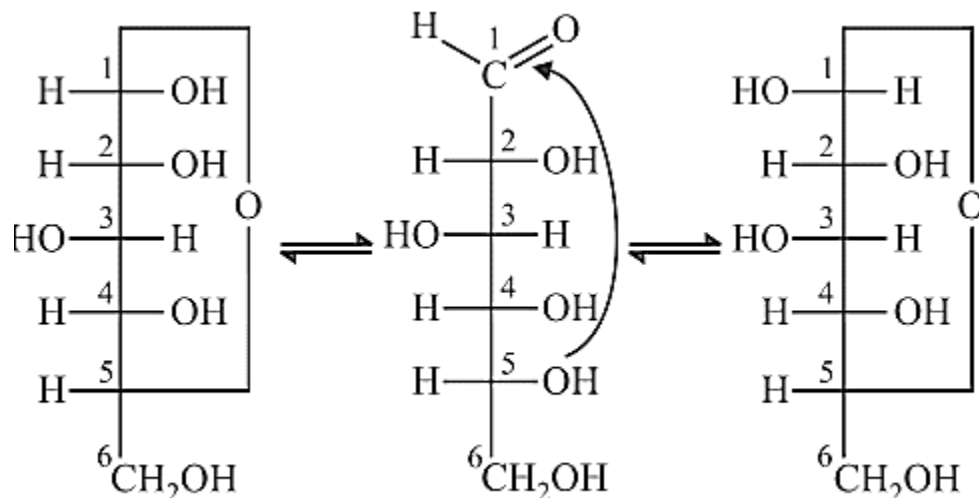
The only difference between the two cyclic hemiacetal forms of glucose is the configuration of the hydroxyl group at C1, which is referred to as anomeric carbon (the aldehyde carbon before cyclisation). Such isomers, namely -form and -form, are referred to as anomers. In analogy with pyran, the six-membered cyclic structure of glucose is known as the pyranose structure (– or –). Pyran is a cyclic organic compound with a ring containing one oxygen atom and five carbon atoms. The Haworth structure more accurately represents the cyclic structure of glucose.

Pyran $\alpha - D - (+) - $ Glucopyranose $\beta - D - (+) - $ Glucopyranose
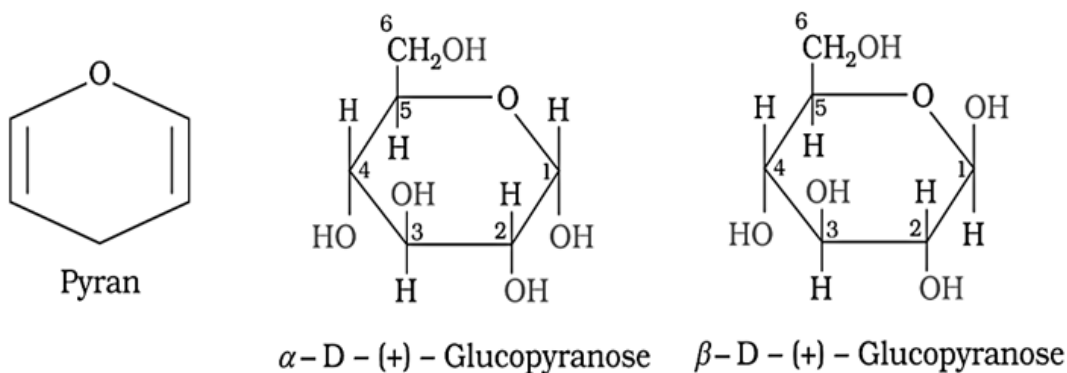
3.4.1 How to draw a Haworth Projection

A ring of 6 atoms (5 'C' and 1 'O') is drawn, with the 'O' atom in the upper right hand corner, as shown below.
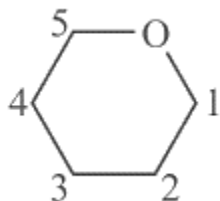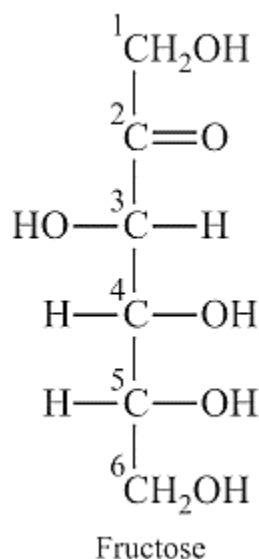
Number one is assigned to the carbon atom on the right side of oxygen. Then, in a clockwise fashion, other carbon atoms are assigned numbers 2, 3,........... . In Fischer projection, groups attached to a carbon on the right side are placed below the ring, while groups attached to the carbon on the left side are placed above the ring. However, by convention, the CH_2OH group of carbon 5 is placed above the plane of the ring.
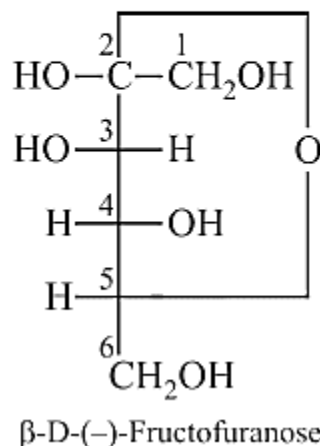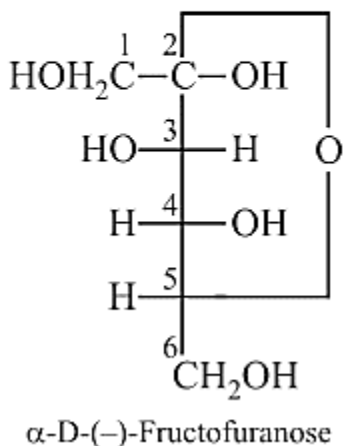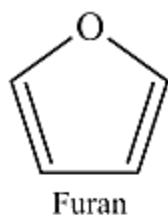

α-D-Glucose

Haworth Projection
of α-D-Glucose
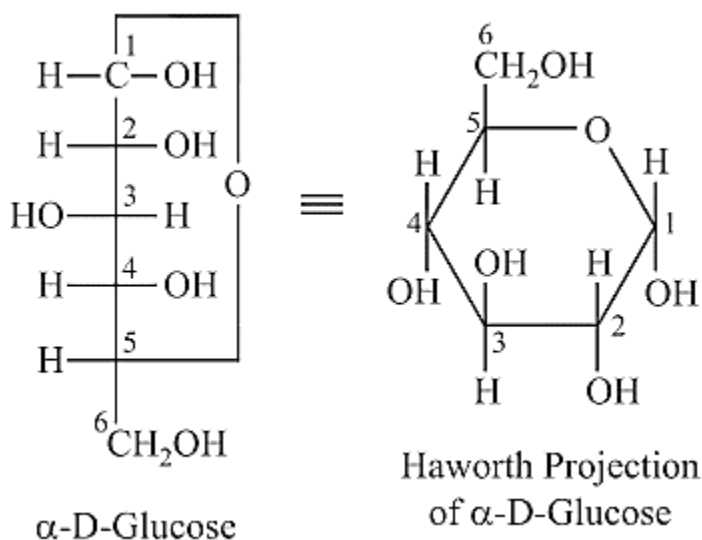
4. FRUCTOSE (KETOHEXOSE)
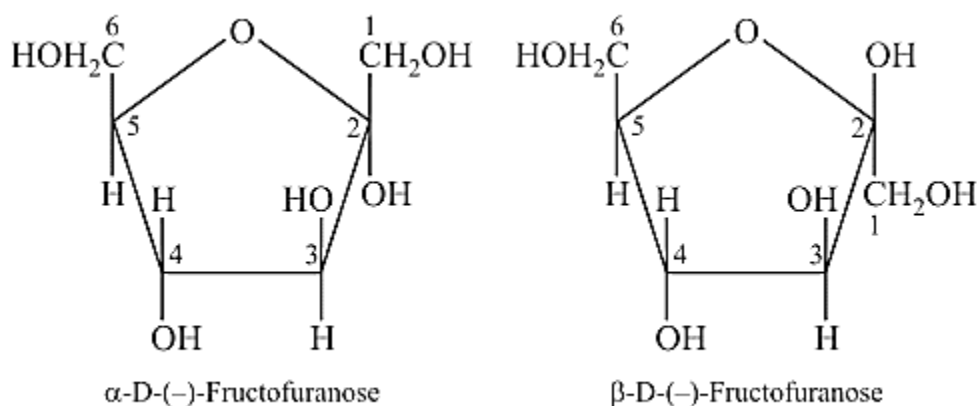
Fructose has the molecular formula $C_6H_{12}O_6$, and based on its reactions, it was discovered to have a ketonic functional group at carbon number 2 and six carbons in a straight chain, just like glucose. It is a laevorotatory compound from the D-series. D-(–)-fructose is the correct spelling. Its open chain structure is depicted below.

$$
\begin{array}{c}
{}^{1}CH_2OH \\
| \\
{}^{2}C=O \\
| \\
HO-{}^{3}C-H \\
| \\
H-{}^{4}C-OH \\
| \\
H-{}^{5}C-OH \\
| \\
{}^{6}CH_2OH
\end{array}
$$

Fructose

It also exists in two cyclic forms, which are obtained by adding –OH to the carbonyl group at C5. The resulting ring is a five-membered ring known as furanose, after the compound furan. Furan is a five-membered cyclic compound that contains one oxygen atom and four carbon atoms.

Furan

α-D-(–)-Fructofuranose   β-D-(–)-Fructofuranose

Haworth structures are used to represent the cyclic structures of two anomers of fructose.

α-D-(−)-Fructofuranose   β-D-(−)-Fructofuranose

5. COMPARISON OF GLUCOSE AND FRUCTOSE

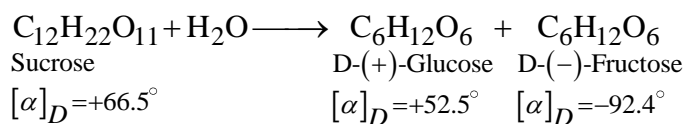| Property	Glucose
Molecular formula	$C_6H_{12}O_6$
Nature	Polyhydroxy aldehyde
Melting point	146^oC
Optical nature	Dextro rotatory
Fehling's solution	Silver mirror
Tollen's reagent	Red ppt
Molisch test	Violet colour
Phenyl hydrazine	Forms osazone
Oxidation by concentrated HNO_3	Saccharic acid

6. DISACCHARIDES

An oxide linkage formed by the loss of a water molecule connects the two monosaccharides. The linkage of two monosaccharide units via an oxygen atom is known as glycosidic linkage.

6.1 Sucrose

Sucrose is a common disaccharide that, when hydrolyzed, yields an equimolar mixture of D-(+)-glucose and D-(−)-fructose.

$$C_{12}H_{22}O_{11}+H_2O \longrightarrow C_6H_{12}O_6 \ + \ C_6H_{12}O_6$$

Sucrose   D-(+)-Glucose   D-(−)-Fructose

$[\alpha]_D = +66.5°$ $[\alpha]_D = +52.5°$ $[\alpha]_D = -92.4°$

A glycosidic linkage between C1 of α-glucose and C2 of β-fructose holds these two monosaccharides together. Sucrose is a non-reducing sugar because the reducing groups of glucose and fructose are involved in the formation of glycosidic bonds.
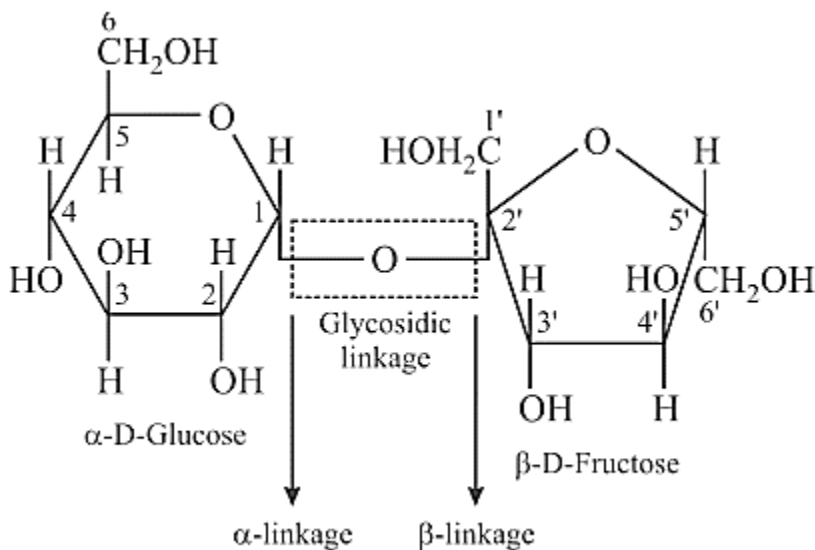
Sucrose is a dextrorotaty compound that when hydrolyzed yields an equimolar solution of glucose and fructose.

Because the laevo rotation of fructose is greater than the dextro rotation of glucose, this solution is laevorotaty.

Thus, hydrolysis of sucrose causes a change in the sign of rotation, from dextro (+) to laevo (–), and the product is known as invert sugar, and the phenomenon is known as sugar inversion.

6.2 Maltose

Maltose, another disaccharide, is made up of two -Dglucose units, with C1 of one glucose (I) linked to C4 of another glucose unit (II). Because the free aldehyde group can be produced at C1 of second glucose in solution and has reducing properties, it is classified as a reducing sugar.
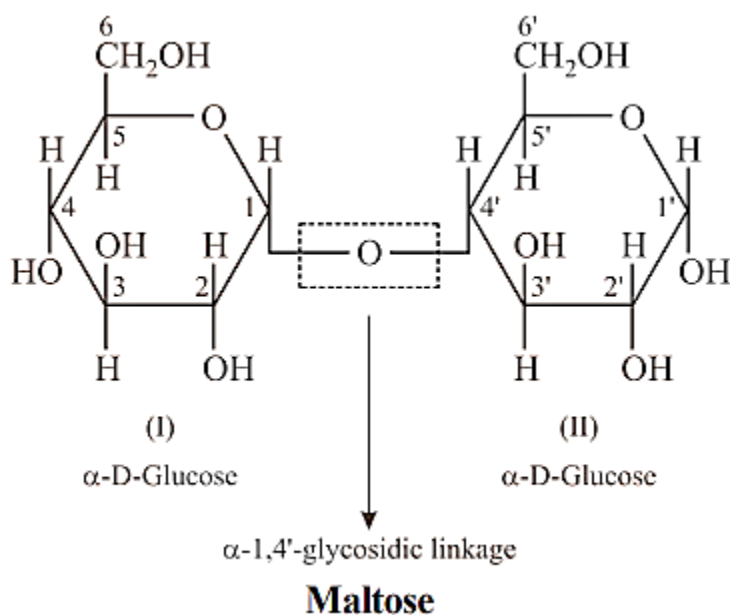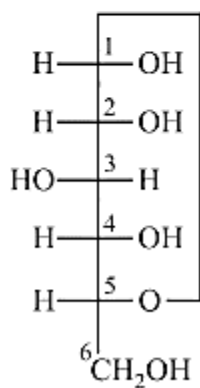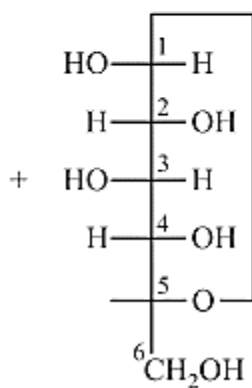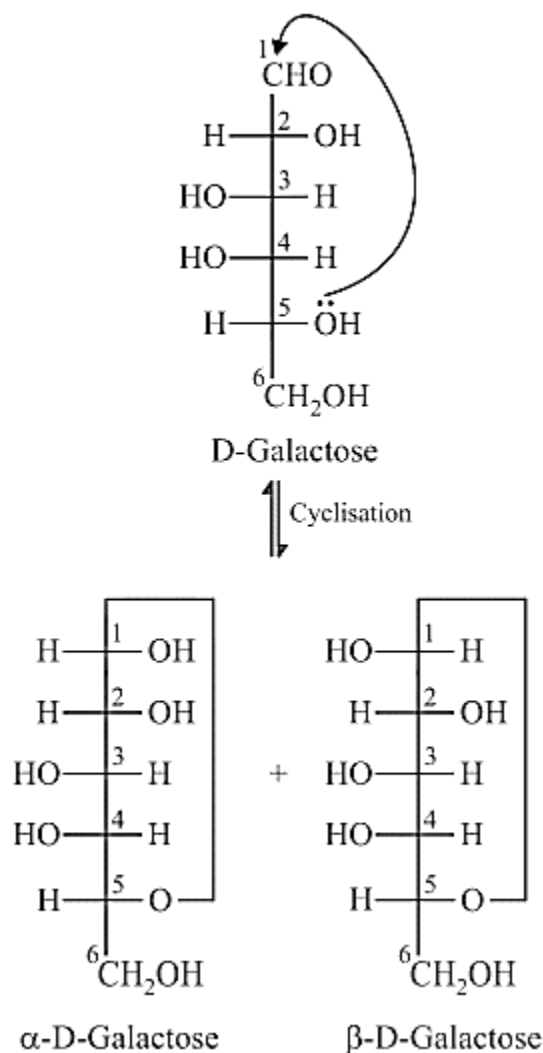

6.3 Lactose

It is more commonly known as milk sugar since this disaccharide is found in milk. It is composed of α-D-galactose and β-D-glucose. Fischer projections of -D-Glucose and -D-Galactose are drawn below:

D-Glucose

Cyclisation

α-D-Glucose   +   β-D-Glucose
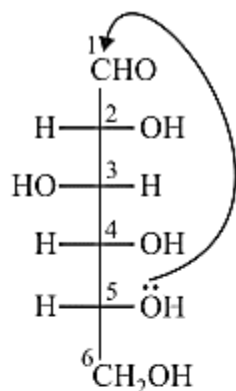
D-Galactose

Cyclisation

α-D-Galactose   +   β-D-Galactose

Except for C-4, the configurations of all the carbon atoms in β-D-Glucose and β-D-Galactose are the same. Such stereoisomers that differ in configuration at only one carbon other than anomeric carbon are referred to as epimers, and the C atom in question is referred to as an epimeric carbon atom. As a result, β-DGlucose and β-D-Galactose are epimers, and C-4 is an epimeric carbon atom. The linkage in lactose is between C1 of galactose and C4 of glucose. As a result, it is also a reducing sugar.

β-D-Galactose   β-D-Glucose

β-1,4'-glycosidic linkage

Lactose
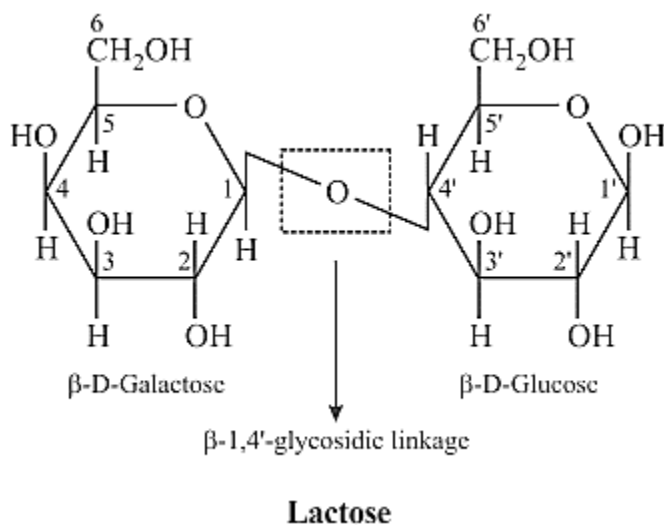
7. POLYSACCHARIDES

Polysaccharides are composed of many monosaccharide units linked together by glycosidic linkages. They primarily serve as food storage or structural materials.

7.1 Starch

Plants' primary storage polysaccharide is starch. It is the most important source of nutrition for humans. Cereals, roots, tubers, and some vegetables have a high starch content. It is a -glucose polymer composed of two components: Amylose and Amylopectin. Amylose is a water-soluble component that accounts for about 15-20% of starch. Amylose is a long unbranched chain containing 200-1000 α-D-(+)-glucose units held together by a C1-C4 glycosidic linkage. Amylopectin is insoluble in water and accounts for approximately 80-85 percent of starch. It is a branched chain polymer of α-D-glucose units with a chain formed by C1-C4 glycosidic linkage and branching caused by C1-C6 glycosidic linkage.
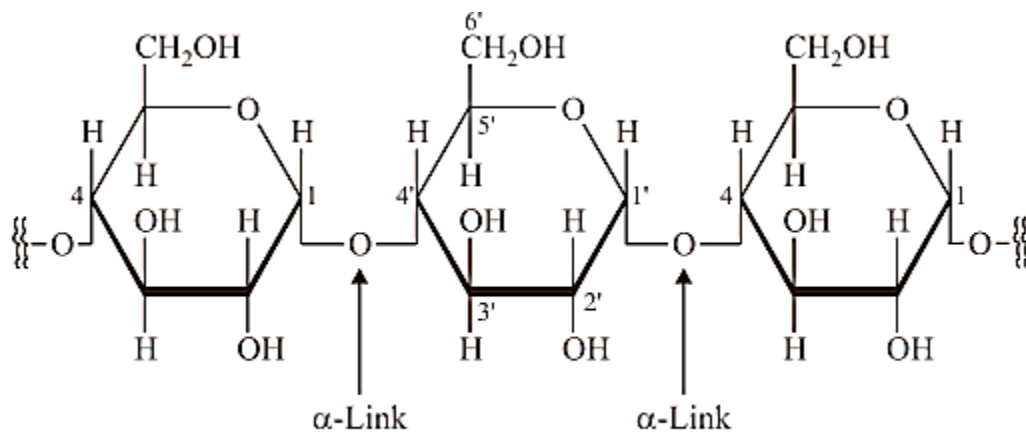
Amylose
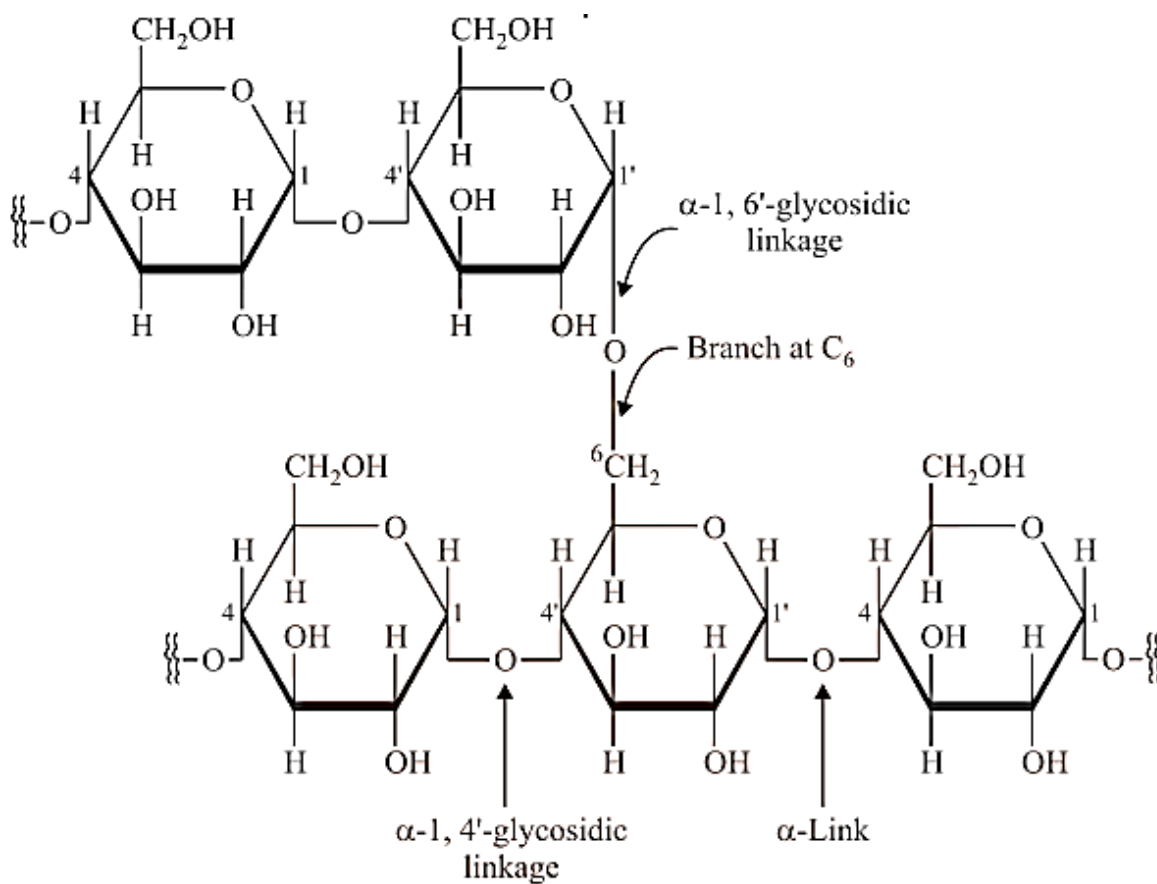
Amylopectin

7.2 Cellulose

Cellulose is found only in plants and is the most abundant organic substance in the plant kingdom. It is a major component of the cell wall of plant cells. Cellulose is a straight-chain polysaccharide made up entirely of β-D glucose units linked together by a glycosidic linkage between C1 of one glucose unit and C4 of the next glucose unit.

Cellulose
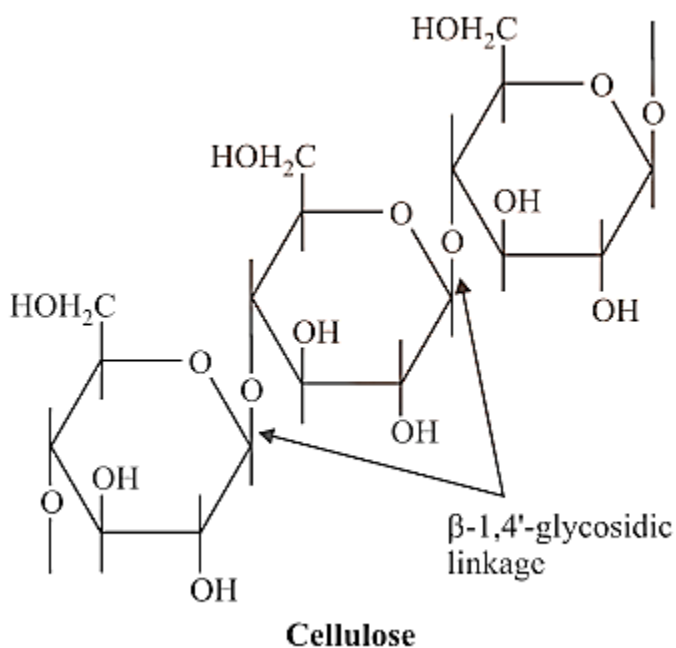
7.3 Glycogen

Carbohydrates are stored as glycogen in the animal body. It is also known as animal starch due to its structure, which is similar to amylopectin but more highly branched. It can be found in the liver, muscles, and brain. When the body requires glucose, enzymes convert glycogen to glucose. Glycogen is found in yeast and fungi as well.

7.4 Summary

Note:

1. Reducing sugars are all carbohydrates that contain the CHO group, the α-Hydroxy ketonic group, or the hemiacetal group.

2. Mutarotation is a phenomenon that occurs in all reducing sugars.

8. PROTEINS

Protein is derived from the Greek word "proteios," which means "primary" or "of primary importance." Proteins are all polymers of α-amino acids.

8.1 Amino Acids

Amino acids have both amino (–NH_2) and carboxyl (–COOH) functional groups. The amino acids are classified as $\alpha, \beta, \gamma, \delta$ and so on based on the relative position of the amino group with respect to the carboxyl group. When proteins are hydrolyzed, only α-amino acids are produced. They may also contain other functional groups.

$$R - CH - \overset{\overset{\textstyle O}{\|}}{C} - O - H$$
$$\overset{|}{:NH_2}$$
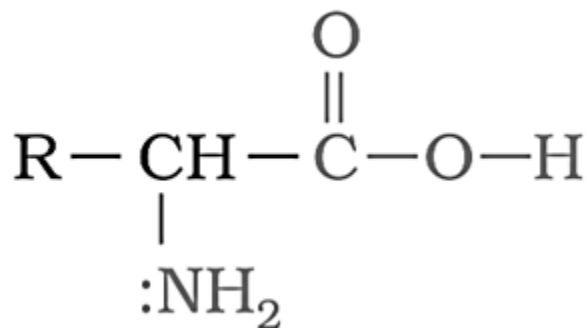
All α-amino acids have innocuous names that usually reflect the compound's or its source's property. Glycine is named after its sweet taste (glykos means sweet in Greek), and tyrosine was first obtained from cheese (tyros means cheese in Greek).

8.2 Natural Amino Acids

$$
\begin{array}{c}
\text{COOH} \\
| \\
\text{H}_2\text{N} \text{——} | \text{——} \text{H} \\
| \\
\text{R}
\end{array}
$$
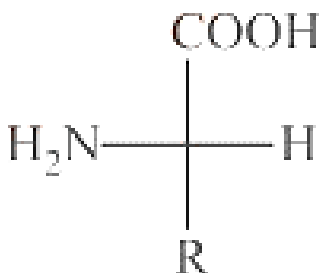
8.3 Classification of Amino Acids

The relative number of amino and carboxyl groups in an amino acid molecule determines whether it is acidic, basic, or neutral.

Non-essential amino acids are amino acids that can be synthesized in the body. Essential amino acids, on the other hand, are those that cannot be synthesized in the body and must be obtained through diet.

8.4 Properties of Amino Acids

Amino acids are crystalline, colorless solids. These are water-soluble, high-melting-point solids that act more like salts than simple amines or carboxylic acids. The presence of both acidic (carboxyl group) and basic (amino group) groups in the same molecule causes this behavior.

$$
\text{R}-\text{CH}-\overset{\displaystyle \overset{O}{\|}}{\text{C}}-\text{O}-\text{H} \rightleftharpoons \text{R}-\text{CH}-\overset{\displaystyle \overset{O}{\|}}{\text{C}}-\text{O}^{-}
$$

$$
\underset{:\text{NH}_2}{|} \qquad\qquad \underset{\overset{+}{\text{NH}}_3}{|}
$$
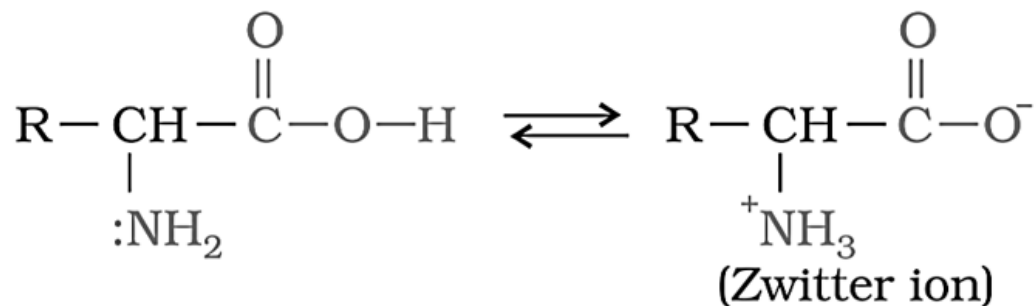
(Zwitter ion)

In aqueous solution, the carboxyl group can lose a proton and the amino group can accept a proton, resulting in zwitter ion, a dipolar ion. This is neutral, but it does have both positive and negative charges. Amino acids exhibit amphoteric behavior in zwitter ionic form, reacting with both acids and bases.

Except for glycine, all other naturally occurring α-amino acids are optically active due to the asymmetry of the -carbon atom.

These are available in both 'D' and 'L' forms. The majority of naturally occurring amino acids have an L-configuration. The $-NH_2$ group on the left side is used to represent L-amino acids.

8.4.1 Isoelectric Point

An amino acid's isoelectric point (pI) is the pH at which it has no net charge. In other words, it is the pH at which the negative charge on an amino acid exactly balances the positive charge. pI (isoelectric point) = pH at which no net charge exists. The pI of an amino acid with no ionizable side chain, such as alanine, is halfway between its two pK_a values. This is due to the fact that at pH = 2.34, half of the molecules have a negatively charged carboxyl group and half have an uncharged carboxyl group, and at pH = 9.69, half of the molecules have a positively charged amino group and half have an uncharged amino group. As the pH rises from 2.34, more molecules' carboxyl groups become negatively charged; as the pH falls from 9.69, more molecules' amino groups become positively charged.

As a result, the number of negatively charged groups equals the number of positively charged groups when the two pKa values are averaged.

$$pK_a = 2.34$$

$$CH_3CHCOH$$
$$\overset{\oplus}{NH_3}$$
Alanine
$$pK_a = 9.69$$
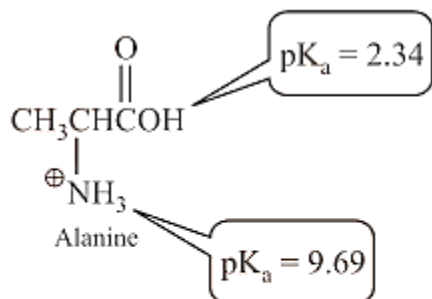
$$pI = \frac{2.34 + 9.69}{2} = \frac{12.03}{2} = 6.02$$

If an amino acid has an ionizable side chain, its pI is calculated by averaging the pKa values of similarly ionizing groups (positive ionizing to uncharged or uncharged ionizing to positive). For example, the pI of lysine is the average of the pKa values of two groups that are positively charged in their acidic form but uncharged in their basic form. The pI of glutamate, on the other hand, is the average of the pKa values of the two groups, which are uncharged in their acidic form and negatively charged in their basic form.

$$pK_a = 2.18$$

$$H_3\overset{\oplus}{N}CH_2CH_2CH_2CH_2CHCOH$$
$$\overset{\oplus}{NH_3}$$
Lysine
$$pK_a = 10.79$$
$$pK_a = 8.95$$

$$pI = \frac{8.95 + 10.79}{2} = \frac{19.74}{2} = 9.87$$

Glutamic acid

$$pI = \frac{2.19 + 4.25}{2} = \frac{6.44}{2} = 3.22$$

8.5 Structure of Proteins –

The Peptide Bond Proteins are polymers of α-amino acids that are linked together by peptide bonds or peptide linkage. Peptide linkage is chemically defined as an amide formed between the – COOH group and the –NH_2 group.

The reaction between two molecules of similar or different amino acids is initiated by the combination of one molecule's amino group with the carboxyl group of the other. This causes the removal of a water molecule and the formation of a peptide bond –CO–NH–.

8.6 Classification of Proteins

Proteins can be classified into two types on the basis of their molecular shape.

(A) Fibrous Proteins

A fibrelike structure is formed when polypeptide chains run parallel and are held together by hydrogen and disulphide bonds. In general, such proteins are insoluble in water.

Keratin (found in hair, wool, and silk) and myosin (found in muscles) are two common examples.

(B) Globular Proteins

This structure is formed when polypeptide chains coil around to form a spherical shape. These are usually water soluble. Insulin and albumin are two common globular proteins. Protein structure and shape can be studied at four different levels: primary, secondary, tertiary, and quaternary.

(i) Primary Structure

One or more polypeptide chains can be found in proteins. Each polypeptide in a protein contains amino acids that are linked together in a specific sequence, and this sequence of amino acids is referred to as the protein's primary structure. Any change in this primary structure, i.e., the amino acid sequence, results in a different protein.

(ii) Secondary Structure

A protein's secondary structure is the shape in which a long polypeptide chain can exist. They have been discovered to exist in two different structures: α-helix and β-pleated sheet. These structures form as a result of the regular folding of the

polypeptide chain's backbone caused by hydrogen bonding between the peptide bond's $C = O$ and $-NH-$ groups.

The $-NH$ group of each amino acid residue is hydrogen bonded to the $C = O$ of an adjacent turn of the α helix in one of the most common ways in which a polypeptide chain forms all possible hydrogen bonds by twisting into a right handed screw (helix).

All peptide chains in β-structure are stretched to nearly maximum extension and then laid side by side, held together by intermolecular hydrogen bonds.

(iii) Tertiary Structure

Protein tertiary structure represents overall folding of polypeptide chains, i.e., further folding of the secondary structure. It produces two major molecular shapes: fibrous and globular. Hydrogen bonds, disulphide linkages, van der Waals forces, and electrostatic forces of attraction are the main forces that keep proteins' 2° and 3° structures stable.

(iv) Quaternary Structure

Some proteins are made up of two or more polypeptide chains known as sub-units. The relationship of subunits to one another is referred to as quaternary structure.

8.7 Denaturation of Proteins

A native protein is a protein found in a biological system that has a distinct three-dimensional structure and biological activity. When a protein in its native form is subjected to physical change, such as temperature change, or chemical change, such as pH change, the hydrogen bonds are disrupted. As a result, globules unfold, helixes uncoil, and protein loses biological activity. This is referred to as protein denaturation. A common example of denaturation is the coagulation of egg white

when heated. Another example is milk curdling, which is caused by the bacteria present in milk producing lactic acid.
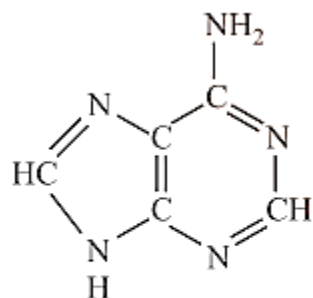
9. NUCLEIC ACIDS

Every generation of every species resembles its ancestors in a variety of ways. How are these traits passed down from one generation to the next? It has been discovered that the nucleus of a living cell is in charge of the transmission of inherent characteristics, also known as heredity. The particles in the nucleus of the cell that are responsible for heredity are known as chromosomes, and they are made up of proteins and another type of biomolecule known as nucleic acids. These are primarily of two kinds: deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) (RNA). Because nucleic acids are long chain polymers of nucleotides, they are also referred to as polynucleotides.

9.1 Chemical Composition of Nucleic Acids

When DNA (or RNA) is completely hydrolyzed, it produces a pentose sugar, phosphoric acid, and nitrogen-containing heterocyclic compounds (called bases). The sugar moiety in DNA molecules is β-D-2-deoxyribose, whereas the sugar moiety in RNA molecules is β-D-ribose.

β-D-ribose   β-D-2-deoxyribose
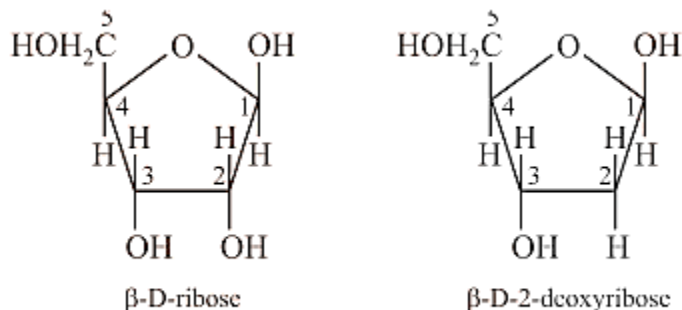
Adenine (A), guanine (G), cytosine (C), and thymine are the four bases found in DNA (T). The first three bases of RNA are the same as those of DNA, but the fourth is uracil (U).
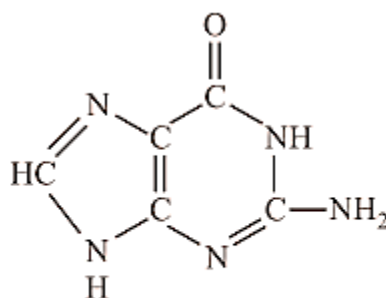
Adenine (A)   Guanine (G)
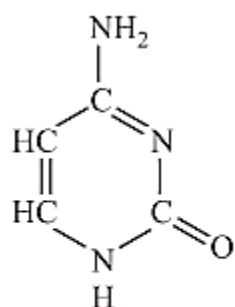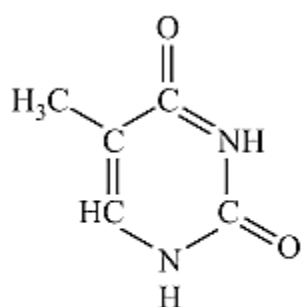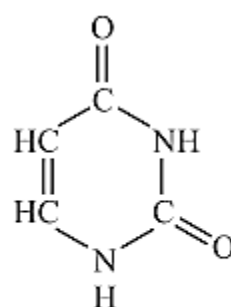
Adenine (C)   Thymine (T)   Uracil (U)

9.2 Structure of Nucleic Acids

A nucleoside is a unit formed by the attachment of a base to the 1' position of a sugar. The sugar carbons in nucleosides are labeled as 1', 2', 3', and so on. To differentiate these from the bases. A nucleotide is formed when a nucleoside is linked to phosphoric acid at the 5'-position of the sugar moiety.

Structure of (a) a nucleoside and (b) a nucleotide

The phosphodiester linkage between the pentose sugar's 5' and 3' carbon atoms connects nucleotides. The following is a simplified version of the nucleic acid chain.

The primary structure of a nucleic acid is information about the sequence of nucleotides in its chain. Secondary structure is also present in nucleic acids. The double strand helix structure of DNA was proposed by James Watson and Francis Crick. Two nucleic acid chains are wrapped around each other and held together by hydrogen bonds formed by base pairs. Because hydrogen bonds form between specific pairs of bases, the two strands are complementary to one another. Adenine and thymine form hydrogen bonds, whereas cytosine and guanine form hydrogen bonds. There are helices in the secondary structure of RNA that are only single stranded. They can fold in on themselves to form a double helix structure. There are three types of RNA molecules, each of which serves a different purpose. They are known as messenger RNA (m-RNA), ribosomal RNA (r-RNA), and transfer RNA, respectively (t-RNA).

Double strand helix structure for DNA

9.3 DNA Vs RNA

9.4 Biological Functions of Nucleic Acids

DNA is the chemical basis of heredity and can be thought of as a repository of genetic information. Over millions of years, DNA has been solely responsible for maintaining the identity of various species of organisms. During cell division, a DNA molecule can self-replicate, and identical DNA strands are transferred to daughter cells. Protein synthesis in the cell is another important function of nucleic acids. Actually, proteins are synthesised by various RNA molecules in the cell, but the message for a specific protein's synthesis is present in DNA.

10. ENZYMES

Enzymes function as biological catalysts. Enzymes are all globular proteins chemically. The following are some important enzymes and their functions.

	Enzyme	**Reaction catalysed**
(i)	Invertase or sucrose	Sucrose $\rightarrow$ Glucose + Fructose
(ii)	Maltose	Maltose $\rightarrow$ Glucose + Glucose
(iii)	Lactase	Lactose $\rightarrow$ Glucose + Galactose
(iv)	α-Amylase	Starch $\rightarrow n \times$ Glucose
(v)	Emulsin	Cellulose $\rightarrow n \times$ Glucose
(vi)	Urease	$NH_2CONH_2 \rightarrow CO_2 + 2NH_3$
(vii)	Carbonic anhydrase	$H_2CO_3 \rightarrow CO_2 + H_2O$
(viii)	Pepsin	Protein $\rightarrow \alpha -$ Amino acids
(ix)	Trypsin	Proteins $\rightarrow \alpha -$ Amino acids
(x)	Nucleases	DNA or RNA $\rightarrow$ Nucleotides
(xi)	DNA polymerase	Deoxynucleotide $\rightarrow$ DNA Triphosphate
(xii)	RNA polymerase	Ribonucleotide $\rightarrow$ RNA triphosphates

11. Vitamins

	Vitamin	**Sources**	**Deficiency diseases**
(i)	Vitamin-A- (Retinol or eye vitamin)	Milk, cod liver oil, butter, carrots, green leaves, tomatoes, eggs etc.	Night blindness, xerosis
(ii)	Vitamin-B1 Thiamine or	Pulses, nuts, green vegetables, polished rice, yeast and egg	Beriberi and loss apetite

		yolk.	
(iii)	Vitamin-B2 or Riboflavin or Lactoflavin	Aneurin Milk, meat, green vegetables and yeast.	Dard red tongue and cheilosis
(iv)	Vitamin-B6 or Pyridoxine or Adernine	Rice, bran, yeast, meat, fish, egg, yolk, maize, spinach and lettuce.	Pellagra anaemia, convulsions and specific dermatitlis called acrodynia.
(v)	Vitamin-B12 or Cyanocoblamin	Milk, liver, kidney and eggs.	Inflammation of mouth, tongue and pernicious anaemia etc.
(vi)	Vitamin-C or L-ascorbic acid	Citrous fruits, amla, (oranges, lemons), sprouted pulses, germinated.	Brittleness and scurvy of bones, swelling and loosening of teeth.
(vii)	Vitamin D or Ergocal eiferol (or antirachtic Vitamin of sunshine vitamin)	Fish liver oil, cod liver oil, milk and eggs.	Rickets in children, controls calcium and phosphorus metabolism.
(viii)	Vitamin-E or Tocopherols (α, β, γ) or Antisterility factor	Eggs, milk, wheat germ, oil cotton seed oil etc.	Loss of sexual power and reproduction
(ix)	Vitamin-H (Biotin)	Yeast, kidney, liver and milk.	Loss of hair, dermatitis and paralysis.
(x)	Vitamin-K or Phylloquinones or Antihaemorrhagic vitamin	Cabbage, spinach, alfalfa and carrot tops.	Lengthens time of blood clotting and dermatitis
(xi)	Coenzyme Q10	Chloroplasts of green plants and	Low order of body immune system against

			mitochondria of animals.	many diseases.

12. HORMONES

Hormones are biomolecules that are produced in the ductless (endocrine) glands and transported by the bloodstream to various parts of the body where they control various metabolic processes. These are required in minute amounts and, unlike fats and carbohydrates, are not stored in the body but are constantly produced.

12.1 Steroidal Hormones

	Name	**Organ of secretion**	**Functions**
A	Sex hormones (a) Androgens (Testosterone)	Testes	Control the growth and normal function of androsterone and male sex organs.
	(b) Estrogens (Estrone, Estradiol, Estriol)	Ovary	Control the growth and normal function of female sex organs.
	(c) Gestogens (Progesterone)	Corpus Iuteum	Control the onset and continuation of pregnancy.
B	Adenal Cortex hormones or corticoids (Cortisone, Corticosterone Aldesterone etc.)	Adernal cortex	Control the balance of water and minerals in the body; regulate the metabolism of fats, proteins, and carbohydrates.

12.2 Peptide Hormones

Name	Organ of secretion	Functions
(i) Oxytocin	Posterior pituitary gland	Controls uterine contractions after childbirth and releases milk from the mammary glands.
(ii) Vasopressin	Posterior pituitary gland	Controls water reabsorption in the kidney.
(iii) Angiotensin II	Blood plasma of persons	High blood pressure is a potent vasoconstrictor, which means it contracts the blood vessels.
(iv) Insulin	Pancreas	Controls glucose metabolism and keeps blood glucose levels stable.

12.3 Amine Hormones

Name	Organ of secretion	Functions
(i) Adrenaline or Epinephrine	Adrenal medulla	It is an amine compound and the first hormone discovered. Prepare animals and humans for emergencies in a variety of ways, including increasing pulse rate, blood pressure, and stimulating the breakdown of glycogens in the liver into blood glucose and fats into fatty acids during an emergency. Adrenaline is one of the most valuable drugs used in medicine because of these

		properties.
(ii) Thyroxine	Thyroid gland	Controls carbohydrate, lipid, and protein metabolism.

13. TEST FOR BIOMOLECULES

13.1 Test of Carbohydrates

13.1.1 Molish Test

The Molish test detects all types of carbohydrates, including monosaccharides, disaccharides, and polysaccharides. Molisch reagent (1 percent alcoholic solution of α-naphthol) is added to an aqueous carbohydrate solution, followed by conc. H_2SO_4 along the test tube's sides. At the intersection of the two layers, a violet ring forms.

13.2 Test for Proteins

13.2.1 Biuret Test

An alkaline solution of a protein when treated with a few drops of 1% $CuSO_4$ solution, produces a violet colouration. The colour is due to the formation of a coordination complex of Cu^{+2} with carbonyl group and –NH– groups of the peptide linkages.

13.2.2 Xanthoproteic Test

When a protein is treated with concentrated HNO_3, it turns yellow. This test is performed by a protein composed of α-amino acids containing a benzene ring, such as tyrosine, phenylalanine, and others, and the yellow color is caused by benzene ring nitration. An important example of this test is when concentrated

HNO_3, is spilled on your hands, the skin turns yellow due to nitration of the benzene ring of the amino acids in your skin's proteins.

13.2.3 Millon's Test

Millon's reagent is a nitric acid solution of mercurous nitrate and mercuric nitrate with little nitrous acid. When Millon's reagent is added to an aqueous protein solution, a white ppt. is formed. All proteins containing phenolic α-amino acids, such as tyrosine, pass this test. As a result, gelatin that does not contain phenolic α-amino acids fails this test.

13.2.4 Ninhydrin Test

A blue-violet color is produced when proteins are boiled in a dilute aqueous solution of ninhydrin (2, 2-dihydroxyindane-1,3-dione). This test is provided by all α-amino acids. Proteins and peptides both pass this test because they give α-amino acids when hydrolyzed.