

# Unit

## 7

# Biomolecules

### 7.1 Introduction

Chemical compounds present in living systems are known as **biomolecules**. Carbohydrates, proteins, vitamins, nucleic acids, enzymes and lipids are biomolecules. These molecules mainly contain carbon, hydrogen, oxygen, nitrogen, phosphorus and sulphur elements. Biomolecules play the important role in living systems so they are called basic constituents of living systems. We have general information about these biomolecules from the study during previous standards. In this unit we will study about classification, different structures and importance of biomolecules such as carbohydrates, proteins, vitamins, enzymes and nucleic acids.

### 7.2 Carbohydrates

Carbohydrates are the most important class of organic compounds. Generally they are obtained from plants. They fulfil basic requirements of human life, like foods, clothes and abode. **Carbohydrates are chemically polyhydroxy aldehydes or polyhydroxy ketones or such compounds which can be hydrolysed to these compounds.** Carbohydrates contain carbon, hydrogen and oxygen elements. In formulae of these compounds, the proportion of hydrogen and oxygen elements is 2 : 1. This proportion is equal to proportion of hydrogen and oxygen elements (2 : 1) in water molecule. Therefore, initially these compounds are known as hydrates of carbon. e.g.,

Carbohydrates	Molecular formula
(1) Glucose	$C_6H_{12}O_6$ OR $C_6(H_2O)_6$
(2) Sucrose	$C_{12}H_{22}O_{11}$ OR $C_{12}(H_2O)_{11}$
(3) Starch	$(C_6H_{10}O_5)_n$ OR $[C_6(H_2O)_5]_n$

Thus, **general formula of carbohydrates can be written as  $C_x(H_2O)_y$ , but it is not utterly true.** Some members of carbohydrate class do not possess 2:1 proportion of hydrogen and oxygen in their molecule. e.g., Rhamnose ( $C_6H_{12}O_5$ ). Moreover, some compounds are not members of carbohydrate class but their molecules contain 2 : 1 proportion of hydrogen and oxygen. e.g., formaldehyde ( $CH_2O$ ), acetic acid ( $C_2H_4O_2$ ), lactic acid ( $C_3H_6O_3$ ) etc. Thus, molecules of some members of carbohydrate class having 2:1 proportion of hydrogen and oxygen elements is like an accidental coincidence. All types of sugars, starch, cellulose etc. compounds are known as carbohydrates. Carbohydrates are often referred to as saccharides because of the sweet taste of the simpler members of the family, the sugars (sugar means saccharum in Latin and sakcharon in Greek)

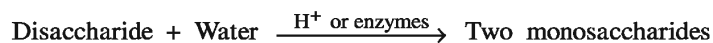
### 7.2.1 Classification of Carbohydrates :

Carbohydrates are classified as monosaccharide, oligosaccharide or polysaccharide on the basis of hydrolysis of their molecules.

**(1) Monosaccharide :** Simplest carbohydrates are included in this class. A carbohydrate that cannot be further hydrolyzed to simpler carbohydrate is called **monosaccharide**. Carbohydrates containing two to ten carbon atoms are included in this class. Their general formula is  $C_nH_{2n}O_n$ . Glucose ( $C_6H_{12}O_6$ ) and fructose ( $C_6H_{12}O_6$ ) are six carbon atoms containing monosaccharide. They occur in nature.

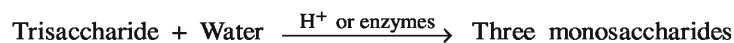
**(2) Oligosaccharide :** Oligosaccharide is sugar containing two to four monosaccharide units. Oligosaccharide can be classified as disaccharide, trisaccharide or tetrasaccharide.

**(A) Disaccharide :** A carbohydrate that can be hydrolyzed to two monosaccharide molecules is called a **disaccharide**.



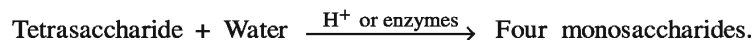
Carbohydrates containing ten to twelve carbon atoms are included in this class. Their general formula is  $C_nH_{2n-2}O_{n-1}$ . Sucrose ( $C_{12}H_{22}O_{11}$ ), maltose ( $C_{12}H_{22}O_{11}$ ), lactose ( $C_{12}H_{22}O_{11}$ ), cellobiose ( $C_{12}H_{22}O_{11}$ ) etc. are disaccharides.

**(B) Trisaccharide :** A carbohydrate that can be hydrolyzed to three monosaccharide molecules is called a **trisaccharide**.



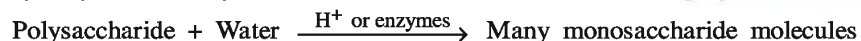
General formula of trisaccharides is  $C_nH_{2n-4}O_{n-2}$ . Raffinose ( $C_{18}H_{32}O_{16}$ ) is an example of trisaccharides. Raffinose is also known as melitriose.

**(C) Tetrasaccharide :** A carbohydrate that can be hydrolyzed to four monosaccharide molecules is called **tetrasaccharide**.



General formula of tetrasaccharide is  $C_nH_{2n-6}O_{n-3}$ . Stachyose is an example of tetrasaccharide.

**(3) Polysaccharide :** Polysaccharides are macromolecular substances. A carbohydrate that can be hydrolyzed to many monosaccharide molecules is called a **polysaccharide**.

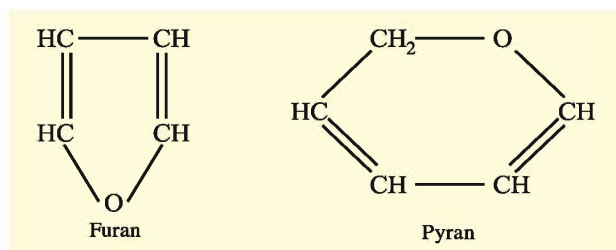


Starch, cellulose, glycogen, dextrin etc. are common examples of polysaccharides. Starch and cellulose occur in nature.

Generally monosaccharides and oligosaccharides are crystalline, water soluble and sweet in taste. They are known as sugar. Polysaccharides are amorphous, water insoluble and tasteless. They are known as nonsugar.

### 7.2.2 Nomenclature of Carbohydrates :

Generally the compounds of carbohydrate class contain 'ose' suffix in their names. e.g., Glucose, fructose, lactose, sucrose, maltose, cellobiose, rhamnose, raffinose, stachyose. If carbohydrate compound contains an aldehyde group it is called an aldose and that containing a keto group is called a ketose. Moreover, the number of carbon atoms present in these compounds are indicated by addition of Greek word like tri, tetra, penta and hexa before suffix 'ose' in the name of carbohydrate for three, four, five and six carbon atoms, respectively. e.g., Three carbon atoms and aldehyde group containing carbohydrate compound is called an aldotriose. Three carbon atoms and ketone group containing carbohydrate compound is called ketotriose. Glucose contains six carbon atoms and aldehyde group, so it is known as aldohexose. In the same manner fructose contains six carbon atoms and ketone group so it is known as ketohexose. Moreover, after detailed study of carbohydrate compounds we will know that they generally exist in cyclic form. Many times a proper word is used to mention the five membered or six membered cyclic compounds. e.g., **Pyranose** word is six membered (five carbon atoms and one oxygen atom) cyclic compound. **Furanose** word is used for five membered (four carbon atoms and one oxygen atom) cyclic compound.



Cyclic structure of glucose contains six membered ring so it is known as glucopyranose. Cyclic structure of fructose contains five membered ring so it is known as fructofuranose.

### 7.3 Monosaccharides

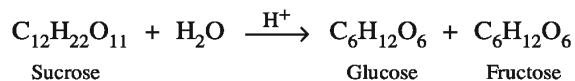
As seen earlier, glucose and fructose are common examples of monosaccharide. So, in this unit, we will study about preparation and different types of structures of glucose as a representative member of monosaccharide class.

#### 7.3.1 Glucose :

Glucose is present in ripe fruits and honey. Grapes contain 20 to 25 % glucose, so glucose is also known as grape sugar. It is also present in human blood and urine in fixed amount.

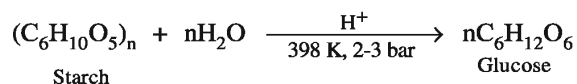
##### Preparation of glucose :

(1) **From cane sugar** : Mixture of glucose and fructose can be obtained by hydrolysis of alcoholic solution of cane sugar (sucrose) with the help of dilute hydrochloric acid or sulphuric acid as catalyst.



After completion of this reaction, excess amount of alcohol is added to this mixture. Glucose is insoluble in alcohol so it settles down at the bottom of the vessel as precipitate and fructose is soluble in alcohol so it is present in solution. Therefore, glucose separates out easily by filtration.

(2) **From starch** : In industry, glucose is obtained by hydrolysis of starch with help of dilute  $\text{H}_2\text{SO}_4$  at 393 K under 2-3 bar pressure.



After completion of hydrolysis, excess sulphuric acid is neutralised by calcium carbonate. Due to this reaction insoluble calcium sulphate is formed. It is removed by filtration. Filtrate is made colourless by adsorption with charcoal. After concentrating this filtrate in absence of air, the crystals of glucose are formed.

**Structure of Glucose :** Structure of glucose and other aldose compounds are decided by following methods and reactions.

**Open chain structure of glucose :**

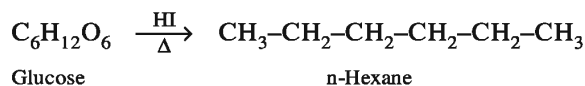
- (1) From the analysis of glucose following results are obtained:

**Empirical formula :**  $\text{CH}_2\text{O}$

**Molecular mass :**  $180 \text{ gram mol}^{-1}$

**Molecular formula :**  $\text{C}_6\text{H}_{12}\text{O}_6$

- (2) When glucose is heated for a long time with hydrogen iodide results in formation of n-hexane. It indicates that all six carbon atoms of glucose are linked in linear chain.



Thus, C-C-C-C-C-C chain is present in the structure of glucose.

- (3) Glucose gives typical reactions with reagents for carbonyl group. e.g., Glucose forms cyanohydrin with hydrogen cyanide (HCN); glucose forms oxime with hydroxylamine ( $\text{NH}_2\text{OH}$ ); glucose forms phenylhydrazone with phenylhydrazine ( $\text{C}_6\text{H}_5\text{NHNH}_2$ ). These reactions suggest that carbonyl group ( $>\text{C}=\text{O}$ ) is definitely present in glucose molecule, because these reactions are specific reactions of carbonyl group.
- (4) Oxidation of glucose by bromine water forms equal carbon containing acid-gluconic acid. Solution of ammonical silver nitrate (Tollens' reagent) is reduced to silver by glucose. Glucose can reduce Fehling's solution to cuprous oxide (precipitate) and will be self oxidized to acid. These three reactions prove the presence of aldehyde group in glucose, because all these reactions are specific tests for aldehyde functional group. As per general rule aldehyde group is attached to the end of the carbon chain.

Thus,  $\text{OHC-C-C-C-C-C}$  chain is present in the structure of glucose.

- (5) Glucose is oxidized by strong oxidizing agent nitric acid to equal number of carbon atoms containing dicarboxylic acid-saccharic acid. It suggests that aldehyde group is attached at one end of carbon chain of glucose and primary alcohol ( $-\text{CH}_2\text{OH}$ ) group is attached at the other end of carbon chain of glucose.

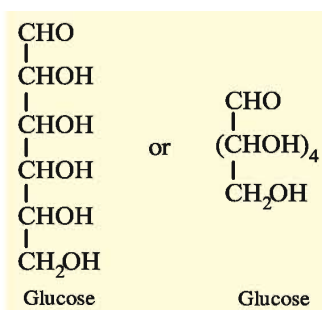
Thus,  $\text{OHC-C-C-C-C-CH}_2\text{OH}$  chain is present in the structure of glucose.

- (6) Glucose forms five acetyl groups containing penta acetyl glucose with acetic anhydride in presence of anhydrous zinc chloride or pyridine. It suggests that five hydroxyl groups are present in glucose molecule. Moreover these five hydroxyl groups are attached at

different carbon atoms because if two or more hydroxyl groups are attached at the same carbon atom then that compound is unstable and it loses water molecule easily. But glucose molecule does not lose water molecule and it is a stable compound.

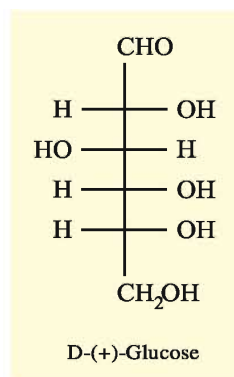
Thus,  $\text{OHC}-\underset{\text{OH}}{\text{C}}-\underset{\text{OH}}{\text{C}}-\underset{\text{OH}}{\text{C}}-\underset{\text{OH}}{\text{C}}-\text{CH}_2\text{OH}$  chain is present in the structure of glucose.

- (7) In deciding the chain at point-6, the valency of second to fourth carbon atoms are satisfied by hydrogen atom, as a result structure of glucose obtained is as follows :



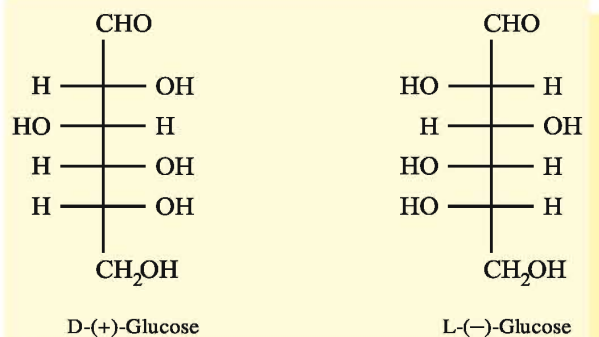
Now for understanding the structure of glucose molecule we will study about arrangement of its atoms and groups in space.

**Configuration of Glucose :** An arrangement of atoms or groups of molecule in space is called the configuration of that compound. Scientist Emil Fischer determined the configuration of glucose after studying many reactions. It is as following :



Scientist Emil Fischer determined the configuration of almost all aldopentose and aldohexose in a period of only four years (1888-1891). In 1902, the Nobel prize was awarded to him for his research works in chemistry. We have learnt about D, L, d or (+), l or (-) in unit 6 of semester III.

In Fischer projection of carbohydrate compounds, if the -OH group is attached to the bottom most chiral carbon atom on the right side, the compound possesses D-configuration. If -OH group is attached on the left-side, the compound possesses L-configuration. D- and L-compounds are enantiomers. Optically active organic compound rotates the plane of polarized light. This value of rotation (in degree) is known as angle of rotation ( $\alpha$ ) shown by that compound. This rotation is measured by **polarimeter instrument**. If only optically active organic compound shows this rotation in a clockwise direction or on a right side direction then (+) sign is put before its rotation value. This compound is called **dextrorotatory**. It is mentioned with d or (+) sign. If any optically active organic compound shows this rotation in an anticlockwise direction or on left side direction then (-) sign is put before its rotation value. This compound is called **levorotatory**. It is mentioned with l or (-) sign. d or (+) (dextrorotatory) and l or (-) (levorotatory) compounds are also enantiomers. There is no direct relation of D and L with d or l.



The specific rotation  $[\alpha]_{\lambda}^T$  can be calculated from the value of angle of rotation ( $\alpha$ ) of optically active compound. The specific rotation is required for the comparison of optical activities of two compounds.

$$[\alpha]_{\lambda}^T = \frac{\alpha}{l \times C}$$

where,  $[\alpha]$  = specific rotation

T = Temperature (K)

$\lambda$  = Wavelength of the incident light

(D symbol is used for wavelength of sodium light)

$\alpha$  = Observed angle of rotation (by polarimeter)

l = Length of tube (in decimeter) (10 cm = 1 dm)

C = Concentration of compound (gram ml<sup>-1</sup>)

**Example 1 :** The observed angle of rotation of 2.0g of sucrose in 10 ml of aqueous solution in a polarimeter tube 10 cm long is +13.3°. What is the specific rotation of the solution of sucrose ?

**Solution :** Here C = 2.0 g/10 ml = 0.2 gml<sup>-1</sup>

$$l = 10 \text{ cm} = 1 \text{ dm}$$

$$\alpha = + 13.3^\circ$$

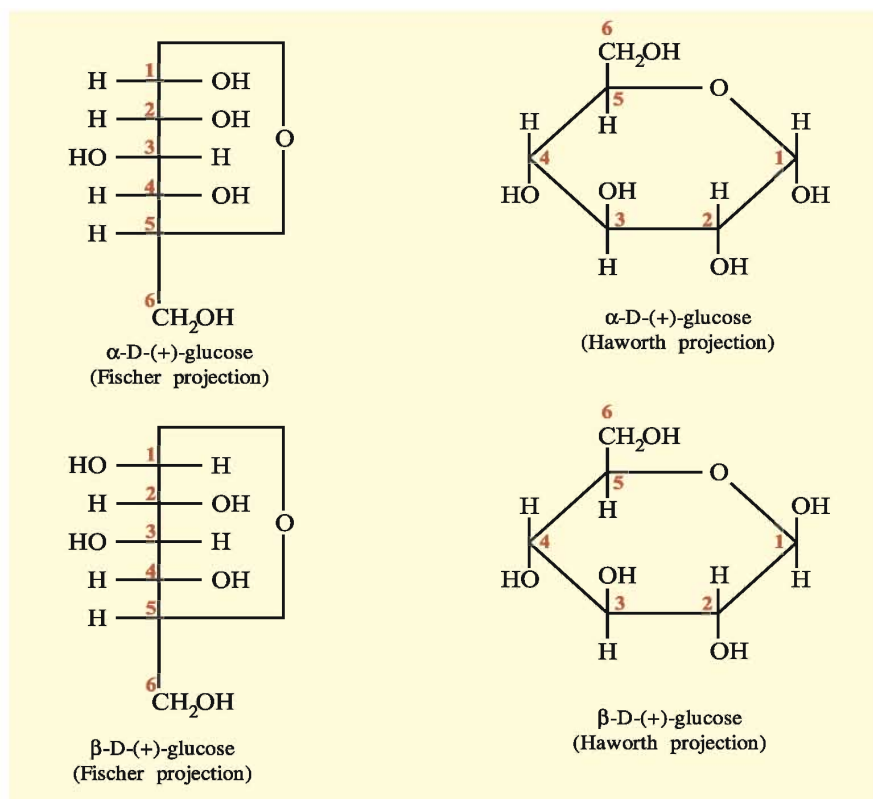
$$\begin{aligned}
 \text{Now, } [\alpha]_{\lambda}^T &= \frac{\alpha}{l \times C} \\
 &= \frac{+ 13.3}{1 \times 0.2} \\
 &= + 66.5^\circ
 \end{aligned}$$

Thus, specific rotation of sucrose is + 66.5°

**Cyclic structure of glucose :** -CHO group is present in configuration of glucose, but glucose does not give some reactions of aldehyde. Moreover glucose also gives some reactions which are not given by an aldehyde.

- (1) Glucose does not form addition product with sodium bisulphite ( $\text{NaHSO}_3$ ). Generally aldehyde group containing compounds form addition product with sodium bisulphite.
- (2) An aldehyde reduces Tollens' reagent and Fehling's solutions. It also gives violet colour with Schiff's reagent. Glucose gives first two reactions but does not give violet colour with Schiff's reagent.
- (3) An aldehyde does not show mutarotation property (process of changes in specific rotation) while glucose shows this property.

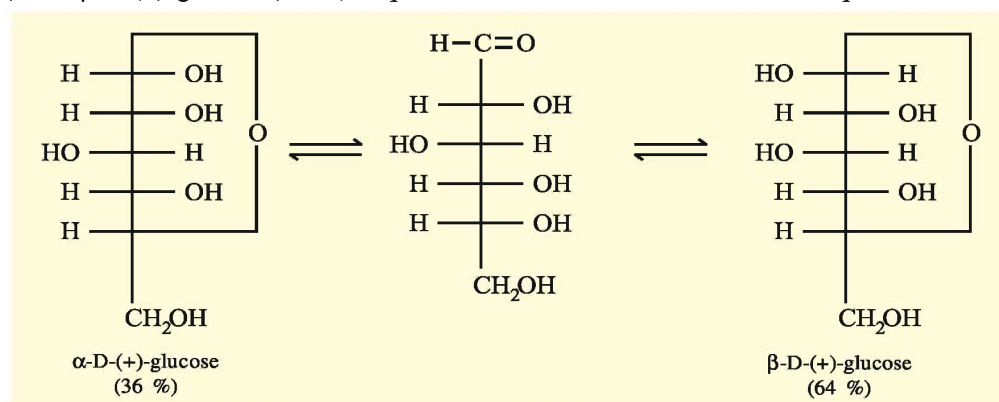
Thus, these reactions create doubt about the open chain structure of glucose. Experimental results have decided that glucose exists in two configurations  $\alpha$  and  $\beta$ . Existence of these two configurations of glucose cannot be explained by its open chain structure. In 1895 scientists Fischer, Tollens and Tanret have suggested that structure of glucose should not be an open chain but it is a cyclic form. In 1925, Haworth and Hirst from experimental evidences suggested that glucose molecule may contain pyranose ring (ring contains five carbon atoms and one oxygen atom). Study of X-rays also supported this point. Thus, glucose consists of pyranose ring containing cyclic structure. It can be shown as below :



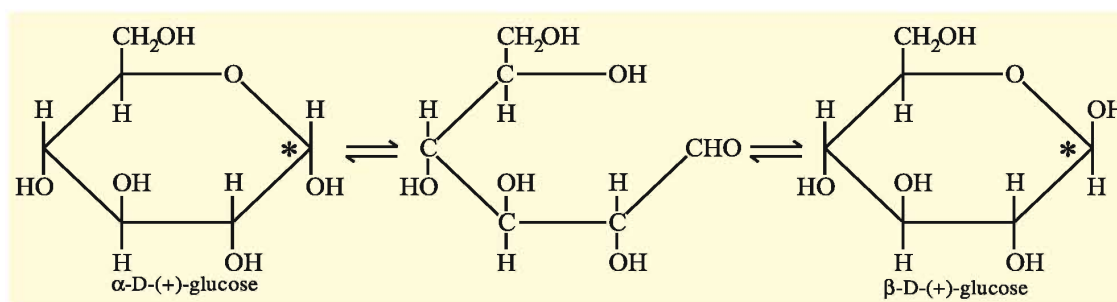
Generally the carbon of cyclic structure which is carbonyl carbon in open chain structure is called **anomeric carbon**. The first carbon atom of cyclic structure of glucose is anomeric carbon because it is a carbonyl carbon in open chain structure of glucose. The isomers differ in configuration at anomeric carbon and are called **anomers**.  $\alpha$ -D-(+)-glucose and  $\beta$ -D-(+)-glucose are anomers, because the  $-\text{OH}$  group is attached at right side to anomeric carbon (C1) of Fischer projection of  $\alpha$ -D-(+)-glucose, while the  $-\text{OH}$  group is attached at left side to anomeric carbon (C1) of Fischer



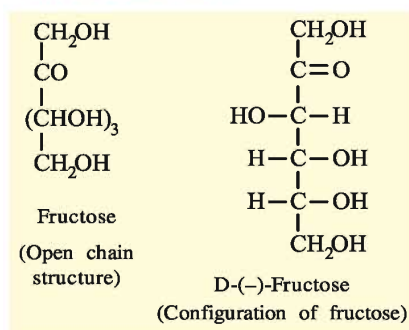
projection of  $\beta$ -D-(+)-glucose. Atom or group on the right side in Fisher projection is below in Haworth projection.  $\alpha$ -D-(+)-glucose can be obtained by crystallization from water at 303 K. It can also be obtained by crystallization from ethyl alcohol or glacial acetic acid. The crystals obtained in this way are dissolved in water and the specific rotation of this freshly prepared solution of glucose is  $+112^\circ$ . After some time it decreases to  $+52.5^\circ$ .  $\beta$ -D-(+)-glucose can be obtained by crystallization from water at 371 K. It can also be obtained by crystallization from pyridine. The crystals obtained this way are dissolved in water and the specific rotation of this freshly prepared solution of glucose is  $+19^\circ$ . After some time it increases to  $+52.5^\circ$ . This process of change in specific rotation is called **mutarotation**. This mutarotation is shown by glucose and it should be due to conversion of  $\alpha$ -form to  $\beta$ -form and  $\beta$ -form to  $\alpha$ -form. If the solution of glucose shows a specific rotation of  $+52.5^\circ$  then mixture of  $\alpha$ -D-(+)-glucose (36 %) and  $\beta$ -D-(+) glucose (64 %) is present in it. This conversion can be explained as follows :



It can be easily understood by Haworth projections also.



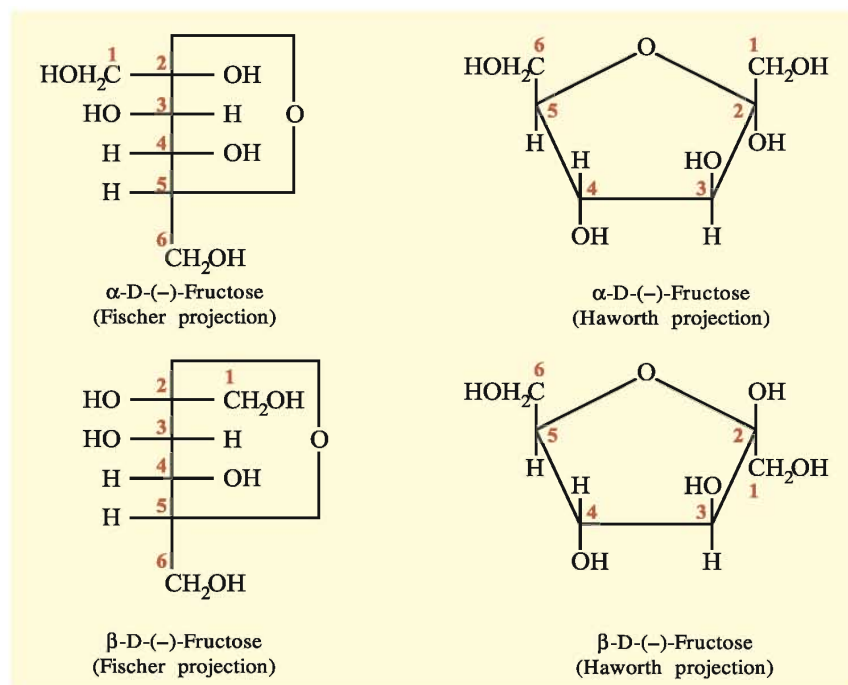
### 7.3.2 Fructose :



Fructose is a white crystalline substance. It is soluble in water, partially soluble in alcohol and insoluble in ether. It is levo rotatory optically active compound. It is sweet in taste. Its sweetness is higher compared to glucose, table sugar and also all other sugars. Molecular formula of fructose is  $\text{C}_6\text{H}_{12}\text{O}_6$ . It contains ketone group and six carbon atoms, so it is known as ketohexose. Experimentally established structures of fructose are mentioned below :

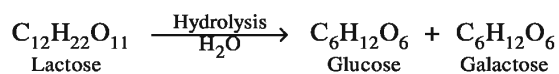
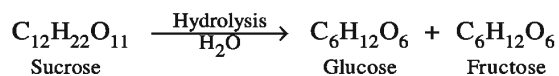
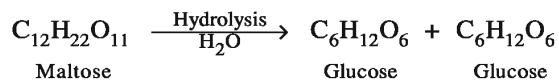


Experimental results have proved that fructose exists in two configurations  $\alpha$ - and  $\beta$ - and consists of furanose ring containing cyclic structure. C2 is anomeric carbon in fructose. Fructose shows mutarotation property. Cyclic structure of fructose is as follows :



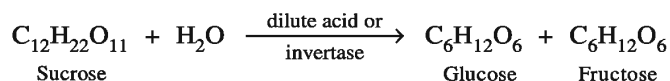
#### 7.4 Disaccharides

Disaccharide molecule is formed by two monosaccharide units. Hydrolysis of disaccharide by diluted acid or enzyme gives same type or two different types of monosaccharides. Molecular formula of disaccharide is  $C_{12}H_{22}O_{11}$ .

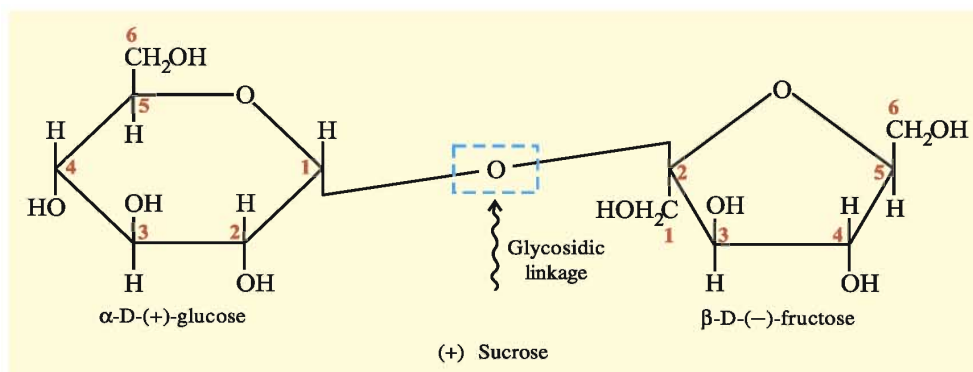


In disaccharide, the linkage of two monosaccharides joined with each other by linkage of oxygen atom is called glycosidic linkage. Disaccharides are sweet in taste, crystalline and soluble in water.

**(1) Sucrose :** Sucrose is table sugar used in our daily life. It is mostly found in sugar cane and beets. Therefore it is called cane sugar. Sucrose is colourless, crystalline, sweet in taste and water soluble. This sugar is dextrorotatory (+). Specific rotation of its aqueous solution is  $+66.5^\circ$ . Mutarotation does not occur in it. If sucrose is boiled with dilute acid (HCl or H<sub>2</sub>SO<sub>4</sub>) or hydrolyzed by invertase enzyme then mixture of D-(+)-glucose and D-(-)-fructose in equal proportion (1 : 1) is obtained.

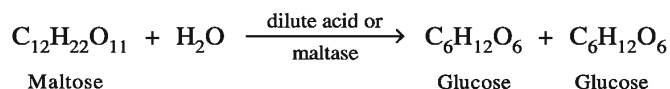


The aqueous solution of sucrose is dextrorotatory (+) before hydrolysis, but at the end of hydrolysis, produces aqueous solution of glucose and fructose mixture is found as levorotatory (-). The specific rotation of this solution observed is  $-20^\circ$ . The process of change in sign of rotation of sucrose solution is called inversion. The mixture of glucose and fructose obtained at the end of hydrolysis is called invert sugar. The specific rotation in inverted sugar during hydrolysis due to specific rotation of glucose solution is  $+52.5^\circ$  and specific rotation of fructose solution is  $(-92^\circ)$ . In this, the specific rotation of fructose is higher than that of glucose; as a result final mixture formed is levorotatory (-). Experimental results have proved that the glycosidic linkage is formed between C1 of  $\alpha$ -D-(+)-glucose and C2 of  $\beta$ -D-(-)-fructose in structure of sucrose. Thus, **in sucrose, two monosaccharide units are joined to each other by C1-O-C2 linkage.**

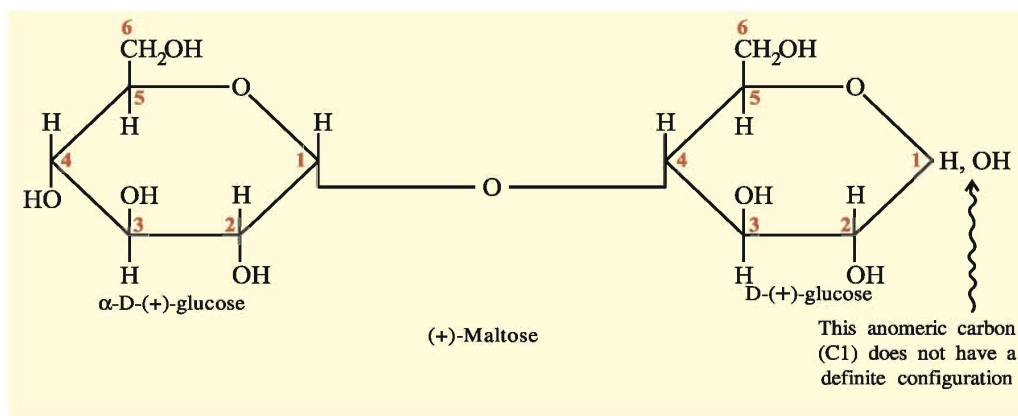


In sucrose both monosaccharide units viz. glucose and fructose are reducing sugars. The  $-\text{OH}$  group attached to C1 in cyclic structure of glucose and to C2 in cyclic structure of fructose acts as reducing agent group. In sucrose, the reducing agent groups of two monosaccharide units are involved in glycosidic bond, because of which they are not free. Therefore sucrose does not reduce the Fehling's solution and does not form phenylhydrazone with phenylhydrazine. Thus, **sucrose is non-reducing sugar.** Sucrose is taken as a standard for comparison of sweetness of other sugars. Its sweetness index is considered as 100. As per this, glucose, fructose and lactose possess sweetness index as 74, 173 and 16, respectively. When sucrose is heated to 483 K it loses water and forms a brown amorphous substance called **caramal**. This caramal is used as a colouring agent in preparation of sweets and ice-creams.

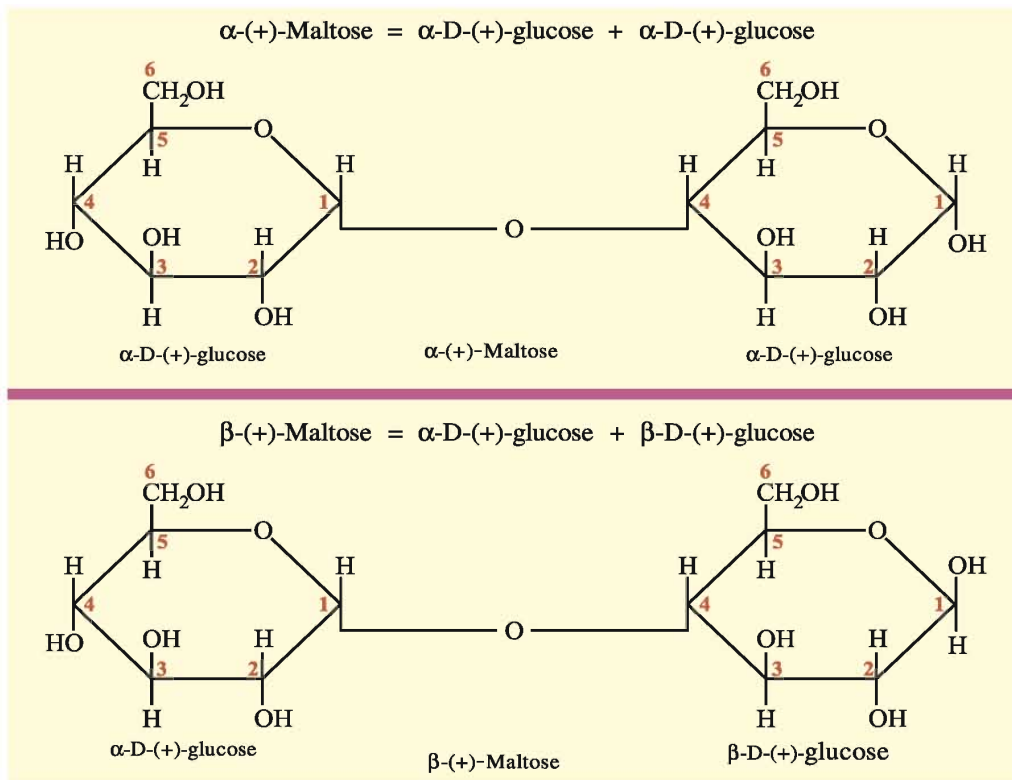
**(2) Maltose :** Barley contains malt. Maltose is the main constituent of malt. Therefore maltose is known as malt sugar. Maltose is formed before alcohol is formed from the starch containing compounds. Maltose is colourless and has needle shaped crystals. It is very soluble in water but insoluble in alcohol. Maltose is dextrorotatory (+) and shows mutarotation. Its hydrolysis occurs by dilute acid or maltase enzyme and as a result D-(+)-glucose is formed.



Experimental results have proved that in structure of maltose, the glycosidic linkage is formed between C1 of  $\alpha$ -D-(+)-glucose and C4 of another D-(+)-glucose unit. Thus, **in maltose two monosaccharide units are joined by C1-O-C4 linkage.**

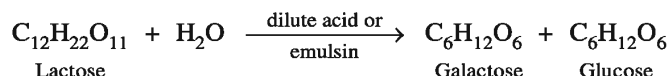


Here, anomeric carbon of one glucose unit, out of two glucose units is not involved in formation of glycosidic bond. The configuration of this anomeric carbon is changed and two forms of maltose are formed. They are called anomers of maltose. If the configuration of this anomeric carbon is similar to  $\alpha$ -D-(+)-glucose then it is called  $\alpha$ -maltose and if it is similar to  $\beta$ -D-(+)-glucose then it is called  $\beta$ -maltose. Thus,

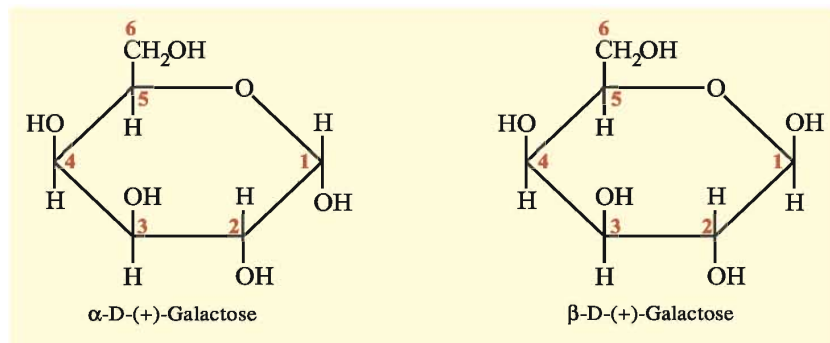


In maltose, both the monosaccharide units viz. glucose are reducing sugars. In cyclic structure of glucose, –OH group attached to C1 act as reducing agent. Two glucose units are joined by C1–O–C4 linkage. Thus, reducing agent group of one glucose unit is involved in formation of glycosidic bond but reducing agent group of another glucose unit is free. Therefore maltose reduces Fehling's solution and forms phenylhydrazone with phenylhydrazine. Thus, **maltose is reducing sugar**.

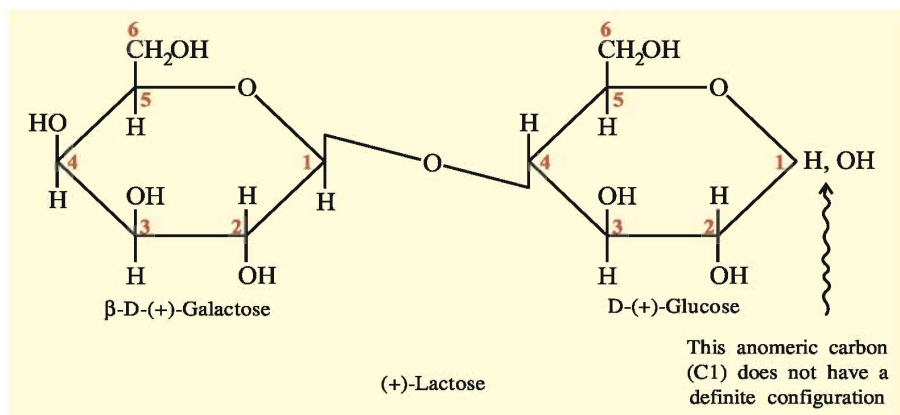
**(3) Lactose :** Lactose is present in the milk of animals, so it is known as milk sugar. This sugar is not present in plants. Casein is separated from milk; then after this fats are also taken out of it. Remaining milk contains lactose. Lactose sugar can be obtained by concentrating this milk in evacuated vessel. Lactose is soluble in water but insoluble in alcohol. It is dextrorotatory (+) and shows mutarotation. Its hydrolysis occurs by dilute acid or emulsin enzyme and as a result mixture of D-(+) -galactose and D-(+)-glucose in equal proportion (1:1) is formed.



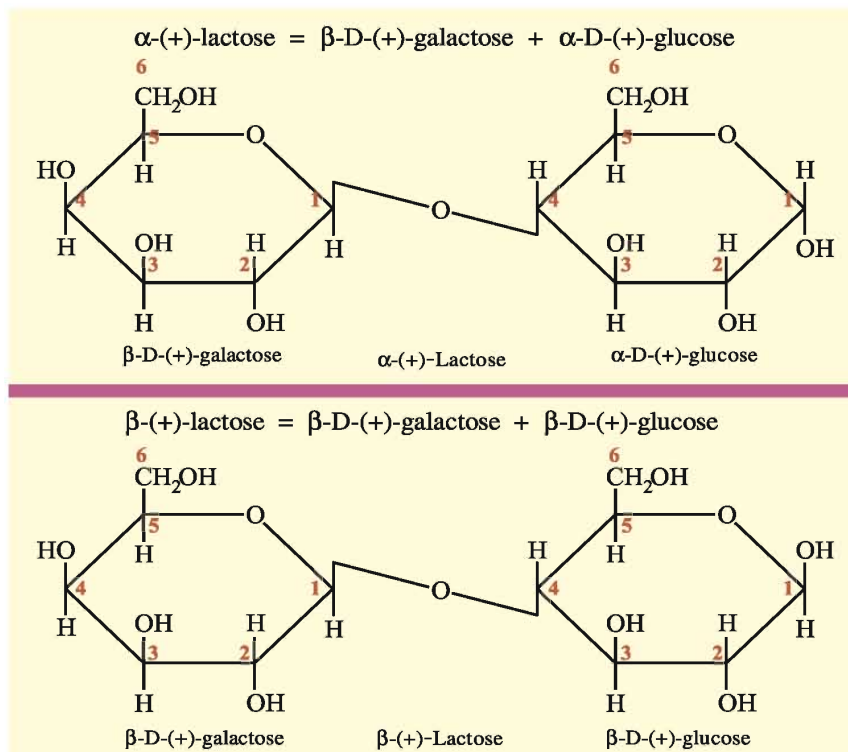
It is necessary to know the structure of galactose before knowing the structure of lactose. Experimental results have proved the cyclic structure of galactose (C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>) as follows :



Experimental results have proved that in structure of lactose, the glycosidic linkage is formed between C1 of  $\beta$ -D-(+)- galactose and C4 of D-(+)-glucose. Thus **in lactose two monosaccharide units are joined by C1–O–C4 linkage**.



Here, anomeric carbon of D-(+)-glucose unit out of two monosaccharides is not involved in formation of glycosidic bond. The configuration of this anomeric carbon is changed and two forms of lactose are formed. They are called anomers of lactose. If configuration of this anomeric carbon is similar to  $\alpha$ -D-(+)-glucose, then it is called  $\alpha$ -lactose and if it is similar to  $\beta$ -D-(+)-glucose then it is called  $\beta$ -lactose. Thus,



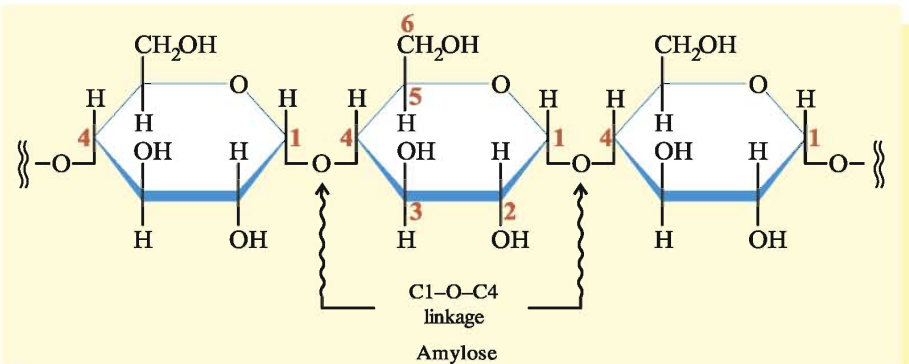
In lactose, both the monosaccharides viz. galactose and glucose, are reducing sugars. In cyclic structures of glucose and galactose,  $\text{-OH}$  group attached to C1 acts as reducing agent. Galactose and glucose units are joined by C1–O–C4 linkage in lactose. Thus, reducing agent group of glucose unit is free. Therefore lactose reduces Fehling's solution and forms phenylhydrazone with phenylhydrazine. Thus, **lactose is a reducing sugar.**

### 7.5 Polysaccharides

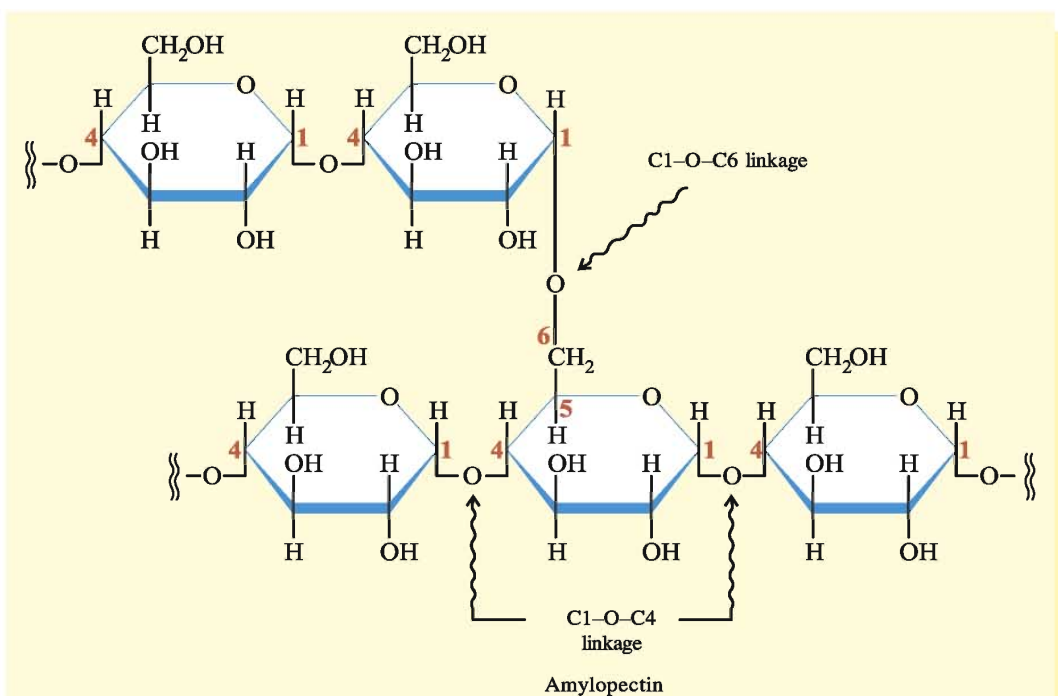
Many monosaccharide molecules are joined with one another in polysaccharide molecule. Starch, cellulose, glycogen and dextrin are examples of polysaccharide. Polysaccharide compounds possess very high molecular mass. Molecular mass of starch may be as high as 8 lakh to 10 lakh. Determination of exact molecular mass of polysaccharide compound is difficult. Therefore, their general formula of them can be written as  $(\text{C}_6\text{H}_{10}\text{O}_5)_n$ . These compounds are tasteless and amorphous. They are also insoluble in hot water. Hydrolysis of polysaccharide compounds by dilute acid or enzyme form disaccharide and in the end hexose and pentose are formed.

**(1) Starch :** In nature, the starch is found in all green plants, roots and seeds. Its main sources are wheat, rice, potatoes, maize and sorghum. They occur in the form of granules which vary in size and shape. Starch is colourless, odourless and solid insoluble compound in water. Starch is a mixture

of amylose (about 20%) and amylopectin (about 80%) polysaccharides. Amylose structure consists of a long unbranched chain with 200 to 1000 glucose molecules. In this chain  $\alpha$ -D-(+)-glucose units are joined by C1–O–C4 linkage.



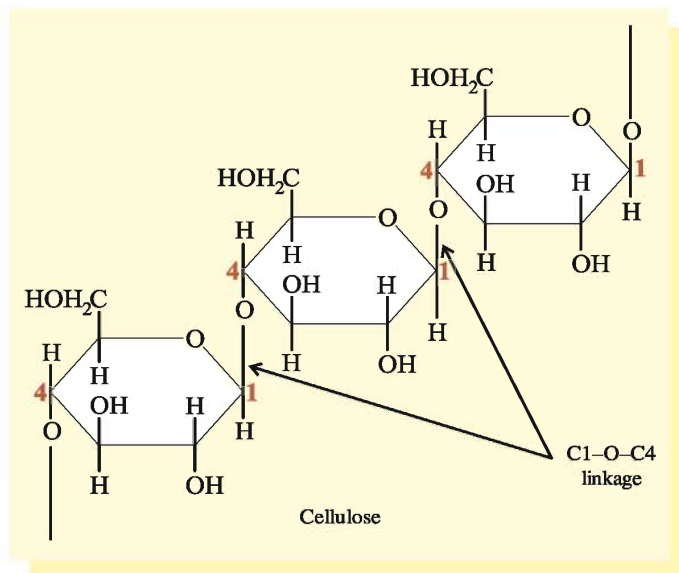
In structure of amylopectin  $\alpha$ -D-(+)-glucose units are joined by C1–O–C4 linkage, but some  $\alpha$ -D-(+)-glucose units are joined by C1–O–C6 linkage and they make branches.



**(2) Cellulose :** Cellulose is the main component of cell walls of plants. Cotton is pure form of cellulose. Moreover cellulose is obtained from wood (50% cellulose) and jute (65% cellulose) in moderate proportion. Cellulose is a colourless fibrous compound. It is insoluble in water and in most organic solvents but it is completely soluble in ammonical cupric hydroxide solution. Molecular mass of cellulose is approximately 3 lakh to 5 lakh (1800 to 3000 glucose units). Hydrolysis of cellulose by acid gives D-(+)-glucose. Experimental results have proved that cellulose consists of long chain of



$\beta$ -D-(+)-glucose. In this chain, the glycosidic linkage is formed between C1 of one  $\beta$ -D-(+)-glucose unit and C4 of next  $\beta$ -D-(+)-glucose unit. Thus, **in cellulose, two monosaccharide molecules are joined by C1-O-C4 linkage.**



## 7.6 Importance of Carbohydrates

- Cellwall of bacteria and plants is made up of cellulose.
- New growing plant uses the starch which is stored in seeds as food for their growth.
- The stored glycogen in animals is converted into glucose and gives energy when required.
- Major component of our food materials is carbohydrates. e.g., table sugar, jaggery, wheat, rice etc.
- Linen, rayon and acetate fibre are form of cellulose. They are used for making clothes.
- Wood is used for construction of building and furniture, wood is also cellulose.
- Carbohydrate compounds are used for preparation of paper, photographic - film, explosive substances, plastics etc.

## 7.7 Proteins

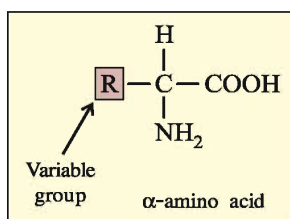
Protein compounds possess very high molecular mass (Approximate 20000 to 2 crore). They are biopolymer complexes of amino acids. They are present in all living cells. Therefore proteins are of prime physiological importance in all living cells. Enzymes, hormones, antibodies are all proteins. A large number of different amino acids are obtained by the hydrolysis of protein. All proteins contain C, H, O, N elements while some may also contain non-metal elements like S,P and metal elements like Fe, Cu, Zn, Mn in trace amount.



It is necessary to study amino acids before studying the proteins and peptides.

### 7.7.1 Amino Acids :

In 1901, scientist Emil Fischer had obtained several amino acids by hydrolysis of proteins. Thus, amino acids are the building block of protein structure. The name amino acid indicates that they contain both an amino ( $-\text{NH}_2$ ) and carboxyl ( $-\text{COOH}$ ) group. Those amino acids which are obtained from hydrolysis of protein are all  $\alpha$ -amino acids. This means that in their structure, amino group is on  $\alpha$ -carbon atom adjacent to carboxyl group. General structure of  $\alpha$ -amino acid is as follows :



Here  $-\text{R}$  is not restricted to alkyl group.  $-\text{R}$  may be open chain, cyclic or aromatic hydrocarbon group; amino, carboxyl, hydroxyl or sulphur containing group (table 7.1). It is necessary to note here that structures of all  $\alpha$ -amino acid possess primary amino group, while only proline contains secondary amino group. In this compound nitrogen atom of amino group is involved in five membered ring (table 7.1). All  $\alpha$ -amino acids are known

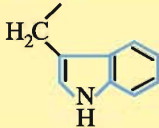
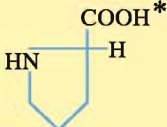
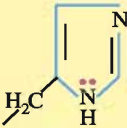
by trivial names. From these names general properties or their sources can be known but any information about their structure is not obtained. Glycine got its name because of its sweet taste (in Greek 'Glykos' means 'sweet'). Tyrosine got its name because it was first obtained from cheese (in Greek, 'tyros' means cheese). As we know that amino acid contains one acidic group ( $-\text{COOH}$ ) and one basic group ( $-\text{NH}_2$ ), therefore acidic, basic and neutral nature of amino acid depends on the nature of attaching group R. Amino acids can be classified in neutral, acidic and basic forms as follows :

- (1) **Neutral amino acid** : The amino acid in which the, attaching group-R possesses neutral nature it is known as neutral amino acid (table 7.1). e.g., glycine, alanine.
- (2) **Acidic amino acid** : The amino acid in which the, attaching group-R possesses acidic nature, it is known as acidic amino acid (table 7.1) e.g., aspartic acid, glutamic acid.
- (3) **Basic amino acid** : In which amino acid, attaching group-R possesses basic nature is known as basic amino acid (table 7.1). e.g., lysine, arginine.

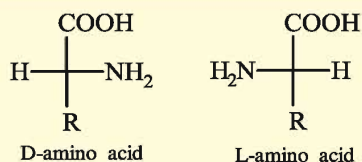
Amino acids which can be synthesised in body are known as **non-essential amino acids** and those which cannot be synthesised in the body and must be obtained through diet are called **essential amino acids**. Leucine, isoleucine, lysine, methionine, phenyl alanine, threonine, tryptophan, valine, arginine and histidine are essential amino acids. Name and structure of twenty important naturally occurring amino acids are mentioned in table 7.1.

Table 7.1 Important naturally occurring amino acids (For information only)

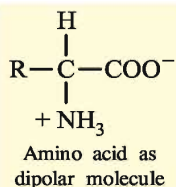
Sr.	Name of the amino acids	Structure of R	Three letters symbol	One letter symbol
<b>Neutral amino acid</b>				
1.	Glycine	$-\text{H}$	Gly	G
2.	Alanine	$-\text{CH}_3$	Ala	A
3.	Valine	$-\text{CH}(\text{CH}_3)_2$	Val	V

4.	Leucine	$-\text{CH}_2\text{CH}(\text{CH}_3)_2$	Leu	L
5.	Isoleucine	$-\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_3$	Ile	I
6.	Phenylalanine	$-\text{CH}_2-\text{C}_6\text{H}_5$	Phe	F
7.	Asparagine	$-\text{CH}_2\text{CONH}_2$	Asn	N
8.	Glutamine	$-\text{CH}_2\text{CH}_2\text{CONH}_2$	Gln	Q
9.	Serine	$-\text{CH}_2\text{OH}$	Ser	S
10.	Threonine	$-\text{CH}(\text{CH}_3)\text{CHOH}$	Thr	T
11.	Cysteine	$-\text{CH}_2\text{SH}$	Cys	C
12.	Methionine	$-\text{CH}_2\text{CH}_2\text{SCH}_3$	Met	M
13.	Tyrosine	$-\text{CH}_2-\text{C}_6\text{H}_4-\text{OH}$	Tyr	Y
14.	Tryptophan		Trp	W
15.	Proline		Pro	P
<b>Acidic amino acids</b>				
16.	Aspartic acid	$-\text{CH}_2\text{COOH}$	Asp	D
17.	Glutamic acid	$-\text{CH}_2\text{CH}_2\text{COOH}$	Glu	E
<b>Basic amino acids</b>				
18.	Lysine	$-(\text{CH}_2)_4\text{NH}_2$	Lys	K
19.	Arginine	$-(\text{CH}_2)_3\text{NH}-\text{C}(=\text{NH})-\text{NH}_2$	Arg	R
20.	Histidine		His	H

\* It is not only structure of R but it is entire structure of amino acid

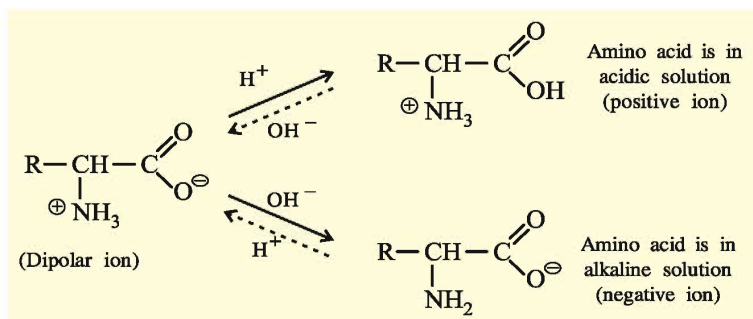


is a **D-amino acid** if the  $-\text{NH}_2$  group is on the right of the horizontal axis and is an **L-amino acid** if  $-\text{NH}_2$  is on the left. Most of the amino acids found in nature have L-configuration.



**Amino acid as dipolar molecule :** We know that amino acids contain both the acidic group ( $-\text{COOH}$ ) and basic group ( $-\text{NH}_2$ ). In dry solid form, the amino acid exists as dipolar molecule in which carboxyl group is present as carboxylate ion ( $\text{COO}^-$ ) and amino group is present as aminium ion ( $\text{NH}_3^+$ ). This dipolar ion is also known as **zwitter ions**.

In acidic solution, dipolar ion of amino acid exists as a positive ion while in alkaline solution it exists as a negative ion.



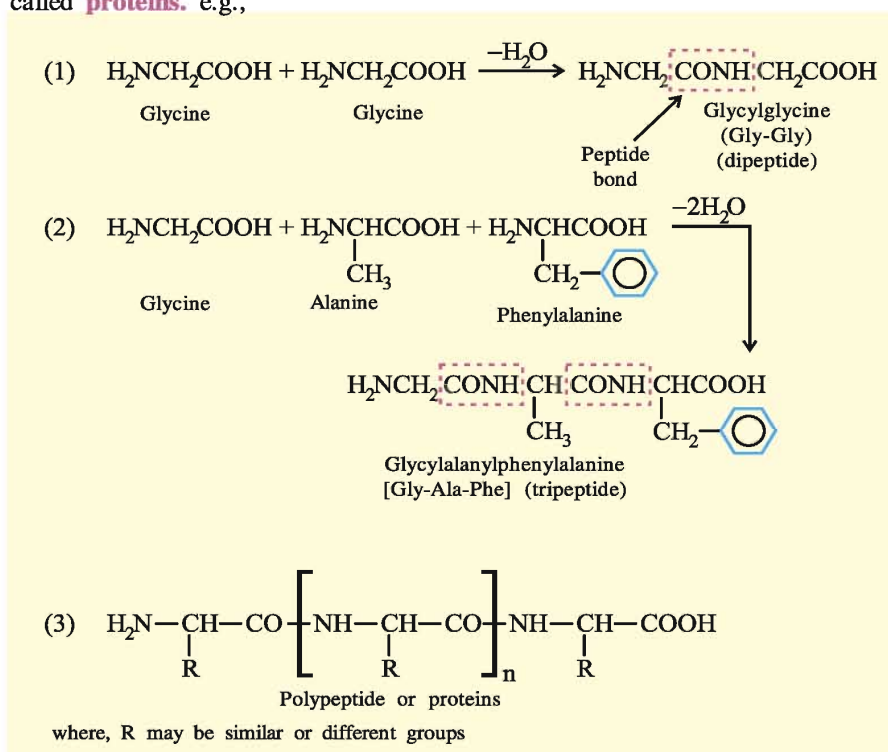
Thus, amino acids exist as positive ion ( $\text{pH} < 7$ ) or negative ion ( $\text{pH} > 7$ ) or dipolar ion ( $\text{pH} = 7$ ) corresponding to  $\text{pH}$  of their aqueous solution. If solution of amino acid is put in an electric field then the ions present will migrate towards the specific electrode. If amino acid is present as positive ion in its solution then it will migrate towards cathode (negative electrode) and if it is present as negative ion in its solution then it will migrate towards anode (positive electrode). If amino acid is dipolar ion in its solution then it will not migrate towards anode or cathode, because of dipolar ion is neutral with respect to balancing of charge. In electric field, the  $\text{pH}$  value at which the amino acid does not migrate towards any electrode is called the **isoelectric point (pI) of amino acid**. Different amino acid have different isoelectric points.

Most of the amino acids react with acid or base and form salt, so they are known as **amphoteric compounds**. A mixture of amino acids can be separated by electrophoresis and different types of chromatographic techniques.

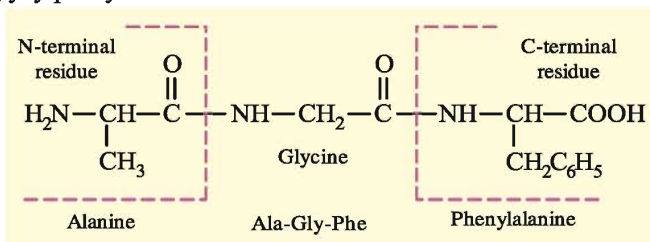
### 7.7.2 Peptides :

Scientist Emil Fischer suggested that reaction between  $-\text{NH}_2$  group of one amino acid and  $-\text{COOH}$  group of another amino acid loses the water molecule and forms amide. This amide bond ( $-\text{CONH}-$ ) is known as **peptide bond or peptide linkage**. If two amino acids are joined by peptide bond and form a chain then it is called the **dipeptide**. If three amino acids are joined by peptide bond

and form a chain is called the **tripeptide**. If four to ten amino acids are joined by peptide bond and form a long chain then it is called the **oligopeptide**. If many amino acids are joined by peptide bond and form a long chain then it is called **polypeptide or protein**. Generally peptides having molecular mass upto 10,000 are called **polypeptides** and which peptides which have molecular mass above 10,000 are called **proteins**. e.g.,



Out of two amino acids (first and last) of peptide chain, the  $-\text{NH}_2$  group of one amino acid and  $-\text{COOH}$  group of another amino acid are not involved in formation of peptide bond. Thus,  $-\text{NH}_2$  group at one end and  $-\text{COOH}$  group at other end are free in polypeptide chain. According to simple convention for representation of peptide structure, the free  $-\text{NH}_2$  group containing end is written at left side in peptide chain. It is known as **N-terminal residue**. The free  $-\text{COOH}$  group containing end is written at right side in peptide chain. It is known as **C-terminal residue**. According to this convention tripeptide alanyl-glycylphenylalanine can be mentioned as follows :



The sequence of amino acids is most important in peptide chain. If amino acids are joined with different sequences then different peptides are formed. e.g., Three amino acids A, B, C are joined in different sequences to form six different types of tripeptides A-B-C, A-C-B, B-A-C, B-C-A, C-A-B, C-B-A.

### 7.7.3 Structures of Proteins :

Proteins can be classified into two types on the basis of their molecular shapes: (i) Fibrous proteins (ii) Globular proteins.

(i) **Fibrous Proteins** : When the polypeptide chains run parallel and are held together by **hydrogen and disulphide bonds**, then fibre like structure is formed. Such proteins are generally insoluble in water. e.g., Keratin (present in hair, wool, silk) and myosin (present in muscles) etc.

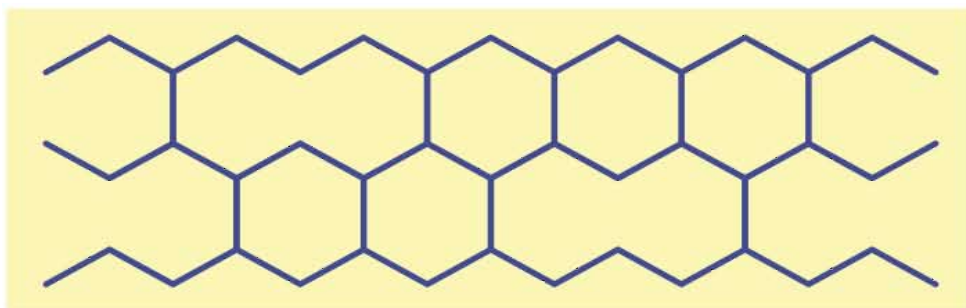


Fig. 7.1 Fibrous proteins

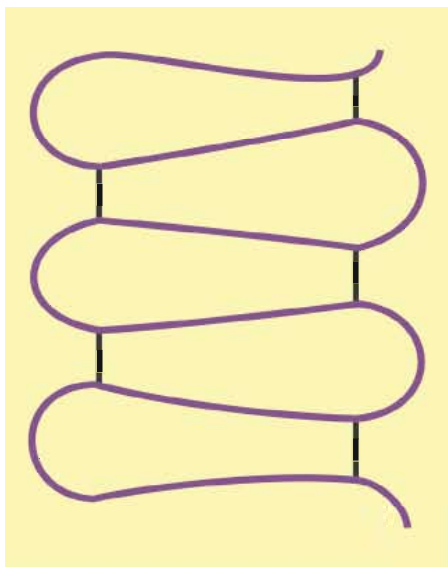


Fig. 7.2 Globular proteins

(ii) **Globular Proteins** : This structure results when the chains of polypeptides coil around to give a spherical shape. These are usually soluble in water. e.g., insulin, albumins etc.

Four different types of protein structures viz. primary, secondary, tertiary and quaternary have been discovered. In 1954 scientist Linus Pauling was awarded the Nobel Prize in chemistry for work on protein-structure.

(1) **Primary structure of proteins** : Primary structure of proteins consists of one or more chains of polypeptides. In this, the amino acids present are joined in a specific sequence. Two polypeptide chains are joined with each other by **disulphide linkage (-S-S-)** in primary structure of insulin in human.

(2) **Secondary structure of proteins** : This type of structure is shown in long chain of polypeptides. Secondary structure can be explained by two different types. (a)  $\alpha$ -helix shape (b)  $\beta$ -pleated sheet shape (zig zag shape)

In  $\alpha$ -helix shaped protein, polypeptide chain is coiled in helix shape. Approximate 3.6 amino acids are included per turn of the helix. In this structure, hydrogen bond is formed between oxygen atom of  $\text{>C=O}$  and hydrogen atom of  $\text{-NH}$  of peptide bond. This structure is presented in Fig. 7.3.



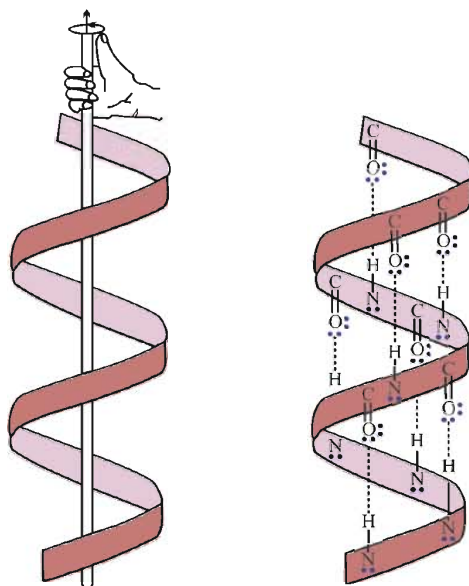


Fig. 7.3  $\alpha$ -Helix structure of proteins (For information only)

In  $\beta$ -pleated sheet shaped protein, one polypeptide chain forms intermolecular hydrogen bond (between oxygen atom of  $\text{>C=O}$  and H atom of  $\text{H-N}<$ ) with adjacent polypeptide chain. Therefore these protein chains are formed like zig zag shaped sheet. This structure is presented in Fig. 7.4.

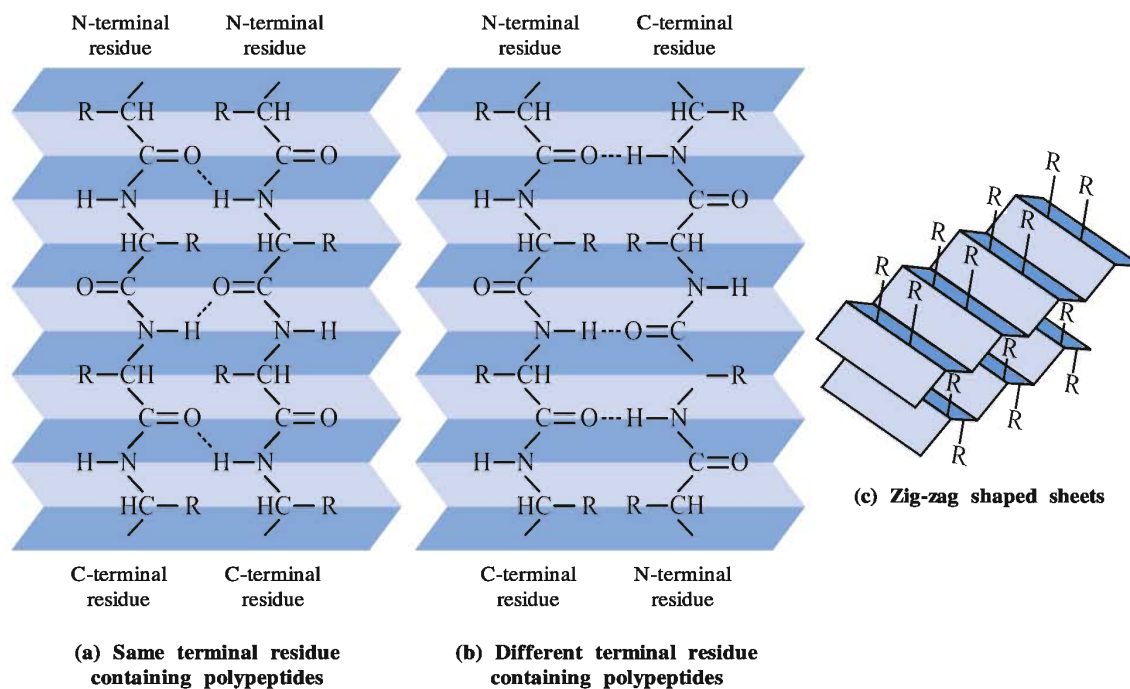


Fig. 7.4  $\beta$ -Pleated sheet structure of proteins (For information only)

**(3) Tertiary structure of proteins :** The tertiary structure of a protein is the three dimensional arrangement of all the atoms in the protein. In this structure, long chain of polypeptides is folded at many points and forms coil shape. Side chains of amino acids are joined to each other by van der Waals' attraction forces, hydrogen bond, ionic bond and disulphide bond. Tertiary structure of myoglobin protein is presented in Fig. 7.5.

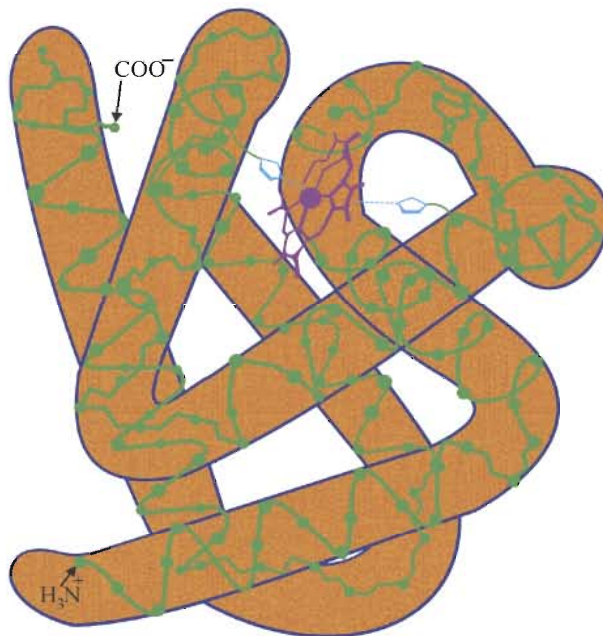


Fig. 7.5 Tertiary structure of myoglobin protein (For information only)

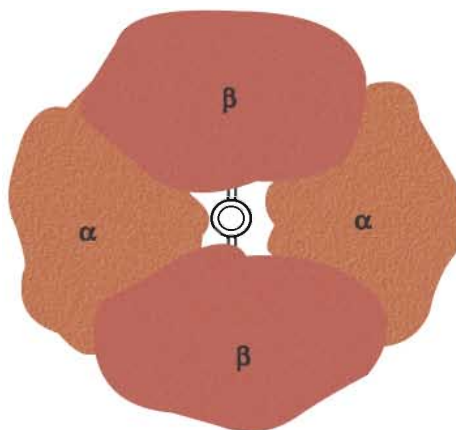


Fig. 7.6 Quaternary structure of haemoglobin protein (For information only)

#### 7.7.4 Denaturation of Proteins :

Proteins found in living organisms are remarkably sensitive to changes in environment. Relatively small changes in pH, temperature or solvent composition, even for only a short period, may cause

proteins to become denatured. In proteins, occurrence of this denaturing is known as denaturation of proteins. Due to this denaturation, proteins lose their biological activity. Reasons of denaturation of proteins are as follows :

(1) **Increase in temperature** : Most globular proteins become denatured when heated above 323 K - 333 K. e.g., If an egg is fried or boiled in water at 373 K or above then white protein becomes denatured, forming an insoluble mass.

(2) **Changes in pH** : Adding concentrated acid or alkali to a protein in aqueous solution causes changes in the characteristics of ionizable side chains in it and hydrogen bond and different types of attractions are broken down. In certain clinical chemistry tests removal of all protein material is first required. For this the trichloroacetic acid is added to sample and resulting protein is converted into precipitates by denaturation. They can be removed easily.

(3) **Detergents** : Detergent such as sodium dodecyl sulphate is associated with the non polar groups of proteins. It creates interference with the hydrophobic interactions in protein, due to which protein becomes denatured.

(4) **Organic solvents** : Organic solvents such as alcohol, acetone and ether denature the proteins by interference of hydrophobic interactions.

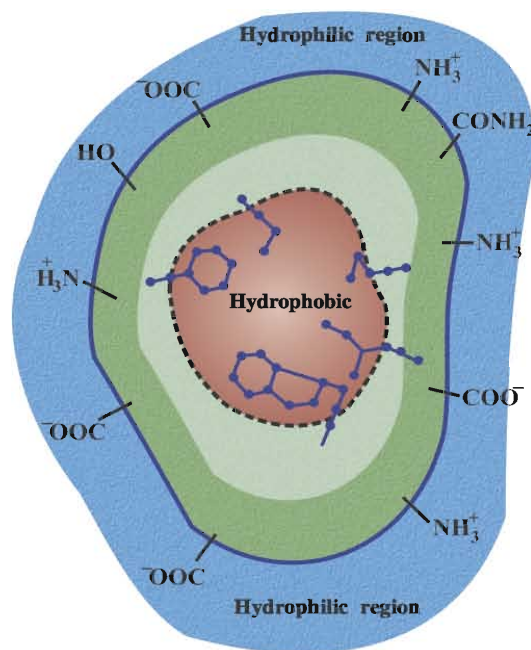


Fig. 7.7 Hydrophilic and hydrophobic regions in proteins (For information only)

## 7.8 Enzymes

The substance which acts as a catalyst in biochemical reactions is known as **enzyme**. Enzymes are globular proteins. Enzymes participate in biochemical reactions and increase the reaction rate. They are not utilized in reaction which means that they are obtained as such in original form at the end of the reaction. Some enzymes can increase the rate of reaction by  $10^{12}$  times. e.g., Hydrolysis of a fat (an ester) to a carboxylic acid and an alcohol is extremely slow, but this reaction occurs rapidly in the

presence of lipase enzyme. Some enzymes consist of only of proteins. Some enzymes which consist of other chemical components except proteins which are necessary for their proper functioning of them. Such a component is called a **cofactor**. Cofactors may be inorganic components such as zinc ( $Zn^{2+}$ ), manganese ( $Mn^{2+}$ ), magnesium ( $Mg^{2+}$ ), iron ( $Fe^{2+}$ ) or copper ( $Cu^{2+}$ ) metal ions. If the cofactor is organic in nature, it is called a **coenzyme**. Thus, coenzyme is a non-protein. It is necessary to note here that if inorganic component is cofactor in enzyme then it is not called coenzyme. The protein part of an enzyme is called **apoenzyme**. Both the coenzyme and the apoenzyme must be present for enzymatic activity to take place.



(Non-protein)                      (Protein)                      (Active)  
(inactive)                              (inactive)

**Working mechanism of enzyme :** Enzyme (E) and substrate (S) combine to form an enzyme-substrate intermediate (E-S) complex. This intermediate decomposes to give product (P) and regenerate the enzyme (E).

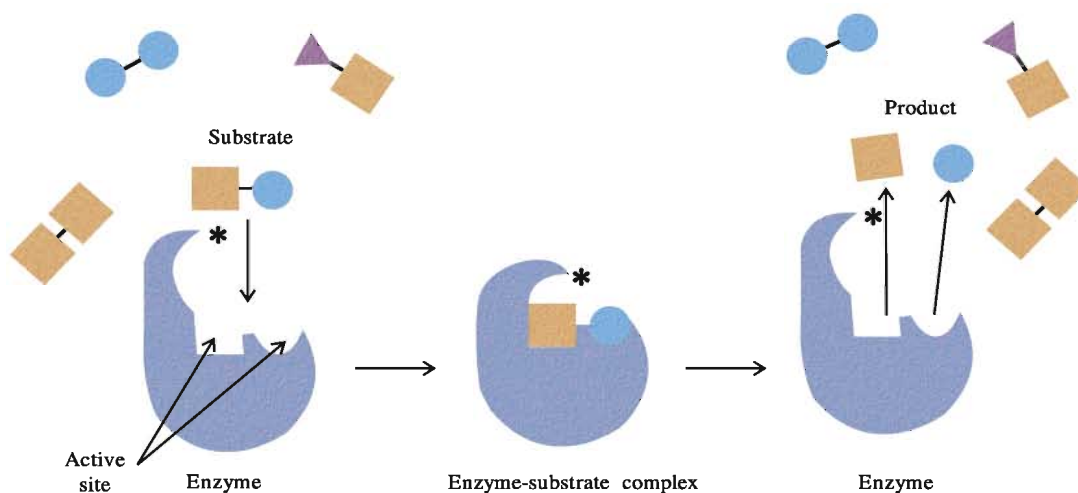
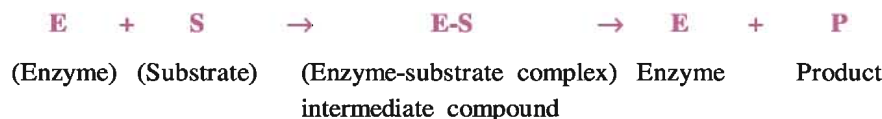
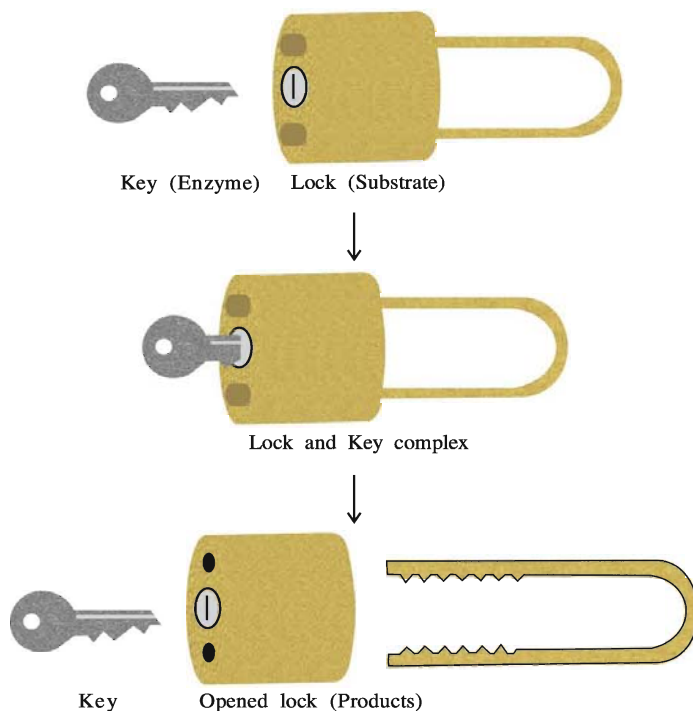


Fig. 7.8 Working mechanism of enzyme (For information only)

The substrate must fit in portion of the enzyme, called the **active site**. The specific amino acids which are present in protein part of enzyme bind the substrate. Therefore this protein part acts as an active site. Mostly an enzyme binds to specific substrate suitable with its active site. It does not bind with other substrate. For example, maltase hydrolyses the maltose but it is not useful in hydrolysis of other disaccharides-lactose or sucrose. Lactose is hydrolysed by emulsin and sucrose is hydrolysed by invertase enzyme. Thus, **each enzyme is specific for each specific reaction**. This type of working mechanism of enzyme can be explained by the lock and key model. Specific lock (substrate) is opened only by the specific key (enzyme) which is suitable for that lock. You have learnt in detail about lock and key model in unit 2 : on surface chemistry.



**Fig. 7.9 Working mechanism of enzyme (Lock and Key model) (For information only)**

Names of enzyme can be assigned in two ways. Enzyme can be named by adding the suffix 'ase' to the root of its substrate name. e.g., one which affects maltose is called maltase and which affects lipid is called lipase. In another way, the name of enzyme is decided by the type of reaction on which enzyme is affected. e.g., Enzyme that catalyses the hydrolysis is called hydrolase and enzyme that catalyses the oxidation is called oxidase.

## 7.9 Vitamins

Certain organic compounds are required in small amounts in our diet. The deficiency of these compounds causes specific diseases in our body. These organic compounds are called **vitamins**. The word vitamine was coined from the word vital + amine, because the earlier work showed that these organic compounds contained amino group. But later work showed that most of these compounds did not contain amino group, so the letter 'e' was dropped and the term vitamin is familiar nowadays. Most of the vitamins cannot be synthesised in our body but plants can synthesise them. Therefore vitamins are considered as essential food constituents. Vitamins are designated by alphabets A,B,C,D etc. Some of them are further named as sub-groups e.g., B<sub>1</sub>, B<sub>2</sub>, B<sub>6</sub>, B<sub>12</sub> etc. Human body synthesises vitamin A from carotene and it also synthesises vitamin D in skin with the help of sunlight. Vitamin B complex and vitamin K are formed by microorganism in intestine. High proportion of vitamin is harmful to us, so we should not use pills of vitamins without the advice of the doctor.

Vitamins are classified as two types **(1) Fat soluble : e.g., Vitamin A, D, E, K** **(2) Water soluble : e.g., Vitamin B complex, C. Vitamin H (biotin) is insoluble in both water and fat.** Important vitamins, their sources and diseases caused by their deficiency are presented in table 7.2.



**Table 7.2. Vitamins, sources and diseases caused their deficiency**

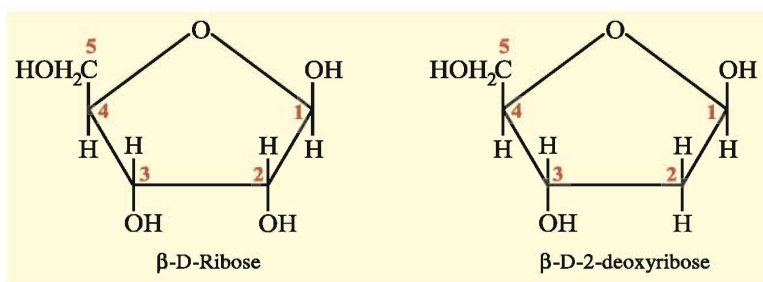
No.	Vitamin	Source	Diseases caused by their deficiency
1.	Vitamin A (Retinol)	Liver oil of fish, carrot, butter, cheese and milk	Xerophthalima
2.	Vitamin B <sub>1</sub> (Thiamine)	Yeast, milk, green vegetables and cereals	Beri-Beri
3.	Vitamin B <sub>2</sub> (Riboflavin)	Milk, egg white, liver, kidney	Dark-red tongue and skin diseases
4.	Vitamin B <sub>6</sub> (Pyridoxine)	Cereals, gram, milk, yeast, egg white	Skin diseases and convulsions
5.	Vitamin B <sub>12</sub> (Cyanocobalamine)	Egg, fish, liver, meat (not found in plants)	Pernicious anemia
6.	Vitamin C (Ascorbic acid)	Tomato, green pepper, orange, citrus fruits and green vegetables	Scurvy
7.	Vitamin D (Calciferol)	Sunlight, fish, egg white	Bone deformation in children and soft bones and joint pain in adults
8.	Vitamin E ( $\alpha$ -Tocopherol)	Vegetable oil, green vegetables, egg white, meat	Sterility
9.	Vitamin K (Phylloquinone)	Green vegetables	Haemorrhage
10.	Vitamin H (Biotin)	Milk, yeast, liver	Loses of hair, skin diseases, paralysis

### 7.10 Nucleic Acids

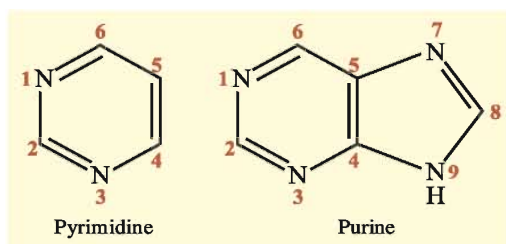
Every generation of each and every species shows similarity with its ancestors in many ways. The process of transmission of these characteristics from one generation to the next generation is called heredity. For this, chromosomes are responsible which are present in nucleus of living cell. These chromosomes are made up of proteins and nucleic acids. Deoxyribonucleic acid (DNA) and Ribonucleic acid (RNA) are two types of nucleic acids. **Nucleic acids are long chain polymers of nucleotides, so nucleic acids are also called polynucleotides.** Complete hydrolysis of nucleic acids (DNA and RNA) forms a pentose sugar, nitrogen containing heterocyclic compounds and phosphoric acid. It indicates that nucleic acids are formed of these three constituents. Thus, it is necessary to know structure of these three constituents for understanding the structure of nucleic acid.



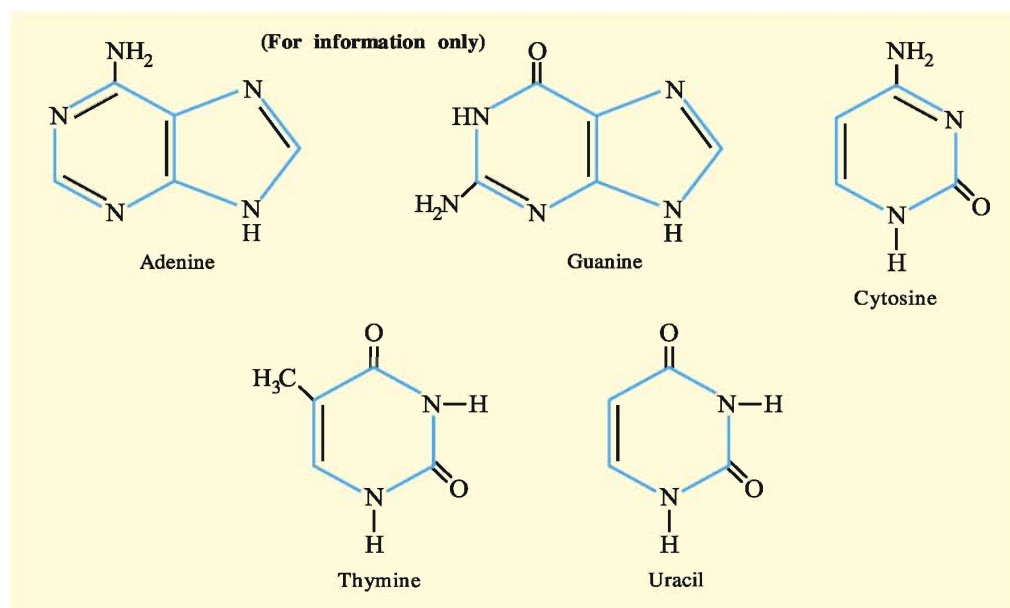
(1) **Sugar** :  $\beta$ -D-ribose sugar is present in RNA and  $\beta$ -D-2-deoxyribose sugar is present in DNA.



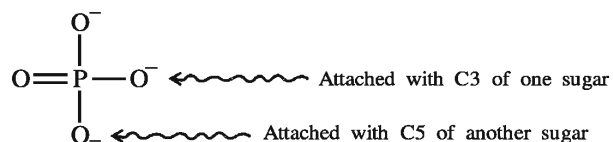
(2) **Heterocyclic base** : In nucleic acids, purine and pyrimidine heterocyclic systems act as base. Pyrimidine is monocyclic compound whereas purine is dicyclic compound.



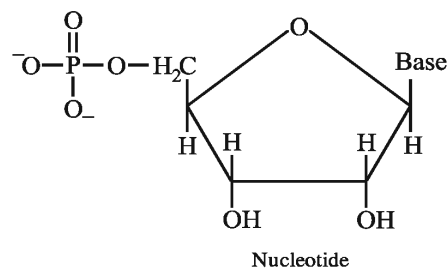
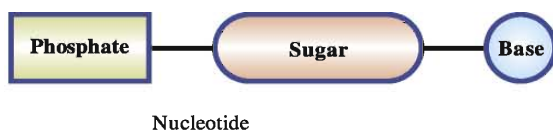
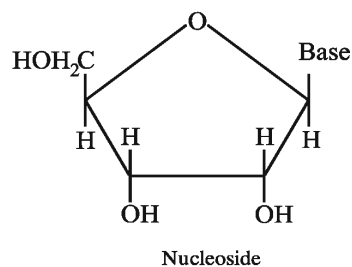
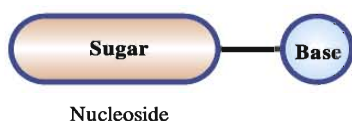
Adenine (A), guanine (G), cytosine (C), thymine (T) and uracil (U) are present in nucleic acids as heterocyclic bases. Out of them A and G are purine derivatives and C, T and U are pyrimidine derivatives, they are known as purine bases and pyrimidine bases, respectively. **DNA contains A, G, C and T bases, while RNA contains A, G, C and U bases.**



(3) **Phosphoric acid** : In nucleic acid, sugars are joined together by phosphate ion ( $\text{PO}_4^{3-}$ ) of phosphoric acid



A unit formed by the attachment of a base to first position of sugar is known as **nucleoside**.  
 A unit formed by the attachment of a nucleoside to phosphate ion is known as **nucleotide**.



Two nucleotides are joined together by **phosphodiester linkage**. This linkage is formed between C3 of one sugar and C5 of another sugar. Formation of dinucleotide is shown in Fig. 7.10.

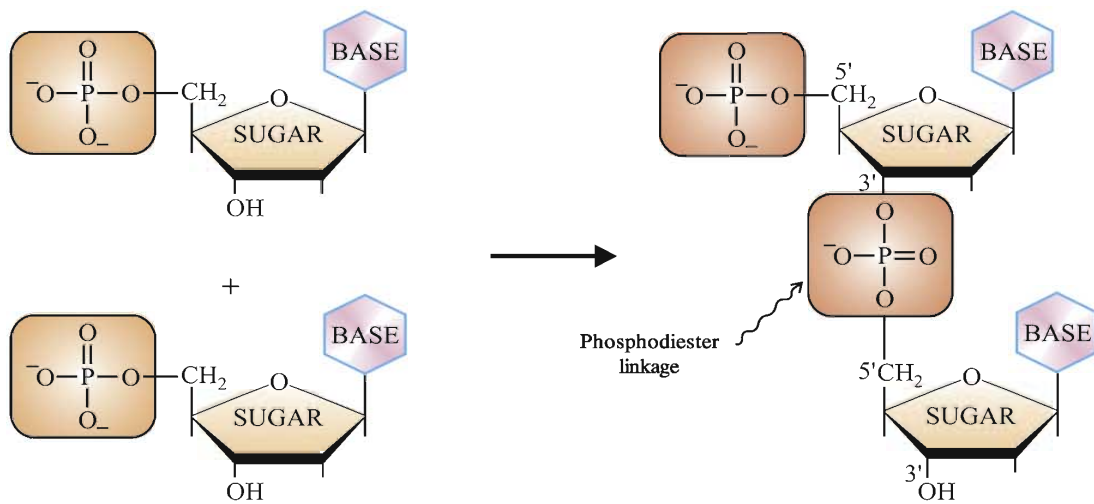
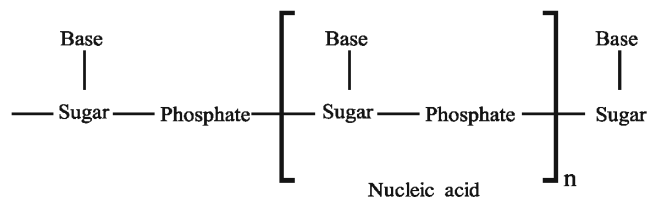


Fig. 7.10 Formation of dinucleotides (For information only)

Many nucleotides join together and form polynucleotides. It is known as nucleic acid. Structure of nucleic acid can be shown in an easy way as follows.



### 7.10.1 Double Helix Structure of DNA :

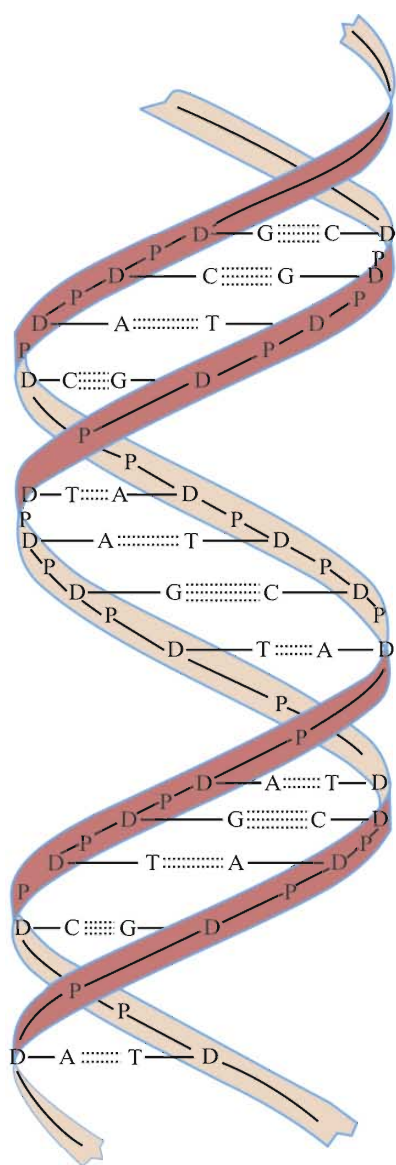


Fig. 7.11 Double helix structure of DNA  
(For information only)

It is proved that the molecular shape of DNA is like a twisted rope which is shown in Fig. 7.11. It contains **phosphoric acid units on outer side and base compounds in central part.** In the nucleus of the cell, these nucleic acids are divided, which are present in gene of chromosomes during reproduction. These nucleic acids are arranged similarly in new cell. Due to this heredity, characteristics are transmitted from one generation to next generation. In 1953 J.D. Watson and H.C. Crick proposed a double helix structure for DNA from X-ray diffraction studies of DNA. This structure looks like a spiral staircase. In connection of two polynucleotide chains, purine base of one nucleotide is joined with pyrimidine base of opposite nucleotide by hydrogen bond. In this adenine (A) base is always joined with thymine (T) and guanine (G) is always joined with cytosine (C). **A and T are joined together with two hydrogen bonds and C and G are joined together with three hydrogen bonds.**

P = Phosphate

D = Deoxyribose

A = Adenine

T = Thymine

C = Cytosine

G = Guanine

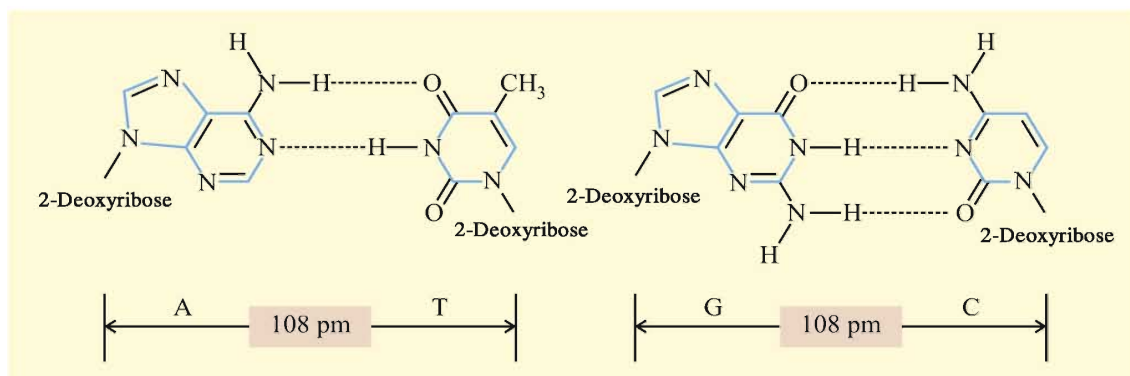


Fig. 7.12 Hydrogen bonds between A and T / G and C (For information only)

### 7.10.2 Biological Importance of Nucleic Acids :

DNA is the responsible chemical for heredity. It reserves the genetic information. DNA is exclusively responsible for maintaining the identity of different species of organisms over millions of years. A DNA molecule is capable of self duplication during cell division and identical DNA strands are transferred to new cell. Another function of nucleic acids is the protein synthesis in the cell. Actually, the proteins are synthesised by various RNA molecule in the cell but the message for the synthesis of a specific protein is present in DNA.

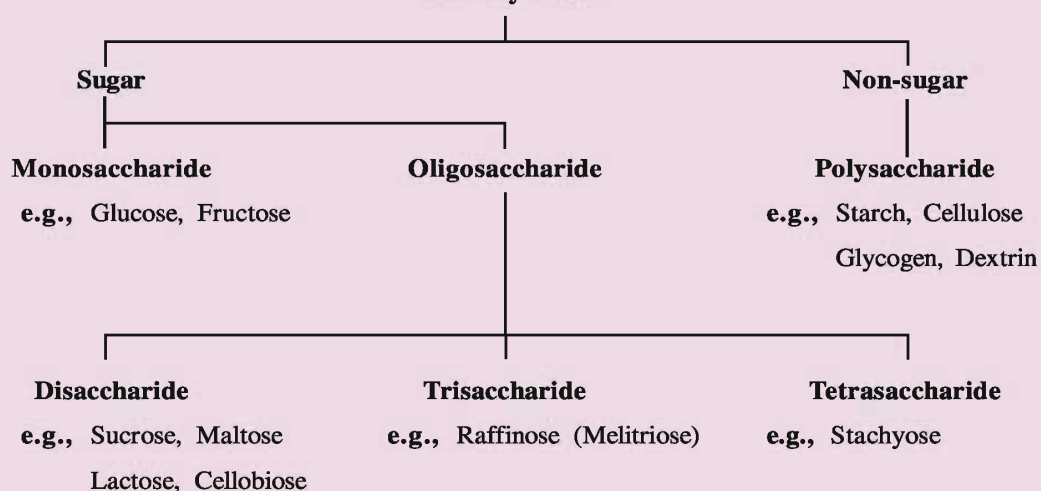
#### SUMMARY

- Chemical compounds present in living systems are known as biomolecules.
- Carbohydrates, proteins, vitamins, nucleic acids enzymes and lipids are biomolecules.

#### Carbohydrates

- Carbohydrates are chemically polyhydroxy aldehydes or polyhydroxy ketones or such compounds which can be hydrolysed to these compounds.

#### Carbohydrates



### Monosaccharides

Monosaccharide	General class	(+) or (-)	Does it show mutarotation ?	Anomers	Is it reducing sugar ?
Glucose	Aldohexose	(+)	Yes	$\alpha$ -D-(+)-glucose $\beta$ -D-(+)-glucose	Yes
Fructose	Ketohexose	(-)	Yes	$\alpha$ -D-(-)-fructose $\beta$ -D-(-)-fructose	Yes

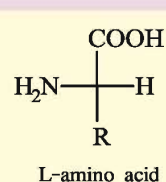
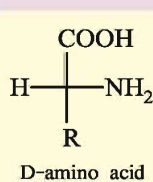
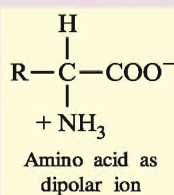
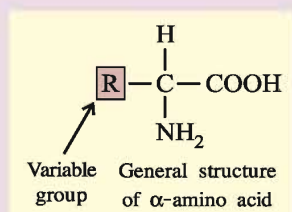
### Disaccharides

Disaccharide	(+) or (-)	Monosaccharide unit	Glycosidic linkage	Does it show mutarotation ?	Anomers	Is it reducing sugar ?
Sucrose	(+)	Glucose Fructose	$\alpha$ -D-(+)-glucose(C1) -O-(C2)- $\beta$ -D-(-)-fructose	No	No	No
Maltose	(+)	Glucose Glucose	$\alpha$ -D-(+)-glucose(C1) -O-(C4)-D-(+)-glucose	Yes	$\alpha$ -(+)-Maltose $\beta$ -(+)-Maltose	Yes
Lactose	(+)	Galactose Glucose	$\beta$ -D-(+)-galactose (C1)-O-(C4)-D-(+)-glucose	Yes	$\alpha$ -(+)-Lactose $\beta$ -(+)-Lactose	Yes

### Polysaccharides

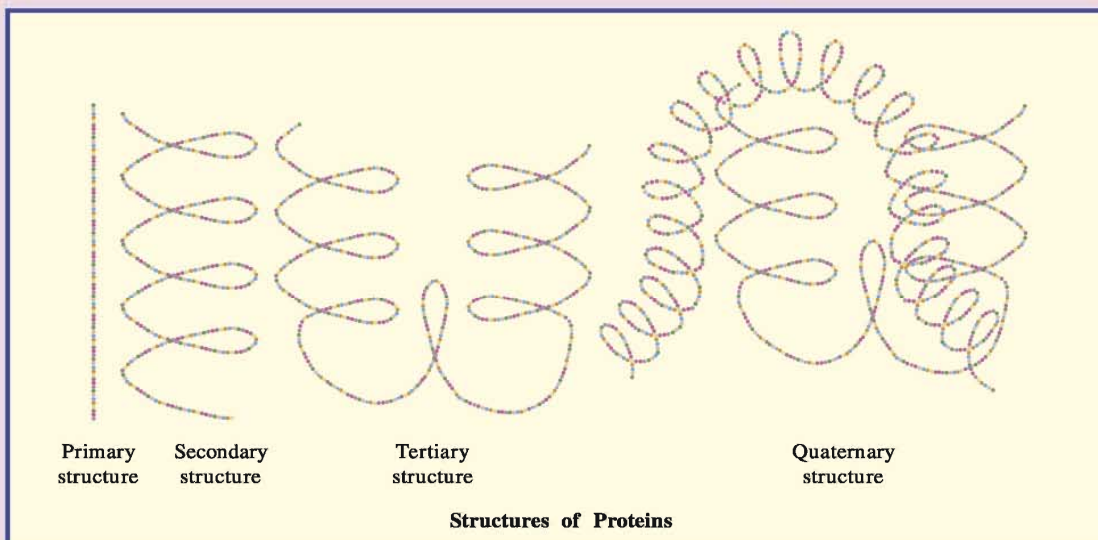
Polysaccharide	Monosaccharide unit	Glycosidic linkage
<b>Starch</b> Amylose Amylopectin	Glucose Glucose	$\alpha$ -D-(+)-glucose(C1)-O-(C4)- $\alpha$ -D-(+)-glucose $\alpha$ -D-(+)-glucose(C1)-O-(C4)- $\alpha$ -D-(+)-glucose and $\alpha$ -D-(+)-glucose(C1)-O-(C6)- $\alpha$ -D-(+)-glucose
Cellulose	Glucose	$\beta$ -D-(+)-glucose(C1)-O-(C4)- $\beta$ -D-(+)-glucose

### Amino acids



## Proteins

- Proteins  $\xrightarrow{\text{Hydrolysis}}$  Peptides  $\xrightarrow{\text{Hydrolysis}}$  Amino acids
- Amino acid + amino acid  $\rightarrow$  Dipeptide  
 Amino acid + amino acid + amino acid  $\rightarrow$  Tripeptide  
 Amino acid + amino acid + amino acid + amino acid  $\rightarrow$  Tetrapeptide  
 n (Amino acid)  $\rightarrow$  Polypeptide or proteins



## Enzymes

- The substance which acts as a catalyst in biochemical reaction is known as enzyme.
- **Coenzyme** + **Apoenzyme**  $\rightarrow$  **Enzyme**  
 (Non Protein) (Protein) (active)  
 (inactive) (inactive)
- **E** + **S**  $\rightarrow$  **E-S**  $\rightarrow$  **E** + **P**  
 (Enzyme) (Substrate) (Enzyme-substrate complex) Enzyme Product  
**(Working mechanism of enzyme)**

## Vitamins

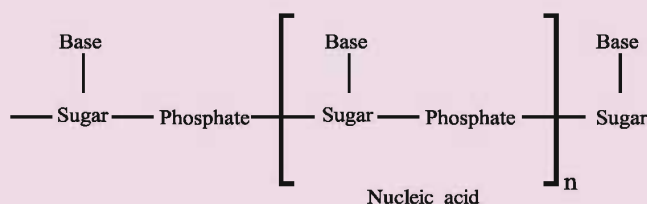
- Vitamin A, B<sub>1</sub>, B<sub>2</sub>, B<sub>6</sub>, B<sub>12</sub>, C, D, E, K and H are known.
- All vitamins are most important for human body. Deficiency of specific vitamin causes specific diseases.

## Nucleic acids

- Two types of nucleic acids are  
 (i) Deoxyribonucleic acid (DNA) and (ii) Ribonucleic acid (RNA)



- Nucleic acid means polynucleotides
- Nucleotide means nucleoside + phosphate
- Nucleoside means sugar + base
- DNA is the responsible chemical for heredity



### EXERCISE

#### 1. Select the proper choice from the given multiple choices :

- Which compound from the following is a disaccharide ?  
 (A) Glucose      (B) Fructose      (C) Maltose      (D) Melitriose
- What is the name of total four carbon atoms and one aldehyde group containing carbohydrate ?  
 (A) Aldotetrose      (B) Aldopentose      (C) Ketotetrose      (D) Ketopentose
- Which sugar from the following is not a reducing sugar ?  
 (A) Glucose      (B) Sucrose      (C) Maltose      (D) Lactose
- Which type of peptide chain is present in  $\text{H}_2\text{NCH}_2\text{CONH} \underset{\text{CH}_3}{\text{CH}} \text{CONHCH}_2\text{NH}_2$  ?  
 (A) Dipeptide      (B) Tripeptide      (C) Tetrapeptide      (D) Polypeptide
- Which structure of protein is having  $\beta$ -pleated sheet shape?  
 (A) Primary      (B) Secondary      (C) Tertiary      (D) Quaternary
- Which of the following statements is true ?  
 (A) Enzymes are carbohydrates  
 (B) Enzymes are not obtained at the end of reaction  
 (C) Enzymes are obtained in the changed form at the end of reaction  
 (D) Enzymes are obtained in the original form at the end of reaction.
- Which vitamin is insoluble in water and fat ?  
 (A) A      (B) B complex      (C) C      (D) H

- (8) Which of the following statements is incorrect ?
- (A) A, G, C and T bases are present in DNA  
(B) A and T are joined together by two hydrogen bonds in DNA  
(C) A and C are purine bases.  
(D) T and U are pyrimidine bases.
- (9) By which linkage, two monosaccharides are joined together in disaccharide ?
- (A) Peptide (B) Phosphodiester (C) Glycosidic (D) Disulphide
- (10) Which of the following units are present in  $\alpha$ -(+)-lactose ?
- (A)  $\beta$ -D-(+)-galactose +  $\alpha$ -D-(+)-glucose  
(B)  $\beta$ -D-(+)-galactose +  $\beta$ -D-(+)-glucose  
(C)  $\alpha$ -D-(+)-galactose +  $\alpha$ -D-(+)-glucose  
(D)  $\alpha$ -D-(+)-galactose +  $\beta$ -D-(+)-glucose

**2. Write the answers of the following questions in brief :**

- (1) Write two examples of disaccharide.  
(2) Write two examples of trisaccharide.  
(3) Write two examples of polysaccharide.  
(4) Write one example each of aldohexose and ketohexose.  
(5) Write the empirical formula and molecular formula of glucose.  
(6) Draw the Haworth projections of anomers of glucose.  
(7) Draw the Fischer and Haworth projections of  $\alpha$ -D-(–)-fructose.  
(8) Which enzymes hydrolyse sucrose and maltose ?  
(9) Mention the general structure of amino acid.  
(10) Write two examples of neutral amino acids.  
(11) Write two examples of acidic amino acids.  
(12) Write two examples of basic amino acids.  
(13) Write general structure of D- and L-amino acids.  
(14) Write two names of separation techniques for amino acid mixture.  
(15) Which two amino acids form glycylalanine dipeptide chain ?  
(16) Based on the molecular shape which two types of protein are there ?

- (17) Mention two factors for denaturation of protein.
- (18) Mention the names of fat soluble vitamins.
- (19) Mention the names of water soluble vitamins.
- (20) At which position is the base joined with sugar in nucleoside ?
- (21) By which linkage are two nucleotides joined to each other ?
- (22) Which two bases are joined together with two hydrogen bonds in DNA ?
- (23) Which three bases are joined together with three hydrogen bonds in DNA ?
- (24) At which side N-terminal residue is written in peptide chain ?
- (25) Which forms of dipolar ion of amino acids are present in acidic and basic medium ?
- (26) In the following compounds, glycosidic linkage occurs between which monosaccharide molecules and at which position :
- |                 |                |
|-----------------|----------------|
| (i) Sucrose     | (ii) Maltose   |
| (iii) Lactose   | (iv) Amylose   |
| (v) Amylopectin | (vi) Cellulose |

**(27) Write definitions :**

- |                                      |                        |
|--------------------------------------|------------------------|
| (i) Carbohydrate                     | (ii) Dextrorotatory    |
| (iii) Levorotatory                   | (iv) Anomeric carbon   |
| (v) Anomers                          | (vi) Mutarotation      |
| (vii) Caramal                        | (viii) Zwitter ion     |
| (ix) Isoelectric point of amino acid | (x) N-terminal residue |
| (xi) C-terminal residue              | (xii) Enzyme           |
| (xiii) Cofactor                      | (xiv) Coenzyme         |
| (xv) Active site of enzyme           | (xvi) Vitamin          |
| (xvii) Nucleoside                    | (xviii) Nucleotide     |

**3. Write the answers of the following questions :**

- Write the formula of calculation for specific rotation of optically active compound and explain all the terms involved.
- Draw the open chain structure of D-(+)-glucose and L-(-)-glucose.
- Draw the open chain structure of D-(-)-fructose and L-(+)-fructose.
- What are essential amino acids ? Mention their names.



(iii) Cytosine, Adenine, Thymine, Uracil

(iv) Vitamin A, Vitamin C, Vitamin D, Vitamin E

**Explain with reasons (Q.13 to 15)**

(13) Sucrose is a non-reducing sugar.

(14) Maltose is a reducing sugar.

(15) Why lactose has anomers ?

**4. Write the answers of the following questions in detail :**

(1) Write classification of carbohydrates.

(2) Discuss the two methods for preparation of glucose.

(3) Describe chemical reactions for proving the open chain structure of glucose.

(4) Describe the importance of carbohydrates.

(5) Explain the primary, secondary, tertiary and quaternary structure of protein.

(6) Discuss the reasons for denaturation of proteins.

(7) Explain working mechanism of enzyme.

(8) Discuss the constituents of nucleic acid structure.

(9) Describe the double helix structure of DNA.

**(10) Solve the problems :**

(i) The specific rotation of 3.0 g of maltose in 20 ml of aqueous solution in a polarimeter tube 2.0 dm long is  $+136^{\circ}$ . What is the observed angle of rotation of solution of maltose ?

(ii) Fructose has a specific rotation of  $(-92.4^{\circ})$ . An aqueous solution of a fructose has an observed angle of rotation of  $(-27.7^{\circ})$  when placed in a polarimeter tube 10 cm long. How much amount of fructose is dissolved in 100 ml of aqueous solution ?