14

Biomolecules

14.1 Introduction

All living organisms are made from biomolecules. Biomolecules are complex organic compounds which exist as important composition in all living cells. The energy for growth, repair and other functions, gain in our body etc. are done by various bio chemical reactions of these complex organic compounds.

Biomoleules are made with more than 25 elements. Due to organic nature of biomolcules, their important components are carbon (C) and hydrogen (H). Apart from these, nitrogen (N), oxygen (O), phosphorous (P) and sulphur (S) are also other important components of biomolecules. Biological systems have many types of biomolecules such as carbohydrates, proteins, vitamins, nucleic-acid, enzyme, lipid, hormones, etc. Each one has its own importance and their deficiency cause to generate deformation in living system. Here, we explain about the composition, structure, chemistry and functions of biomolecules.

14.2 Cell and Energy Cycle

Cell is the fundamental and functional unit of life. Cell was discovered by Robert Hook in 1665. All the necessary substances of living organism are stored in the cell and all biochemical reactions are done inside the cell. Its size is very small that can only be seen by microscope.

A normal animal cell can be divided into three parts–

(i) cell membrane

(ii) cytoplasm

(iii) nucleus

(i) Cell membrane– Each cell contains selectively permeable, electrically charged membrane around cytoplasm, which is known as cell membrane or plasma membrane. Transportation of chemical substances done by cell membrane. Cell membrane is a double membrane formed by protein and lipid.

(ii) Cytoplasm– Nucleusless protoplasm within a cell is called cytoplasm. Cytoplasm is the base of many biochemical and metabolic reactions which are occuring in the cell. Cell-organells of cell such as mitochondria, ribosomes, lysosomes, golgi bodies, etc. are present in cytoplasm.

(iii) Nucleus– Bio-chemical reactions take place in the central part of cytoplasm, known as Nucleus and also called as control-centre of the cell. It was discovered by Robert Brown in 1831. In mammals, nucleus is present in all type of cells, except in red blood cells. Nucleus is surrounded by double layers of protein.

14.2.1 Cell and Energy Cycle

Energy is must for growth, maintenance and devlopment of living things. Energy is also required for mechanical-function, various chemical reactions and transportation of molecules in our body and this energy is obtained by decomposition food-molecules. Various molecules are also synthesized by livings and for synthesis of these molecules, required energy is taken from released energy by decomposition of food molecules. All these reactions occur inside the cells. All the reactions taking place in the living organism, which produce or utilise energy, are called metabolic reactions. The metabolic reactions can be divided in two parts–

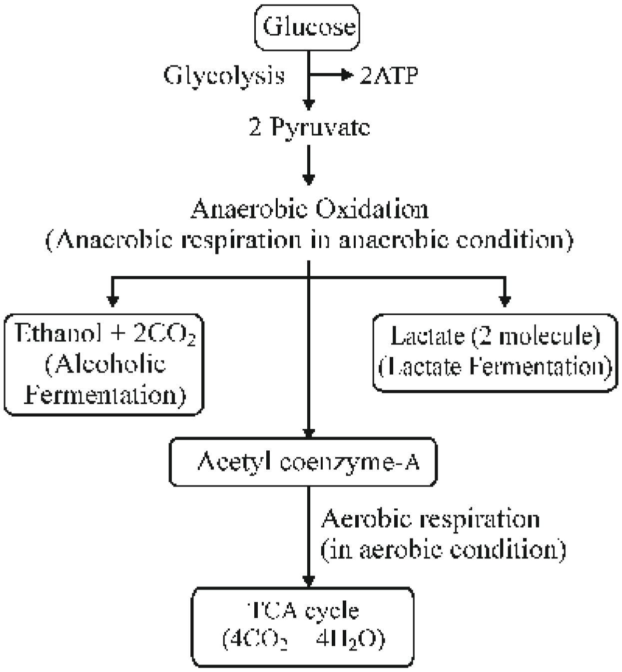
(i) Anabolism and

(ii) Catabolism

(i) **Anabolism–** Anabolism is a constructive process. In this process, synthesis of complex molecules for growth, maintenance and storage, etc. from simple molecule or substance are considered. Energy is consumed in the anabolic processes.

(ii) **Catabolism–** Catabolism is a destructive process. In this process, complex organic substances are broken down into simple or basic molecule with release of energy. Anabolism and catabolism both reactions take place simultaneously and related to each other. For example, synthesis of protein from amino-acids is a anabolism reaction whereas conversion of carbohydrate into simple molecules (CO_2 & water) is a catabolism reaction.

Cell gain energy by oxidation of food molecules. This oxidation mainly occurs in mitochondria in the presence of enzyme. Therefore, the mitochondria is also known as power house of the cell. Some of the energy obtained by oxidation of food is used in the formation of ATP molecules and this molecule act as energy source for other bio-chemical processes. Carbohydrates, fats and proteins are main sources of energy. Among them, oxidation of glucose is very important. The oxidation of glucose occurs inside the cell in the presence of air and energy is released. The oxidation of glucose can be represented by following process–



Oxidation reaction of glucose can be represented as–

$$6C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O,\ \Delta G^{o} = -880\text{kJ}$$

Some of the part of this energy is used by cell and remaining part is stored in the form of ATP. The complete process of oxidation of glucose can be represented as–

$$C_6H_{12}O_6 + 36ADP + 36H_3PO_4 + 6O_2 \longrightarrow$$
$$6CO_2 + 42H_2O + 36\ ATP$$

14.3 Carbohydrate

Carbohydrate word is formed by combination of two words "Carbo" and "hydrate". "Carbo" means "carbon" and "hydrate" means "water", therefore water hydrated carbon compounds are known as carbohydrates. Carbohydrates are natural organic compounds and that are formed in plants by the photosynthesis process.

$$xCO_2 + yH_2O \xrightarrow[\text{light}]{\text{Chlorophyll}} C_x(H_2O)_y + xO_2$$

14.3.1 Definition–

Most of the carbohydrates have a common formula $C_x(H_2O)_y$ and they are considered as hydrates of carbon. **For example**, sugar, glucose, starch, etc. But some carbohydrates also exist, which do not have same formula $C_x(H_2O)_y$ that means they are not hydrates of carbon. **For example-** Rhamnose ($C_6H_{12}O_5$) and 2-deoxyribose ($C_5H_{10}O_4$), etc.

In the same manner, some organic compounds such as Formaldehyde (CH_2O) and acetic acid ($C_2H_4O_2$) are shown common formula $C_x(H_2O)_y$ that means, these are hydrates of carbon but these do not show properties of carbohydrates. Hence the carbohydrates may be defined as "optically active polyhydroxy carbonyl (aldehyde or ketone) compound," or the compounds which produce such units by hydrolysis.

14.3.2 Functions of Carbohydrates–

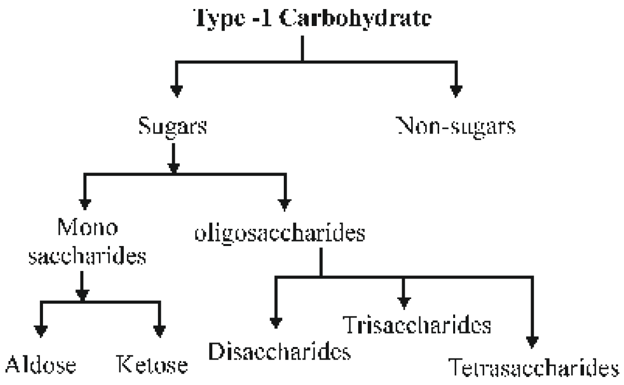
(i) The main function of carbohydrate is to provide heat and energy to the body.

(ii) Carbohydrates are collected as starch in plants and as glycogen in animals.

(iii) Cell wall of cells are made by carbohydrates. **Example-** cellulose found in cell wall.

14.3.3 Classification of Carbohydrates–

Carbohydrates can be classify into two types as–

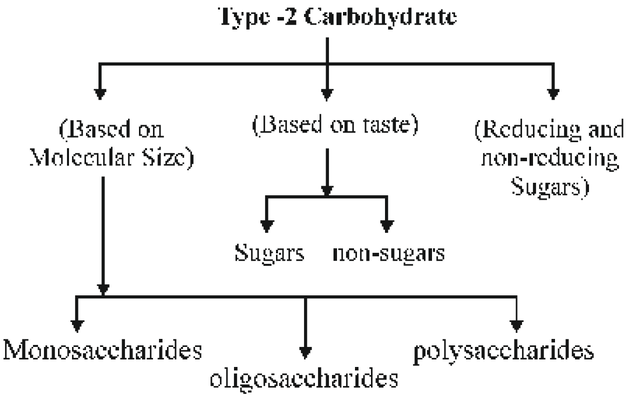


(i) **Sugar and Non sugar–** Carbohydrates having sweet taste are called sugars and without sweet taste Carbohydrates are known as non-sugars.

(ii) **Reducing and non-reducing sugars–** Those carbohydrates which are reduced by Fehling solution and Tollen's reagent (ammonical silver nitrate) known as reducing sugars.

Example– Glucose and Fructose and those carbohydrates which are not reduced by Fehling solution and Tollen's reagent are known as non-reducing sugars.

Example– Sucrose



(i) **Monosaccharides–** The carbohydrates that cannot be hydrolysed further to give simpler unit of compound are called monosaccharides. General formula is $C_nH_{2n}O_n$.

Example– Glucose & Fructose.

General Properties–

1. Monosaccharides are also called simple sugars and these are made from 3-7 carbon atoms.
2. Monosaccharides are generally crysatlline, solid, sweet and soluble in water due to the presence of hydroxy (-OH) group and presence of H-bond between water molecules and monosaccharide molecules.
3. About 20 type of monosaccharides are available in nature.

(ii) **Oligosaccharides–** Those carbohydrates which can be hydrolysed and give two or more than two units (maximum ten) of monosaccharides are called oligosaccharides.

Example– Sucrose or can sugar (it is hydrolysed and give one-one unit of glucose & fructose), maltose is hydrolysed & gives two units of glucose.

General Properties–

1. Inside the monosaccharides, monosaccharide units are connected by glycosidic bond.
2. Monosaccharide units are obtained by hydrolysis of oligosaccharides. They may be same or different.
3. Oligosaccharides are further classified on the basis of number of monosaccharide units obtained from hydrolysis of the oligosaccharides.

(iii) **Polysaccharides–** Carbohydrates which on hydrolysis give ten or more than ten units of monosaccharide are known as polysaccharides. e.g.- starch, cellulose, glycogen, gum, etc.

General Properties–

1. These polysaccharides are the polymers of monosaccharides and their general formula is $(C_6H_{10}O_5)n$, where, $n > 40$.
2. These polysaccharides are tasteless and insoluble in water they give monosaccharides on hydrolysis.
3. Since of polysaccharides are not sweet in taste, therefore they are also called non-sugars.

4. In polysaccharides, monosaccharide units are connected by glycosidic bond.

14.3.3 Monosaccharides–

Monosaccharide's properties are studied earlier (in 14.3.3)

14.3.3.1 Glucose and Fructose–

The molecular formula of both glucose and fructose is $C_6H_{12}O_6$. Glucose is an aldohexose and fructose is a ketohexose.

Glucose:

(1) Introduction– Glucose is the most abundant naturally occuring organic compound. Glucose is the monomer of many carbohydrates like cellulose, starch etc. Glucose is available in both free or combined form in nature. It is found in free form in riped grapes, honey and many sweet fruits. Human blood contains almost 0.1% amount of glucose. Glucose is found in many disaccharides and polysaccharides in combined form and glucose is obtained by their hydrolysis.

Preparation of Glucose : Two main source of glucose are sucrose and starch.

Monosaccharides are classified in two parts–

(1) Aldose (2) Ketose

(1) Aldoses– Those monosaccharides which are formed by –CHO, are known as aldose. In aldose, –CHO group is attached at the end of carbon C–1 of carbon series.

(2) Ketoses– Those monosaccharides which are fromed by keto (>C = O) group are known as ketose. In ketose, (>C = O) group is attached at anywhere other than end-carbon of carbon series.

Monosaccharides are classified further as Triose, Tetrose, pentose, hexose on the basis of number of atoms present in the monosaccharide.

Table 14.1 : Different monosaccharides and examples

carbon atoms	General term	aldehyde	example (aldehyde)	ketone	example (ketone)
3	triose	aldotriose	glyceraldehyde	ketotriose	dihydroxy ketone
4	tetrose	aldotetrose	erythreose, threose	ketotetrose	erythrulose
5	pentose	aldopentose	ribose, xylose	ketopentose	ribulose, xylulose
6	hexose	aldohexose	glucose, mannose, galactose	ketohexose	fructose, sorbose

(i) From Sucrose– Sucrose (canesugar) is a disaccharide. Its general formula is $C_{12}H_{22}O_{11}$. When sucrose aqueous solution is boiled with dilute HCl or H_2SO_4 then glucose and fructose are obtained in equal amount.

$$\underset{\text{sucrose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{H^{\oplus}} \underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{fructose}}{C_6H_{12}O_6}$$

(ii) From Starch– Starch is a polysaccharide. When starch is heated with dilute H_2SO_4 at 393 K and 2 to 3 atmospheric pressure, then glucose is obtained.

$$\underset{\text{starch or cellulose}}{(C_6H_{10}O_5)_n} + nH_2O \xrightarrow[\substack{\text{393K and} \\ \text{2-3-atmospheric} \\ \text{pressure}}]{H^+} \underset{\text{glucose}}{nC_6H_{12}O_6}$$

(3) Physical Properties of Glucose–

(i) Glucose is an aldohexose and it is also called as dextrose. It is white orystalline solid and sweet in taste.

(ii) Melting point of glucose is 419 K and in the form of monohydrate its melting point is 319 K.

(iii) Glucose is easily soluble in water, partially soluble in alcohol and insoluble in ether.

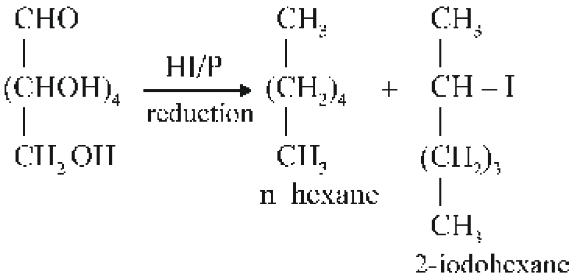
(iv) Glucose is dextro rotatory in nature.

(4) Structure and configuration of glucose

Structure:- Glucose's chemical formula [CH_2OH $(CHOH)_4$ CHO] is confirmed by analysis that means that a molecule of glucose exhibits one aldehyde group (–CHO), one primary alcohol group (–CH_2OH) and 4 secondary alcohol groups. General chemical reactions of glucose are given below which are shown by their functional groups and also confirm the structure by these chemical reactions.

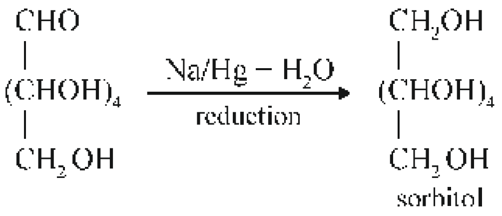
(I) Reduction–

(i) On prolonged heating with hydrgoen iodide (HI) and phosphorous (P), gives mixture of n-hexane and 2-iodohexane. It reveals that all six carbons are alinged with a straight series of carbons in glucose molecule.



$$\begin{array}{c}CHO\\|\\(CHOH)_4\\|\\CH_2OH\end{array}\xrightarrow[\text{reduction}]{HI/P}\begin{array}{c}CH_3\\|\\(CH_2)_4\\|\\CH_3\\\text{n hexane}\end{array}+\begin{array}{c}CH_3\\|\\CH-I\\|\\(CH_2)_3\\|\\CH_3\\\text{2-iodohexane}\end{array}$$

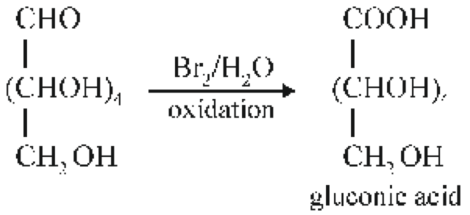
(ii) when glucose is reduced by Na/Hg amalgam with water then sorbitol is formed which shows the presence of aldehyde group in glucose.



$$\begin{array}{c}CHO\\|\\(CHOH)_4\\|\\CH_2OH\end{array}\xrightarrow[\text{reduction}]{Na/Hg-H_2O}\begin{array}{c}CH_2OH\\|\\(CHOH)_4\\|\\CH_2OH\\\text{sorbitol}\end{array}$$

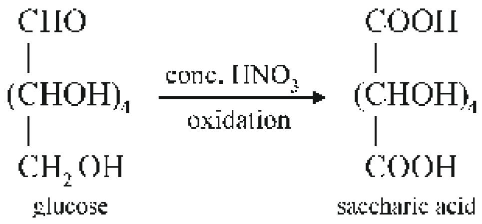
(II) Oxidation

(i) Glucose reacts with bromine water to give monocarboxylic acid and gluconic acid. This reaction is proceed by aldehyde group (-CHO) of glucose.



$$\begin{array}{c}CHO\\|\\(CHOH)_4\\|\\CH_2OH\end{array}\xrightarrow[\text{oxidation}]{Br_2/H_2O}\begin{array}{c}COOH\\|\\(CHOH)_4\\|\\CH_2OH\\\text{gluconic acid}\end{array}$$

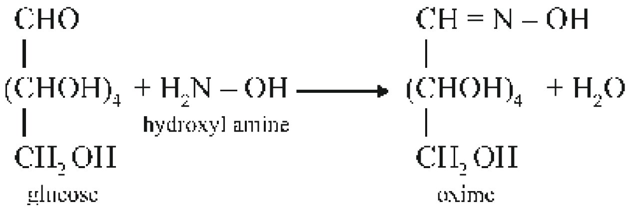
(ii) On oxidation of glucose with con. HNO_3 it gives dicarboxylic acid and saccharic acid. In this reaction primary alcoholic group is also oxidized.



$$\begin{array}{c}CHO\\|\\(CHOH)_4\\|\\CH_2OH\\\text{glucose}\end{array}\xrightarrow[\text{oxidation}]{\text{conc. }HNO_3}\begin{array}{c}COOH\\|\\(CHOH)_4\\|\\COOH\\\text{saccharic acid}\end{array}$$

(III) Reaction with hydroxyl amine–

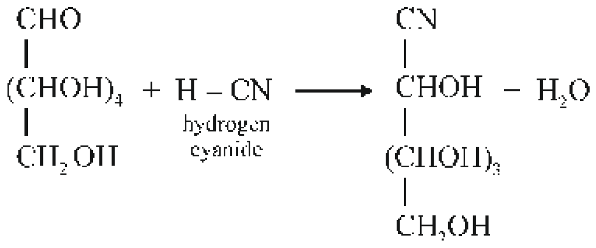
Glucose reacts with hydroxylamine and form an mono moxime.



$$\begin{array}{c}CHO\\|\\(CHOH)_4\\|\\CH_2OH\\\text{glucose}\end{array}+\underset{\text{hydroxyl amine}}{H_2N-OH}\longrightarrow\begin{array}{c}CH=N-OH\\|\\(CHOH)_4\\|\\CH_2OH\\\text{oxime}\end{array}+H_2O$$

This reaction reveals that the carbonyl group is present in glucose.

(IV) Reaction with hydrogen cyanide–



$$\begin{array}{c}CHO\\|\\(CHOH)_4\\|\\CH_2OH\end{array}+\underset{\text{hydrogen cyanide}}{H-CN}\longrightarrow\begin{array}{c}CN\\|\\CHOH\\|\\(CHOH)_3\\|\\CH_2OH\end{array}-H_2O$$

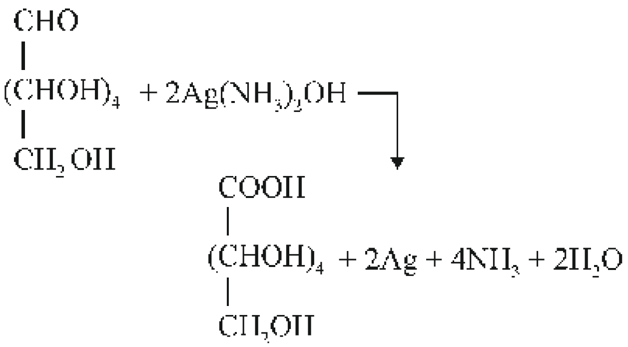
Glucose reacts with hydrogen cynide and forms cynohydrin. This reaction also shows the presence of carbonyl group in glucose.

(V) Reaction with Tollen's and Fehling's reagent–

Glucose reduces Tollen's reagent and Fehling's reagent and itself oxidized to form gluconic acid. Above both reactions (III and IV) show the presence of carbonyl group in glucose and this reaction shows that this carbonyl group is an aldehyde (–CHO) group.

$$AgNO_3 + NH_4OH \rightarrow AgOH + NH_4NO_3$$

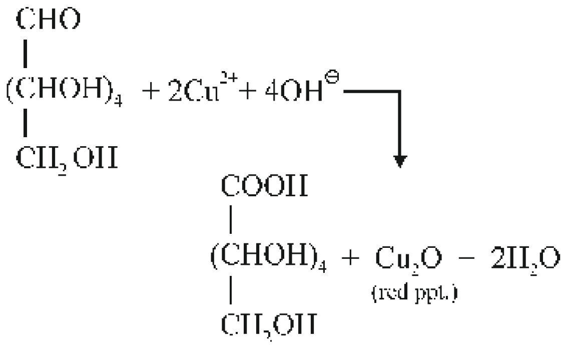
$$AgOH + 2NH_4OH \rightarrow Ag(NH_3)OH + 2H_2O$$



$$\begin{matrix}CHO\\|\\(CHOH)_4\\|\\CH_2OH\end{matrix} + 2Ag(NH_3)_2OH \longrightarrow \begin{matrix}COOH\\|\\(CHOH)_4\\|\\CH_2OH\end{matrix} + 2Ag + 4NH_3 + 2H_2O$$

"When glucose is heated with Tollen's reagent in test-tube, a silvery-mirror is obtained at the bottom of the test tube." Similarly, when glucose is heated with Fehling's solution, gluconic acid is formed and red precipitate (of Cu_2O) is obtained.

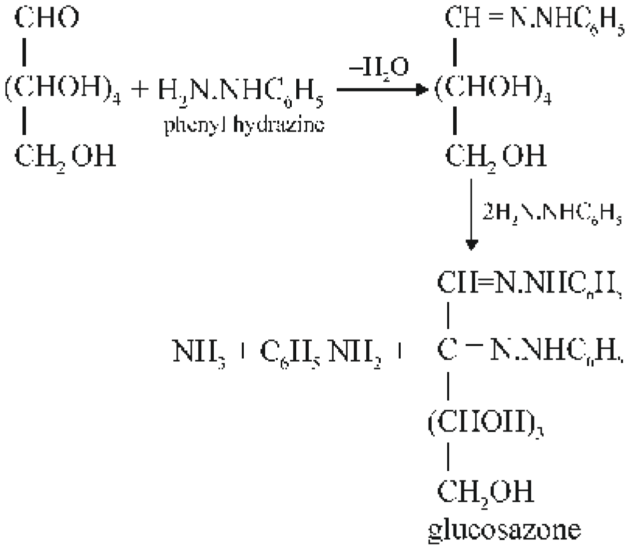
Fehling solution A (aqueous solution of $CuSO_4$) and Fehling solution B (aqueous solution of NaOH formed with Rochelle salt) mixed in equal proportion and gives blue solution known a Fehling solution.



$$\begin{matrix}CHO\\|\\(CHOH)_4\\|\\CH_2OH\end{matrix} + 2Cu^{2+} + 4OH^{\ominus} \longrightarrow \begin{matrix}COOH\\|\\(CHOH)_4\\|\\CH_2OH\end{matrix} + \underset{\text{(red ppt.)}}{Cu_2O} - 2H_2O$$

(VI) Reaction with phenyl hydrazine–

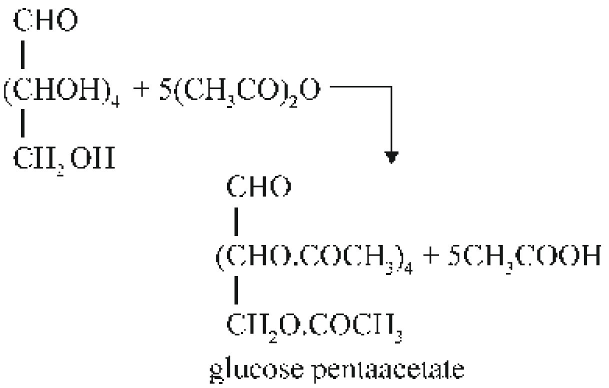
Aldehyde group of glucose reacts with phenyl hydrazine and forms soluble phenyl hydrazone. If excess of phenyl hydrazine is used dihydrazone is formed and it is also known as osazone or glucosazone.



$$\begin{matrix}CHO\\|\\(CHOH)_4\\|\\CH_2OH\end{matrix} + \underset{\text{phenyl hydrazine}}{H_2N.NHC_6H_5} \xrightarrow{-H_2O} \begin{matrix}CH=N.NHC_6H_5\\|\\(CHOH)_4\\|\\CH_2OH\end{matrix} \xrightarrow{2H_2N.NHC_6H_5} NH_3 + C_6H_5NH_2 + \underset{\text{glucosazone}}{\begin{matrix}CH=N.NHC_6H_5\\|\\C-N.NHC_6H_5\\|\\(CHOH)_3\\|\\CH_2OH\end{matrix}}$$

(VII) Acetylation–

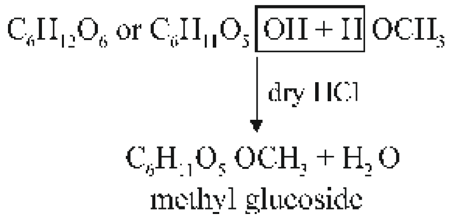
When glucose is heated with acetic anhydride or acetyl chloride it forms pentaacetyl derivative (penta acetate) formation of pentacetate which shows the presence of hydroxy groups in glucose.



$$\begin{matrix}CHO\\|\\(CHOH)_4\\|\\CH_2OH\end{matrix} + 5(CH_3CO)_2O \longrightarrow \underset{\text{glucose pentaacetate}}{\begin{matrix}CHO\\|\\(CHO.COCH_3)_4\\|\\CH_2O.COCH_3\end{matrix}} + 5CH_3COOH$$

(VIII) Methylation–

When glucose reacts with methyl alcohol in presence of dry-HCl it igves ether, i.e. methyl glucoside.



$$C_6H_{12}O_6 \text{ or } C_6H_{11}O_5\boxed{OH + H}OCH_3 \xrightarrow{\text{dry HCl}} \underset{\text{methyl glucoside}}{C_6H_{11}O_5OCH_3} + H_2O$$

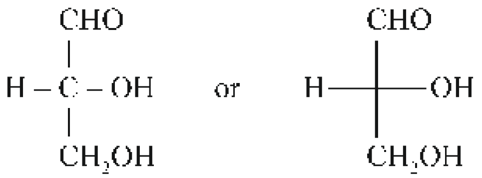
Configuration of Glucose–

Correct spatial arrangement of glucose is presentated by Fischer in structure (I), that is based on chemical characteristics and some other structural interventions.

Spatial arrangement means tetrahadral chiral carbon is surrounded by substitutions of hydrogen (-H) and hydroxy (-OH) groups. Glucose's real name is D (+) glucose.

Meaning of 'D' and 'L' sign– 'D' before the name of glucose represents the configuration whereas (+) sign represents dextro rotatory rotation of plane polarised light by glucose molecules. 'D' and 'L' signs are not related to dextro-rotatory rotation. They only represent the relative positions of atoms or groups surrounded on chiral carbon.

Glyceraldehyde ($C_3H_6O_3$) is an aldotriose of chiral carbon (asymmetric carbon). Glyceraldehyde has two mirror images that are as (diagram 14.1)


D–glyceraldehyde

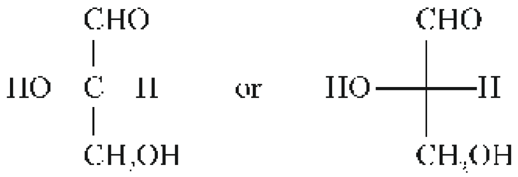
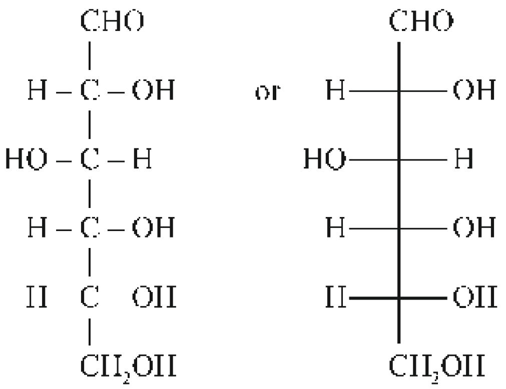
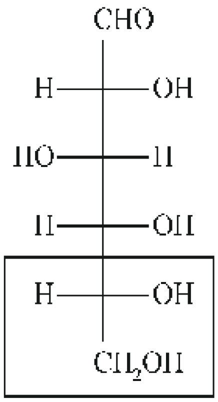

L–glyceraldehyde

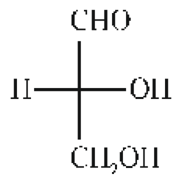
Fig. 14.1 : D- and L- glyceraldehyde

Monosaccharide's orientations/spatial arrangements are related to glyceraldehyde and that are called relative arrangement or configuration. For determination of monosaccharide's arrangements or configuration, take the lowest asymmetric carbon atom and at this carbon the configuration is like D-configuration of glyceraldehyde then it will be the D-configuration of monosaccharide, and if it is like L-configuration of glyceraldehyde, then the configuration of monosaccharide will be L-configuration.


D (+) structure of glucose (I)

In above structure (I) of glucose, the configuration at lowest asymmetric carbon atom is similar to D-glyceraldehyde so that it is known as D-configuration and that is dextro ratatory, so the configuration is written as D(+)-glucose.


glucose


D–glyceraldehyde

5. Cyclic Structure for D(+) Glucose–

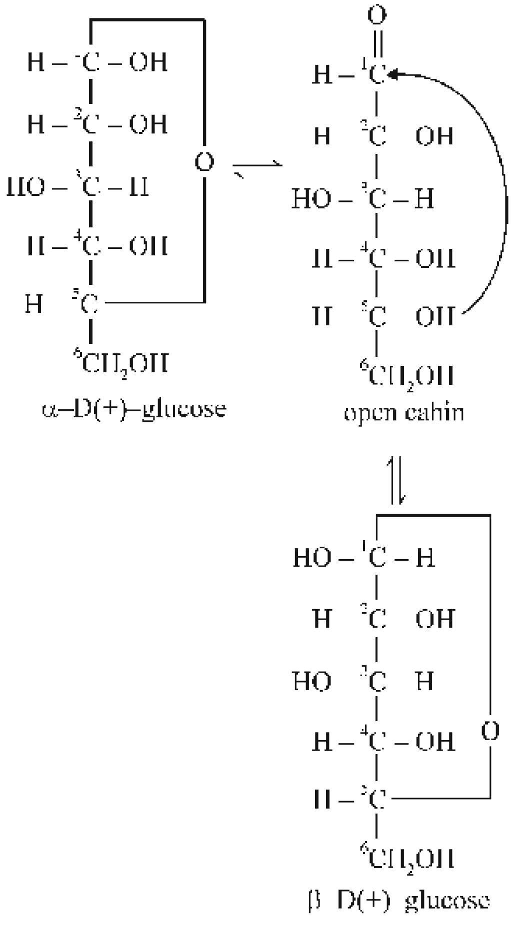
The structure (I) of glucose explained most of its properties but some reactions and facts could not be explained by this structure, these are–

(i) Although glucose gives maximum characteristic reactions of aldehyde group but it does not give addition product of hydrogen sulphite with sodium bisulphite ($NaHSO_3$). It also does not give 2,4-dinitrophenyl hydrazine (2, 4 DNP) test and Schiff's test.

(ii) The penta acetate of glucose, made by reaction of acetic anhydride with glucose, does not react with hydroxyl amine, indicating the absence of free –CHO group in glucose.

(iii) Glucose exist in α and β, two crystalline forms. The α–form of glucose is obtained by crystallization of concentrated solution of glucose at 303K, which has m.p. 419 K and the β–form is obtained by crystallization of concentrated solution of glucose at 371K which has 423K melting point. It means that both forms are originally different.

Considering above all the limitations, Tollen gives a cyclic structure for glucose which is known as Hemi-acetal structure. In this structure, aldehyde group (-CHO), forms a ring or cycle with hydroxyl group present at C-5 of glucose. These two cyclic forms of glucose exist in equlibrium with open chain structure. Both forms (α & β) with ring structure are shown below–



Due to similarity with pyran 6-membered ring with one oxygen, structure of glucose is called phyranose structure. The ring/cyclic structure of glucose is more correctly representated by Haworth structure. (diagram 14.2)

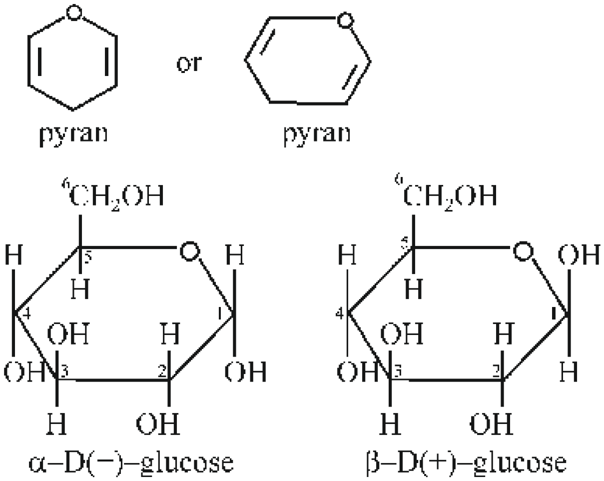


Fig. 14.2 : Haworth structure of glucose

5.1 Anomeric Carbon

Both cyclic structures (α & β) of glucose differ only in the configuration of the hydrogen atom and hydroxy (-OH) group at C1. This C1 carbon is called anomeric carbon and this type of isomers (α & β form) are known as anomers.

In monosaccharides, cyclic structures are formed due to formation of hemiacetal/hemiketal and in which carbon atom becomes asymmetric. This carbon atom called aomeric carbon and the optical isomers formed, are called anomers. It is to be noted that anomers, which have different configuration of -H and -OH groups only at C-1 carbon are not mirror images of each other (they are not enantiomers).

Above cyclic structure (α & β) of glucose explain most of its properties. It is assumed that when glucose reacts with HCN, NH_2OH, Tollen's reagent and Fehling solution, cyclic structure is changed into chain structure where aldehyde group becomes free to react with these reagents. Whereas reactions with sodium bisulphite and 2, 4-dinitro phenyl hydrazine, etc. reagents, provide base for the cyclic structure where aldehyde group is not available in free form and therefore these reagents are not able to react with aldehyde group.

Mutarotation–

The change in specific rotation of solution of any optically active substance with time, is called mutarotation. Change in the specific roation is due to change in equilibrium between two anomers. Specific rotation value at equilibrium is the value of mutarotation.

This property is found in many carbohydrates (Example-Glucose).

Specific rotation of fresh aqueous solution of α-glucose is +112° which is continuously decreases with time and becomes stable at +52.5°.

In the same manner, the specific rotation of fresh aquous solution of β-glucose is +19° which continuously increases with time and becomes stable at +52.5°.

The reason of specific property (specific rotation) of glucose is that when either α-form (+112°) of these two forms is dissolved in water and allowed to stand then it converts into β-form by chain structure and the specific rotation is decreased and in the same way, when β-form (+19°) is dissolved in water and allowed to stand then β-form converts into α-form and the specific rotation increases. This conversion (decrease and increase) is continuous until equilibrium mixture achieves the specific rotation of almost +52°. It has been already proved that at equilibrium α-form contributes 36%, β-form contributes 63.5% and open chain contributes 0.5% in aqueous solution of glucose.

Fructose

(i) Introduction– Fructose is a monosaccharide. Fructose's general formula is $C_6H_{12}O_6$ (equal to glucose) but it is ketohexose while glucose is aldohexose.

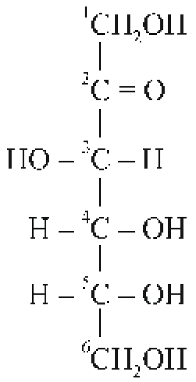
Fructose is obtained by hydrolysis of sucrose ($C_{12}H_{22}O_{11}$).

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{\text{hydrolysis}} \underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{fructose}}{C_6H_{12}O_6}$$

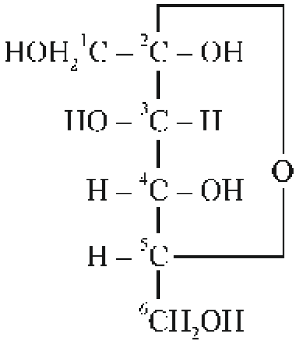
(2) Structure of Fructose

On the basis of chemical reactions of fructose, it is clear that fructose also has a chain of 6 carbon-atoms and ketonic group is present at C-2. Open chain form of fructose also does not explain some properties. Therfore, fructose's ring or cyclic structure was given by Fischer. This cyclic structure is obtained by the addition of –OH and C=O groups. This is a five membered oxide-ring and also called γ–oxide-ring. Due to similarity with furan ring structure, it is called "Furanose".

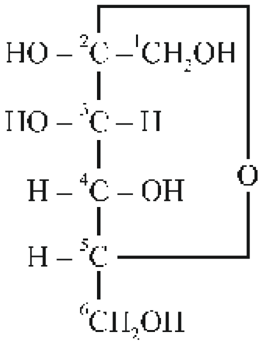
In fructose, levo-rotatory rotation exists and it means that it rotates the plane polarized light to the left (anti clock wise) and that is written as 'D(-) fructose'. All structure of fructose are given below (Diagram 14.3)–



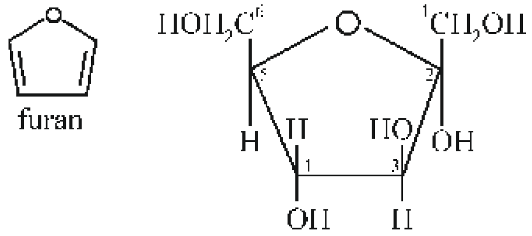
D – (–)–fructose
(open chain)



α–D – (–)–fructose
(ring structure)

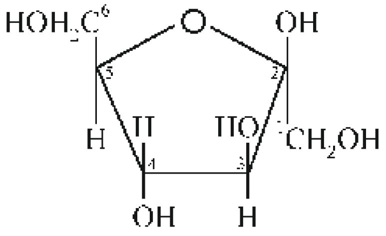


β–D – (–)–fructose
(ring structure)



furan

α D ( ) fructose



β-D-(–) fructose
(Haworth structure)

Fig. 14.3 : Structures of fructose

14.3.4 Oligosaccharides (Disaccharides-

Disaccharide is an oligosaccharide which is made by two molecules of monosaccharide. In other words, those carbohydrates which gives two monosaccharides after their hydrolysis are called disaccharide. Both monosaccharide units may be same or different. These monosaccharide units are joined together by glycosidic bonds. All disaccharide are crystalline solid, sweet in taste and soluble in water. Some important disaccharides are- Sucrose, Lactose, Maltose, etc. These are of two types–

(i) Reducing

(ii) Non reducing

(i) Reducing– Those disaccharides in which carbonyl group of one monosaccharide does not take part in glycosidic bond formation are called reducing. Example– Lactose and Maltose

(ii) Non reducing– Those disaccharides in which carbonyl group of both monosaccharides form glycosidic bond with each other, are called non-reducing. Example– Sucrose.

Sucrose (Table sugar)–

Sucrose is an important disaccharide. It is also known as can sugar. Sucrose is found in nature in maximum amount as in juices, fruits, seeds and in many plants of flowers. The main source of sucrose is sugarcane and sugar beet. Sugarcane contains 15-20% sucrose and sugar beet contains 10-17% sucrose.

(1) Properties of Sucrose

(i) The formula of sucrose is $C_{12}H_{22}O_{11}$. Sucrose is white crystalline, sweet in taste and soluble in water.

(ii) Melting point of sucrose is 180° C and when it is heated above its melting point changes to brown substance which is known as caramel.

(iii) Sucrose reacts with concentrated H_2SO_4 and changed in to a brown coloured substance which is completely known as carbon.

(iv) It is non-reducing sugar.

(v) Sucrose is dextro-rotatory in nature and does not show mutarotation.

(2) Structure of Sucrose–

Sucrose is a disaccharide and its maolecular formula is $C_{12}H_{22}O_{11}$. Its structure is given on the following facts–

(i) Only hydrolysis of sucrose with dil acids (HCl) or enzyme (invertase), gives equimolar mixture of D(+) and D (–) fructose.

$$\underset{\text{sucrose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow[\text{or lactase}]{\text{dil. acid}} \underset{\substack{\text{D(+)}\\ \text{glucose}}}{C_6H_{12}O_6} + \underset{\substack{\text{D(–)}\\ \text{fructose}}}{C_6H_{12}O_6}$$

Sucrose is dextrorotatory whereas after hydrolysis of sucrose, mixture of glucose & fructose is obtained which is levorotatory.

Specific Note– Mixture obtained after hydrolysis of sucrose contain dextro-rotatory glucose (+52°) in least amount than levorotatary fructose (-92.4°) hence the mixture is levorotatory (-19.9°).

It means that after hydrolysis of sucrose, inversion in rotation takes place, this reaction is called Invert Reaction and resultant glucose and fructose are formed in equimolar mixture on hydrolysis of sucrose and it is called invert sugar (honey sugar).

(ii) Glucose and fructose are reducing sugars but sucrose is non-reducing sugar. Because sucrose–

(a) Does not form oxime with hydroxylamine.

(b) Does not form osazone with phenyl hydrazine.

(c) Does not reduce Fehling's solution and Tollen's reagent and also does not show mutarotation. It is justified from above facts that in sucrose, aldehyde group of glucose and keto-group of fructose are not free. Also sucrose shows that both functional groups (-CHO & >C = O) are joined by the glycosidic bond.

(iii) Apart from this, sucrose is hydrolysed in the presence of maltase enzyme (this enzyme is specific for α-glycosidic bond) and invertase enzyme (this enzyme is specific for β-fructose). It is concluded that in sucrose, aldehyde carbon of glucose and ketonic carbon of β-fructose are connected by glycosidic linkage. The structure of sucrose can be given on the basis of above fact as– (Fig. 14.4)

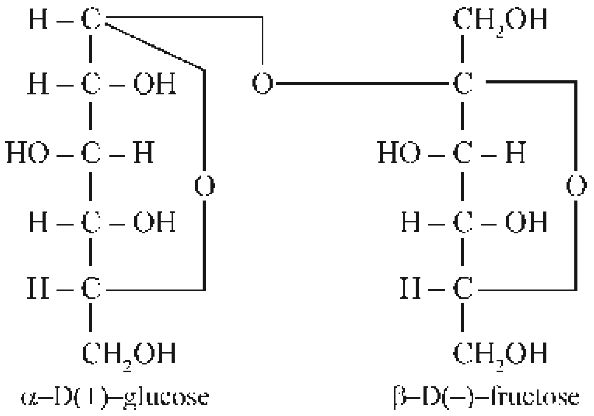


Fig. 14.4 : Structure of sucrose

It's Haworth structure is given below as– (Fig. 14.5)

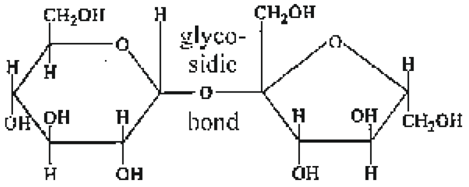


Fig. 14.5 : Haworth structure of sucrose

Maltose–

Maltose is a disaccharide which is obtained by reaction of malt of starch, therefore, it is known as maltsugar. Maltose is present in sprouted seeds especially in wheat in the form of starch. Maltose is formed by partial hydrolysis of starch. This hydrolysis is done by dilute mineral acid or by diastase enzyme present in malt or β-amylase.

(2) Properties of Maltose–

(i) The molecular formula of maltose is $C_{12}H_{22}O_{11}$ it is white crystalline, soluble in water and insoluble in alcohol and ether.

(ii) Its melting point is 160°-165°C

(iii) Maltose is a reducing sugar.

(iv) Maltose is dextrorotatory and it does not show mutarotation. Specific rotation of α-form of maltose is +168°, specific rotation of β-form of maltose is +112° and specific rotation is +136° at equilibrium.

(2) Structure of Moltose–

Maltose is a disaccharide and the molecular formula of maltose is $C_{12}H_{22}O_{11}$.

The structure of maltose is given by following facts–

(i) Maltose is hydrolysed by dilute mineral acids or maltose enzyme to give two molecules of glucose.

$$\underset{\text{maltose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow[\text{or maltase}]{\text{dil. acid}} \underset{\text{glucose}}{2C_6H_{12}O_6}$$

(ii) Maltose also–

(a) Forms oxime with hydroxylamine.

(b) Forms osazone with phenyl hydrazine.

(c) Reduces Fehling's solution that means maltose is a reducing sugar.

(iii) it is dextro rotatory and it does not show mutarotation.

From the above facts it is clear that two glucose units in maltose are connected in such a way that aldehyde group (–CHO) of one glucose molecule is free and it is also clear from its reactions that C-4, of reducing glucose is connected with C-1 of non reducing glucose by α-glycosidic linkage. Thus, maltose can be represented by the following structure– (14.6)

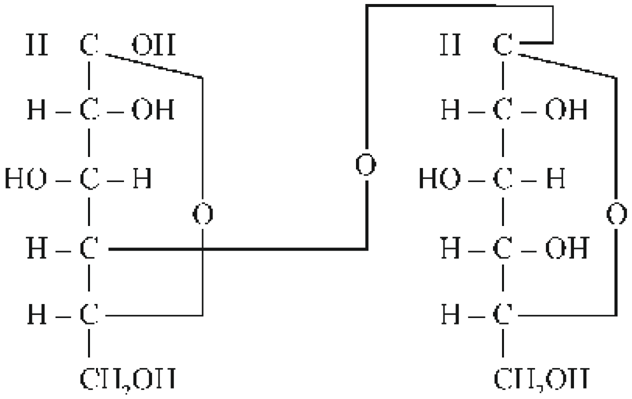
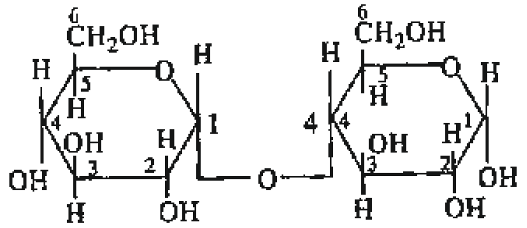


Fig. 14.6 : Structure of maltose

Its Haworth structure is as follows– (Fig. 14.7)



(I) α–D(+) glucopyranose (II) α D(+) glucopyranose

Fig. 14.7 : Haworth Structure of maltose

Lactose (milk sugar)

It is also a disaccharide and also known as milk sugar. Lactose is present in milk of all mammals. Commercially, lactose is obtained as by product in the process of formation of paneer. After formation of paneer, lactose is obtained by evaporation of aqueous solution which is obtained in this process.

(1) Properties of Lactose

(i) Lactose is white crystalline substance which is soluble in water and isoluble in alcohol & ether.

(ii) Its melting point is 203°C, it is also decomposed at this temperature.

(iii) Lactose is a reducing sugar.

(iv) Lactose is a dextro rotatory and it shows mutarotation.

(2) Structure of Lactose

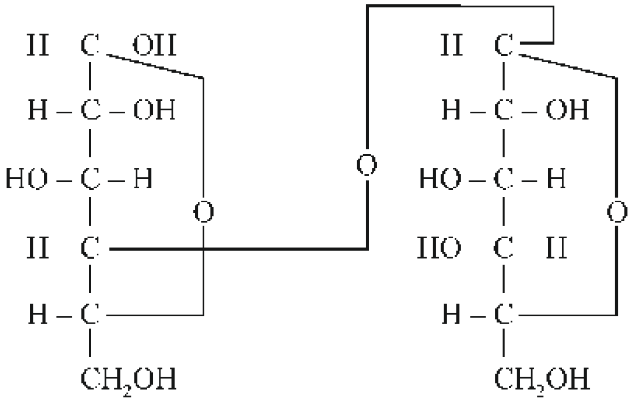
The molecular formula of lactose is $C_{12}H_{22}O_{11}$. Its structure is based on following facts.

(i) Lactose on hydrolysis by dilute acids or lactase enzyme gives equal molecular mixture of D-(+) glucose and D-(+) galactose.

$$\underset{\text{lactose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow[\text{or lactase}]{\text{dil acid}} \underset{\text{D(+) glucose}}{C_6H_{12}O_6} + \underset{\text{D(+) - galactose}}{C_6H_{12}O_6}$$

(ii) Lactose also– (a) Forms oxime with hydroxyl amine. (b) Forms osazone with phenyl hydrazine. (c) Reduces Fehling's solution means lactose is a reducing sugar. It also shows mutarotation. It is cleare from above facts and reactions of lactose that glucose is reducing part and C-4 carbon is connected with C-1 carbon of galactose by β-glycosidic bond.

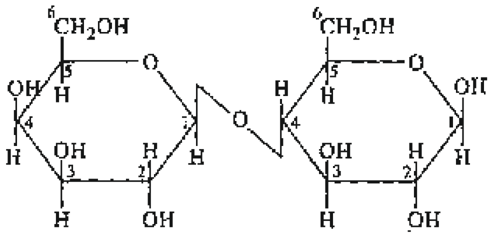
Lactose can be represented by the following structure (Fig. 14.8)



reducing part (glucose unit) non reducing part (galactose unit)

Fig. 14.8 : Structure of lactose

Its Haworth structure can be represented as (Fig. 14.9)



β–D-galactose β–D-glucose

Fig. 14.9 : Haworth structure of lactose

14.3.5 Polysaccharides

Polysaccharides are natural polymers. Its monomer units are monosaccharides or oligosaccharides. Molecular weight of polysaccharides may be many thousands of lacks.

(i) Polysaccharide's molecular formula is $(C_6H_{10}O_5)n$ and the value of 'n' stands from 100 to 3000.

(ii) They are noncrystalline, taste less and insoluble in water so they are called non-sugar.

(iii) These are two types–

(a) Homopolysaccharide– In homopolysaccharides, all monosaccharide units are same.

(b) Heteropolysaccharide– In this, two or more than two units of monosaccharides are present.

(iv) Starch, cellulose, glycogen, gum, insulin, etc. are important polysaccharides. Starch & cellulose are important and useful for human being which are found in plants. Details are as follows–

Starch–

Starch is a main source of carbohydrates and polysaccharides are stored in plants. It is most important dietary source of human beings and it provides energy to our body.

Its molecular formula is $(C_6H_{10}O_5)n$. Main sources of starch are wheat, maize, rice, barley, potatoes and sorghum, etc. and starch is also found in some vegitables.

(1) Structure of Starch

Hydrolysis of starch with dilute acids gives α-glucose and by diastase enzyme, it gives maltose that means it is polymer of α-glucose.

Starch is made from two compounds–

(i) Amylose, which is soluble in water.

(ii) Amylopectin, which is non-soluble in water.

(i) Amylose– Amylose is a water soluble component of starch and it forms 10-20% of starch, that is known as α-amylose. When amylose is hydrolysed it gives maltose and D (+) glucose. In hydrolysis process, any other mono or disaccharide is not formed, therefore, amylose is formed by a long chain of D(+) glucose. In this, a carbon of one glucose units is connected with C_4 carbon of other glucose unit by glycosidic– linkage (α–1, 4–glycosidic bond). Amylose structure is represneted in Fig. 14.10.

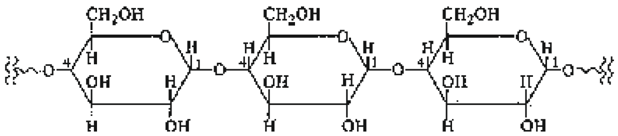


Fig. 14.10 : Structure of amylose

(ii) Amylopectin– Amylopectin is in soluble in water which forms 80-90% part of starch and it is also called β-amylose. It is branched chain and high molecular weight polymer. In this, 25-30 glucose unit chains are present and C_1 of one glucose unit is connected with C_4 of other glucose unit by glycosidic-linkage (α–1, 4 + glycosidic linkage).

These unbranched chains are connected with each other by α–1, 6 glycosidic linkage. In this, C_1 atom of last glucose molecule in a chain is connected with C_6 of last other glucose molecule of second chain. Amylopectin's structure can be given as– (Fig.14.11)

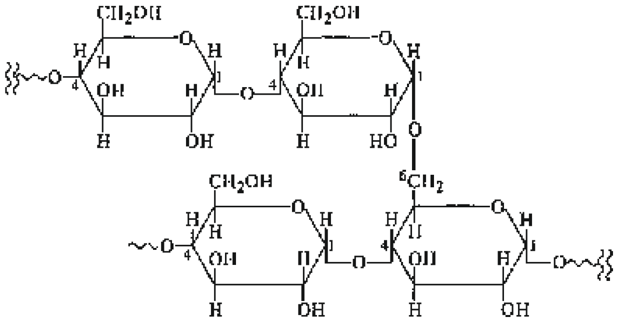


Fig. 14.11 : Structure of amylopectin

Cellulose–

Cellulose is also a polysaccharide with molecular formula $(C_6H_{10}O_5)n$. It is only found in plants and it is a main component of cell-wall of plants. Cellulose is also useful for human beings but where starch is used in food, cellulose is used as source of clothes, etc.

It is present in wood, cotton clothes, jute, cotton, etc. In wood, it is 50%, in dry grass 40-50%, in jute 60-65%, in cotton 90-95% and remaining are fats and wax.

Structure of Cellulose

Cellulose is non reducing sugar. On hydrolysis, cellulose gives only D–glucose that means it is linear polymer of D–glucose. There is experimetal evidence that these glucose units exist as β–D(+) glucose units and not α–D(+) glucose units. These β–D(+) glucose units are connected with each others by β −1, 4 glycosidic linkage. That means, C_1 carbon of one glucose unit is connected with C_4 carbon of other glucose unit. (Fig. 14.12)

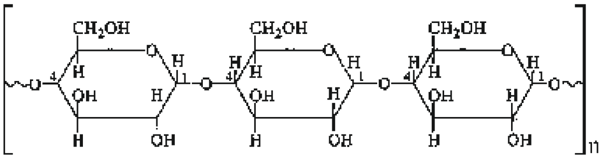


Fig. 14.12 : Structure of cellulose

14.4 Protein

The name 'Protein' is given by Berzelius in 1938. The word protein is taken by Greek word "Proteios", which means primary or of prime important because proteins are the most important chemical substances which are necessary for growth, repair and development of life.

Proteins are found in all living cells. It plays an important role in metabolism and structure of cells. In livings, their hairs, skin, haemoglobin, nails, enzymes and animal's cell-wall, etc. are made from proteins.

14.4.1 Composition of Proteins–

Proteins are the high molecular weight biopolymers of amino acids. 'Chemically, all protein are nitrogen containing organic compounds, in which other than nitrogen, carbon, hydrogen, oxygen, sulphur elements are present and some of these proteins also contains phosphorous, iodine and other metals such as iron, copper, zinc and manganese.

Proteins are hydrolysed as follows–

$$\text{protein} \xrightarrow{\text{hydrolysis}} \text{peptide} \xrightarrow{\text{hydrolysis}} \alpha\text{- amino acid}$$

On partial hydrolysis of protein, peptides of different molecular weight are obtained which give α–amino acids after complete hydrolysis. This means that, proteins are made from polypeptides of α–amino acids. Their molecular weight is more than 10,000. These are monodisperse natural polymers.

14.4.1.1 Classification of Protein

(I) Proteins are classified in two types on the basis of their compositions–

(1) Fibrous Proteins– These are made from a linear chain of protein molecules in which many polypeptide chains are connected by intra-molecular hydrogen bonds. These have long thread like strucutres and their structure is not changed by change in temperature and pH. These proteins are insoluble in water and there are structural material of animal tissues. Example–Collagen, myosin, keratin, etc.

(2) Globular Proteins– These protein are mae from coiled molecules of aminoacids, which are connected with many polypeptide chains by inter-molcular hydrogen bonds. These proteins are soluble in aqueous solution of acids, base and salts. Their functions are to control and maintain the life cycles. Example– Hemoglobin, insulin, Albumin, etc.

(II) Proteins can be classified on the basis of products obtained after hydrolysis of proteins which are–

(1) **Simple Protein–** On hydrolysis, these proteins give only α–amino acids. Example–albumin and globulin.

(2) **Conjugated protein–** In this protein, protein part is conjugated with a protein part, which is called prosthetic group. Conjugated proteins are three types–

(a) **Nucleoproteins–** In these protein, prosthetic group is nucleic acid. Example– Nuclein.

(b) **Glycoproteins–** In these protein, prosthetic group is carbonhydrate. Example– Mycin.

(c) **Chromoproteins–** In these protein, prosthetic group is some pigments. Example– Haemoglobin, chlorophyll.

14.2.2 Amino Acids

Proteins are natural polymers of α–aminoacids. The name of "amino acid" acknowledge that in these, amino ($-NH_2$) and carboxylic ($-COOH$) groups are present. 20 amino acids are known which are conjugated in many different pattern and form thousand types of protein molecules. It means all types of proteins are made from these 20 types of α–amino acids.

14.4.2.1 Classification of Amino Acids–

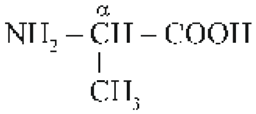
Amino acids are classified as follows–

(I) On the bases of the relative position of amino & carboxylic groups, the amino acids can be classified as α, β, γ, λ etc.

(1) α-amino Acids– In these, amino group is present at α-position of carboxylic group that means both groups are attached to the same carbon atom. Example –

$$\mathrm{H_2N\quad \overset{\alpha}{C}H_2\quad COOH}$$

glycine



$$\mathrm{NH_2-\underset{\displaystyle CH_3}{\underset{|}{\overset{\alpha}{C}H}}-COOH}$$

alanine

(2) β-amino acids– In these, amino group is present at β-position of carboxylic group. Example –

$$\mathrm{H_2N\quad \overset{\beta}{C}H_2\quad \overset{\alpha}{C}H_2\quad COOH}$$

β-amino propanoic acid

(3) Similarly, in γ-amino acid and λ-amino acid, amino group is present at γ and λ position from carboxylic group, respectively.

Example – γ-amino butanoic acid.

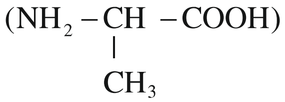
$$\mathrm{H_2N-\overset{\gamma}{C}H_2-\overset{\beta}{C}H_2-\overset{\alpha}{C}H_2-COOH}$$

γ–amino butanoic acid

(II) On the basis of number of amino and carboxylic acid groups, these are classified as neutral, acidic and basic amino acids. They are –

(1) Neutral Amino Acid– In neutral amino acids, amino and carboxylic groups are equal in numbers.

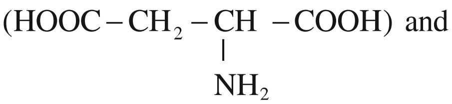
Example – glycine (NH_2-CH_2-COOH) & alanine



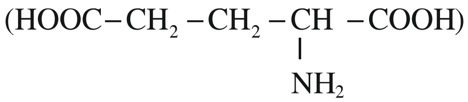
$$\mathrm{(NH_2-\underset{\displaystyle CH_3}{\underset{|}{CH}}-COOH)}$$

(2) Acidic Amino Acids– In these type, carboxylic groups are more than amino groups.

Example –

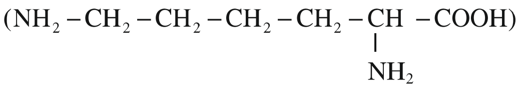


Aspartic acid $\mathrm{(HOOC-CH_2-\underset{\displaystyle NH_2}{\underset{|}{CH}}-COOH)}$ and



glutamic acid $\mathrm{(HOOC-CH_2-CH_2-\underset{\displaystyle NH_2}{\underset{|}{CH}}-COOH)}$

(3) Basic amino acids– In these type, number of amino groups are more than carboxylic groups. **Example –**

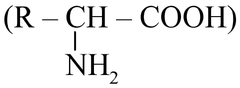


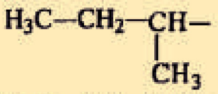
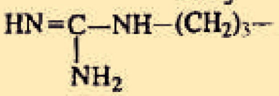
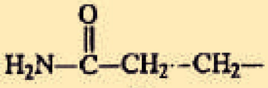
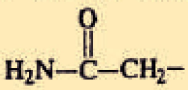
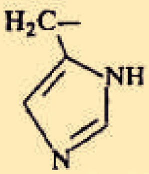
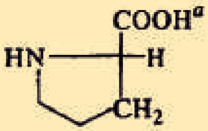
Lysine $\mathrm{(NH_2-CH_2-CH_2-CH_2-CH_2-\underset{\displaystyle NH_2}{\underset{|}{CH}}-COOH)}$

(III) Essential and Non-essential amino acids– Those amino acids that can be shynthesized by the body are called non essential amino-acids and those amino acids that can not be synthesized by the body are called essential amino acids.

As discussed earlier that there are total 20 types of α–aminoacids and that can form many types of proteins.

Table 14.2 : α–amino acid (R – CH – COOH)


$R-\underset{\displaystyle NH_2}{\underset{|}{CH}}-COOH$

Name of amino acid	Nature of side chain, R	Three letter symbol	One Letter code
1. Glycine	H	Gly	G
2. Alanine	$-CH_3$	Ala	A
3. Valine*	$(H_3C)_2CH-$	Val	V
4. Leucine*	$(H_3C)_2CH-CH_2-$	Leu	L
5. Isoleucine*	 $H_3C-CH_2-\underset{\displaystyle CH_3}{\underset{|}{CH}}-$	Ile	I
6. Arginine*	 $HN=\underset{\displaystyle NH_2}{\underset{|}{C}}-NH-(CH_2)_3-$	Arg	A
7. Lysine*	$H_2N-(CH_2)_4-$	Lys	L
8. Glutamic acid	$HOOC-CH_2-CH_2-$	Glu	G
9. Aspartic acid	$HOOC-CH_2-$	Asp	A
10. Glutamine	 $H_2N-\overset{\displaystyle O}{\overset{\|}{C}}-CH_2-CH_2-$	Gln	G
11. Asparagine	 $H_2N-\overset{\displaystyle O}{\overset{\|}{C}}-CH_2-$	Asn	A
12. Threonine*	$H_3C-CHOH-$	Thr	T
13. Serine	$HO-CH_2-$	Ser	S
14. Cysteine	$HS-CH_2-$	Cys	C
15. Methionine*	$H_3C-S-CH_2-CH_2-$	Met	M
16. Phenylalanine*	$C_6H_5-CH_2-$	Phe	P
17. Tyrosine	$(p)HO-C_6H_4-CH_2-$	Tyr	T
18. Tryptophan*		Trp	W
19. Histidine*		His	H
20. Proline		Pro	

*Proline is an exception. Here, secondary amino group (>NH) is attached to α-carbon. Thus, proline is imino carboxylic acid.

*Essential amino acid, a = complete structure

In these 20 amino acids, 10 essential aminoacids are such type of amino acids that cannot be synthesized in some animals of high species and human beings. These essential amino acids are essential to take by outer source through food and their deficiency can aquire many diseases. These deficiency are fulfilled by those proteins which have these essential amino acids. Example– casein, milk protein, have all essential amino acids.

These essential amino acids are following–

(1) Tryptophan
(2) Valine
(3) Methionine
(4) isoleucine
(5) Leucine
(6) Lysine
(7) Phenyl alanine
(8) Arginine
(9) Threonine
(10) Histidine

14.4.2.2 Physical Properties of Amino Acids–

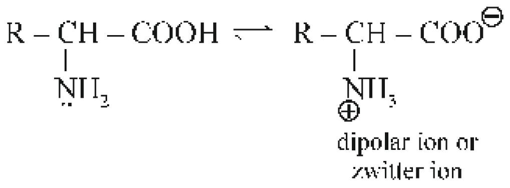
The physical properties of amino acids are–

(i) Amino acids are colourless and crystalline solids.

(ii) They are soluble in water, acids and base.

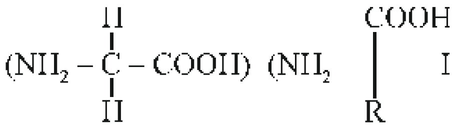
(iii) Their melting points are very high.

(iv) Amino acids have both amino & carboxylic groups. Amino is base and carboxylic is acidic in nature, therefore both groups interact with each other and forms inert-salt, which has dipolar structure, hence, aminoacid is called Zwitter ion or Ampholite ion.



$$R-\underset{\underset{\cdot\cdot}{NH_2}}{\underset{|}{CH}}-COOH \rightleftharpoons R-\underset{\underset{\oplus}{NH_3}}{\underset{|}{CH}}-COO^{\ominus}$$

(v) Other than first member glycine, all amino acids have asymmetric carbon atom



$\left(NH_2-\overset{\overset{H}{|}}{\underset{\underset{H}{|}}{C}}-COOH\right)$ $\left(NH_2 \overset{\overset{COOH}{|}}{\underset{\underset{R}{|}}{}} H\right)$, Hence and they are optically active.

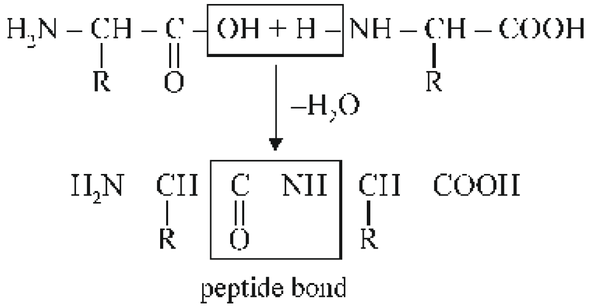
(vi) Chemically, amino acids show both important characteristics of primary amine and carboxylic acid.

(viii) They have isoelectric point. Each amino acid has a definite isoelectric point.

Isoelectric point- If an electric potential is applied on the solution of amino acid then at particular pH, the amino acid does not show any type of movement towards any electrode, (i.e. amino acid molecule becomes electrically neutral i.e. Zwitter ion concentration is maximum) this value of pH is known as isoelectric point. At this point the solubility, conuctivity, viscosity and osmotic pressure are minimum.

14.4.3 Peptides–

When two or more than two molecules of amino acids are combined to form peptide bond (-CO-NH) then these compounds are known as peptides. Amino acids are combined to form amide are called peptide. Hydroxy (-OH) part of carboxylic acid group of one amino acid is linked with hydrogen (-HN) of amino group of other amino acid, resultant is the elimination of a water molecule and a peptide bond is formed.



On the basis of the number of amino acids, peptides are of three types–

(1) **Oligopeptide–** These contain 2-9 amino acids. When two, three and four amino acids are combined then dipeptide, tripeptide and tetrapeptides are formed, respectively.

(2) **Polypeptide–** These contain 10 to 100 amino acids.

(3) **Protein–** In proteins, more than 100 amino acids are present.

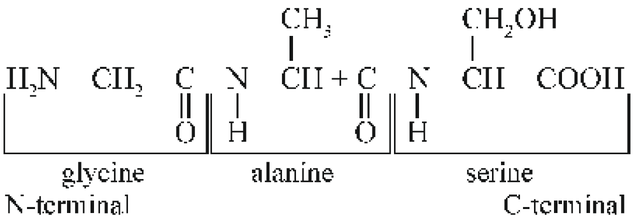
14.4.3.1 Nomenclature of Peptides–

Peptide bond is present in peptides which are formed by interaction between carboxylic group

(-COOH) and amino group (-NH_2). One end of peptide contains free amino group which is known as "N-terminal end" or "N-end". Similarly free carboxylic group containing end is called "C-terminal end" or "C-end". When structure of peptide or polypeptide is written, then N-end is written on the left side and C-end is written on the right side.

The name of peptide is started from N-terminal amino acid then ends at the C-terminal amino acid. In its nomenclature, except the C-terminal residue, each amino acid will be written with suffix "-yl" at the place of "-ine" and writing is started from left.

For Example –



$$H_2N-CH_2-\underset{\underset{O}{\|}}{C}-\underset{\underset{H}{|}}{N}-\overset{\overset{CH_3}{|}}{CH}+\underset{\underset{O}{\|}}{C}-\underset{\underset{H}{|}}{N}-\overset{\overset{CH_2OH}{|}}{CH}-COOH$$

gly-ala-ser(G-A-S). (glycylalanyl serine)

14.4.4 Polypeptide–

In polypeptides, 10 to 100 aminoacids are connected by peptide linkage.

"When the number of amino acids are ten or more than ten, then this peptide is called as polypeptide.

(i) The name of polypeptide starts from N-terminal residue.

(ii) Polypeptides are also amphoteric in nature.

(iii) Chemically, they give all the reactions of primary amine and carboxylic groups.

(iv) Polypeptides have isoelectric point.

14.4.5 Strcture of Protein-

Proteins are polymers of α–amino acid, which are linked by peptide bond (-CO-NH-). The structure of protein is very complex, thus the structure and shape of polymers can be explain by four different steps in following manner–

(1) Primary Structure of Proteins– Proteins are formed by α–amino acids. Each polypeptide in a protein has different amino acids linked with each other in a specific sequence and numbers in the primary structure of protein.

Any changes in sequence of amino acids, changed the properties and biological activities of entire protein molecules.

Example – Haemoglobin is a chromoprotein which is found in red blood cells and its function is to transport oxygen which is taken by lungs in breathing. This chromoprotein is made from 574 amino acids. By the replacement of one specific amino acid in the sequence of amino acids in haemoglobin, can change its structure and it is responsible for disease of sickle cell anaemia. It happens when valine amino acid is introduced in haemoglobin istead of glutamine amino acid. This disease can cause death in human beings.

Normal Haemoglobin

$$-Val-His-Leu-Thr-Pro-\boxed{Glu}-Lys$$

Sickle cell Haemoglobin

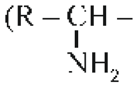
$$-Val-His-Leu-Thr-Pro-\boxed{Val}-Lys$$

The sequence of amino acid is very difficult to find. Primary structure of protein can be known by various products of different molecular weight which are obtained by hydrolysis of protein by acid, base or enzyme. First, protein structure of "insulin" was discovered by Frederick Sagner in 1958 and he got nobel prize for his discovery. Insulin is a polypeptide hormone which is produced in pancreas. Insulin is made from 51 amino acids and deficiency of insulin causes diabetes.

(2) Secondary Structure of Proteins – The secondary strucutre of protein refers to the shape in which a long polypeptide chains exist. These specific shape are arised by the formation of H-bond between (>C=O) keto group and (>N-H) amino group of peptide molecule, which are known as secondary structure of protein. These chains are made of two different structures–

(i) α–helix structure

(ii) β–Flat sheet or β-Pleated sheet structure)

(i) α–helix structure- The common formula of amino acids is  $(R - \underset{NH_2}{\underset{|}{C}H} - COOH)$. If shape of R-group is large in polypeptide series of amino acids, the H-bonds are formed between >C=0 group of one amino acid unit and >N-H group of fourth amino acid unit. This causes polypeptide chains to coil up in ring-shape and form helical strucutre. This is shown in diagram 14.13.

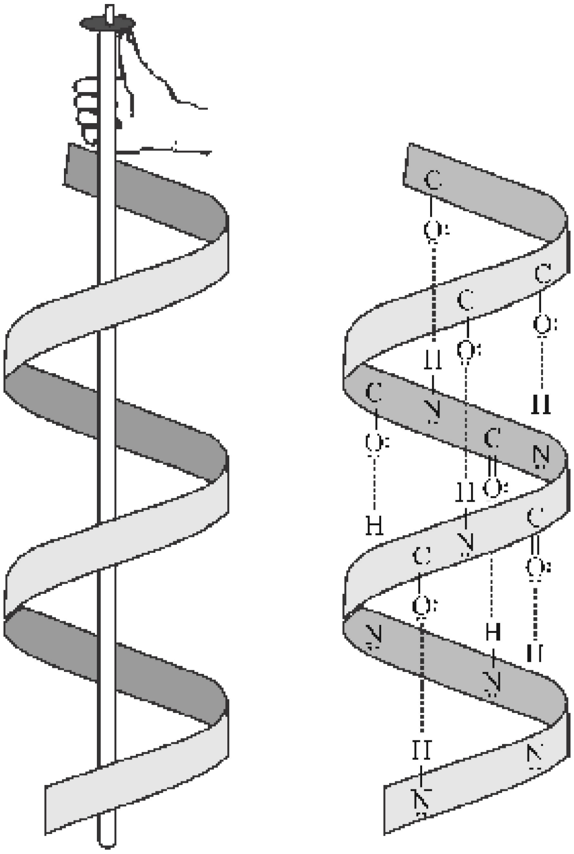


Fig. 14.13 : α-helix structure of protein

In this helix, there is no free movement exist, therefore, helix is rigid. In these protein, all helix are right handed. These protein are flexible, which means they can be stretched. Wool, hair, muscles, etc. have this type of structures. The α–helix structure for proteins is proposed by Linus Pauling in 1951.

(ii) β–Flat sheet or β-Pleated sheet structure- In this structure, polypeptide chains of protein are in open state and make a joint sheet like structure by the inter molecular H-bonds. These pleated sheet like structures are assemble upon one sheet to other sheet and slip with each other. That means they are soft but not flexible. Example – Silk have this type of structure.

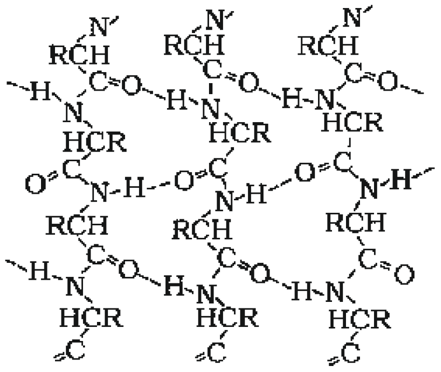


Fig. 14.14 : β-Flat Sheet structure of protein

(3) Tertiary Structure of Proteins- The tertiary structure of protein is three dimensional structure. These polypeptide rings are folded more than secondary structure of protein. Tertiary structure of protein is more coiled and stable structure is due to the attraction forces like H-bond, ionic-bonds, disulphur bonds and electrostatic attraction forces. The life and activeness are depends only on the tertiary strcuture of protein. Tertiary structure of protein gives globular and fibrous shapes of entire protein molecule.

(4) Quaternary Structure of Protein- All proteins do not have quaternary structure. Some of the proteins are composed by two or more than two polypeptide chains, referred to as sub-units. The spatial arrangement of these subunits is known as quaternary structure of protein (Haemoglobin contains four subunits).

14.4.6 Denaturation of Protein-

Protein is a complex three dimensionl structured molecule. With the change in temperature, pressure, pH and salt or chemical factors, the natural structure of protein is destroyed and this is called denaturation of protein.

The hydrogen bonds are disturbed due to these various changes, due to this specified & well shaped proteins are unfolded and coverted in to unsymmetric shape. Due to denaturation, protein loses its biological activities. Secondary and tertiary structure are affected due to denaturation by chemical reactions but no changes occur in primary structure. Denaturation process is an irreversible process–

Example – (i) Egg white is changed (coagulation) after boiling of egg. (ii) Coagulation or precipitation of milk.

Uses : Denaturation of proteins is used in tests for the presence of glucose, urea, etc. molecules in blood or serum. The sample of blood or serum is denaturated by treating with acid which is precipited by centrifugal method. The test solution obtained after isolation of glucose, urea, etc. is sent for chemical analysis.

14.4.7 Enzyme-

Enzymes are called bio catalyst. These are synthesized by living cells.

First of all J.Berzelius discovered Amylase enzyme. The name "enzyme" was given to these bio catalysts by W. Kuhen. First of all J.B. Summer in 1926, synthesized the enzyme Urease in laboratory in crystalline form and said that enzymes are protein molecules.

Definition– Meyerbeck difined enzymes as, "Enzymes are simple or conjugated proteins which acts as specific catalyst" or enzymes are complex organic substances which catalyse biological reactions without itself undergoing any changes.

14.4.7.1 Characteristics of Enzymes

(i) Generally all enzymes are colourless and soluble in water and dilute solution of salts.

(ii) Chemically enzymes are made from proteins.

(iii) Enzymes are not uitlized in reaction, thus the same enzyme can take part in a new reaction with other substrate.

(iv) Very low quantity of enzymes is required for catalysation of any reaction. It can be reused.

(v) Enzymes increases the rate of reaction by decreasing activation energy of the reaction. Their presence can increase the reaction rate by 10^{20} times.

(vi) Enzymes are very specific which means one type of enzyme can catalyse a single and particular type of reaction. Example– Amylase enzyme catalyse only starch-hydrolysis but it does not catalyse cellulose.

(vii) Enzymes only increases rate of reaction. There is no other effect on the direction and equilibrium of the reaction.

(viii) The activity of enzymes can be controlled or slow down from organic and inorganic substances.

(ix) Enzymes are more active at 310 K temperature and at normal pH (6-8).

(x) High temperature, U.V. light, acid, high salt concentration and basic reactants cause denaturation of enzyme. These destroy the activity of enzymes.

(xi) Some artificial molecules also show catalytic activity like enzymes. These are known as artificial enzymes.

14.4.7.2 Nomenclature and Classfication of Enzymes–

Till now about 3000 enzymes are indentified and about 300 enzymes are produced commercially. According to modern nomenclature method, enzymes are named by adding suffix "ase" after the name of substrate on which enzyme works. For example – (i) The enzyme that changes lipid into glycerol is called lipase, the enzyme that changes protein into amino acid is called protease, the enzyme that catalyse hydrolysis of maltose into glucose is called as maltase.

I.U.B. (International Union of Biochemistry) commission in 1965 classified enzymes into six groups.

Table 14.3 Types of enzymes

S.No.	Group	Enzymes	Nature of Reaction
1.	group-1	Oxido-reductases	These are related to biological oxidation and reduction (respiration and fermentation)
2.	group-2	Transferases	Catalyse the transfer of any group from one substrate to another substrate.
3.	group-3	Hydrolases	These catalyse hydrolysis reactions.
4.	group-4	Lyases	Reactions where the removal of functional groups are catalysed to form double bond or the reverse.
5.	group-5	Isomerases	These catalyse the Intramolecular rearrangement.
6.	group-6	Ligases	These catalyse the synthesis of two groups from condensation process. In this process, ATP or any other triphosphate is required.

Table 14.4 Functions of some enzymes

1.	Maltase	intestinal juices	maltose	glucose
2.	Amylase	gastric juices	carbohydrate	glucose
3.	Lipase	gastric juices	fat	glycerol and fatty acids
4.	Trypsin	pancreatic juices	protein	amino acid
5.	Renin	pancreatic juices	milk	milk denatured
6.	Ptyalin	saliva	polysaccharides (starch)	dextrin and maltose
7.	Pepsin	gastric juices	protein	polypeptide
8.	Deoxyribonuclease and ribonuclease	Intenstinal pancreatic juices	DNA and RNA	oligo and mono nucleotide

14.4.7.3 Mechanism of Enzyme action-

Enzymes increase the rate of biochemical reactions but at the end of reaction, itself remains unchanged. They gives a type of platform or tamplet on which molecules can reacts. Enzymes decreases the activation energy resulting in the increase of rate of reaction at low temperature. The mechanism of enzyme action was given by Michealis and Menten in 1913. According to this, an intermidiate, enzyme-substrate complex is formed. Enzyme action proceed in following two steps–

Step–1 : Formation of complex by reaction of enzyme and substrate :

$$\underset{(\text{enzyme})}{E} + \underset{(\text{substrate})}{S} \longrightarrow \underset{(\text{enzyme}-\text{substrate complex})}{[ES]}$$

Step–2 : Conversion of this complex in an intermediate complex :

$$[ES] \longrightarrow [EI]$$

Step–3 : In this step, intermediate complex is converted to enzyme-product complex.

$$[EI] \longrightarrow [EP]$$

Stpe–4 : Decomposion of enzyme product complex to product & enzyme

$$[EP] \longrightarrow \underset{(\text{enzyme})}{E} + \underset{(\text{product})}{P}$$

14.4.7.4 Application of Enzymes–

1. Enzymes are mainly helpful in digestion.
2. Enzyme resin is used in commercial production of paneer.
3. These are used in commercial production of alcoholic drinks as wine, beer, softening of leather, production of healthy drinks as Maltova and invert sugars.
4. Enzymes are also used in treatment of diseases. Example– Deficiency of enzyme tyro sinase is the cause of Albinism disease. This enzyme is used in diet for treatment of their defeciency.

Example– Enzyme Streptokinase is used in treatment of heart diseases. It is used as dissolution agent for blood clots.

14.4.8 Hormones-

Hormones are complex organic substrate released by cells and glands. They control and regulate various biochemical reactions, growth and development, reproduction of living beings. These are also known as 'glandular juice" because they are secreted by endocrine glands. Hormones are called chemical messengers because they work in the cells which are away from their origin. Very less quantity of hormone is more effective, these are destroyed after their function and not stored for long time and they are ejected by body through excretion.

Functions

1. **Plant Hormones :** These are found in plants and helpful in growth and development, budding, cell-division, germination of seeds, formation of fruits, development of roots, prevention of falling of unripened fruits and leaves and control various biological reactions.
2. **Animal Hormones :** In animals, hormones are secreted by endocrine glands and transported to work place by blood. These control, regulate and coordinate various chemical reactions, growth, development, reproduction, etc. Their deficiency and excess quantity both are harmful.

14.4.8.1 Enzymes vs Hormones

Hormones also act like enzymes. These are used in very less amount and are not utilized during reaction. Hormones are different from enzymes in the following properties–

(i) These act on those glands which are different from their origin organs or glands.

(ii) Structurally, they are not always proteins. These can be proteins of 30,000 or less molecular weight, small polypeptide, single amino acids and steroids.

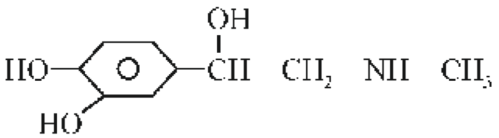
(iii) These are released before use in to blood.

14.4.8.2 Classification of Hormones-

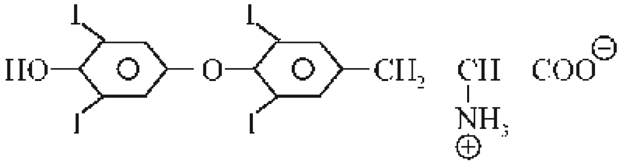
Hormones can be classified on the basis of their chemical composition as–

(i) **Peptide Hormones**– Peptide bonds are found in these hormones, therefore these hormones are known as protein hormones. Example– Insulin, Vasopressin and Oxytocin.

(ii) **Amino Hormones** – These contain amino group (-NH_2 group) and are soluble in water. Example– Adrenaline and Thyroxin.

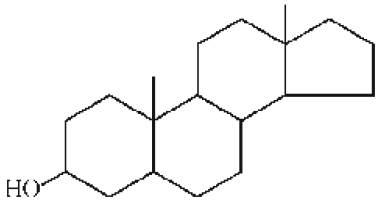


Adrenaline

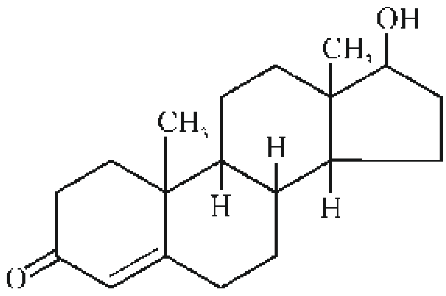


Thyroxine

(iii) Steroid Hormones- These hormones contain steroid nucleus. Steroid nucleus is made from four rings and of these rings, three rings are cyclohexane and one ring is cyclopentane. Example– Sex hormones (like testosterone), cholesterol, adrenocortical and bile acid, etc.



Steroid Nucleus



Testosterone

14.4.8.3 Biological function of Hormones–

Each hormone is released by a specific endocrine gland and perform a specific biological function. Following endocrine glands are found in human beings.

	Name of gland	Number
1.	Pituitary gland	one
2.	Thyroid gland	one
3.	Parathyroid gland	four
4.	Adrenal gland	two
5.	Island of longerhans	–
6.	Testis	two in men
7.	Ovary	two in female
8.	Placenta	one in female
9.	Thymus gland	one
10.	Pineal gland	one

Biological function of any hormone is influenced by their structure. For example–

(i) Peptide hormone like vasopressin, etc. act on peptide linkage.

(ii) Iodine is present in structures of thyroxine thus it controls the amount of iodine in the body.

(iii) Similarly, cholesterol is a solid alcohol which is deposited on the walls of blood vessels and create obstacle in blood circulation.

Following table shows some important hormones and their functions–

S.N.	Hormones	Sectretary gland	Main biological function
1.	growth hormone	anterior pituitary gland	stimulates growth of bones, cartilage, muscles and whole body.
2.	adreno cortico tropic hormone	anterior pituitary gland	important in pysical and emotional stress.
3.	thyrotropic hormone	anterior pituitary gland	control thyroid gland
4.	oxytocin	posterior pituitary gland	induce uterine contraction during parturition (child birth)
5.	vasopressin/anti diuretic hormone	anterior pituitary gland	increases water absorption from kidney and regulates urination.
6.	thyroxine	thyroid gland	regulates mtabolic reactions
7.	aldosterone	outer part of adrenal gland (adrenal cortex)	reabsorption of sodium and chloride ions.
8.	corticosterone	adrenal cortex	regulates metabolism of protein, lipid and carbohydrate
9.	adrenaline/ epinephrine	inner part of adrenal gland (adrenal medulla)	flight or fight hormone, regulates heart-beats and blood pressure
10.	insulin	pancrease	regulates levels of glucose in blood and glucose metabolism
11.	testosterone	testis	regulates male reproductive system and secondary sexual character
12.	estrogen and estradiol	ovary	regulates female reproductive system and secondary sexual character.
13.	progesterone	ovary	regulates ovary and induces uterus for implantation of foetus.
14.	human chorionic gonadotropin (hcg)	placenta	regulation of pregnency and protection of foetus.
15.	thymosin	thymus	stimulates development of T-cells
16.	parathormone (para thysin)	parathyroid	regulates calcium in serum.

14.4.9 Vitamins-

Vitamins are essential components of diet in which all are required in small amounts. First of all, Funk used the word 'vitamin' that means 'vital amines' hence found in living systems. Generally they can not be formed by livings. All vitamins are synthesized in plants. Vitamins are taken by human beings in the form of food. Chemically they are nutrients other than main nutrients like carbohydrates, protein and fat. Although these are not source of energy or cell formation but these are important for biological acitivites. Deficiency of vitamins creates specific disease. Vitamins can be defined as "Vitamins, instead of carbohydrates, protein and fats, are a group of bio-molecules, essential for metabolic reactions and growth, life and health of human beings". Very low amount of vitamins is essential.

14.4.9.1 Classfication of vitamins–

Vitamins are complex organic molecules. The term vitamin was given earlier because they are having amino groups but later work showed that most of them did not contain amino groups. Almost 25 vitamins are known and generally they are shown as alphabets like A, B, C, D, E, and K. Vitamins are classified into two kinds. On the basis of their solubility.

(i) **Water insoluble vitamin or Fat soluble vitamin-** Those vitamins which are insoluble in water and soluble in fat. They are oily in nature and these type of vitamins like A, D are found maximum in liver cells. Vitamins A, D, E & K are fat soluble.

(ii) **Water soluble vitamin-** These are soluble in water. Acid is stored in low quantity in cells. Vitamin B-complex (B_1, B_2, B_5, B_6, B_{12}) and vitamin C are soluble in water.

Exception– Vitamin H (Biotin) is neither soluble in water nor in fat.

14.4.9.2 Function of Vitamin–

Vitamins are required in very small amount but they are very essential because each vitamin performes a specific function. Their deficiency show symptoms of specific disease. The amount of vitamin is not fixed for an individual but its requirement is more in adults.

Following table shows different vitamins and their properties, sources, functions and deficiency disease caused by them.

Sr. No.	Vitamin	characters	source	function	deficiency disease
1.	Vitamin-A (retinol)	thermally stable and soluble in oil and fat.	milk, butter, eggs, fish, and fishoil. Carotenoids are harbingers of vitamin A. Yellow, green vegetables (cabbage), carrots, totmatoes, mangoes, etc.	promotes growth and vision in animals and resistance to diseases.	Night blindness xerosis (dry skin) xerophthalmia (hardening of cornea) cornea becomes non transparent.
2.	Vitamin B complex				
(i)	vitamin B_1 (Thiamine)	soluble in water destroyed above 310K temperature	nuts, pulses, whole cereals (rice, wheat, etc.) egg yolk, yeast, milk, green, vegetables and fruits.	helps in strengthening theimmune system and in functioning.	beri-beri (paralysis of legs) and general weakness, loss of appetite.
(ii)	Vitamin B_2 (riboflavin)	soluble in water sensitive to light, thermally stable	Green vegetables, milk, yeast, meat, liver, kidney, egg white, etc.	essential for growth and general health.	growth is retarded, inflammation of skin, cracking at corners of mouth and lips, blisters.
(iii)	Vitamin B_6 (It is a mixture of three substance, pyridoxine, pyridoxal and pyridoxamine)	Soluble in water	Rice bran, yeast, fish, egg yolk, cereals, etc.	blood circulation	pellagra, anaemia, affects central nervous system irratibility, general weakness.
(iv)	VitaminB_{12} (cyanoco-balamine)	Soluble in water, thermally stable	milk, egg, liver, fish, all animal tissues.	metabolic reactions	pernicious anaemia, numbness, inflammation of tongue and mouth, restlessness, tingling in legs and hands, unconciousness.

Sr. No.	Vitamin	characters	source	function	deficiency disease
3.	Vitamin C (Ascorbic acid)	soluble in water, destroyed by cooking and prolonged exposure to air.	citrus fruits (lemon, orange tomatoes, grapes, amla, cabbage, guava, etc.	increases body's immune system, healthy skin and heal cuts and wounds.	Scurvy (bleeding of gums), pyorrhea (loosening and bleeding of teeth), weakness.
4.	Vitamin D (ergocalciferol or sunshine vitamin)	soluble in oil and fats, stable to heat and resistant to oxidation	sunlight, egg, meat, fish, liver oil, butter, in presence of light, it is formed from ergestrol.	it absorbs calcium and phosphorous from intestine, controls the calcium and phosphorus metabolism, protects from blindness, growth, etc.	Rickets (bending of bones) in children. Deformation of bones and teeth, osteomalacia.
5.	Vitamin-E, (It is a mixture of four vitamins, called α, β, γ and δ- tocopherols)	soluble in oil and fats. It is stable to heat, light and oxidation.	Eggs, milk, fish, wheat, germ oil, cotton seed oil, soyabean oil, peanut oil, oil of almond and valnut, sprouted wheat.	Antioxidant	Sterility, malnutrition, loss of of hair, leg cramp, muscular weakness.
6.	Vitamin K (phylloquinone) It is a mixture of two vitamins called K_1 and K_2	soluble in oil and fat. Sensitive to light and alkali.	Vitamin K_1 is found in green leafy vegetables, tops of carrot, cabbage, spinach. Vitamin K_2 occurs mainly in bacteria.	helps in coagulation of blood. (blood clotting), synthesis of prothrombin.	Bleeding (Haemorrhage), lengthens the time of blood clotting.
7.	Vitamin–H (Biotin)	soluble in fat as water both	liver, yeast, kidney and milk	metabolic reactions	loss of hairs, paralysis, dermatitis. (skin inflammation)

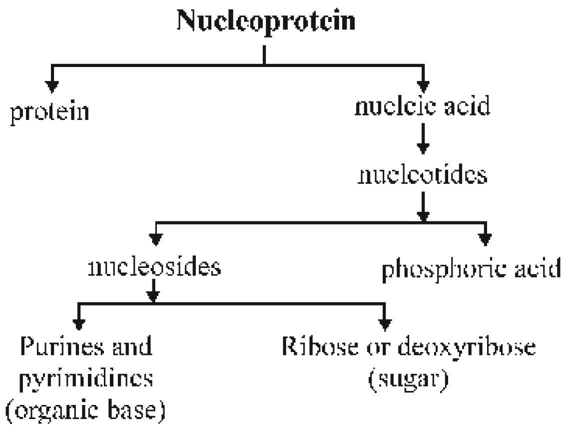
14.4.9 Nucleic Acids– Nucleic acids are biopolymers of nucelosides.

These polymeric molecules are made by carbon, hydrogen, oxygen, nitrogen and phosphorus which determines heredity characteristics of living beings. These specific characters are transmitted from one generation to the next generation. Particles in nucleus of the cell, responsible for heredity, are called "chromosomes". Chromosomes are made by protein and nucleic acid. In natural state, the combination of protein and nucleic acids are known as nucleoproteins.

Nucleic acids are very important for life as the 'genes' having genetic code in chromosomes are made from nucleic acids. Nucleic acids control the synthesis of protein in various cells.

14.4.9.1 Molecular organization of Nucleic acid-

First of all, in 1869, Swiss scientist Friedrich Miescher isolated nucleic acid in nucleus of Pus cells and termed it as nuclein. After that, in 1889, Richard Altman gave the name "Nucleic acids".



Nucleic acids are colourless complex and shapeless compounds and these are two types–

(i) De-oxyribose nucelic acid (DNA)

(ii) Ribose nucleic acid (RNA)

DNA is found mainly in nucleus and some amount is found in cytoplasm, mitochondria and chloroplast. RNA is mostly found in cytoplasm and least found in nucleus. On hydrolysis, nucleic acids give nucleotides which on further hydrolysis gives nuceloside and phosphoric acid. These nucleosides are again hydrolysed and gives sugars (Ribose or De-oxyribose) and organic base (purines and pyrimidines). Hydrolysis of Nucleic acid is shown –

$$\text{nucleic acid} \xrightarrow[\text{115°C or enzyme nuclease or Ba(OH)}_2]{\text{aq. NH}_3} \text{nucleotides} \xrightarrow[\text{175°C}]{\text{aq. NH}_3}$$

$$\underset{(H_3PO_4)}{\text{phosphoric acid}} - \text{nucleosides} \xrightarrow{\text{Inorganic acid}} \text{sugar} - \text{organic base}$$

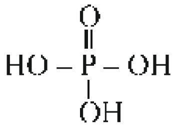
Hence, hydrolysis of nucleic acid give three types of compounds means nucelic acid is made from units as–

(i) phosphoric acid (H_3PO_4)

(ii) sugars

(iii) organic base

(i) Phosphoric acid

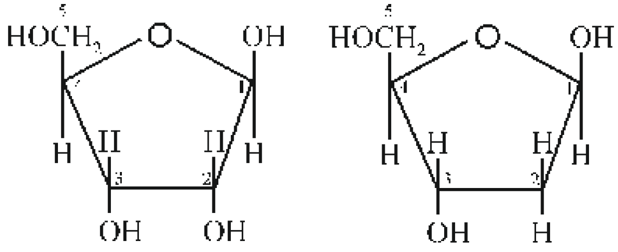


$$HO-\overset{\overset{O}{\|}}{\underset{\underset{OH}{|}}{P}}-OH$$

(ii) Sugar- Nucleic acid have two types of pentose sugars– (1) Ribose/D-Ribose (2) Deoxyribose/ D-2-Deoxyribose.

In deoxyribose, $H-\overset{|}{\underset{|}{C}}-OH$ group is at C-2, in ribose it is replaced by $H-\overset{|}{\underset{|}{C}}-H$ group.

The sugar contain in DNA is De-oxyribose and in RNA is oxyribose sugars. Both sugar molecules are in the form of Furanose and β-isomers.

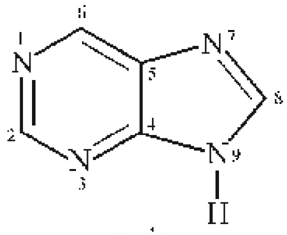


β–D-ribose β–D-2-deoxyribose

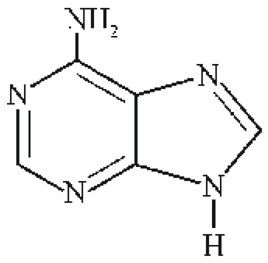
(iii) Organic Base- These are nitrogenous base. Two types of organic or nitrogneous base in nucleic acid are–

(1) Purines- One purine forms a six membered ring which is condensed with five membered ring. Adenine (A) and Guanine (G) are main purines. These are found in both DNA & RNA.

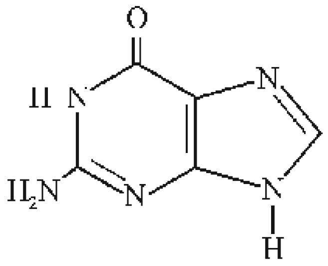
(2) Pyrimidines– These are heterocyclic single units. Uracil (U), Thymine (T) & Cytosine (C) are main pyrimidines found in nucleic acids. DNA have Thymine (T) and Cytosine (C) and in RNA, Uracil (U) and Cytosine (C) are found as pyrimidines. Adenine is always bonded with thymine and cytosine with guanine. (A–T and C–G).



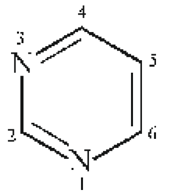
purine



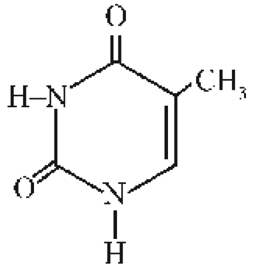
Adenine (A)



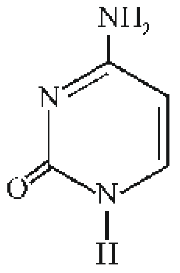
Guanine (G)



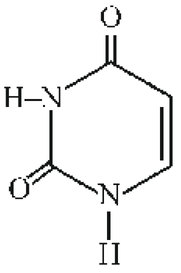
Pyrimidine



Thymine (T)



Cytosine (C)



Uracil (U)

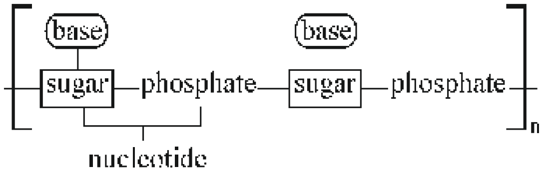
Fig. 14.14 : Sturcture of purines and pyrimidines

14.4.9.2 Arrangement of Constituents in Nucleic acids- In nucleic acid, three constitutents are–

(i) Nucleoside

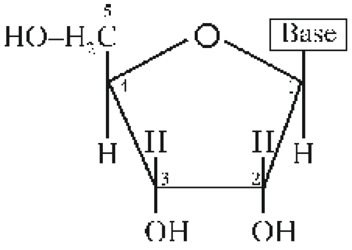
(ii) Nucleotide

(iii) Polynucleotide

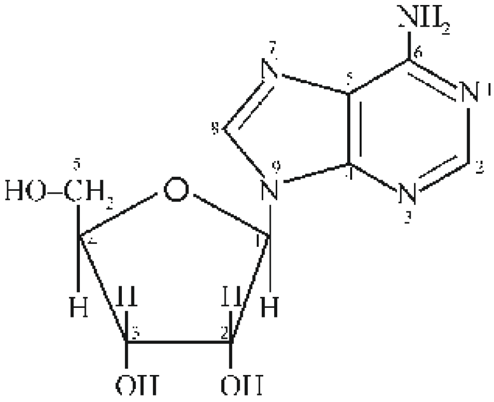


(i) Nucleoside- A combination form of one sugar molecule and one base is known a nuceloside. In a nucleoside C-1 of sugar is attached with N-9 of purine and N-1 of pyrimidine base.

Example –



or



Example– Adenine + Ribose → Adenosine

The name of nucleoside is based upon their components. Each RNA & DNA have various types of four nucleosides. Example–

Adenine + Ribose → Adenosine

Guanine + Ribose → Guanosine

Cytosine + Ribose → Cytidine

Uracil + Ribose → Uridine

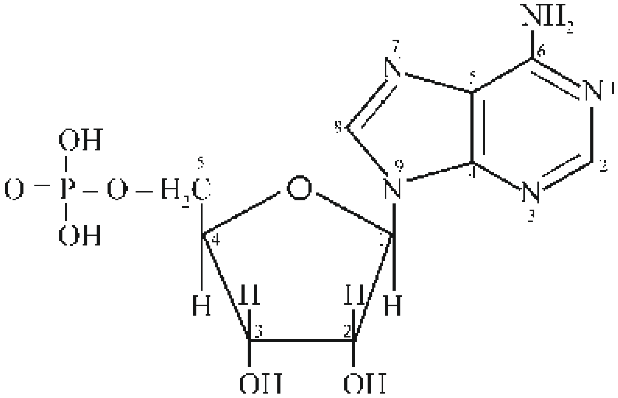
Similarly,

Thymine + deoxyribose → deoxythymidine

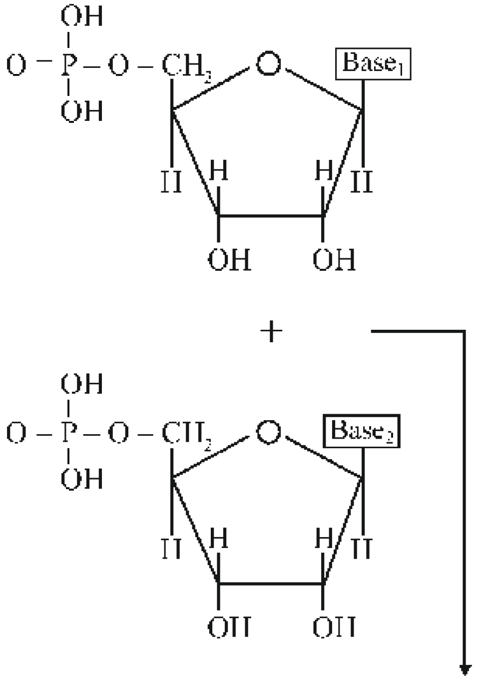
(ii) Nucleotide- The combination of one nucleoside and one phosphoric acid molecule form one nucleotide.

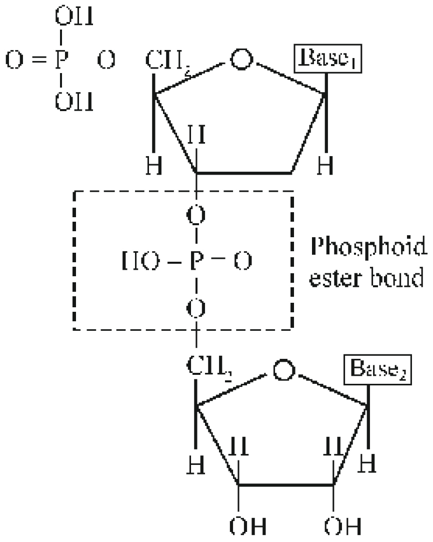
Phosphoric acid can attach with C-5 or C-3. In ribose sugar it can also attach with C-2. Nucleotide is represented by 3 capital alphabates.

Example– Adenine + one phosphoric acid → Adenosine monophosphate (AMP)



(iii) Polynucleotide– When nucelotides are joined at C-5 & C-3 of sugars from phosphodiester linkage and forms polyncleotides. These polynucleotide are nucleic acids and these can be represented as–





The sequence in which sugar, phosphate and organic base are attached in that sequence known as primary structure of nucleic acid. These can be represented as–

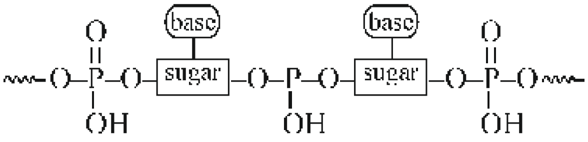
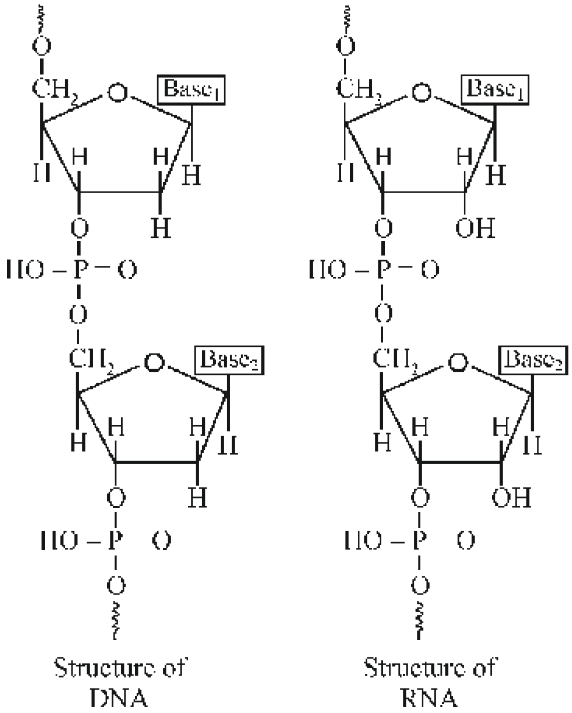


Fig. 14.15 : Primary structure of nucelic acid



Structure of DNA

Structure of RNA

Fig. 14.16 : Primary structure of DNA and RNA

14.4.9.3 Difference between DNA and RNA

S.No.	DNA	RNA
1.	This is found in nucleus of the cell (in chromosomes).	1. This is found in cytoplasm.
2.	DNA have deoxyribose sugar.	2. RNA have ribose sugar.
3.	In DNA, organic bases are Adenine (A), Guanine (G), Thymine (T), & Cytosine(C)	3. In RNA, organic base are– Adenine (A), Guanine (G), Uracil (U) & Cytosine (C)
4.	It plays an important role to trasmit heredity characters.	4. It helps in synthesis of protein.
5.	Its structure is Double helical.	5. Its structure is Single stranded.
6.	Its molecules are large in size so that their molecular weight is also high.	6. Its molecules are small in size so their molecular weight is least comparatively.
7.	DNA shows replication itself.	7. It can not show replication.
8.	DNA contains over a million nucelotides	8. With the type of RNA, it contains 70–12000 nucleotides

14.4.9.4 Molecular Structure of DNA–

DNA is a double stranded molecules. The primary structure of DNA is shown in diagram 14.16. DNA is a large molecule whose molecular weight is about thousands. Chargaff done a chemical analysis in 1950 and he concluded that (1) number of adenine (A) is alsways equal to thymine (T) and number of cytosine is equal to guanine. (2) The ratio of bases in DNA is different in different groups but (A) always bond to (T) and (C) with (G).

In 1953, Wilkins and his companions studied DNA by X-ray crystallorgraphy. After Wilkins, J.D. Watson and F.H.C. Crick in 1953, give double helical structure of DNA by X-ray diffraction studies. For these, they got nobel prize in 1962.

14.4.9.4.1 Double Helical structure of DNA–

Double helical structure of DNA was given by Watson and Crick and according to them–

(1) DNA is made by double helix which is coiled around a axis and each strands is a polydeoxynucleotide.

(2) Both polynucleotide chains are coiled as antiparallel and these are linked by H-bond which formed in base- group of double helix.

(3) Sugar molecules are linked with phosphodiester bond and formed as backbone of chain and base molecules are attached in form of branches.

(4) In DNA, adenine always linked with thymine and guanine always linked with cytosine (AT & CG)

(5) 2 hydrogen bonds are present in adenine & thymine linkage whereas guanine & cytosine are linked with 3 hydrogen bonds hence it is a most stable arrangement in helix.

(6) The distance between sugar molecules in both chain is 11Å. Each turn of coil has distance about 34Å and 10 nucleotide pairs are found in one turn. The distance between double helix is 20Å (2.0 nm) therefore the diameter of helix is 20Å. The distance between two base pairs is 3.4Å .

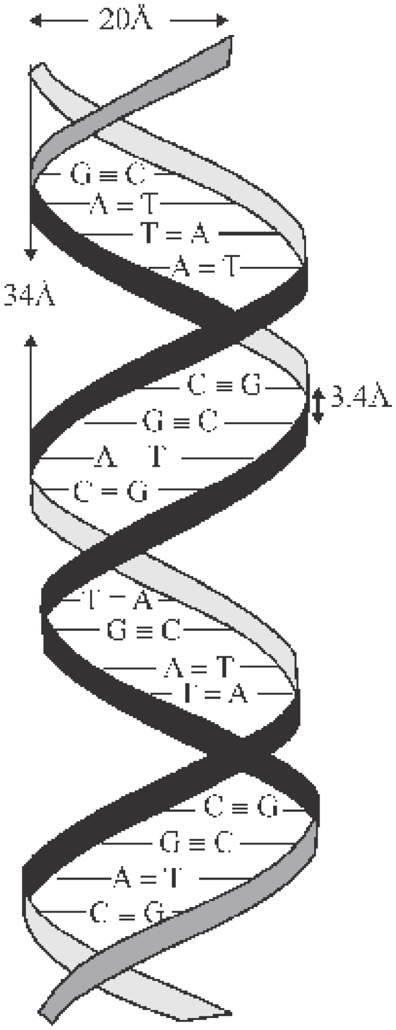


Fig. 14.17 : Double helix structure of DNA (Watson and Crick)

(7) The ratio $\frac{A+C}{C+G}$ have value 1.52 in human beings.

RNA structure is similar to DNA but mainly RNA is found in the form of single strand molecules. RNA is also made from hundreds to thousands nucleotides. RNA have three types as–messenger RNA(m-RNA, ribosomal RNA (r-RNA) and transfer RNA (t-RNA)

14.4.9.5 Biological Functions of Nucleic acid

There are two main biological functions of nucleic acids–

(1) Replication of DNA

(2) Synthesis of Protein

(1) Replication of DNA– Replication can be difined as "the process in which any biomolecule synthesise same identical molecule" or "the method in which a DNA molecule produces same & identical molecule of DNA.

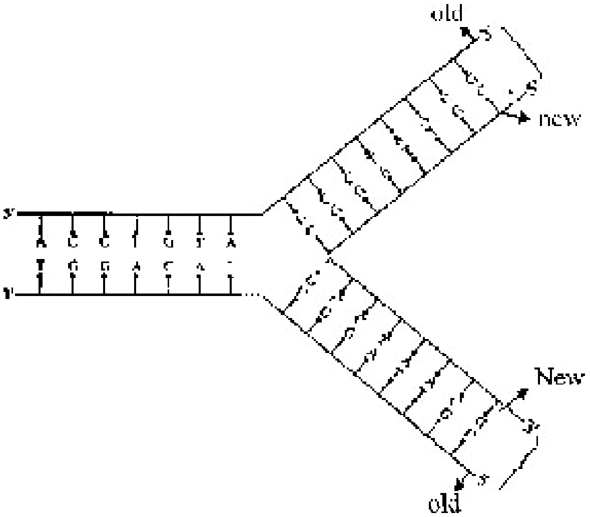


Fig. 14.18 : Doubling of DNA

(i) Due to this property of DNA, hereditary characters are transferred to offsprings.

(ii) Replication is a enzyme catalysed process.

(iii) In replication process, double strand of DNA unwinds slowly and base-pairs are isolated by breaking of H-bond. The isolated strands act as templates for the synthesis of new strands. (Fig. 14.17)

(iv) The characteristics of base-pair is that each new strands is complementary to old strand. According to this character, nucleotides are produced by formation of complementary base infront of each base of a strand and thus accordingly two copies of one DNA molecule are formed.

(v) Each replicated copy of DNA is entered in daugther cell which is formed during every cell division. Such is the way to transmit genetic characters from one cell to other cell.

(vi) Replication of DNA cocurs only in $5^1 \rightarrow 3^1$ direction, therefore, one strand starts synthesis from upper side then new strand is synthesised from lower side of strand.

(vii) Hence, the replication of DNA is semi conserved because one strand is conserved of parent DNA and only one strand is synthesized. (Fig. 14.18)

(2) Synthesis of Protein- Protein synthesis is a second important function of nucleic acids. The process of protein synthesis is a very complex process in all bio-synthesis mechanisms. As said earlier, 20 nucleic acids combine in different ways to synthesise protein. In living cells, more than 200 enzymes and more than 70 RNA takes part in protein synthesis. Protein synthesis is done by different RNA molecules but the message for synthesis of a specific protein is present in DNA.

The code for synthesis of protein is given by DNA which is present in cell nucleus.

The synthesis of protein can be explained as–

(1) Transcription- Transmission of genetic information from DNA to RNA.

(2) Translation- Transmission of genetic information from RNA to protein. Synthesis of protein from DNA to can be represented as–

$$\text{DNA} \xrightarrow{\text{replication}} \text{DNA} \xrightarrow{\text{transcription}} \text{RNA} \xrightarrow{\text{translation}} \text{Protein}$$

(1) Transcription-

Transcription is a process, which leads the synthesis of RNA. Essential types of RNA in protein synthesis are m-RNA, r-RNA and t-RNA and these are synthesized by DNA molecules.

This process starts from the bond breaking of H-bonds in base pairs and partial isolations of both strands of DNA molecules of double-helix takes place.

Synthesis of RNA or DNA template is known as transcription and this process is conducted by presence of "RNA-polymerase enzyme".

The base-sequences of synthesized RNA strand is complementary to base-sequences of DNA strand where the transcription is done. The difference is only that in synthesis of RNA, thymine (T) is replaced by uracil (U) and ribose sugars are present instead of deoxyribose sugars. After the transcription, m-RNA come out from nucleus and enter in ribosome of cytoplasm where this acts as template for protein synthesis.

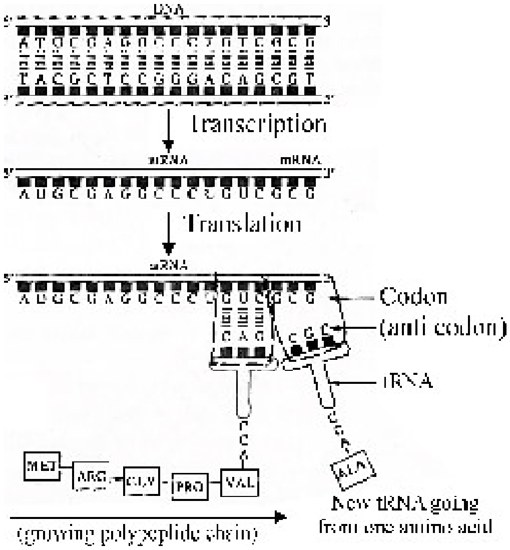


Fig. 14.19 : Synthesis of protein

2. Translation-

This process is very complex. The formation of protein from m-RNA, is known as translation. More than 100 macromolecules are used in this process such as m-RNA, t-RNA, Ribosomes, etc.

Protein synthesis is done in cytoplasm of cell. After translation, m-RNA moves from cell nucleus to ribosome in cytoplasm. r-RNA is component of ribosome. The bases of RNA strands are read in sequence of three groups and this every triplet is known as "Codon". Each codon represent sequence of three DNA or RNA nucelotides that corresponds with specific amino acid.

t-RNA has a specific sequence of bases at the ends which are complementary to bases sequence of m RNA. At the other end of t-RNA, a specific amino acid is attached. In ribosomes, aminoacids whose base sequence of t RNA is complementary to base sequence in m RNA and are bonded by r-RNA through peptide linkage and hence polypeptide chain is increased and protein synthesis takes place. (Fig. 14.18)

In proteins, sequence of amino acids is determined by m RNA and in m RNA, base sequence (means nucleotides) is determined by DNA. That means that translation of" amino acids takes place by

DNA of ribosomes.

14.4.9.5.1 Genetic Code–

The relation between nucleotide triplet and amino acid, is called the genetic code which is represented by triplet base group of m RNA.

As told earliear that code of specific protein synthesis exist in DNA. The sequence of nucleotides in DNA, is known as Gene. In living cells, each protein has a specific gene.

20 amino acids are combined to form all types of proteins. Thus nucleotides should have proper units to code these 20 amino acid. To represent 20 amino acids, three letters (Triplet) are used because if 4 or 2 letters are used, total 16 mixtures are found which are not adequate to represent all amino acids. By taking three letters, total number of mixtures formed is 64(4^3) which are suffificient to represent all 20 amino acids. It is known that base group of triplet is called "Codon" therefore all protein have only 20 various amino acids and many codons are available for one type of amino acid.

Example : Two triplets UUU & UUC code is available for same phenyl alanine amino acid hence codon has their synonyms and genetic code are degenerate means more than one codon encodes for the same amino acid.

Instead of 64 triplets, 61 triplets are available to specify particular amino acids (20) and three triplets designate the termination of translation. These three triplets are known as "stop codon".

Therefore, the main characteristics of genetic code are follows as–

(i) Genetic code is triplet.

(ii) These are equal to all cells of livings and it is universal.

(iii) To represent a single amino acid, more than one codons are available means they have degeneracy.

(iv) AUG codon sequence is **start codon** and this represents the methionine, means firstly methi onine is attached in the synthesis of all proteins.

(v) UAA, UAG and UGA are known as "stop codon".

Points :

- All living organism are made of biomolecules.
- Naturally occuring molecules are known as biomolecules.
- Carbohydrates, protein, vitamins, nucleic acid, enzymes, lipids, hormones, etc. are biomolecules and each has its own importance.
- Cell is the smallest, structural and functional unit of body and all biological reactions take place in cell.
- Carbohydrates are polyhydroxy carbonyl compounds.
- Generally, carbohydrates are classified as monosaccharides, disaccharides and polysaccharides.
- Glucose and fructose are examples of monosaccharides.
- Glucose is aldohexose and fructose is ketohexose.
- Specific rotation of solution of a substance changes with time. This is known as Mutarotation.
- Disaccharides are classified as reducing and non-reducing sugars.
- Sucrose is a disaccharides, non-reducing sugar and it is also known as table sugar.
- Maltose and lactose are disaccharides and reducing sugars.
- Maltose is known as "Malt sugar" & lactose is known as "milk sugar".
- Starch and cellulose are polysaccharides.
- Proteins are polymers of high-molecular weight amino acids.
- All proteins are made up of 20 amino acids bonded with different ways.
- Amino acids have both amino (-NH_2) and carboxylic (-COOH) groups.

- Condensation of α-amino acids produce poly peptides and proteins.
- Amino acids are linked with peptide linkage in polypeptides and proteins.
- Physical changes change the structure of protein and this is known as denaturation of protein.
- Those proteins which catalyse biochemical reactions are known as enzymes.
- Hormones are known as gland secretion and are secreted by endocrine glands. These regulate and control various bio-chemical reactions in living beings.
- Vitamins are complex organic molecules which are essential in small amount for growth and metabolic reactions in human beings.
- DNA & RNA are in combined form called as nucleic acids.
- Nucleic acids are formed by three units, i.e., phosphoric acid, sugars and organic base.
- Deficiency of vitamins cause diseases, therefore vitamins are essential element for life.
- 1 codon = 3 nucleotides.

EXERCISE QUESTIONS

Multiple Choice Questions

1. "Power house" of cell is called.
(a) golgibody (b) mitochondria
(c) cytosom (d) ribosome

2. Which of the following is disaccharide–
(a) Starch (b) Fructose
(c) Lactose (d) Cellulose

3. The produce of hydrolysis of starch is–
(a) Fructose (b) Sucrose
(c) Maltose (d) Glucose

4. The common formula of most common disaccharide is–
(a) $(C_6H_{12}O_6)_2$ (b) $C_{12}H_{22}O_{11}$
(c) $C_{10}H_{22}O_{11}$ (d) $C_{18}H_{22}O_{11}$

5. Which of the following is not a reducing sugar.
(a) Glucose (b) Fructose
(c) Sucrose (d) Maltose

6. The product obtained after hydrolysis of protein in the presence of enzyme is–
(a) Amino acid (b) Hydroxy acid
(c) Aromatic acid (d) D-carboxylic acid

7. Example of globular protein is–
(a) collagen (b) insulin
(c) myosin (d) karetin

8. Alanine is an example of–
(a) α–amino acid (b) α–fructose
(c) α–Lactose (d) α–Cellulose

9. Basic amino acid is–
(a) glycine (b) as partic acid
(c) lysine (d) glutamine

10. Enzymes are–
(a) carbohydrate (b) protein
(c) fat (d) salt

11. The conversion of protein to amino acid is takes place by which of the following enzymes–
(a) lipase (b) maltase
(c) trypsin (d) renin

12. Chemical messengers are–
(a) hormones (b) enzymes
(c) vitamins (d) nucleic acid

13. Number of thyroid gland in human is–
(a) one (b) two
(c) three (d) four

14. Growth hormone is secreted by–
(a) thyroid (b) pituitary
(c) thymus (d) pancreas

15. Disease causes by deficiency of Vitamin A is–
(a) night blindness (b) scurvy
(c) bery-bery (d) anaemia

16. In nucleic acids, nucleotides are joined by–
(a) H-bond
(b) peptide bond
(c) by phosphorous group
(d) glycosidic bond

17. How many nucleotide sequence forms one codon in m-RNA–
(a) one (b) two
(c) three (d) four

18. DNA & RNA have chiral asymmetric carbon atom. The reason for their chirality is–
    (a) asymmetric base
    (b) D-sugar component
    (c) L-sugar component
    (d) asymmetric phosphate ester unit

19. Organic base in RNA is–
    (a) adenine, uracil, cytosine and guanine
    (b) adenine, guanine, thymine and cytosine
    (c) adenine, thymine, guanine and cytosine
    (d) adenine, guanine, uracil, cytosine

20. The sequence in nucleic acid is–
    (a) base-sugar-phosphate
    (b) sugar-base-phosphate
    (c) phosphate-base-sugar
    (d) base-phosphate-sugar

Very Short Answer Questions

21. Write chemical composition of cell.
22. What are monosaccharides?
23. What are non sugars?
24. What is the main structural difference between starch & cellulose?
25. Define essential and non essential amino acids?
26. What is the main function of enzymes?
27. Why are hormones known as "glandular juice"?
28. Which vitamines are soluble in water?
29. What are the name of nitrogenous bases found in DNA?
30. What are the main functions of nucleic acids?

Short Answer Type Questions

31. Write the fucntions of carbohydrates.
32. Write two methods of preparation of glucose?
33. Why sickle cell anaemia occurs.
34. Write reaction of glucose with Fehling's solution and Tollen's reagent.
35. Why hormones are called "chemical messengers".
36. What is isoelectric point of amino acid? Give definition.
37. Write one similarity and one dissimilarity between enzymes and hormones.
38. What is denaturation of protein.
39. What do you mean by genetic code.
40. Differentiate between primary and secondary structures of protein.
41. What is mutarotation.
42. Give the names of diseases caused by the deficiency of vitamin B$_{12}$ and vitamin A. Also write the source of these vitamins.
43. Write four differences between DNA and RNA.
44. Write the Haworth structures of glucose and fructose.
45. Define protein and write their classification.

Long Answer Questions

46. Give the general reactions of glucose.
47. What are the main sources of cellulose and starch. Explain their structures in short.
48. What is the last product of hydrolysis of the following. (1) fructose (2) lactose (3) sucrose (4) starch (5) maltose (6) cellulose
49. Define protein and give its hydrolysis. Write its primary and secondary structures.
50. Write the functions of enzymes. Also give their classification.
51. Give the names and functions of secretion by pituitary and thyroid glands.
52. What is vitamin-B complex. which disease is caused by the deficiency of this vitamin.
53. Explain molecular structure of DNA.
54. How protein is synthesized from nucleic acid. Explain in detail.

Answers (Multiple Choice Questions)

(1)	B	(2)	C	(3)	D	(4)	B
(5)	C	(6)	A	(7)	B	(8)	A
(9)	C	(10)	B	(11)	C	(12)	A
(13)	A	(14)	B	(15)	A	(16)	C
(17)	C	(18)	D	(19)	A	(20)	A

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