

Chemistry Notes for class 12 Chapter 14

Biomolecules

Biomolecules are the organic compounds which form the basis of life, i.e., they build up the living system and responsible for their growth and maintenance.

The sequence that relates biomolecules to living organism is

Biomolecules → Organelles → Cells → Tissues → Organs → Living organism.

Carbohydrates

Optically active polyhydroxy aldehydes (aldoses) or ketones (ketoses) or compounds which on hydrolysis give these units are known as carbohydrates. They are also called saccharides

(Latin Saccharum = sugar) due to sweet taste of simpler members.

Depending upon their behaviour towards hydrolysis, carbohydrates can be of following three types

Monosaccharides

These cannot be hydrolysed to simpler molecules and further subdivided into tetroses, pentoses or hexoses depending upon the number of carbon atoms. These are also called homopolysaccharides.

- **Aldotetroses** Erythrose, Threose
- **Aldopentoses** Xylose, Ribose,
- **Aldohexoses** Glucose, Galactose,
- **Ketohexoses** Fructose

All naturally occurring monosaccharides belong to D-series.

Kiliani synthesis is used to convert an aldose into next higher aldose.

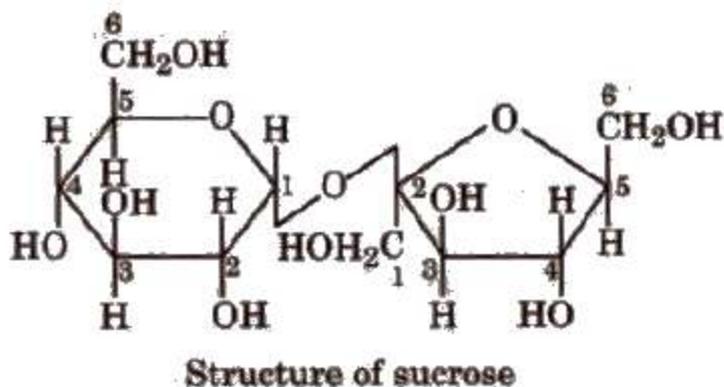
Oligosaccharides

(Greek oligos = few). On hydrolysis, they generally give two to nine monosaccharides (same or different) and are further classified as disaccharides, e.g., sucrose, maltose, lactose, trisaccharides and so on. $C_{12}H_{22}O_{11}$ is a disaccharide because it gives two monosaccharides.



The bond formed between two monosaccharides is called a glycosidic bond and normally it is (1, 4) bond.

Sucrose is most abundant in plants and known as cane sugar or table sugar or invert sugar as equimolar mixture of glucose and fructose is obtained by hydrolysis of sucrose.



Trisaccharides Raffinose ($C_{18}H_{32}O_{16}$)



Polysaccharides

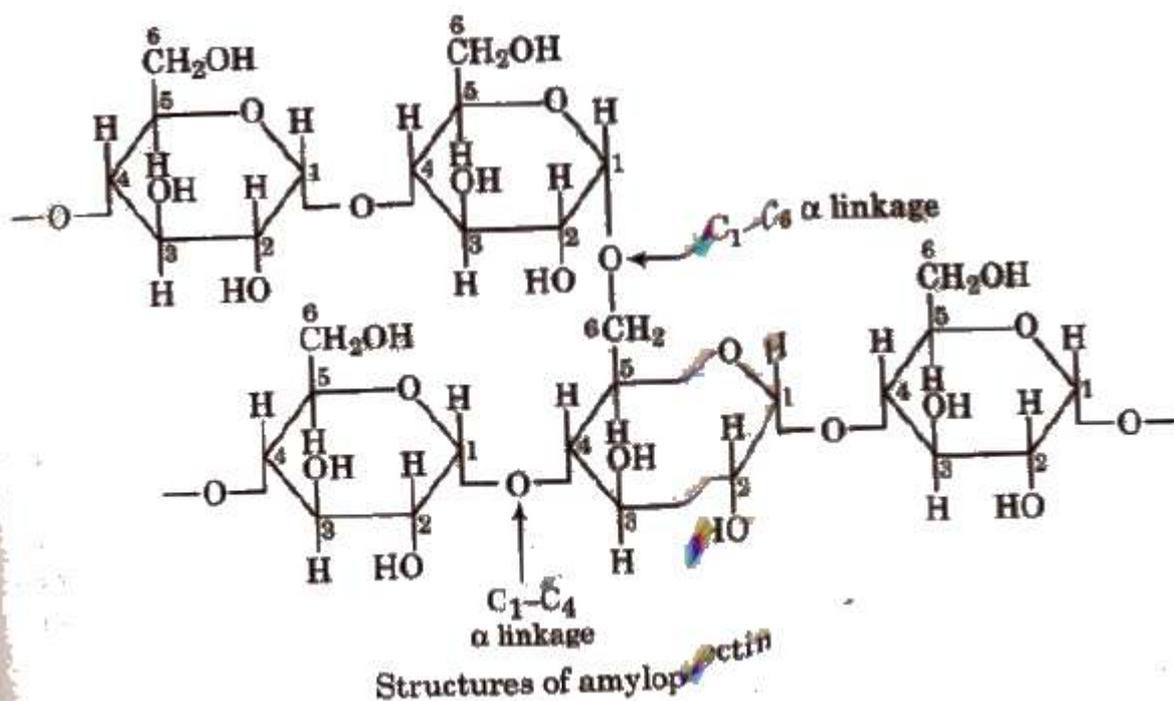
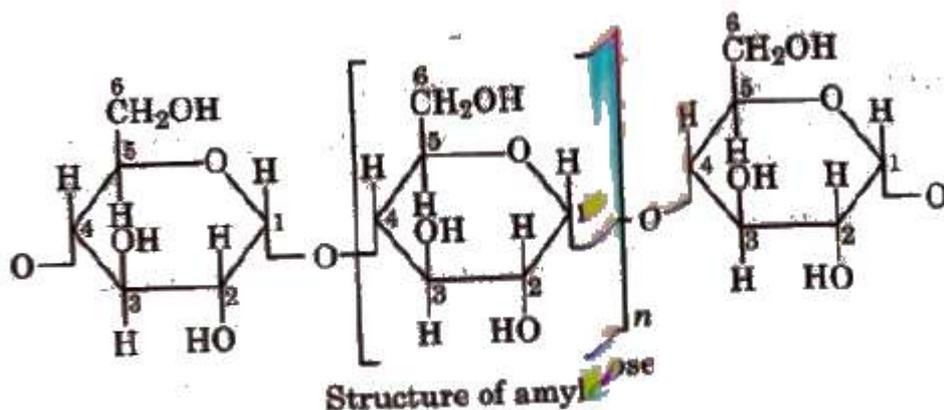
These are polymers of monosaccharides. Examples are starch, cellulose, glycogen, etc.

1. Starch, $(C_6H_{10}O_5)_N$

It is a polymer of α -glucose and a major reserve food in plants. It turns blue with iodine. It is a mixture of two components:

1. Amylose (20%), an unbranched water soluble polymer.
2. Amylopectin (80%), a branched water insoluble polymer.

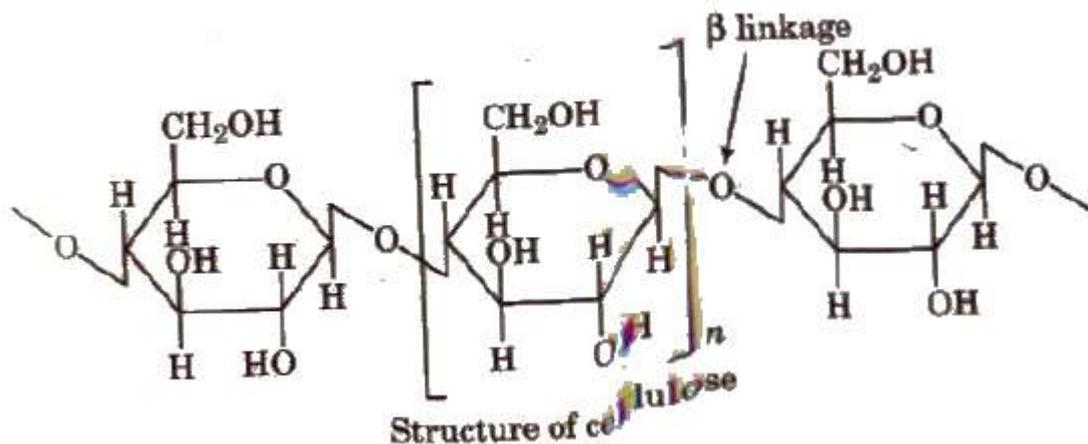
Sources of starch are potatoes, wheat, rice, maize, etc.



2. Cellulose, $(C_6H_{10}O_5)_n$

It is the most abundant and structural, polysaccharide of plants. It is important food source of some animals. It is a polymer of D (+) β -glucose.

The chief sources of cellulose are wood (Contains 50% cellulose rest being lignin, resins, etc) and cotton (contains 90% cellulose rest being fats and waxes).



Several materials are obtained from cellulose:

1. **Mercerised cotton** Cellulose treated with conc. sodium hydroxide solution acquire silky lustre. It is called mercerised cotton.
2. **Gun cotton** It is completely nitrated cellulose (cellulose nitrate), highly explosive in nature and is used in the manufacture of smokeless gun powder, called blasting gelatin.
3. **Cellulose acetate** It is used for making acetate rayon and motion picture films.
4. **Cellulose xanthate** It is obtained by treating cellulose with sodium hydroxide and carbon disulphide and is the basic material for VISCOSE rayon.

Oligosaccharides and heteropolysaccharides are also called heteropolysaccharides.

Reducing and Non-reducing sugars

Based upon reducing and non-reducing properties, carbohydrates are classified as reducing and non-reducing sugars. Carbohydrates reducing Fehling reagent or Tollen's reagent are termed as reducing carbohydrates. e.g., All monosaccharides and disaccharides (except sucrose). But carbohydrates which do not reduce such reagents are known as non-reducing carbohydrates. e.g., sucrose and polysaccharides.

Sugars and Non-sugars

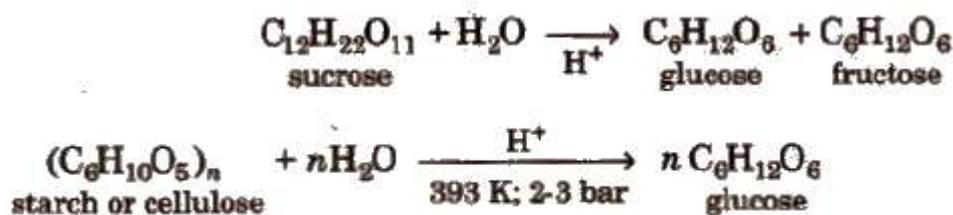
On the basis of their taste, carbohydrates are classified as sugars and non-sugars. The monosaccharides and oligosaccharides having sweet taste are collectively known as sugars. Polysaccharides which are insoluble in water and not sweet in taste, are non-sugars.

Glucose

Dextrose, grape sugar, corn sugar, blood sugar ($C_6H_{12}O_6$).

Manufacture

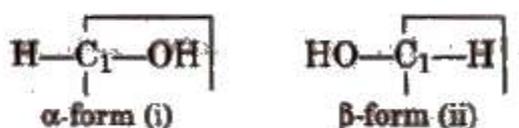
By hydrolysis of starch with hot dil mineral acids and by hydrolysis of sucrose.



Extra glucose is stored in liver as glycogen.

α and β glucose

In intermolecular hemiacetal formation (cyclic structure), -CHO is converted into -CHOH which can have two configurations as shown below.

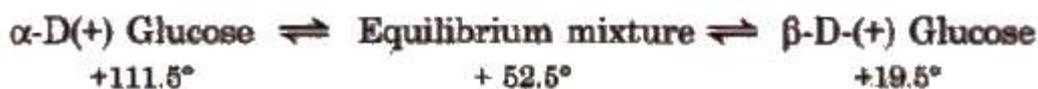


Glucose having (i) configuration about C_1 is the α -glucose and having (ii) configuration about C_1 is β -glucose.

The carbon C_1 is known as anomeric carbon and these compounds are called anomers. Both the forms are optically active. ex-D-glucose has specific rotation $+111.5^\circ$ and β -D-glucose has specific rotation $+19.5^\circ$.

Mutarotation

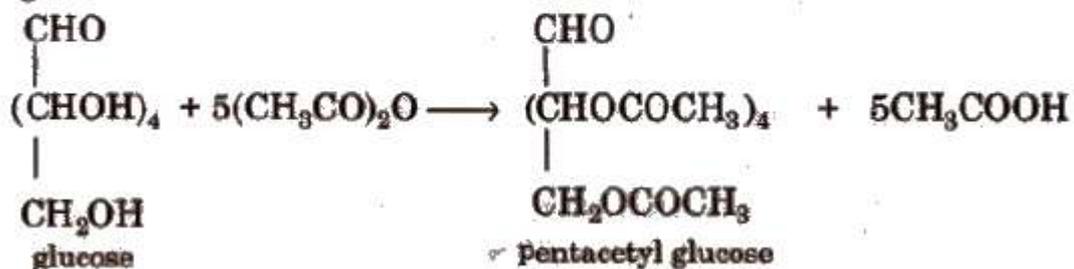
When either of the two forms of glucose is dissolved in water, there is a spontaneous change in specific rotation till the equilibrium value of $+52.5^\circ$. This is known as mutarotation.



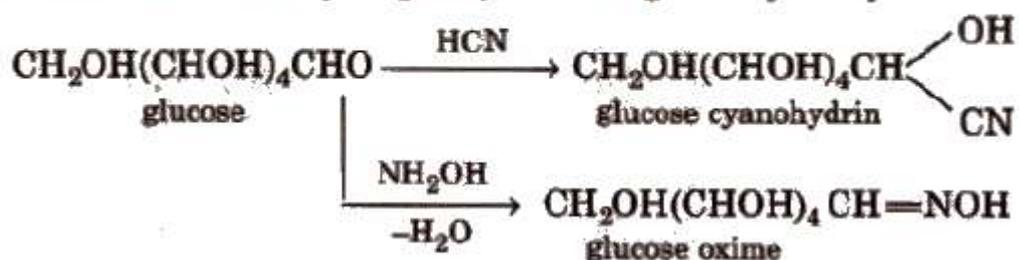
Properties of glucose

Glucose has one aldehyde group, one primary hydroxyl (-CH₂OH) and four secondary hydroxyl (-CHOH) groups and gives the following reactions:

- (i) Glucose on acetylation with acetic anhydride gives a pentaacetate confirming the presence of five hydroxyl groups in glucose.



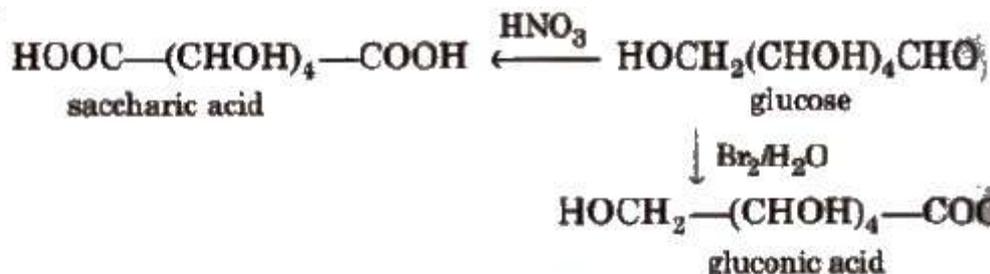
- (ii) Glucose reacts with hydroxylamine to give monoxime and adds with a molecule of hydrogen cyanide to give a cyanohydrin.



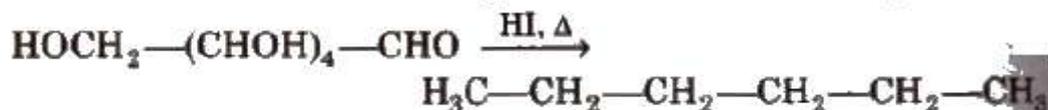
These reactions confirm the presence of a carbonyl group in glucose.

(iii) Glucose reduces ammoniacal silver nitrate solution (Tollen's reagent) to metallic silver and also Fehling's solution or Benedict solution to reddish brown cuprous oxide (Cu_2O) and itself gets oxidised to gluconic acid. This confirms the presence of an aldehydic group in glucose.

(iv) With mild oxidising agent like bromine water, glucose is oxidised to gluconic acid. Glucose on oxidation with nitric acid gives saccharic acid.

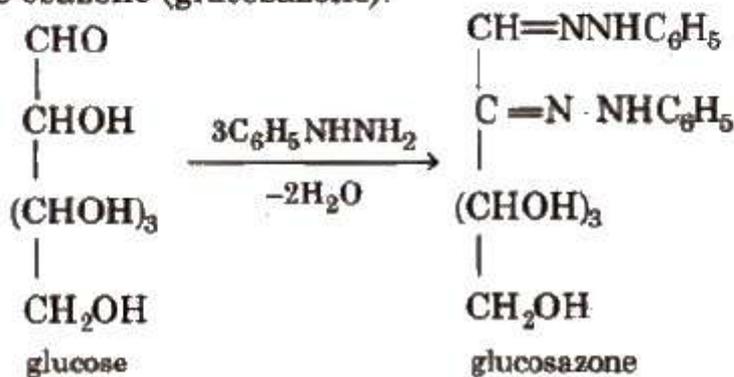


(v) Glucose on prolonged heating with HI forms *n*-hexane, suggesting that all the 6 carbon atoms in glucose are linked linearly.

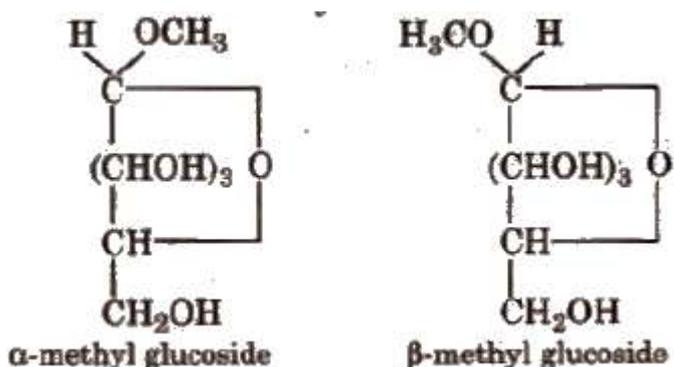


However, with Na/Hg and water, glucose is reduced to sorbitol $\text{HOH}_2\text{C}(\text{CHOH})_4\text{CH}_2\text{OH}$.

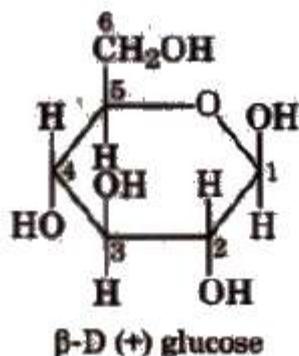
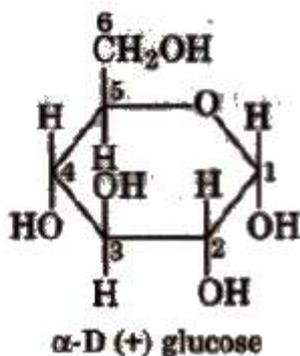
(vi) D-glucose reacts with three molecules of phenyl hydrazine to give osazone (glucosazone).



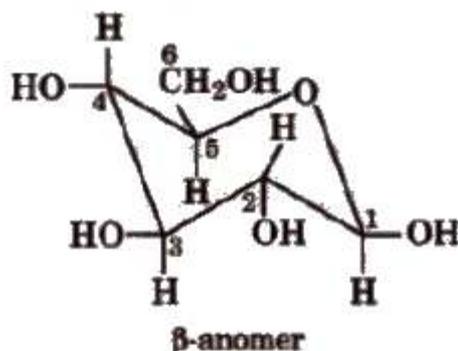
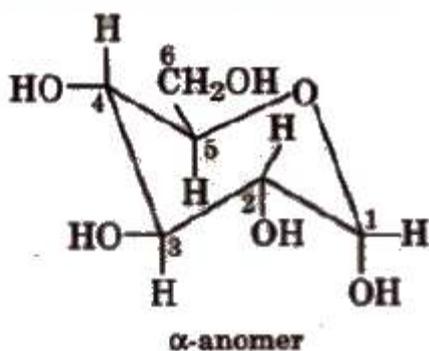
(vii) Glucose on reaction with methyl alcohol in the presence of dry HCl(g) forms α and β -methyl glycosides. The reaction occurs only at the OH of hemiacetylic carbon.



Cyclic structure of glucose Given by Haworth and Hirst.



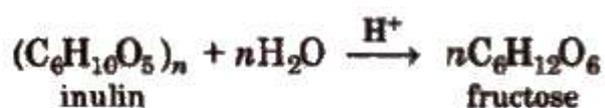
Glucose is sometimes illustrated as a chair form :



Fructose Fruit Sugar ($C_6H_{12}O_6$)

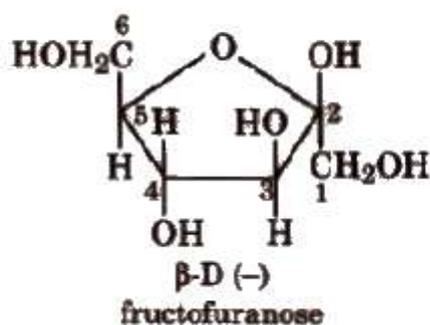
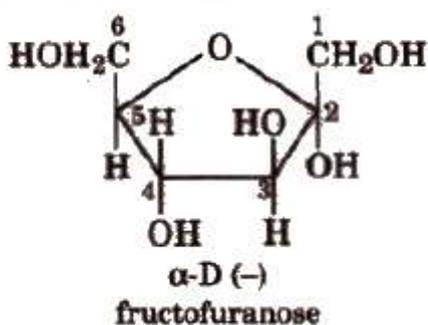
Manufacture

By hydrolysis of inulin.



Structure

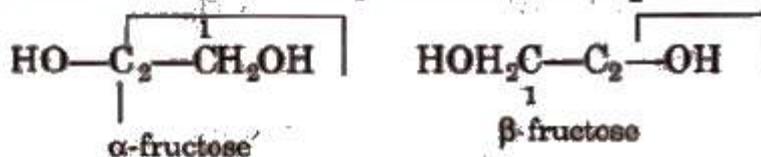
Fructose has furanose structure, i.e., ring structure consisting of four C atoms and one O atom.



α and β -fructose

The two forms have different configuration about C_2 .

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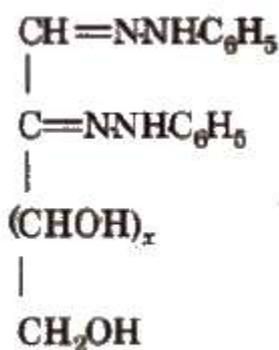
Fructose does not reduce Br_2 water.

Epimers

Monosaccharides differing in configuration at a carbon other than anomeric carbon are called epimers, e.g., glucose and galactose differ in configuration at C_4 , hence called epimers.

Osazones

Monosaccharides and reducing disaccharides react with excess of phenyl hydrazine to form crystalline substances of the structure



It is known as osazones glucose and fructose give same osazone.

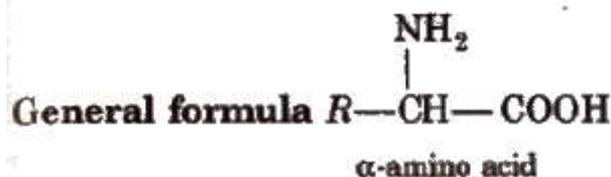
Molisch Test for Carbohydrates

In aqueous solution of compound add solution of α -naphthol in alcohol and then cone. H_2SO_4 along the walls of the test tube. Purple coloured ring is obtained at the junction.

Relative Sweetness of Some Sugars		
Cane sugar is assumed to have a sweetness of 10. The relative sweetness of other sugars is		
Lactose	: 1.6	Invert sugar : 12.6
Fructose	: 17.3	Maltose : 3.2
Saccharin	: 300 (an artificial sweetener)	
Glucose	: 7.4	

Amino Acids

The compounds containing amino group ($-\text{NH}_2$) and carboxylic group ($-\text{COOH}$) are called amino acids.



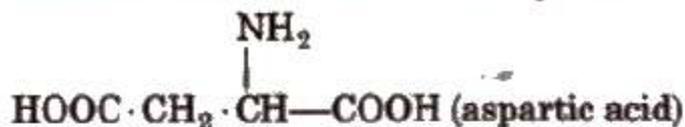
$R = \text{H}$, alkyl or aryl group. Except glycine ($\text{H}_2\text{N}\cdot\text{CH}_2\text{COOH}$), others are optically active in nature.

Classification of Amino Acids

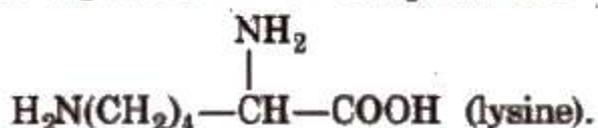
(a) **α , β , γ -amino acids** Depending upon the position of $-\text{NH}_2$ wrt $-\text{COOH}$ group.

(b) **Neutral** Having one $-\text{NH}_2$ and one $-\text{COOH}$, e.g., $\text{NH}_2\cdot\text{CH}_2\cdot\text{COOH}$ (glycine).

(c) **Acidic** Having one $-\text{NH}_2$ and two $-\text{COOH}$, e.g.,



(d) **Basic** Having two or more $-\text{NH}_2$ and one $-\text{COOH}$, e.g.,



Essential and Non-essential Amino Acids

Human body can synthesise ten amino acids, called non-essential amino acids. The remaining ten amino acids required for protein synthesis are not synthesised by body and are called essential amino acids. They are

1. Phenylalanine
2. Histidine
3. Tryptophan
4. Valine
5. Methionine
6. Threonine
7. Arginine
8. Leucine

Two molecules of different amino acids can form two dipeptides. Three molecules of different amino acids can give six tripeptides.

Dipeptide has only one peptide bond, tripeptide has two peptide bonds and so on. Thus, a polypeptide made up of n -amino acids has $(n - 1)$ peptide bonds.

Polypeptides

Condensation Products of many amino acids (‘In Products of many amino acids (≈ 10000) is known as polypeptide and those polypeptides which have molecular mass above than 10000 are called proteins.

Proteins

They are linear polymers of α -amino acids.

Structure of Proteins

(a) Primary structure

It simply reveals the sequence of amino acids.

(b) Secondary structure α -helix structure maintained by hydrogen bonds or β -pleated sheet structure when R is small group.

(c) Tertiary structure The folding and superimposition of polypeptide chains forms a compact globular shape, termed as tertiary structure. It is stabilised by covalent, ionic, hydrogen and disulphide bonds.

The precise arrangement constitutes the quaternary structure.

Classification on the Basis of Hydrolysis Products

(i) Simple These yield only α -amino acids upon hydrolysis.

e.g., albumin.

(ii) Conjugated proteins These yield α -amino acids and non-protein part, called prosthetic group.

Protein	Prosthetic group
Nucleoproteins	Nucleic acid
Phospho proteins	Phosphoric acid
Glycoproteins	Carbohydrates
Metalloproteins	Metals

Lipoproteins Lipids

(iii) Derived proteins These are obtained by partial hydrolysis of simple or conjugated proteins.

Proteins → Proteoses → Peptones → Polypeptides

Classification on the Basis Functions

1. **Structural proteins** Fibrous proteins
2. **Enzymes** Serve as biological catalyst e.g., pepsin, trypsin etc.
3. **Hormones** Insulin
4. **Contractile proteins** Found in muscles, e.g., myosin, actin.
5. **Antibodies** **Gamma** globulins present in blood.
6. **Blood protein** Albumins, haemoglobin and fibrinogen.

Haemoglobin is a globular protein. Its prosthetic group is heme. It Contains 574 amino acid units distributed in four polypeptide chains.

Two chains containing 141 amino acid residues each are called α -chains and the two chains containing 146 amino acid residues are called β -chains.

Sickle cell anaemia is caused by defective haemoglobin obtained by replacing only one amino acid, i.e., glutamic acid by valine.

Denaturation of Proteins

The process that changes the three dimensional structure of native proteins is called denaturation of proteins. It can be caused by Change in pH, addition of electrolyte, heating or addition of solvent like water, alcohol or acetone.

Tests of Proteins

(i) Biuret Test

Protein solution + NaOH + dil. CuSO_4 → pink or violet colour.

(ii) Millon's Test

Protein solution + Millon's reagent → pink colour

Millon's reagent is solution of mercuric nitrate and nitrite in nitric acid containing traces of nitrous acid.

(iii) Iodine reaction

Protein solution + iodine in potassium iodide solution → yellow colour.

(iv) Xanthoprotic test

Protein solution + conc. HNO_3 → yellow colour $\xrightarrow{\text{NaOH}}$ orange colour.

Enzymes

Enzymes constitute a group of complex proteinoid compounds, produced by living organisms which catalyse the chemical reaction.

Non-proteinous components enhance the activity of certain enzymes and are known as co-enzymes. These include metal ions like Mn^{2+} , Mg^{2+} , K^+ , Na^+ , Zn^{2+} , Co^{2+} etc., heterocyclic ring systems (pyrrole, purine, pyridine, etc.), a sugar residue, phosphoric acid residue of vitamins like thiamine, riboflavin etc.

Endoenzyme acts in the same cell in which it is synthesised, while **exo-enzyme** acts outside the cell in which it is synthesised.

Nomenclature

They are usually named by adding the suffix 'ase' to the root name of the substrate e.g., urease, maltase, diastase, invertase, etc.

Oxidative Enzymes

They catalyse oxidation-reduction reaction and are mostly conjugated proteins.

Some Common Enzyme

Name	Substrate	Products
Urease	Urea	$\text{CO}_2 + \text{NH}_3$
Maltase	Maltose	Glucose
Invertase	Sucrose	Glucose + fructose
Amylase	Starch	Maltose
Trypsin	Proteins	Amino acids
Ascorbic acid oxidase	Ascorbic acid	Dehydroascorbic acid

Characteristic Features of Enzymes

- Rate of reaction** They increase the rate of reaction up to 10^6 to 10^7 times.
- Specific nature** Urease catalyse the hydrolysis of urea and not methyl urea, so these are specific in nature.

3. **Optimum temperature** It is about 20-30°C.
4. **pH of medium** It is about 7 but for pepsin, it is 1.8-2.2 and for trypsin, it is 7.5-8.3.
5. **Concentration** Dilute solutions are more effective.
6. **Amount of enzyme** Very small amount can accelerate the reaction.
7. **Enzyme inhibitors** These compounds inhibit the enzyme action. With the help of such compounds, the reaction can be controlled.

Mechanism of Enzyme Action

Enzyme + Substrate \rightarrow [Enzyme substrate] \rightarrow Product + Enzyme Activated complex

Applications of Enzymes

(i) **Treatment of diseases** The congenital disease phenyl ketonurie caused by phenylalanine hydroxylase can be cured by diet of low phenylalanine content. Enzyme streptokinase is used for blood clotting to prevent heart disease.

(ii) **In industry** Tanning of leather, fermentation process etc.

Nucleic Acids

Important Terms of Nucleic Acids

1. Nucleotides

Nucleotides consist of 5-carbon sugar + nitrogenous base + 1, 3-phosphate groups.

2. Pentose sugar

It is either ribose or deoxy ribose (not having oxygen at C₂).

3. Nitrogenous base

Derived from purines having two rings in their structure e.g., Adenine (A) and Guanine (G) and derived from pyrimidines having one ring in their structure e.g.,

Thymine (T), Uracil (U) and Cytosine (C).

Two H-bonds are present between A and T (A = T) while three H-bonds are present between C and G (C \equiv G).

4. Ribonucleotide

Phosphate unit + Ribose + one base unit from A, G, C, or U.

5. Deoxyribo nucleotide

Phosphate unit + Deoxyribose + one base from A, G, C or T.

6. Nucleoside

Ribose-/deoxyribose + one base unit from A, G, C, Tor U.

DNA and RNA

Nucleic acid is polynucleotide, present in the living cells or bacterial cells having no nucleus and in viruses having no cells.

(i) **DNA** Deoxy ribonucleic acid.

$\text{DNA} + \text{H}_2\text{O} \rightarrow \text{Phosphoric acid} + \text{deoxyribose} + \text{A, G, C, T}$

(ii) **RNA** Ribonucleic acid

$\text{RNA} + \text{H}_2\text{O} \rightarrow \text{Phosphoric acid} + \text{Ribose} + \text{A, G, C, U}$

Structure of DNA

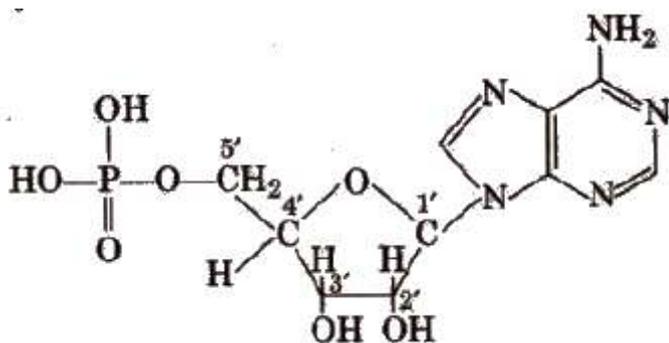
It consists of two polynucleotide chains, each chain form a right handed helical spiral with ten bases in one turn of the spiral. The two chains coil to double helix and run in opposite direction. These are held together by hydrogen bonding.

Structure of RNA

It is usually a single strand of ribonucleotides and take up right handed helical conformation. Up to 12000 nucleotides constitute an RNA.

It can base pair with complementary strands of DNA or RNA according to standard base pairing rules-G pairs with C, A pairs with U or T. The paired strands in RNA-RNA or RNA-DNA are anti parallel as in DNA.

In both DNA and RNA, heterocyclic base and phosphate ester linkages are at C_1 and C_5' respectively of the sugar molecule.



Types of RNA

1. Messenger RNA (m-RNA) It is produced in the nucleus and carries information for the synthesis of proteins.
2. Transfer RNA (Soluble or Adoptive RNA) (s-RNA, t-RNA) It is found in cytoplasm. Its function-is to collect amino acids from cytoplasm for protein synthesis.

Functions of Nucleic Acids

1. Direct the synthesis of proteins.
2. Transfer the genetic information (hereditary characters).

Replication

It is a process in which a molecule of DNA can duplicate.

Template It means pattern. In the process of replication of DNA, the parent strand serves as template.

Gene The portion of DNA carrying information about a specific protein is Called gene.

Genetic code The relation between the amino acid and the nucleotide triplet is called genetic code.

Codons The nucleotide bases in RNA function in groups of three (triplet) in coding amino acids. These base triplets are called codons.

The world code is used with reference to DNA, codon with reference to m-RNA and anticodon with reference to t-RNA.

Lipids

The constituents of animals and plants soluble in organic solvents (ether, chloroform. carbon tetrachloride), but insoluble in water are called lipids. (Greek lipose = fat)

Types of Lipids

(i) Simple lipids

(a) Fats and oils on hydrolysis give long chain fatty acids + glycerol.

(b) **Waxes** Long chain fatty acids + long chain alcohols.

Vegetable and animal oils and fats have similar chemical structure and are triesters of glycerol, called glycerol.

Simple glycerides contain one type of fatty acids. Mixed glycerides contain two or three types of fatty acids.

Common saturated fatty acids $\text{CH}_3-(\text{CH}_2)_n\text{COOH}$.

When $n = 4$ caproic acid; $n = 6$ caprylic acid; $n = 8$ capric acid, $n = 10$ lauric acid $n = 12$ myristic acid; $n = 14$ palmitic acid, $n = 16$ stearic acid.

Common unsaturated acids

$\text{C}_{17}\text{H}_{33}\text{COOH}$ oleic acid; $\text{C}_{17}\text{H}_{33}\text{COOH}$ linoleic acid.

Difference between oils and fats Oils are liquids at ordinary temperature (below 20° and contain lower fatty acids or unsaturated fatty acids.

Fats are solids or semisolids above 20°C and contain higher saturated fatty acids. Oils and fats act as “energy reservoirs” for the cells.

(ii) Phospholipids Phosphate + glycerol + fatty acids + a nitrogen containing base.

Function of phospholipids are

1. As emulsifying agents since they carry hydrophilic polar groups and hydrophobic non-polar groups.

2. They absorb fatty acids from the intestine and transport to blood cells.

(iii) Glycolipids They contain one or more simple sugars and are important components of cell membranes and chloroplast membranes.

(iv) Steroids and Terpenes Menthol, camphor are common plant terpenes. Carotenoids and pigments are also terpenes.

(a) Essential oils The volatile, sweet smelling liquids obtained from flowers, leaves, stems, etc. Example of terpenes are esters of lower fatty acid, e.g., clove oil, rose oil, lemon oil.

(b) Drying oils The oils which are converted into tough, transparent mass when exposed to air by oxidation polymerisation process are called drying oils. e.g., Linseed oil, perilla, poppy seed oils.

Cotton seed oil and til oil are semidrying oils.

Acid Value

It is the number of milligrams of KOH required to neutralise the free acid present in 1 g of oil or fat.

Saponification Value

It is the number of milligrams of KOH required to saponify 1 g of oil or fat or the number of milligrams of KOH required to neutralise the free acid resulting from the hydrolysis of 1 g of an oil or fat.

Iodine Value

It is the number of grams of iodine absorbed by 100 g of oil or fat.

Relchert-Meissel Value (R/M Value)

It is the number of cc of N/10 KOH required to neutralise the distillate of 5 g of hydrolysed fat.

Blood

An average person has about 6.8 L of blood which is about 6-10% of the body weight. pH of blood is about 7.4.

Haemoglobin is globular protein. It is made up of four polypeptide chains which are arranged in tetrahedral manner. Each chain is associated with a non-protein part, called haem.

Haemoglobin

These are the chemical substances which are produced by ductless glands in the body. Hormones act as chemical messengers.

Some examples of ductless (endocrine) glands are thyroid, pituitary, adrenal, pancreas, testes and ovaries.

Hormones are divided into three types:

1. steroids
2. proteins or polypeptides
3. amines.

	Hormone	Source	Chemical name	Function
1.	Thyroxin	Thyroid	Amino acid	Stimulates metabolism.
2.	Adrenaline	Adrenal	Amine	Increases pulse rate and blood pressure, release glucose from glycogen and fatty acids from fats.
3.	Insulin	Pancreas	Peptide	Decreases blood glucose.
4.	Glucogon	Pancreas	Peptide	Increases blood glucose.
5.	Testosterone	Testes	Steroid	Controls normal functioning of male sex organs.
6.	Estrone and Estradiol	Ovary	Steroid	Controls normal functioning of female sex organs.
7.	Progesterone	Ovary	Steroid	Prepare uterus for pregnancy, controls menstrual cycle.
8.	Cortisone	Adrenal cortex	Steroid	Metabolism of water, mineral salts, fats, proteins and carbohydrates.

Insulin is a protein hormone which is secreted by β -cells of the pancreas. Insulin was the first polypeptide in which the amino acid sequence was experimentally determined. Its deficiency leads to diabetes mellitus.

Vitamins

The organic compounds other than carbohydrates, proteins and fats which are required by body to maintain normal health, growth and nutrition are called vitamins.

The vitamins are complex organic molecules. They are represented by letters such as A, B, C, D, E, K.

Vitamins are broadly classified into two types,

1. Water soluble vitamins and
2. oil soluble vitamins.

Vitamins A, D, E and K are oil soluble whereas vitamins B and C are water soluble. Vitamin H is neither fat soluble nor water soluble.

Vitamin	Chemical nature	Deficiency diseases
Vitamin A (Carotenoids or Axerophytol or ratinol)	Soluble in oils and fats, but insoluble in water.	Night blindness, Xerophthalmia (cornea becomes opaque), drying of skin.
Vitamin B ₁ (Thiamine)	Soluble in water, destroyed by heat.	Beriberi, loss of appetite.
Vitamin B ₂ (Riboflavin)	Soluble in water, stable to heat, destroyed by light.	Cracked lips, sore tongue and skin disorders.
Vitamin B ₆ (Pyridoxine)		Nervous disturbances and convulsions (pernicious anaemia).
Vitamin B ₁₂ (Cyanocobalamin)	Soluble in water and contains cobalt, red crystalline.	A serious type of anaemia.
Vitamin C (Ascorbic Acid, C ₆ H ₈ O ₆)	Soluble in water, destroyed by cooking and exposure to air.	Scurvy, dental caries, pyorrhea, anaemia.
Vitamin D (Calciferol)	Mixture of four complex compounds containing C, H and O. Soluble in fats and oils but insoluble in water. Stable towards heat and oxidation. This vitamin regulates the absorption of calcium and phosphate in intestine.	Infantile rickets, deformation of bones and teeth.
Vitamin E (Tocopherol)	Mixture of 3 complex substances containing C, H and O. Soluble in fats and oils but insoluble in water. Stable to heat and oxidation.	Loss of sexual power and degeneration of muscle fibres in animals.
Vitamin K	Mixture of two complex substances containing C, H and O. Soluble in fats but insoluble in water. Stable to heat and oxidation.	Tendency to haemorrhage and impaired clotting of blood.