# 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 → Organ systems → Living organism.

## Carbohydrates

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

## Classification of Carbohydrates

### (i) Reducing and Non-reducing Sugars

Based upon reducing and non-reducing properties, carbohydrates are classified as reducing and non-reducing sugars. Carbohydrates that reduces Fehling's 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.

### (ii) Sugars and Non-sugars

On the basis of 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 known as **non-sugars.**
(Latin *Saccharum* = sugar) due to sweet taste of simpler members.

## (iii) Monosaccharides, Oligosaccharides and Polysaccharides

Depending upon the number of simple molecules produced upon hydrolysis, carbohydrates are classified as, monsaccharides, oligosaccharides and polysaccharides :

# I. Monosaccharides

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

| | |
|---|---|
| **Aldotetroses** | e.g Erythrose, Threose |
| **Aldopentoses** | e.g Xylose, Ribose |
| **Aldohexoses** | e.g Glucose, Galactose |
| **Ketohexoses** | e.g Fructose |

All naturally occurring monosaccharides belong to D-series.

**Killiani synthesis** is used to convert an aldose into next higher aldose.

## 1. Glucose

It is also known as Dextrose. It is present in 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.

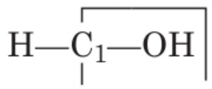
$$\underset{\text{sucrose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow[H^+]{} \underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{fructose}}{C_6H_{12}O_6}$$

$$\underset{\text{starch or cellulose}}{(C_6H_{10}O_5)_n} + nH_2O \xrightarrow[393\text{ K; 2-3 bar}]{H^+} n\,\underset{\text{glucose}}{C_6H_{12}O_6}$$

Extra glucose is stored in liver as glycogen.

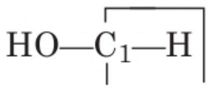
### α and β-glucose

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



$H-C_1-OH$

α-form (i)



$HO-C_1-H$

β-form (ii)

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. α-D-glucose has specific rotation +111.5° and β-D-glucose has specific rotation + 19.5°.

## Mutarotation

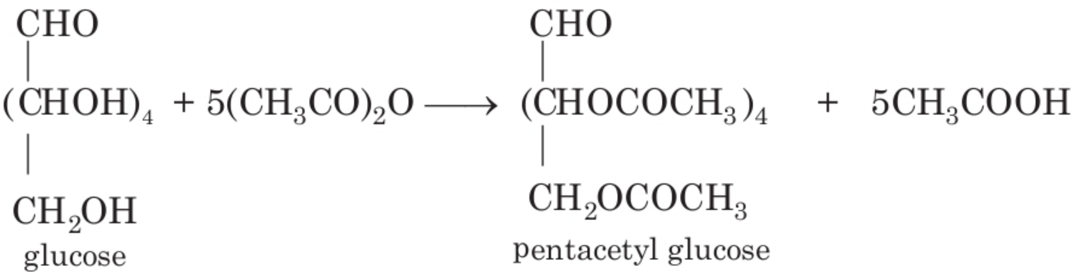
When either of the two forms of glucose is dissolved in water, there is a spontaneous change in specific rotation till the equilibrium value of +52.5°. This is known as mutarotation.

$$\underset{+111.5^\circ}{\alpha\text{-D}(+)\text{ Glucose}} \rightleftharpoons \underset{+\,52.5^\circ}{\text{Equilibrium mixture}} \rightleftharpoons \underset{+19.5^\circ}{\beta\text{-D-}(+)\text{ Glucose}}$$

## Properties of Glucose

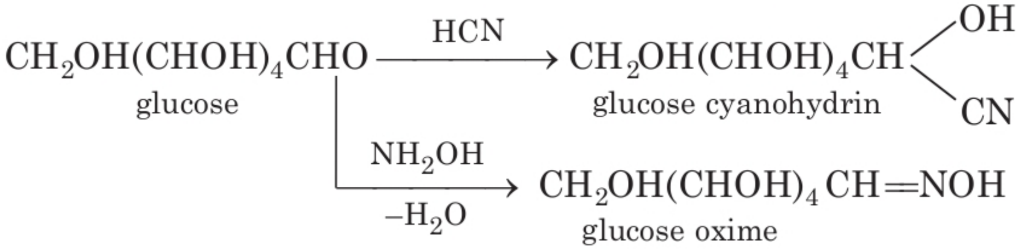
Glucose has one aldehyde group, one primary hydroxyl ($—CH_2OH$) and four secondary hydroxyl ($—CHOH$) groups and gives the following reactions:

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



$$\underset{\text{glucose}}{\begin{array}{c} CHO \\ | \\ (CHOH)_4 \\ | \\ CH_2OH \end{array}} + 5(CH_3CO)_2O \longrightarrow \underset{\text{pentacetyl glucose}}{\begin{array}{c} CHO \\ | \\ (CHOCOCH_3)_4 \\ | \\ CH_2OCOCH_3 \end{array}} + 5CH_3COOH$$

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



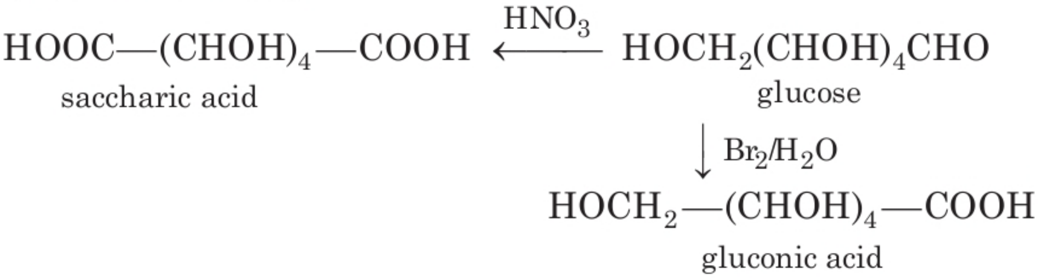
$$\underset{\text{glucose}}{CH_2OH(CHOH)_4CHO} \xrightarrow{HCN} \underset{\text{glucose cyanohydrin}}{CH_2OH(CHOH)_4CH\begin{array}{l} \diagup OH \\ \diagdown CN \end{array}}$$

$$\underset{\text{glucose}}{CH_2OH(CHOH)_4CHO} \xrightarrow[-H_2O]{NH_2OH} \underset{\text{glucose oxime}}{CH_2OH(CHOH)_4CH{=}NOH}$$

These reactions confirm the presence of 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.



$$\underset{\text{saccharic acid}}{HOOC—(CHOH)_4—COOH} \xleftarrow{HNO_3} \underset{\text{glucose}}{HOCH_2(CHOH)_4CHO}$$

$$\underset{\text{glucose}}{HOCH_2(CHOH)_4CHO} \xrightarrow{Br_2/H_2O} \underset{\text{gluconic acid}}{HOCH_2—(CHOH)_4—COOH}$$

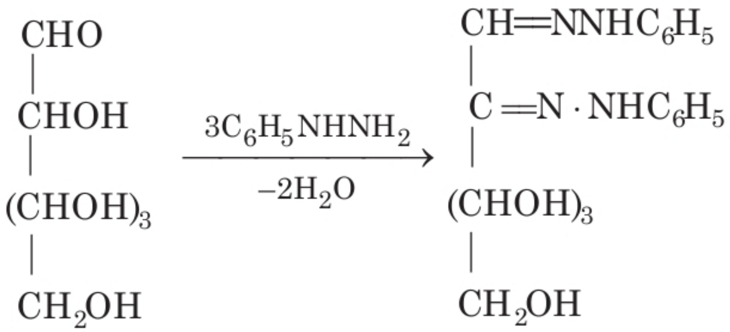
(v) Glucose on prolonged heating with HI forms *n*-hexane, suggesting that all the 6 carbon atoms in glucose are linked linearly.

$$\text{HOCH}_2\text{—(CHOH)}_4\text{—CHO} \xrightarrow{\text{HI, }\Delta}$$

$$\text{H}_3\text{C—CH}_2\text{—CH}_2\text{—CH}_2\text{—CH}_2\text{—CH}_3$$

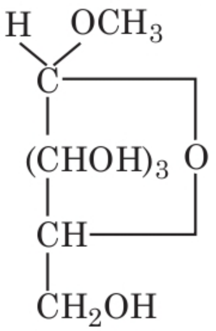
However, with Na/Hg and water, glucose is reduced to sorbitol $HOH_2C(CHOH)_4CH_2OH$.

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

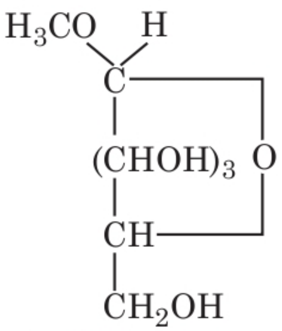


glucose glucosazone

(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.

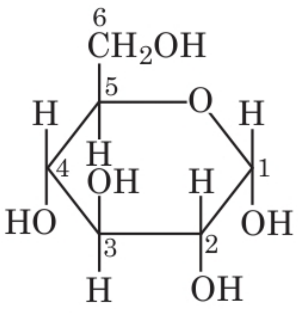


α-methyl glucoside

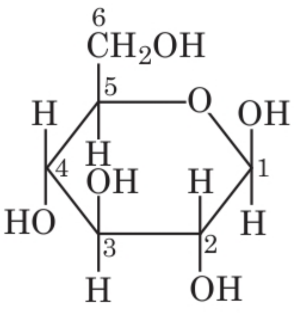


β-methyl glucoside

**Cyclic structure of glucose** Given by Haworth and Hirst.

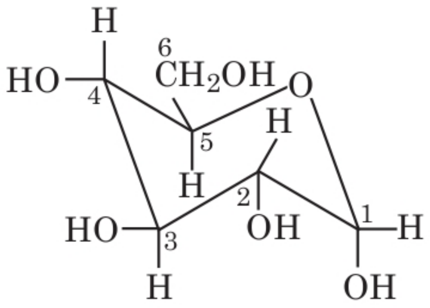


α-D (+) glucose

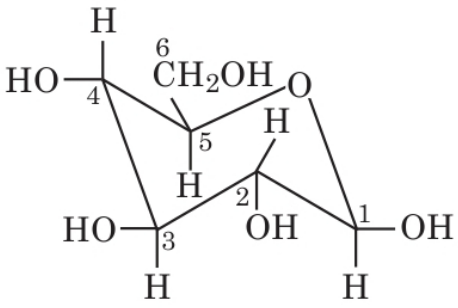


β-D (+) glucose

Glucose is sometimes illustrated as a chair form :



α-anomer



β-anomer

## 2. Fructose [Fruit Sugar ($C_6H_{12}O_6$)]

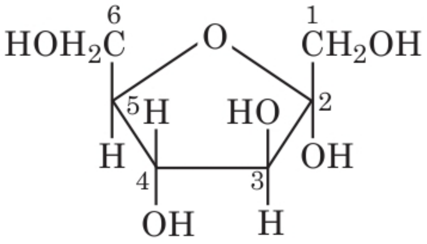
### Manufacture

By hydrolysis of inulin.

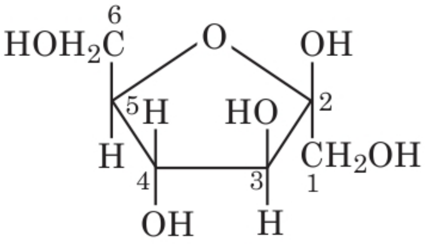
$$\underset{\text{inulin}}{(C_6H_{10}O_5)_n} + nH_2O \xrightarrow{H^+} \underset{\text{fructose}}{nC_6H_{12}O_6}$$

### Structure

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



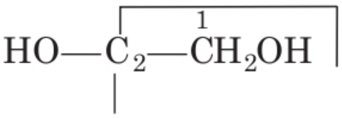
α-D (–)
fructofuranose



β-D (–)
fructofuranose

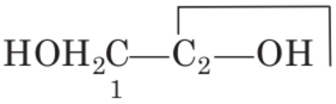
### α and β-fructose

The two forms have different configuration about $C_2$.



$HO-C_2-\overset{1}{C}H_2OH$

α-fructose



$HO\underset{1}{H_2C}-C_2-OH$

β-fructose

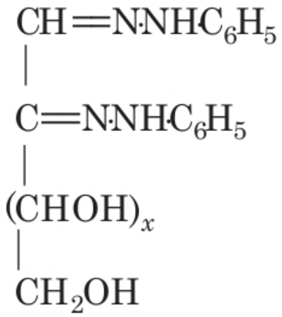
Fructose does not reduce $Br_2$ water.

### 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



$$\begin{array}{l} CH{=}N{\cdot}NHC_6H_5 \\ | \\ C{=}N{\cdot}NHC_6H_5 \\ | \\ (CHOH)_x \\ | \\ CH_2OH \end{array}$$

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

## II. Oligosaccharides

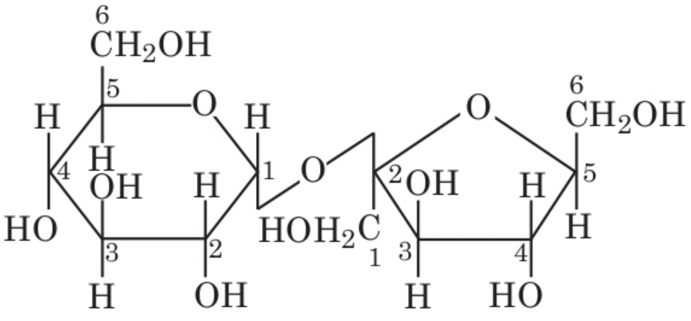
(Greek *oligos* = few). On hydrolysis, they generally give two to nine monosaccharides (same or different) and are further classified as disaccharides, e.g. sucrose, maltose, lactose, trisaccharides and so on. $C_{12}H_{22}O_{11}$ is a disaccharide because it gives two monosaccharides.

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

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

### 1. Sucrose, ($C_{12}H_{22}O_{11}$)

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.



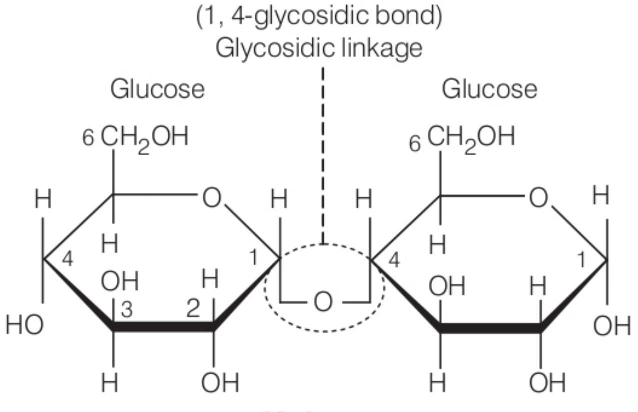
Structure of sucrose

### 2. Lactose or Milk sugar

It is present in milk of mammals and made up of **one glucose** and **one galactose** units. It is reducing sugar. Souring of milk is due to the conversion of lactose to lactic acid.

### 3. Maltose or Malt sugar

It is named because of its occurrence in malted grain of Barley. Mostly found in germinating seeds and tissue where starch is broken down. It is a reducing sugar and formed by condensation of 2 glucose units.



**Maltose**

## Trisaccharides

Carbohydrate that yield three monosaccharide units on hydrolysis are called trisaccharide e.g; Raffinose ($C_{18}H_{32}O_{16}$).

$$(C_{18}H_{32}O_{16}) + 2H_2O \xrightarrow{H^+} \text{Glucose} + \text{Fructose} + \text{Galactose}$$

## III. Polysaccharides

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

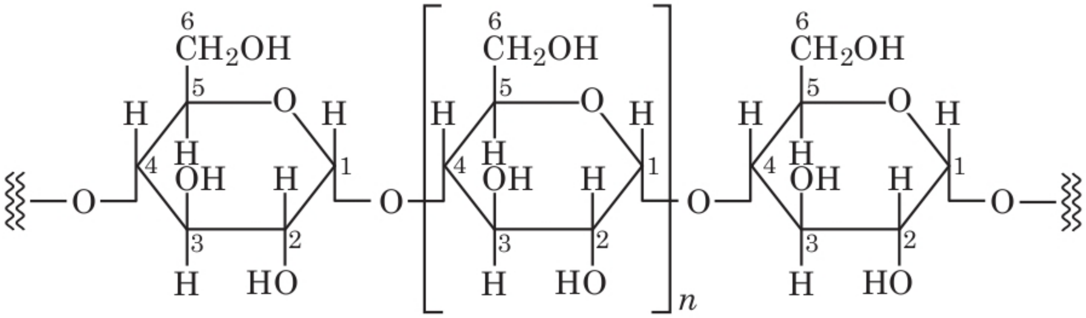
### 1. Starch, $(C_6H_{10}O_5)_n$

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:

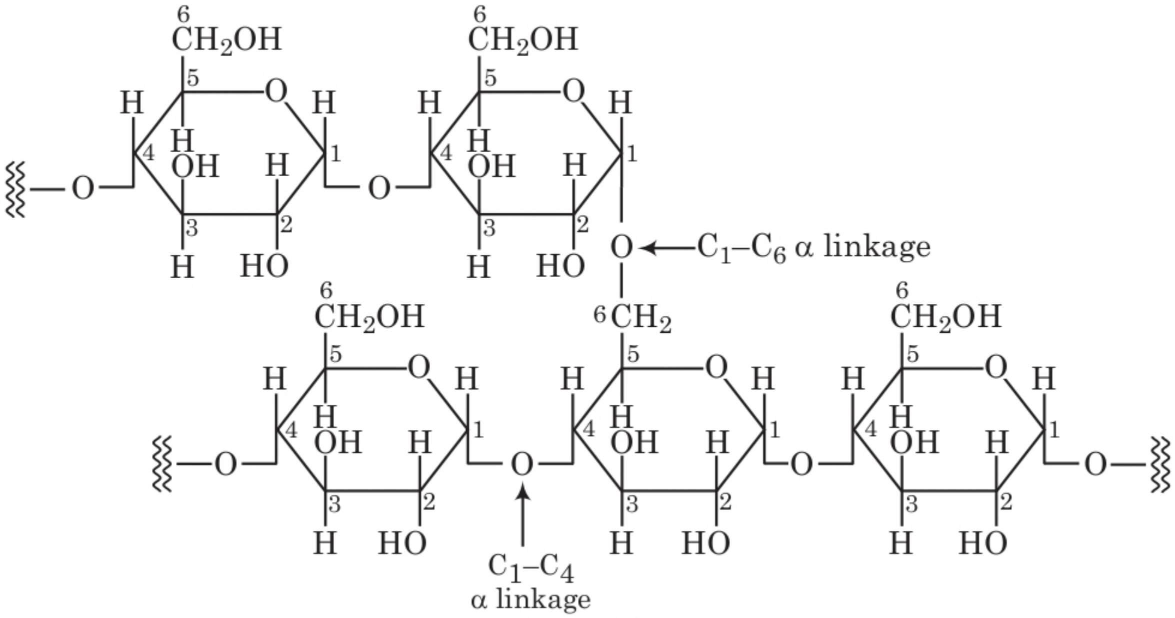
(i) **Amylose** (20%), an unbranched water soluble polymer.

(ii) **Amylopectin** (80%), a branched water insoluble polymer.

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



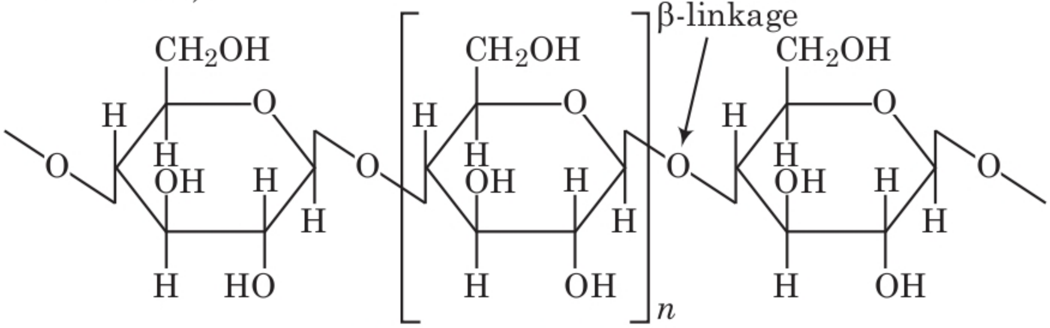
Structure of amylose



Structure of amylopectin

## 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).



Structure of cellulose

Several materials are obtained from cellulose:

(i) **Mercerised cotton** Cellulose treated with conc. sodium hydroxide solution acquire silky lustre. It is called mercerised cotton.

(ii) **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**.

(iii) **Cellulose acetate** It is used for making acetate rayon and motion picture films.

(iv) **Cellulose xanthate** It is obtained by treating cellulose with sodium hydroxide and carbon disulphide and is the basic material for VISCOSE rayon.

**Note** Oligosaccharides and polysaccharides are also called **heteropolysaccharides.**

### Glycogen

It is found in animal body (mainly in liver and muscles) as reserve food and is called animals starch. Like starch, it is a polymer of $\alpha$-D-glucose. When glucose is needed in body it breaks down by the action of enzymes. Structurily, glycogen is highly branched and resemble with the structure of amylopectin.

### Molisch Test for Carbohydrates

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

### Relative Sweeteness of Some Sugars

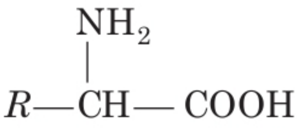
Cane sugar is assumed to have a sweeteness of 10. The relative sweeteness of other sugars is

| | | | |
|---|---|---|---|
| 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 (—$NH_2$) and carboxylic group (—COOH) are called amino acids.

**General formula**



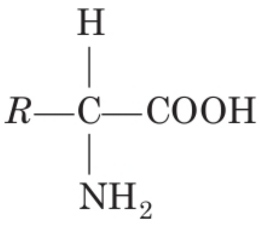
$$R-\overset{\overset{NH_2}{|}}{C}H-COOH$$

$\alpha$-amino acid ($R$ = side chain)

$R$ = H, alkyl or aryl group. Except glycine ($H_2N \cdot CH_2COOH$), others are optically active in nature.

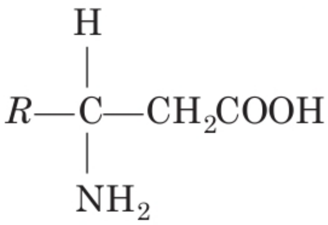
### Classification of Amino Acids

(a) $\alpha, \beta, \gamma$-**amino acids** Depending upon the position of —$NH_2$ on the carbon chain *wrt* —COOH group.



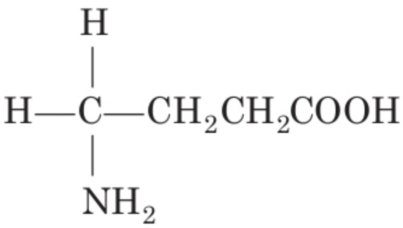
$$R-\underset{\underset{NH_2}{|}}{\overset{\overset{H}{|}}{C}}-COOH$$

$\alpha$-amino acid



$$R-\underset{\underset{NH_2}{|}}{\overset{\overset{H}{|}}{C}}-CH_2COOH$$

$\beta$-amino acid

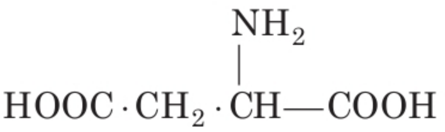


$$H-\underset{\underset{NH_2}{|}}{\overset{\overset{H}{|}}{C}}-CH_2CH_2COOH$$

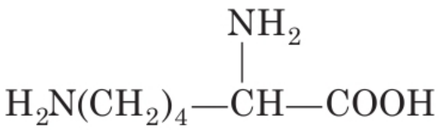
$\gamma$-amino acid

(b) **Neutral** Having one —$NH_2$ and one —COOH,
e.g. $NH_2 \cdot CH_2 \cdot COOH$ (glycine).

(c) **Acidic** Having one —$NH_2$ and two —COOH,

e.g. 
$HOOC \cdot CH_2 \cdot \overset{\overset{\displaystyle NH_2}{|}}{CH}—COOH$ (aspartic acid)

(d) **Basic** Having two or more —$NH_2$ and one —COOH,
e.g.


$H_2N(CH_2)_4—\overset{\overset{\displaystyle NH_2}{|}}{CH}—COOH$ (lysine).

## Essential and Non-essential Amino Acids

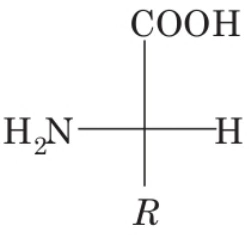
Human body can synthesise ten out of twenty amino acids, called non-essential amino acids. The remaining ten amino acids required for protein synthesis are not synthesised by body and are called essential amino acids. They are

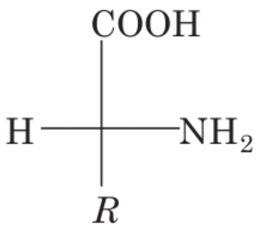
1. Phenylalanine
2. Histidine
3. Tryptophan
4. Valine
5. Methionine
6. Threonine
7. Arginine
8. Leucine
9. Isoleucine
10. Lysine

## Nomenclature

They are known by their common names and abbreviated by first three letters of their common names e.g. glycine as ‘gly’ and alanine as ‘ala’.

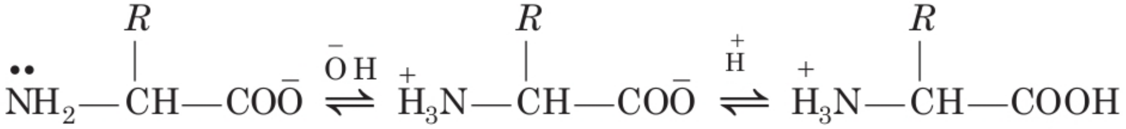
## Configuration of $\alpha$-Amino Acids


L- amino acid
($NH_2$ on LHS)


D- amino acid
($NH_2$ on RHS)

Naturally occurring $\alpha$-amino acids are L-amino acids. D-amino acids occur in some antibiotics and bacterial cell walls.

### Structure of Amino Acids



$$\overset{\bullet\bullet}{N}H_2-\overset{R}{\overset{|}{C}}H-CO\bar{O} \overset{\bar{O}H}{\rightleftharpoons} \overset{+}{H_3N}-\overset{R}{\overset{|}{C}}H-CO\bar{O} \overset{\overset{+}{H}}{\rightleftharpoons} \overset{+}{H_3N}-\overset{R}{\overset{|}{C}}H-COOH$$

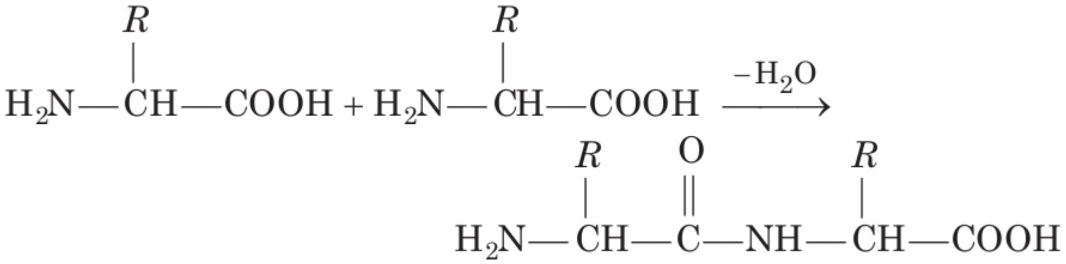
as anion (high pH)

Zwitter ion, (isoelectric point)

as cation (low pH)

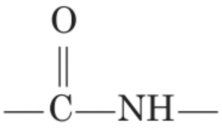
## Peptides

Peptides are condensation products of two or more amino acids.



$$H_2N-\overset{R}{\overset{|}{C}}H-COOH+H_2N-\overset{R}{\overset{|}{C}}H-COOH \xrightarrow{-H_2O} H_2N-\overset{R}{\overset{|}{C}}H-\overset{O}{\overset{\|}{C}}-NH-\overset{R}{\overset{|}{C}}H-COOH$$

dipeptide



$-\overset{O}{\overset{\|}{C}}-NH-$ is known as peptide linkage and C—N as a peptide bond.

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 ($\approx 10000$) 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 Molecular Shape

1. **Fibrous proteins** When the polypeptide chains run parallel and are held together by hydrogen and disulphide bonds, then fibre like structure is formed. Such proteins are insoluble in water. e.g. Keratin (present in hair, wool) etc.
2. **Globular proteins** This structure results when the chains of polypeptides coil around to give a spherical shape. These are usually soluble in water e.g. insulin, albumins.

## Classification on the Basis of Hydrolysis Products

(i) **Simple proteins** These yield only $\alpha$-amino acids upon hydrolysis. e.g. albumin.

(ii) **Conjugated proteins** These yield $\alpha$-amino acids and non-protein part, called prosthetic group.

| Protein | Prosthetic group |
|---|---|
| Nucleoproteins | Nucleic acid |
| Phosphoproteins | Phosphoric acid |
| Glycoproteins | Carbohydrates |
| Metalloproteins | Metals |
| Lipoproteins | Lipids |

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

$$\text{Proteins} \rightarrow \text{Proteoses} \rightarrow \text{Peptones} \rightarrow \text{Polypeptides}$$

## Classification on the Basis Functions

(i) **Structural proteins** Fibrous proteins and globular proteins.

(ii) **Enzymes** Serve as biological catalyst e.g. pepsin, trypsin etc.

(iii) **Hormones** e.g. Insulin

(iv) **Contractile proteins** Found in muscles, e.g. myosin, actin.

(v) **Antibodies** Gamma globulins present in blood.

(vi) **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 $\alpha$-chains and the two chains containing 146 amino acid residues are called $\beta$-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. $CuSO_4 \rightarrow$ pink or violet colour.

(ii) **Millon's Test**

Protein solution + Millon's reagent → red colour

Millon's reagent is solution of mercuric nitrate and traces of sodium nitrate solution.

(iii) **Iodine reaction**

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

(iv) **Xanthoprotein test**

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

# Enzymes

Enzymes constitute a group of complex proteinoid organic 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 and 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 Enzymes**

| Name | Substrate | Products |
|---|---|---|
| Urease | Urea | $CO_2 + NH_3$ |
| 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

(i) **Rate of reaction** They increase the rate of reaction up to $10^6$ to $10^7$ times.

(ii) **Specific nature** Urease catalyse the hydrolysis of urea and not methyl urea, so these are specific in nature.

(iii) **Optimum temperature** It is active at 20-30°C.

(iv) **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.

(v) **Concentration** Dilute solutions are more effective.

(vi) **Amount of enzyme** Very small amount can accelerate the reaction.

(vii) **Enzyme inhibitors** These compounds inhibit the enzyme action. With the help of such compounds, the reaction can be controlled.

## Mechanism of Enzyme Action

$$\text{Enzyme} + \text{Substrate} \rightarrow [\text{Enzyme substrate}] \rightarrow \text{Product} + \text{Enzyme Activated complex}$$

## Applications of Enzymes

(i) **Treatment of diseases** The congenital disease phenyl ketonuria caused by phenylalanine hyroxylase 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.

# 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,

(i) Water soluble vitamins and

(ii) Fat soluble vitamins.

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

**Vitamins and the Diseases Caused by their Deficiency**

| Vitamin | Chemical nature | Deficiency diseases |
|---|---|---|
| Vitamin A<br>(Carotenoids or Axerophytol or retinol) | 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 |
| Vitamin $B_{12}$ (Cyano cobalamin) | Soluble in water and contains cobalt, red crystalline. | A serious type of anaemia. (pernicious anaemia) |
| Vitamin C (Ascorbic Acid, $C_6H_8O_6$) | Soluble in water, destroyed by cooking and exposure to air. | Scurvy, dental caries, pyorrhea, anaemia. |
| Vitamin D (Ergo 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 (phylloquinone) | 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. |

# Nucleic Acids

## Important Terms of Nucleic Acids

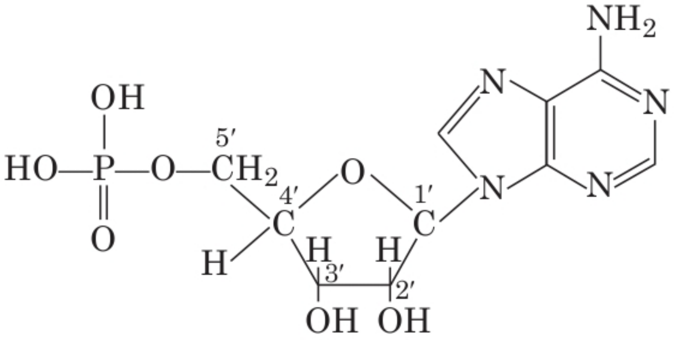
(i) **Nitrogenous base** Derived from purines having two rings in their structure. e.g. Adenine (A) and Guanine (G) and derived from pyrimidines having one ring in their structure e.g. Thymine (T), Uracil (U) and Cytosine (C).

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

(ii) **Pentose sugar** It is either ribose or deoxy ribose (not having oxygen at $C_2$).

(iii) **Nucleoside** Ribose–/deoxyribose + one base unit from A, G, C, T or U.

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



(v) **Ribonucleotide** Phosphate unit + Ribose + one base unit from A, G, C, or U.

(vi) **Deoxyribo nucleotide** Phosphate unit + Deoxyribose + one base from A, G, C or T.

# DNA and RNA

Nucleic acid is polynucleotide, present in the living cells or bacterial cells having no nucleus and in viruses having no cells. These are of two types:

(i) **DNA** Deoxyribonucleic acid.

$$DNA + H_2O \rightarrow \text{Phosphoric acid} + \text{deoxyribose} + A, G, C, T$$

(ii) **RNA** Ribonucleic acid.

$$RNA + H_2O \rightarrow \text{Phosphoric acid} + \text{Ribose} + A, G, C, U$$

## 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

(i) **Messanger RNA** (*m*-RNA) It is produced in the nucleus and carries information for the synthesis of proteins.

(ii) **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).

### IMPORTANT TERMS

**Replication**

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

**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 word 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 glycerides.

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

**Common saturated fatty acids** $CH_3—(CH_2)_nCOOH$.

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 fatty acids**

$C_{17}H_{33}COOH$ oleic acid; $C_{17}H_{33}COOH$ 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) **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.

**Reichert–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.

## Hormones

These are the chemical substances which are produced by endocrine (ductless) glands in the body. Hormones acts as **chemical messengers.**

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

Hormones are divided into three types :

(i) steroids

(ii) proteins or polypeptides

(iii) amines.

### Some Typical Hormones and their Functions

| | 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. | Glucagon | 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.