

UNIT 1

Biomolecules and Bioenergetics

Biomolecules or Macromolecules

Life is composed of lifeless chemical molecules. About 6,000 and 1,00,00 different types of molecules are present in bacterium and man, respectively. Among these only few are characterized till now. Proteins, nucleic acid (such as DNA and RNA), polysaccharides and lipids are the important macromolecules or biomolecules composed of amino acids, nucleotides, monosaccharides and fatty acids, respectively. Strictly speaking lipids are not polymers but fatty acids are present in majority of lipids. The building blocks and functions of important biomolecules of cells are summarized in Table 1.1.

Table 1.1 Building blocks and functions of important biomolecules of cells.

S. No	Macromolecules or Biomolecules	Repeating Unit or Building Blocks	Important Functions
1	Protein	Amino acids	Static and dynamic functions of cell and fundamental basis of structure.
2	Deoxyribonucleic acid (DNA)	Deoxyribonucleotides	Storehouse of genetic information.
3	Ribonucleic acid (RNA)	Ribonucleotides	Essentially needed for biosynthesis of protein.
4	Glycogen or Polysaccharide	Glucose or monosaccharide	Storage form of energy to meet short term demands.
5	Lipid	Fatty acid, glycerol	Structural components of membrane and storage form of energy to meet long term demands.

Carbohydrates

In nature carbohydrates are the most abundant organic molecules and widely distributed in plants and animals. They are synthesized in plants by photosynthesis and serves as storage of energy (e.g. starch and glycogen) and source of energy (e.g. sugars). Earlier, carbohydrates were regarded as the **hydrates of carbon i.e., $C(H_2O)_n$** (carbo indicates "carbon"; hydrates indicates "water"), hence they are named as carbohydrates. The hydrogen and oxygen are present in the same ratio as in water, hence the term hydrates is added. They are primarily composed of carbon, hydrogen and oxygen. **$(CH_2O)_n$ or $C_nH_{2n}O_n$ (where $n > 3$)** is the empirical formula of most of the carbohydrates. **Example:** Glucose ($C_6H_{12}O_6$), ribose ($C_5H_{10}O_5$), etc. But some non-carbohydrates also appear as hydrates of carbon. **Example:** Formaldehyde (CH_2O ; $HCHO$), acetic acid ($C_2H_4O_2$; CH_3COOH), lactic acid ($C_3H_6O_3$; $CH_3CH(OH)COOH$) and inositol ($C_6H_{12}O_6$). In addition, some genuine carbohydrates do not satisfy this empirical formula. **Example:** Rhamnose, ($C_6H_{12}O_5$), digitoxose ($C_6H_{12}O_4$), rhamnohexose ($C_7H_{14}O_6$). Therefore, carbohydrates are not always considered as hydrates of carbon. The general formula for polysaccharides is **$(C_6H_{10}O_5)_n$** .

Carbohydrates are defined as optically active polyhydroxy aldehydes or ketones or compounds which produce them on hydrolysis. Nitrogen, phosphorus, or sulfur is also present in some of the carbohydrates apart from the carbon, hydrogen and oxygen. Because of their sweet taste, the simpler members of carbohydrate family are also known as saccharides (In Latin, **saccharum** means "sugar").

Classification of Carbohydrates

Based on solubility, crystal structure and taste, carbohydrates are broadly classified into two major types as,

1. Sugars
 2. Non-sugars or polysaccharides or glycans
1. **Sugars:** Sugars are soluble in water, crystalline in structure and are sweet in taste. Further based on the number of sugar molecules present sugars are classified into two categories

- A. Monosaccharides
- B. Oligosaccharides

A. Monosaccharides: In Greek, mono means “single” and in Latin, saccharum means “sugar”, hence monosaccharides are composed of single sugar molecules. Monosaccharides are defined as polyhydroxy aldehydes or ketones which cannot be hydrolysed to simpler sugars. Monosaccharides having more than four carbon atoms possess cyclic structures. In nature the most commonly found monosaccharides are D-glucose (aldohexose) and D-fructose (ketohexose). In nucleic acids, nucleotides and nucleosides, aldopentoses such as D-ribose and 2-deoxy-D-ribose are present.

Based on the nature of carbonyl group, present monosaccharides are further sub divided into two types.

- (i) **Aldoses or Aldose sugar:** Carbonyl group present is aldehyde, hence aldoses are monosaccharides composed of polyhydroxy aldehydes.
- (ii) **Ketoses or Ketose sugar:** Carbonyl group present is ketone, hence ketoses are monosaccharides composed of polyhydroxy ketones.

These aldose and ketose sugars are further divided into several types based on the number of carbon atoms in the molecules as follows.

- (a) **Trioses:** Tri means “three”, hence trioses are monosaccharides made up of three carbon atoms. **Example:** Glyceraldehyde (Aldotriose) and dihydroxy acetone (Ketotriose).
 - (b) **Tetroses:** Tetra means “four”, hence tetroses are monosaccharides made up of four carbon atoms. **Example:** Erythrose, threose (Aldotetrose) and erythrulose (Ketotetrose).
 - (c) **Pentoses:** Penta means “five”, hence pentoses are monosaccharides made up of five carbon atoms. **Example:** Ribose, arabinose, xylose, lyxose (Aldopentose) and ribulose, xylulose (Ketopentose).
 - (d) **Hexoses:** Hexa means “six”, hence hexoses are monosaccharides made up of six carbon atoms. **Example:** Allose, altrose, glucose, mannose, gulose, idose, galactose, talose (Aldohexose) and allulose, fructose, sorbose, tagatose (Ketohexose).
 - (e) **Heptoses:** Hepta means “seven”, hence heptoses are monosaccharides made up of seven carbon atoms. **Example:** Glycero mannoheptose (Aldoheptose) and sedoheptulose (Ketoheptose).
 - (f) **Nanoses:** Nano means “nine”, hence nanoses are monosaccharides made up of nine carbon atoms. **Example:** Neuraminic acid (Ketonanose).
- B. Oligosaccharides:** In Greek, oligo means “few” and in Latin, saccharum means “sugar”, hence oligosaccharides are composed of few (two to ten) sugar molecules. In oligosaccharides short chain of monosaccharide units or residues are present and are linked by characteristic linkages known as glycosidic linkage. On hydrolysis these carbohydrates yield two to ten monosaccharide molecules. Hence, further based on the number of monosaccharide units formed on hydrolysis they are divided into various classes as follows.
- (i) **Diasaccharides:** In Greek, di means “two” and in Latin, saccharum means “sugar”, hence disaccharides are composed of two sugar molecules i.e, two monosaccharide residues. These two monosaccharide residues are attached covalently by an O-glycosidic bond, which is formed when a hydroxyl group of one monosaccharide reacts with the anomeric carbon of the other monosaccharide. These sugars on hydrolysis give two moles of the

monosaccharides. **Example:** Maltose on hydrolysis yields two molecules of α -D-glucose (α -1,4-glycosidic linkage); Lactose on hydrolysis yields one molecule each of β -D-glucose and β -D-galactose (β -1,4-glycosidic linkage); Sucrose on hydrolysis yields one molecule each of α -D-glucose and β -D-fructose (1,2-glycosidic linkage); Isomaltose on hydrolysis yields two molecules of α -D-glucose (α -1,6-glycosidic linkage); Cellobiose on hydrolysis yields two molecules of β -D-glucose (β -1,4-glycosidic linkage).

- (ii) **Trisaccharides:** In Greek, tri means “three” and in Latin, saccharum means “sugar”, hence trisaccharides are composed of three sugar molecules i.e, three monosaccharide residues. These sugars on hydrolysis give three moles of the monosaccharides. Most oligosaccharides consisting of three or more units do not occur as free entities but are linked to non-sugar molecules (lipids or proteins) in glycoconjugates. **Example:** Raffinose on hydrolysis yields one molecule each of α -D-glucose, β -D-fructose and α -D-galactose or sucrose and α -D-galactose
- (iii) **Tetrasaccharides:** In Greek, tetra means “four” and in Latin, saccharum means “sugar”, hence tetrasaccharides are composed of four sugar molecules i.e, four monosaccharide residues. These sugars on hydrolysis give four moles of the monosaccharides. **Example:** Stachyose on hydrolysis yields one molecule each of α -D-glucose and β -D-fructose and two molecules of α -D-galactose.
- (iv) **Pentasaccharides:** In Greek, penta means “five” and in Latin, saccharum means “sugar”, hence pentasaccharides are composed of five sugar molecules i.e, five monosaccharide residues. These sugars on hydrolysis give five moles of the monosaccharides. **Example:** Verbascose on hydrolysis yields one molecule each of α -D-glucose and β -D-fructose and three molecules of α -D-galactose.

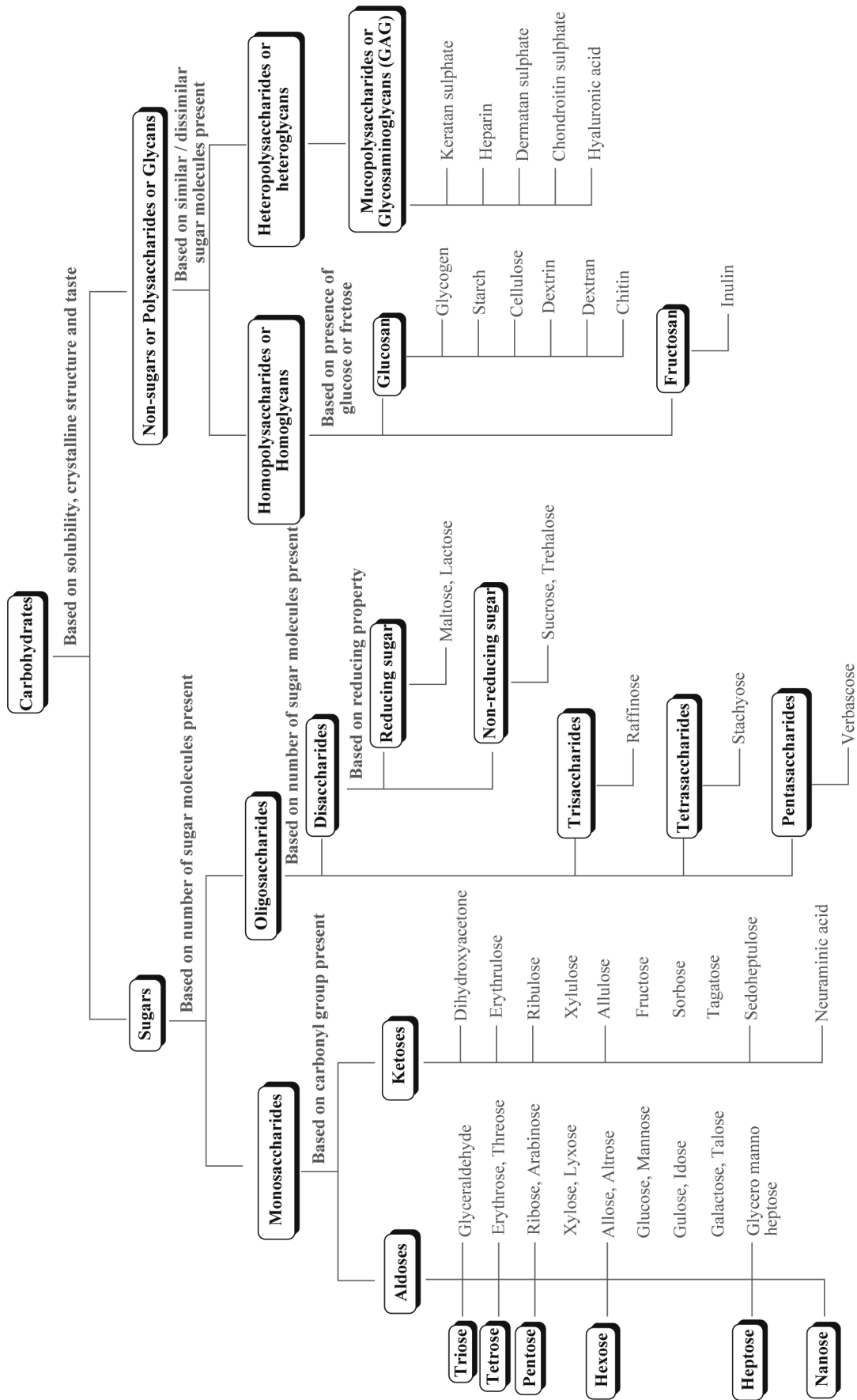
2. **Non-sugars or Polysaccharides or glycans:** (Non-sugars are insoluble in water and forms colloids, non-crystalline in structure and are tasteless (not sweet in taste). In Greek, poly “means” many and in Latin, saccharum means “sugar”, hence polysaccharides are composed of many sugar molecules i.e, many monosaccharide residues. These sugars on hydrolysis give many moles of the monosaccharides. Chemically they are long chain or polymers of monosaccharides. Some polysaccharides, such as cellulose, are linear chains; others, such as starch, glycogen, are branched. Glycosidic linkage can be formed at any one of the hydroxyl group of monosaccharides that’s why branches are occurring in polysaccharides. Further based on composition i.e., repeating units, polysaccharides are further classified into two categories as,

- A. Homopolysaccharides or homoglycans
- B. Heteropolysaccharides or heteroglycans

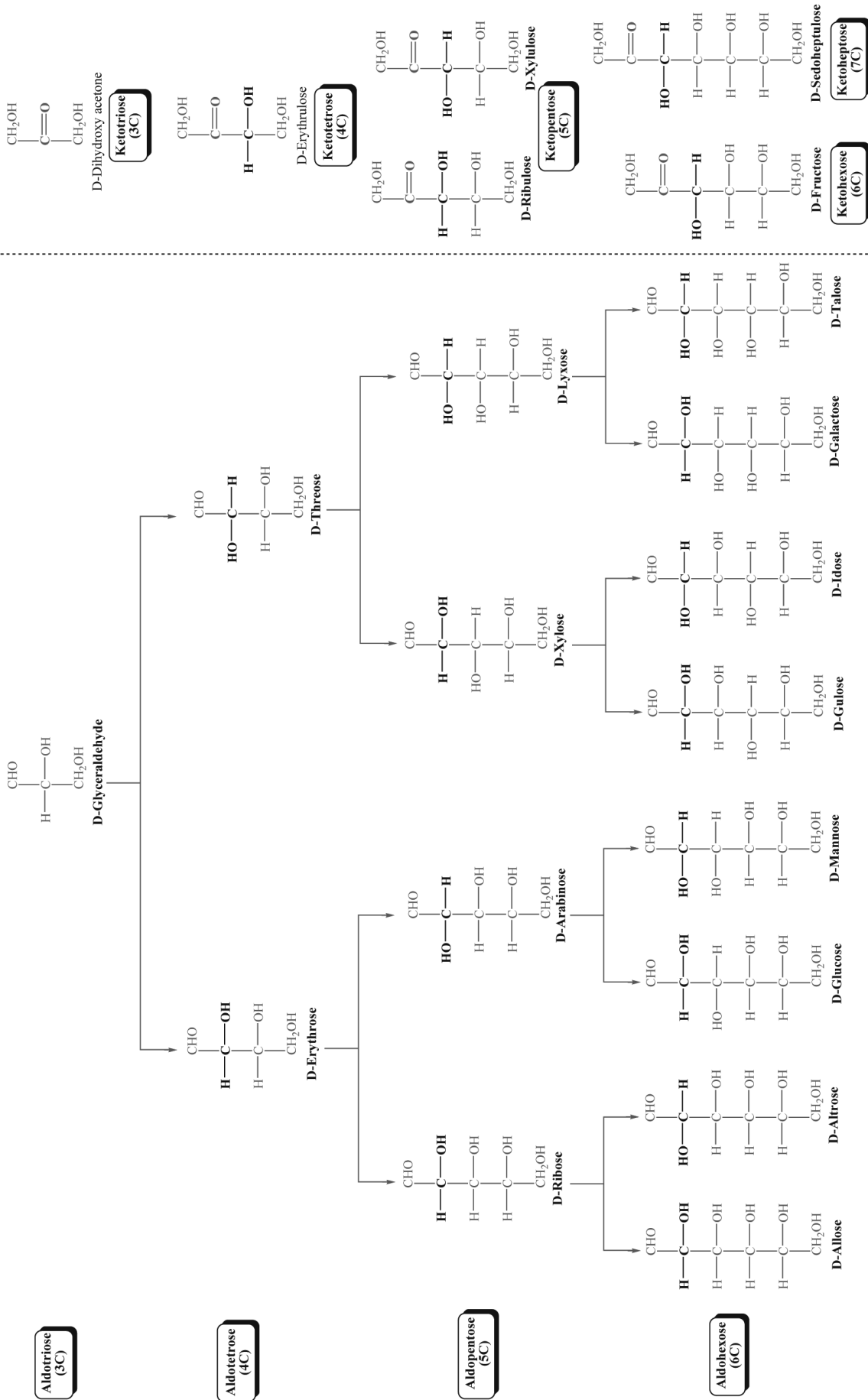
A. **Homopolysaccharides or homoglycans:** (In Greek homo means “same”, poly means “many” and in Latin, saccharum means “sugar”, hence homopolysaccharides are composed of same sugar molecules i.e, same monosaccharide residues. Only a single type of monosaccharide is obtained on hydrolysis of homopolysaccharides. They are further classified into two types based on monosaccharide present as

- (i) **Glucosan:** They are polymers of glucose i.e., repeating unit is glucose. **Example:** Starch, glycogen, cellulose, dextrans, dextrans, chitin, etc.
- (ii) **Fructosan:** They are polymers of fructose i.e., repeating unit is fructose. **Example:** Inulin, etc.

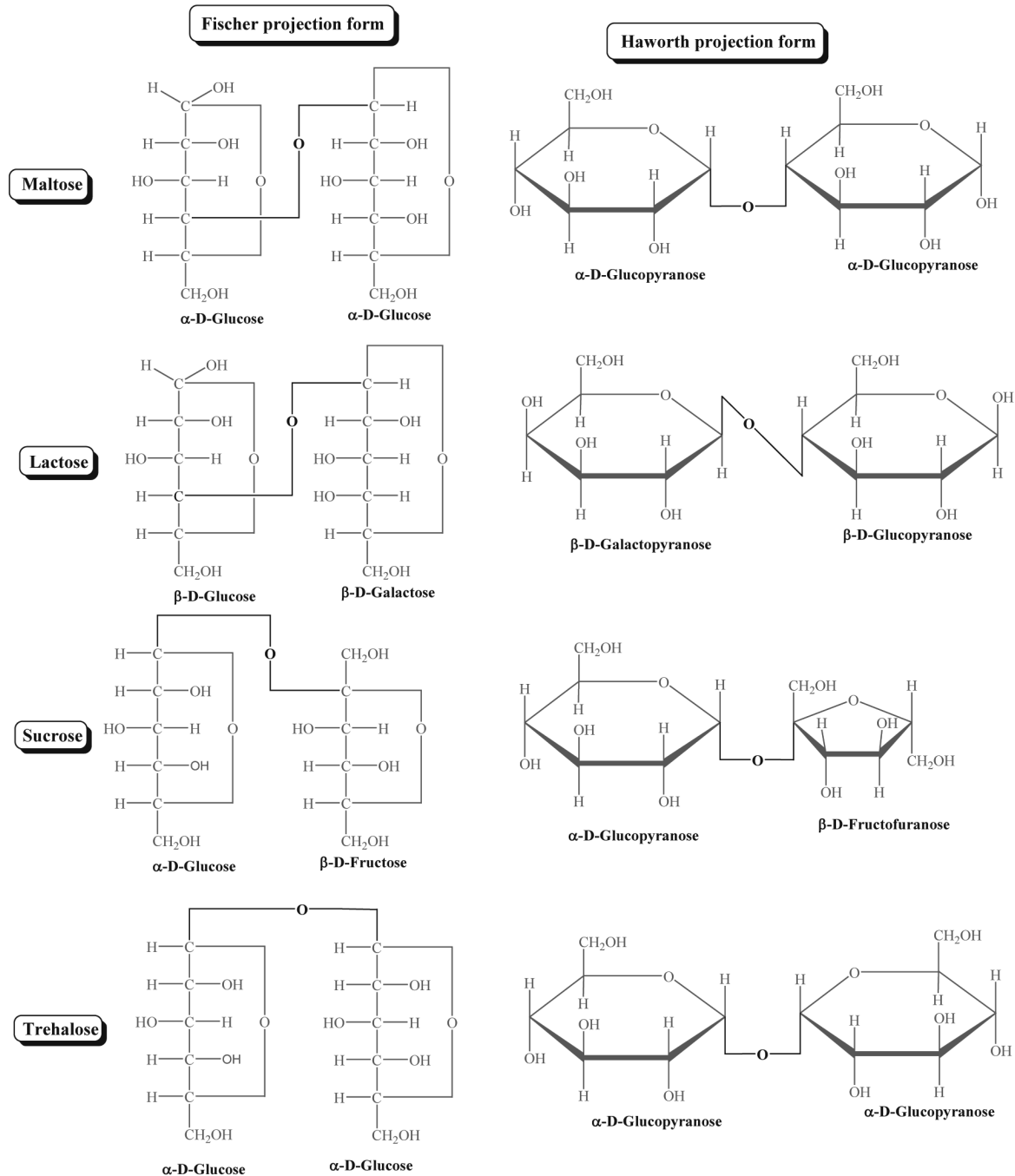
B. **Heteropolysaccharides or heteroglycans:** (In Greek hetero means “different”, poly means “many” and in Latin, saccharum means “sugar”, hence heteropolysaccharides are composed of different sugar molecules i.e, different monosaccharide residues. Mixture of few monosaccharide or its derivatives is obtained on hydrolysis of heteropolysaccharides. Mucopolysaccharides are heteroglycans made up of repeating units of sugar derivatives namely amino sugars and uronic acids. Mucopolysaccharides are commonly known as glycosaminoglycans (GAG). Some of mucopolysaccharides are found in combination with proteins to form proteoglycans or mucoids or mucoproteins. In proteoglycans 5 % protein and 95 % carbohydrates are present. Various examples of mucopolysaccharides are, keratan sulphate, heparin, dermatan sulphate, chondroitin sulphate, hyaluronic acid, etc.



CHEMICAL STRUCTURES OF MONOSACCHARIDES
ALDOSE SUGARS



CHEMICAL STRUCTURES OF DISACCHARIDES



Chemical Nature of Carbohydrates

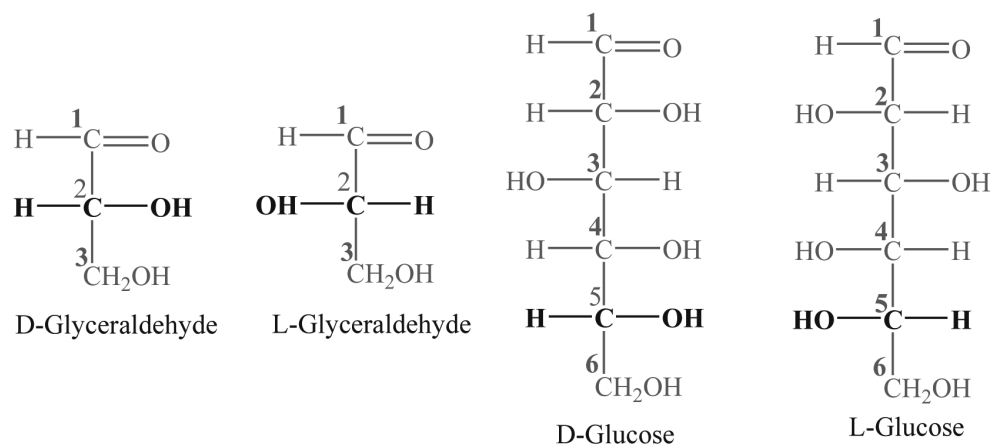
The followings are some important structural aspects of carbohydrates particularly monosaccharides. They are,

1. Stereoisomerism (D- & L-isomers)
2. Optical activity
3. Configuration of D-aldoses and D-Ketoses
4. Epimers
5. Enantiomers & Diastereomers
6. Anomers
7. Mutarotation

1. Stereoisomerism:

The important characteristic of monosaccharides is stereoisomerism. Compounds possessing same molecular formula, but different structural formula are termed as stereoisomer. Asymmetric or chiral carbon is defined as carbon attached to four different atoms or groups. The number of possible isomers (2^n) of given compound is determined from the number of chiral carbon (n) present. Four asymmetric carbons are present in glucose, hence 16 isomers are possible.

D- & L-isomers: The spatial arrangement of hydrogen (-H) and hydroxyl (-OH) group on the carbon atom that is adjacent to the terminal primary alcohol carbon (penultimate carbon or in glucose it is C-5 or in glyceraldehyde it is C-2) will determine whether the monosaccharide is D- or L-isomer. In D-isomer the hydroxyl (-OH) group is present in right side whereas in L-isomer the hydroxyl (-OH) group is present in left side. The simplest asymmetric carbon possessing monosaccharide is glyceraldehyde. Hence, it is chosen as reference monosaccharide to represent all other monosaccharides structure. The D- and L-isomers are mirror images of each other. In mammalian tissue, the naturally occurring monosaccharide are mostly D-isomers only. In addition, D-series of monosaccharide is specifically metabolized by the enzyme machinery of the cell.



2. Optical activity:

The characteristic feature of the asymmetric carbon is optical activity. The optical isomers rotate the plane polarized light into either right side or left side. When normal light (disperse in all direction) is passed into nickel prism it will be converted in to plane polarized light (disperse in only one direction). If optical isomers rotate the plane polarized light into right side, it is known as dextrorotatory compound and is denoted by the symbol "d or +", whereas if optical isomers rotate the plane polarized light into left side, it is known as levorotatory compound and is denoted by the symbol "l or -". Generally, based on the structural relationship with glyceraldehyde optical isomers are denoted as D(+), D(-), L(+) and L(-). Racemic mixture contains equal amount of d- and l-isomers and does not exhibit any optical activity because dextrorotatory and levorotatory activities cancel each other. The term dextrose is used for glucose solution in medical practice because of dextrorotatory nature of glucose.

3. Configuration of D-aldoses and D-ketoses:

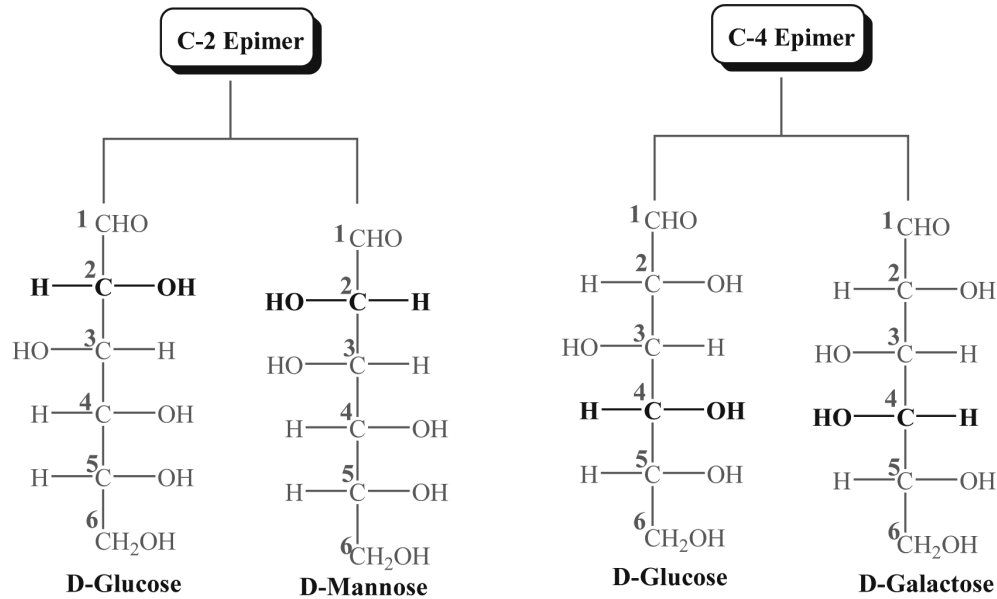
The configurations of various D-aldoses are mentioned by increasing the chain length by one carbon atom at a time in Kiliani Fischer synthesis. Among various aldoses, the most predominant which occurs in nature is glucose.

There are five D-ketoses which are physiologically important are D-erythrulose, D-ribulose, D-xylulose, D-fructose and D-sedoheptulose. The configuration of various D-aldoses and D-ketoses are mentioned under chemical structures of monosaccharides.

4. Epimers:

Epimers are defined as two compounds differing from each other around a single specific carbon (other than anomeric carbon) in their configuration. The reaction involving interconversions of epimers

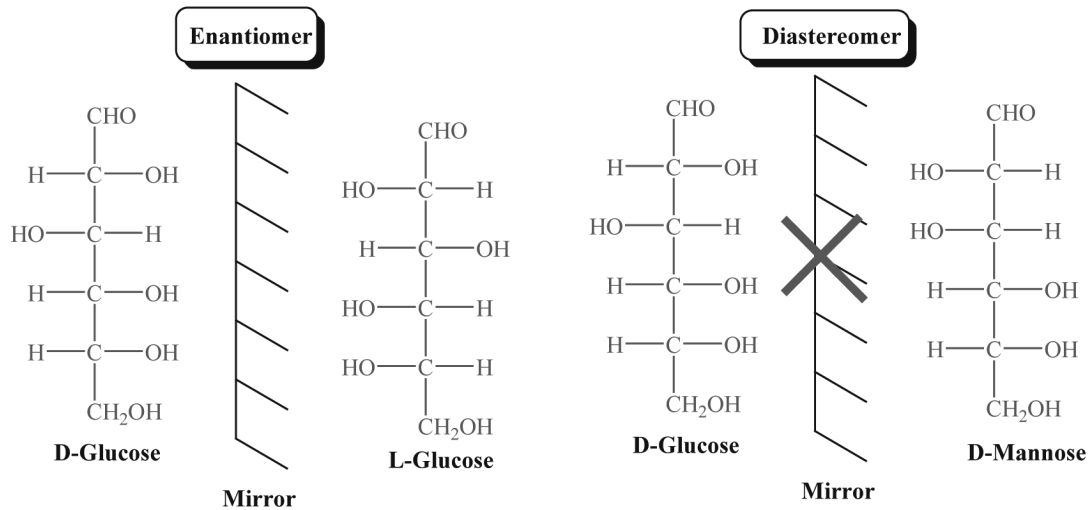
is known as epimerization and the enzyme involved is *epimerase*. **Example:** Glucose and mannose (C-2 epimer because they differ in their configuration around C-2); Glucose and galactose (C-4 epimer because they differ in their configuration around C-4).



5. Enantiomers & Diastereomers:

Enantiomers: The stereoisomers which are mirror images of each other are known as enantiomers. The D- and L-isomers are mirror images of each other, hence they are enantiomers. **Example:** D-Glucose and L-glucose.

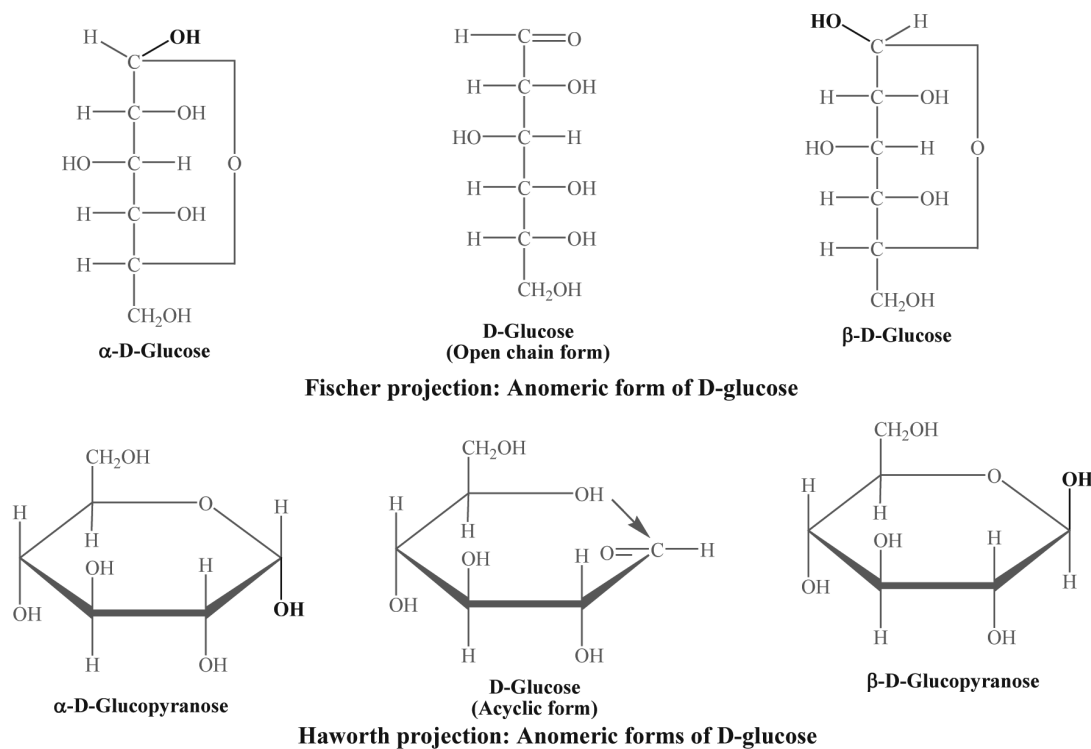
Diastereomers: The stereoisomers which are not mirror images of each other are known as diastereomers. **Example:** D-Glucose and D-mannose.



6. Anomers:

Two isomers differ from each other around a single specific carbon i.e., anomeric carbon in their configuration is known as anomers. Anomeric carbon is the functional group carbon atom which is involved in the formation of hemiacetal or hemiketal. Simply the two isomers differing only in the configuration of C-1 (in aldoses) or C-2 (in ketoses) are known as anomers, while such a carbon atom is known as anomeric carbon atom. **Example:** The α - and β -cyclic forms of D-glucose. In Haworth ring structure of D-glucose if the hydroxyl (-OH) group of anomeric carbon is present on the opposite

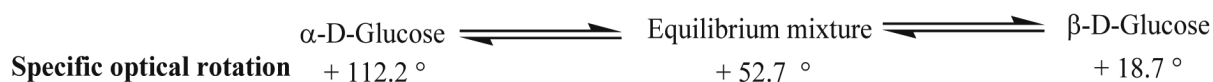
side to the terminal primary alcoholic ($-\text{CH}_2\text{OH}$) group then it is known as α -D-glucose. Similarly, if the hydroxyl ($-\text{OH}$) group of anomeric carbon is present on the same side to the terminal primary alcoholic ($-\text{CH}_2\text{OH}$) group then it is known as β -D-glucose.



7. Mutarotation:

Two distinct configurations (α and β) of the hemiacetals and hemiketals can occur when the cyclic structure open and re-closes due to the rotation of carbon atom bearing the reactive carbonyl group. The carbon atom which is involved in this rotation is known as anomeric carbon and the obtained two forms are termed as anomers. Mutarotation is defined as the change in specific optical rotation representing the interconversion of α - and β -forms to an equilibrium mixture.

Example: The specific optical rotation of freshly prepared solution of α -D-glucose and β -D-glucose in water is $+112.2^\circ$ and $+18.7^\circ$ respectively. But the specific optical rotation of both α -D-glucose and β -D-glucose gradually changes and attains equilibrium with a constant value of $+52.7^\circ$ due to mutarotation of glucose. The equilibrium mixture contains 36 % of α -D-glucose, 63 % of β -D-glucose and 1 % of open chain form.



Biological Significance of Carbohydrates

1. For all organism carbohydrates are the principal dietary source of energy (4 Cal/g).
2. Carbohydrates are used as a precursor for the synthesis of many organic compounds like fats and amino acids. Degradation products of carbohydrates act as "promoters" or "catalysts".
3. In the form of glycoprotein and glycolipids carbohydrates participate in the cell membrane structure and important cellular functions like cell growth, adhesion and fertilization.
4. For many organism carbohydrates are the structural components including cellulose fiber of plants, exoskeleton of some insects and the cell wall of microorganisms.
5. The immediate energy demands of the biological systems are satisfied by carbohydrates as glycogen (storage form of energy).

6. To the mammals except ruminant, glucose is the most important energy source of carbohydrates.
7. In medicinal practice dextrose is frequently used.
8. Erythrocytes and brain cells utilize glucose solely for energy purposes.
9. Glucose can be converted to glycogen (storage form of energy), galactose (component of lactose) and ribose (nucleic acid component).
10. High concentration of fructose is present in the semen which produces energy for motility of sperms. Sperms utilize fructose for energy. Fructose is formed in the seminiferous tubular epithelial cells from glucose.
11. Large amount of maltose present in several food preparations particularly baby foods are produced by hydrolysis of grains. Disaccharides are easily digestible from the nutritional point of view.
12. The lactose is synthesized from glucose in lactating mammary gland by the duct epithelium. For the newborn baby good source of energy is lactose present in breast milk.
13. A non-pathogenic *Coliform bacillus* (*E. coli*) usually ferments lactose, whereas pathogenic *Typhoid bacillus* does not ferment lactose generally. This test is used to distinguish two microorganisms.
14. *E. coli* and *A. aerogenes* present in milk converts milk to lactic acid in many organisms.
15. Osmotic condition of the blood is changed when sucrose is administered parentally which causes flow of water from the tissues into blood.
16. Inulin a homoglycans composed of fructose is used in estimation of GFR (Glomerular filtration rate) to assess the renal function. It is also used for the estimation of body water i.e., ECF (extra cellular fluid).
17. Heparin is a mucopolysaccharide used as anticoagulant.
18. Cellulose is non-digestible carbohydrates which decrease the intestinal absorption of glucose and cholesterol thereby increases bulk of faeces. Hence, cellulose is used to avoid constipation.
19. In joints the mucopolysaccharide hyaluronic acid act as shock absorbent and lubricant.
20. Hyaluronidase is an enzyme present in semen that degrades the gel (contains hyaluronic acid) present around ovum. Hence, it may lead to effective penetration of sperm into the ovum.
21. The solutions of dextrin are used as "mucilages".
22. The solution of dextran having molecular weight approximately 75,000 has been used as plasma expander.
23. In constipation, agar is used as laxative and agar is used in agar plate for culture medium preparation.
24. Certain derivatives of carbohydrates are used as drugs. **Example:** Cardiac glycosides like digoxin and digitoxin and antibiotics like aminoglycosides and streptomycin.
25. Antifreeze glycoprotein present in antarctic fish is responsible for their survival below -2 °C.
26. Derangement of glucose metabolism is seen in diabetes mellitus, glycogen storage diseases and galactosemia.
27. Certain pathological conditions such as cataract, nephropathy is due to the accumulation of sorbitol and dulcitol in the tissues.

Lipids

In Greek, lipos means "fat". **Lipids are defined as organic compounds which are relatively insoluble in water and soluble in organic solvents like alcohol, ether, etc, potentially related to fatty acids and utilized by the living cells.** Chemically, lipids are esters of fatty acids.

The polar groups present in lipids are much smaller than their non-polar portion, hence, they are insoluble in water. Although they have several uses in medicine and industries, the function of oils and fats is mainly the storage of energy. Lipids are the chief concentrated storage form of energy and they play a role in cellular structure and various other biochemical functions. It is a heterogeneous group of compounds and are mostly small molecules. Lipids differ from the rest of body compounds because of their hydrophobic and non-polar nature. Lipids are not polymers like polysaccharides, proteins and nucleic acid.

Throughout the plant and animal kingdom, lipids are distributed widely. In plants, they occur in the seeds, nuts and fruits. In animals, lipids are stored in adipose tissues, nervous-tissues, and bone marrow. Neutral lipids are uncharged lipids. **Example:** Monoacylglycerol, diacylglycerol, triacylglycerol, cholesterol and cholesteryl esters.

Classification of Lipids

Based on the composition, lipids are broadly classified into four major types as follows.

They are,

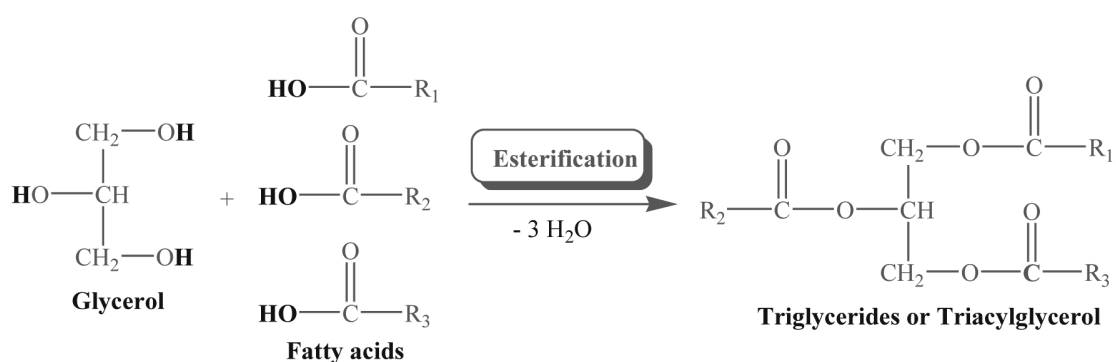
1. Simple lipids
2. Compound lipids (or) Complex lipids
3. Derived lipids
4. Miscellaneous lipids

1. Simple lipids:

These lipids, upon hydrolysis, yield one or more fatty acids and an alcohol. Generally, simple lipids are esters of fatty acids. The simple lipids are further classified based on nature of the alcohol present into two major types as,

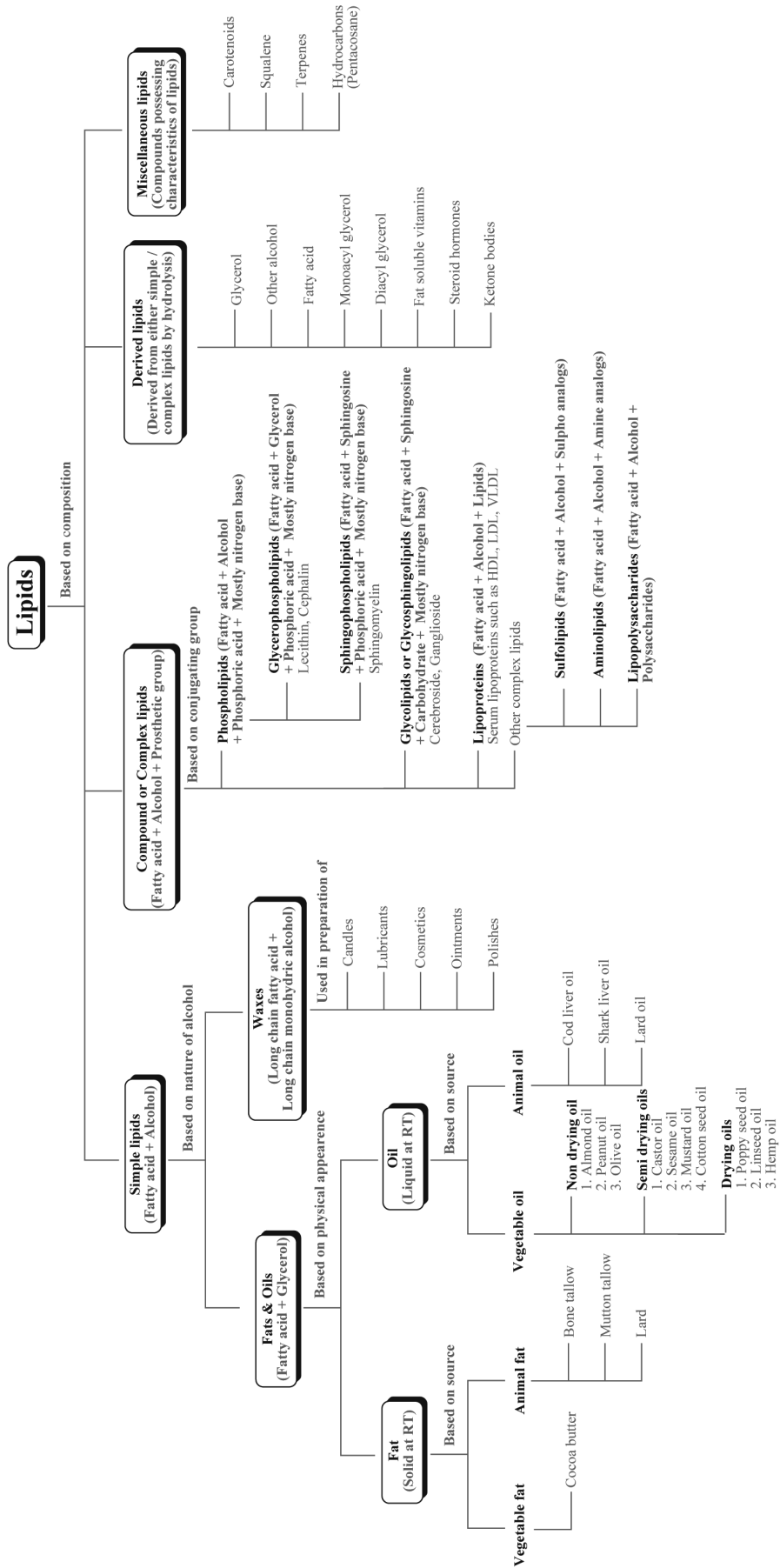
- (a) Fats & oils
- (b) Waxes

(a) **Fats and oils or triacylglycerols:** These are esters of fatty acids with glycerol. Fats and oils are glyceryl esters of higher fatty acids like palmitic, stearic, oleic, linoleic, and linolenic acids. In fats and oils (triglyceride), one molecule of glycerol is linked with three molecules of higher fatty acids by ester linkage.



Triglycerides are of two types based on the nature of fatty acids. If all the three fatty acids attached to glycerol are identical or same, then the triglycerides are known as simple triglycerides. In case if three fatty acids attached to glycerol are not identical or different, then the triglycerides are known as mixed triglycerides. Natural fats are mainly composed of mixed triglycerides. As these glycerides have no free acidic or basic groups, they are often termed as neutral fats.

The composition of fats and oils are the same but they differ in their physical appearance at room temperature (RT). They are distinguished on the basis of their melting ranges. The oils are liquids at ordinary temperature while the fats are solids or semisolids (This distinction is not quite sharp and depends upon the climate and seasonal variation. **Example:** Coconut oil, sesame oil, and ghee are liquids in summer and solids in winter in our country). Fats are solid at room temperature and contain mostly saturated fatty acids like stearic and palmitic acids. Hence, melts at higher temperature. (**Example:** Vegetable fats like cocoa butter and animal fats like bone tallow, mutton tallow and lard).



Oils are liquid at room temperature and contain mostly unsaturated fatty acids like oleic acid. Hence, melts at lower temperature. (**Example:** Non-drying oils like almond oil, peanut oil, and olive oil, semi drying oils like castor oil, sesame oil, mustard oil and cotton seed oil, and drying oils like poppy seed oil, linseed oil and hemp oil).

(b) **Waxes:** These are esters of long chain fatty acids and long chain monohydric alcohols or sterols. The alcohols present in the waxes are other than glycerol. This alcohol may be aliphatic or alicyclic in nature. In general, the waxes are used in many industries for the production of candles, lubricants, cosmetics, ointments, polishes, etc.

2. Complex lipids (or) compound lipids:

These lipids contain additional or prosthetic groups such as phosphoric acid, proteins, carbohydrates, sulphate, nitrogen base, etc. along with fatty acids and alcohol. Based on the nature of additional groups present, the complex lipids are further subdivided into many types as follows.

(a) **Phospholipids:** In this complex lipid, the prosthetic group present is phosphoric acid. Most of the phospholipids also contain nitrogen bases. Based on the alcohol present in the phospholipids, it was further subdivided into two categories as,

1. **Glycerophospholipids:** It is composed of fatty acids, glycerol, phosphoric acid, and nitrogen bases. **Example:** Lecithin and cephalin.

2. **Sphingophospholipids:** It is composed of fatty acids, sphingosine (alcohol), phosphoric acid and nitrogen bases. **Example:** Sphingomyelin.

(b) **Glycolipids:** It is otherwise known as glycosphingolipids because of the presence of alcohol sphingosine. It is composed of fatty acids, sphingosine (alcohol), carbohydrate and nitrogen bases. **Example:** Cerebroside and ganglioside.

(c) **Lipoproteins:** It is composed of fatty acids, alcohol and lipids. **Example:** Serum lipoproteins such as HDL, LDL and VLDL.

(d) **Other complex lipids:** Among various other complex lipids, sulpholipids, aminolipids, and lipopolysaccharides are important.

3. **Derived lipids:** These compounds possess characteristics of lipids and are obtained either from simple or complex lipids by hydrolysis. **Example:** Glycerol, fatty acid, other alcohol, monoacylglycerol, diacylglycerol, fat soluble vitamin, steroid hormones and ketone bodies.

4. **Miscellaneous lipids:** Large numbers of compounds possess the characteristics of lipids and these compounds come under miscellaneous lipids. **Example:** Carotenoids, squalene, hydrocarbons like pentacosane, terpenes, etc.

Biological Significance of Lipids

1. Lipids are the concentrated fuel reserve of the body which is the most important role of lipids.
2. Lipid also acts as an insulating material and protects the internal organs.
3. In addition, lipids also give shape and smooth appearance to the body.
4. Dietary fat is important for the sufficient absorption of the essential fatty acid and fat-soluble vitamins from the food.
5. Lipids, particularly phospholipids and cholesterol are the major constituents of biological membrane structure and regulates the membrane permeability.
6. Lipids serve as a source of fat-soluble vitamins such as vitamin A, D, E, and K.
7. Some biologically active materials which serve as important building blocks of compounds like acetic acid are derived from lipids.
8. Lipids, especially steroid hormones and prostaglandins are important cellular metabolic regulators.
9. The cellular respiration and the conformation of ETC is maintained by the phospholipids particularly lecithin, cephalin and cardiolipin.

10. From the intestine, fats are absorbed by the participation of phospholipids.
11. Lipoproteins are involved in the transport of lipids and the phospholipids are necessary for the synthesis of different lipoproteins.
12. Phospholipids are regarded as lipotropic factors because in the liver it prevents the accumulation of fat.
13. Unsaturated fatty acids and arachidonic acids are released from phospholipids only. Eicosanoids such as prostaglandins, thromboxane, prostacyclins, etc. are biosynthesized from archidonic acid and unsaturated fatty acids only.

Fatty Acids

The simplest forms of lipids are fatty acids. In natural fats and oils, fatty acids occur mainly as esters but do occur in the unesterified form as free fatty acids. Fatty acids are carboxylic acids with hydrocarbon side chains. Fatty acids of natural fats are usually straight chain derivatives, containing even numbers of carbon atoms, as they are synthesized from two carbon units. The chain may be saturated or unsaturated. Compared to plant origin fatty acids (contain epoxy, keto and hydroxyl group and cyclopentane ring in structure), animal origin fatty acids possess a simple structure.

Classification of Fatty Acids

Fatty acids are classified in many different ways as follows,

1. Classification based on total number of carbon atoms
 2. Classification based on length of hydrocarbon chain
 3. Classification based on nature of hydrocarbon chain
1. **Classification based on total number of carbon atoms**

Fatty acids are broadly classified into two major types based on the total number of carbon atoms present is even number or odd number.

- (a) **Even number of carbon atom chain fatty acids:** The total number of carbons present in this fatty acid is an even number (2, 4, 6 and similar series). In general, even carbons (14 to 20 carbons) are present in most of the fatty acids that occur in natural lipids. The reason behind this concept is the occurrence of fatty acid biosynthesis with sequential addition of two carbon units. **Example:** Palmitic acid (contains 16 carbons in total), stearic acid (contains 18 carbons in total), etc.
- (b) **Odd number of carbon atom chain fatty acids:** The total number of carbons present in this fatty acid is an odd number (1, 3, 5 and similar series). Odd numbered fatty acids are present in milk and are also found in microbial cell walls. **Example:** Propionic acid (contains 3 carbons in total), valeric acid (contains 5 carbons in total), etc.

2. **Classification based on length of hydrocarbon chain**

Based on the length of the hydrocarbon chain present in fatty acid, it was broadly classified into three major types. They are,

- (a) **Short chain fatty acids:** This fatty acid consists of 2 to 7 carbon atoms.
- (b) **Medium chain fatty acids:** This fatty acid consists of 8 to 15 carbon atoms.
- (c) **Long chain fatty acids:** This fatty acid consists of 16 and above (usually up to 24) carbon atoms.

3. **Classification based on nature of hydrocarbon chain**

Fatty acids are subdivided into two major groups based on the nature of hydrocarbon chains, particularly saturation conditions. They are,

- (a) **Saturated fatty acids:** Unsaturation (double or triple bonds) is absent in these fatty acids. $\text{CH}_3-(\text{CH}_2)_n-\text{COOH}$ is the general structural formula of saturated fatty acids. They are named by adding the suffix “-anoic” after the hydrocarbon with the same number of carbon atoms.

Example: Propanoic acid, pentanoic acid or valeric acid, n-hexadecanoic acid or palmitic acid, n-octadecanoic acid or stearic acid, etc.

(b) **Unsaturated fatty acids:** Unsaturation (double or triple bonds) is present in these fatty acids. In systematic name, the suffix “-enoic” is added after the hydrocarbon with the same number of carbon atoms. Depending on the number of unsaturated bonds present or the degree of unsaturation, it is further classified into two different types as follows,

1. **Monounsaturated (Monoethenoid, monoenoic) fatty acids:** Contains one double bond.
Example: Palmitoleic acid and oleic acid.

2. **Polyunsaturated (polyethenoid, polyenoic) fatty acids:** It is commonly known as PUFA and contains two or more double bonds. These fatty acids are not synthesized by the body due to the lack of double bond introducing enzymes beyond 9 to 10 carbons. It is necessary to take through dietary sources. Hence, PUFA is also called as **essential fatty acid**.
Example: Linoleic acid, linolenic acid and arachidonic acid.

Nomenclature of Fatty Acids

1. Systematic nomenclature of fatty acids is based on the name of hydrocarbons with the same number of carbon atoms. In systematic nomenclature, the final ‘e’ in the name of the hydrocarbon is replaced by the suffix ‘oic acid’. **Example:** Propanoic acid (the corresponding hydrocarbon is ‘propane’. In this, final ‘e’ is replaced by the suffix ‘oic acid’ i.e., “propane - e + oic acid = propanoic acid”)
2. In general, saturated fatty acids end with a suffix ‘anoic acid’. **Example:** Octanoic acid and decanoic acid. Similarly, unsaturated fatty acids with double bonds end with a suffix ‘enoic acid’. **Example:** Octadecenoic acid (oleic acid) and hexadecenoic acid (palmitoleic acid).
3. The C-1 would be carboxyl carbon of a fatty acid and the C-2 would be α -carbon, the C-3, C-4, C-5 and C-6 would be β , γ , δ and ϵ carbon, respectively. The end methyl carbon is known as the ω carbon or n-carbon atom.

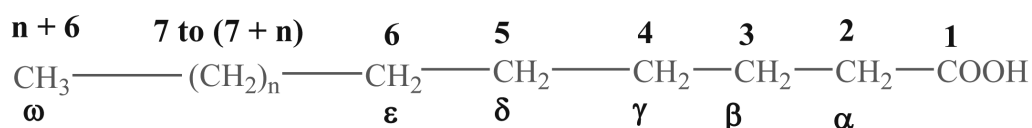


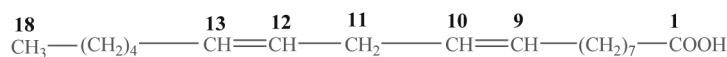
Table 1.2 List of biochemically important fatty acids.

S.No.	Common name	IUPAC name	Structure	Codes
I. Saturated fatty acids				
1	Acetic acid	n-Ethanoic acid	CH ₃ COOH	2: 0
2	Propionic acid	n-Propanoic acid	CH ₃ -CH ₂ -COOH	3: 0
3	Butyric acid	n-Butanoic acid	CH ₃ -(CH ₂) ₂ -COOH	4: 0
4	Valeric acid	n-Pentanoic acid	CH ₃ -(CH ₂) ₃ -COOH	5: 0
5	Caproic acid	n-Hexanoic acid	CH ₃ -(CH ₂) ₄ -COOH	6: 0
6	Caprylic acid	n-Octanoic acid	CH ₃ -(CH ₂) ₆ -COOH	8: 0
7	Capric acid	n-Decanoic acid	CH ₃ -(CH ₂) ₈ -COOH	10: 0
8	Lauric acid	n-Dodecanoic acid	CH ₃ -(CH ₂) ₁₀ -COOH	12: 0
9	Myristic acid	n-Tetradecanoic acid	CH ₃ -(CH ₂) ₁₂ -COOH	14: 0
10	Palmitic acid	n-Hexadecanoic acid	CH ₃ -(CH ₂) ₁₄ -COOH	16: 0
11	Stearic acid	n-Octadecanoic acid	CH ₃ -(CH ₂) ₁₆ -COOH	18: 0
12	Arachidic acid	n-Eicosanoic acid	CH ₃ -(CH ₂) ₁₈ -COOH	20: 0
13	Behenic acid	n-Docosanoic acid	CH ₃ -(CH ₂) ₂₀ -COOH	22: 0
14	Lignoceric acid	n-Tetracosanoic acid	CH ₃ -(CH ₂) ₂₂ -COOH	24: 0

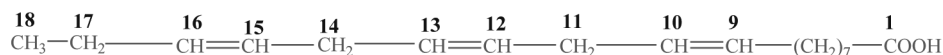
Table 1.2 contd...

II. Unsaturated fatty acids				
15	Palmitoleic acid	cis-9-Hexadecenoic acid	$\text{CH}_3-(\text{CH}_2)_5-\text{CH}=\text{CH}-(\text{CH}_2)_7-\text{COOH}$	16: 1: 9
16	Oleic acid	cis-9-Octadecenoic acid	$\text{CH}_3-(\text{CH}_2)_7-\text{CH}=\text{CH}-(\text{CH}_2)_7-\text{COOH}$	18: 1: 9
17	Linoleic acid	cis, cis-9,12-Octadecadienoic acid	$\text{CH}_3-(\text{CH}_2)_4-\text{CH}=\text{CH}-\text{CH}_2-\text{CH}=\text{CH}-(\text{CH}_2)_7-\text{COOH}$	18: 2: 9, 12
18	Linolenic acid	All cis-9,12,15-Octadecatrienoic acid	$\text{CH}_3-\text{CH}_2-\text{CH}=\text{CH}-\text{CH}_2-\text{CH}=\text{CH}-\text{CH}_2-\text{CH}=\text{CH}-(\text{CH}_2)_7-\text{COOH}$	18: 3: 9, 12, 15
19	Arachidonic acid	All cis-5,8,11,14-Eicosatetraenoic acid	$\text{CH}_3-(\text{CH}_2)_4-\text{CH}=\text{CH}-\text{CH}_2-\text{CH}=\text{CH}-\text{CH}_2-\text{CH}=\text{CH}-(\text{CH}_2)_3-\text{COOH}$	20: 4: 5, 8, 11, 14

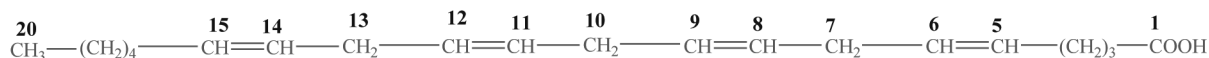
4. For indicating the number and position of the double bonds, various conventions are used. **Example:** In fatty acids, the presence of a double bond between carbon atoms 9 and 10 is indicated by Δ^9 . The number of carbon atoms, the number of double bonds, and the positions of the double bonds are widely indicated by using this convention only.



Linoleic acid [$\text{C}_{18}, \Delta^{9,12}$]



Linolenic acid [$\text{C}_{18}, \Delta^{9,12,15}$]



Arachidonic acid [$\text{C}_{20}, \Delta^{5,8,11,14}$]

5. In biochemistry, fatty acids are represented in shorthand notation using numbers instead of writing the full structures. The general rule followed is that the total number of carbon atoms are written first, followed by the number of double bonds present, and finally the first carbon position of the double bonds starting from the carbonyl end. **Example:** Palmitic acid is written as 16: 0, oleic acid is written as 18: 1: 9 and arachidonic acid is written as 20: 4: 5, 8, 11, 14.
6. Various saturated and unsaturated fatty acids which are biologically important are listed in the Table 1.2.

Biological Significance of Fatty Acids

1. Fatty acids are the cellular fuel sources of the body.
2. Fatty acids are the composition of hormones and lipids.
3. Fatty acids play a role in the modification of proteins.
4. Essential fatty acids are the major lipids present in the biological membrane and are required for the membrane structure and function.
5. Essential fatty acids are useful for the transportation of cholesterol.
6. Essential fatty acids prevent fatty liver.
7. Essential fatty acids are useful for the synthesis of eicosanoids such as prostaglandin, prostacycline, thromboxane, leukotriene, etc.

8. Fatty acids are involved in a wide range of biological signaling pathways.
9. Fatty acids play a role in signal-transduction pathways.
10. Some skin-care products contain fatty acids, which can help to maintain healthy skin appearance and function.
11. Commercially fatty acids are used not only in the production of numerous food products but also in soaps, detergents, and cosmetics.
12. Fatty acids, particularly omega-3 fatty acids, are also commonly sold as dietary supplements.

Nucleic Acids

Nucleic acids are the polynucleotides and nucleotides are composed of nitrogen base, pentose sugar and phosphate group. Nucleic acids primarily serve as repositories and transmitters of genetic information. The pentose sugar present in RNA and DNA is ribose and 2-deoxyribose, respectively. Either directly or indirectly, nucleotides participate in almost all biochemical processes. Nucleotides are the structural components of nucleic acids such as DNA and RNA and co-enzymes. In addition, several metabolic reactions are also regulated by nucleotides.

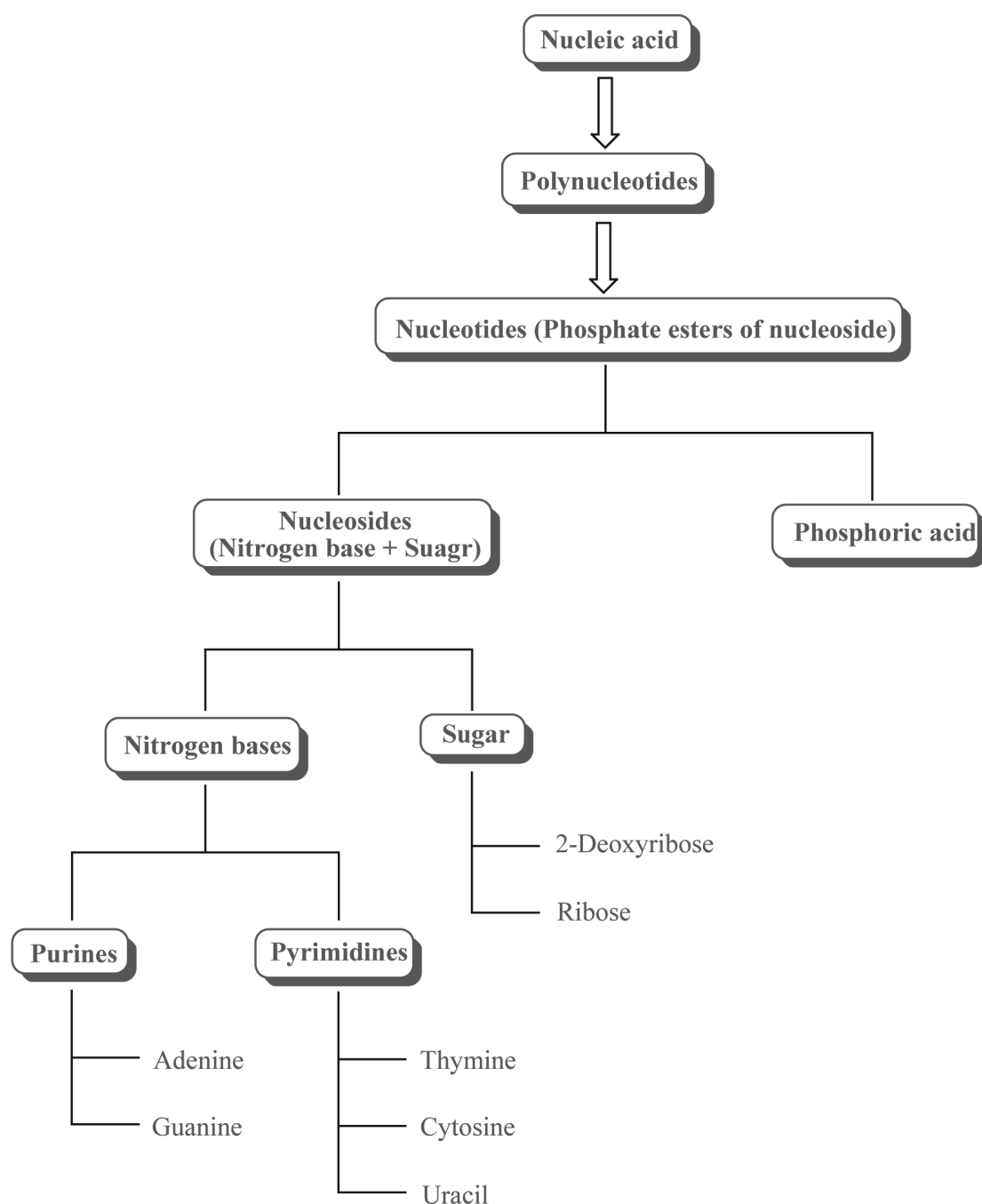
Classification or Types of Nucleic Acids

Nucleic acids are broadly classified into two major types based on the sugar molecules present in them. They are,

1. Deoxyribonucleic acid or DNA
 2. Ribonucleic acid or RNA
1. **Deoxyribonucleic acid or DNA:** It is a polymer of deoxyribonucleotides composed of deoxyribose sugar, nitrogen bases such as purines (adenine & guanine), pyrimidines (thymine and cytosine) and phosphate group.
 2. **Ribonucleic acid or RNA:** It is a polymer of ribonucleotides composed of ribose sugar, nitrogen base such as purines (adenine & guanine), pyrimidines (uracil and cytosine), and phosphate group.

Chemical Nature of Nucleic Acids

Nucleic acids are chemically polynucleotides held by 3'- and 5'-phosphate bridges or nucleic acids are built up by the monomeric units known as nucleotides. Upon hydrolysis, nucleic acids produce nucleotides. Further, the hydrolysis of nucleotides produces nucleosides and phosphoric acid. Hence, **nucleotides are defined as phosphate esters of nucleosides**. Hydrolysis of nucleoside produces nitrogen base and sugar. Nucleosides are chemically composed of nitrogen base and sugars. In nucleic acids, there are two different types of nitrogen bases such as purines and pyrimidines are present. Adenine and guanine are two purine nitrogen bases and thymine, cytosine and uracil are three pyrimidine nitrogen bases present in nucleic acid. Out of three pyrimidine nitrogen bases, thymine and cytosine is present in DNA and cytosine and uracil is present in RNA. In nucleic acids, two different types of sugar molecules such as ribose and deoxyribose are present. In that, deoxyribose sugar is present in DNA and ribose sugar is present in RNA.

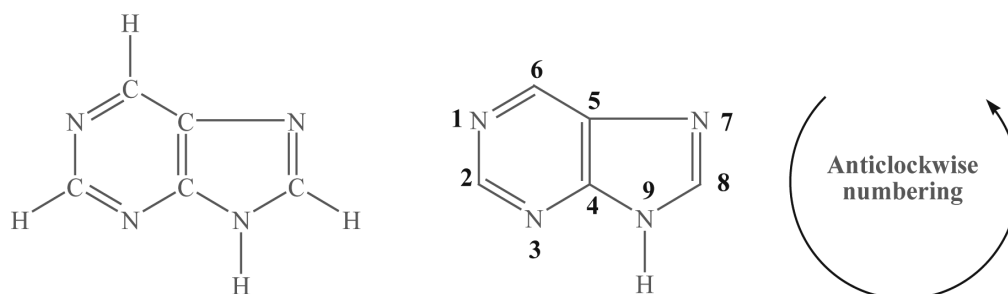


Nitrogen Bases

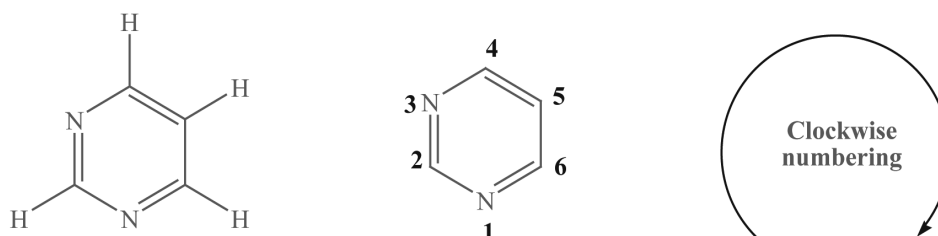
Nitrogen bases are chemically aromatic heterocyclic compounds. Two types of nitrogen bases present in nucleic acid are mentioned below.

1. Purines
2. Pyrimidines

In general, purines are numbered in anti-clockwise direction whereas pyrimidines are numbered in clockwise direction. The general structures of purines and pyrimidines are represented in the below structures.



General structure of purine nitrogen base



General structure of pyrimidine nitrogen base

Purines: Adenine and guanine are the two purine bases present in the nucleic acids. Both adenine and guanine are present in DNA and RNA. Existence of molecules in a lactam (keto) form and lactim (enol) form is known as tautomerism. Purine with an oxo ($C=O$) functional group exhibits tautomeric forms as follows.

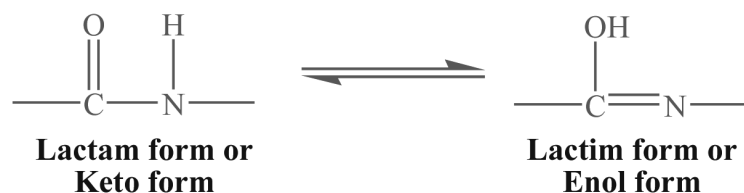
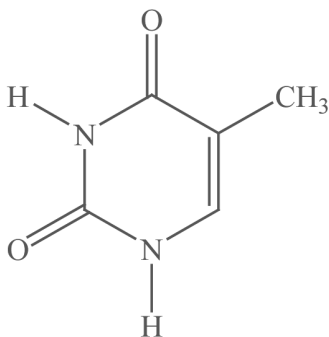
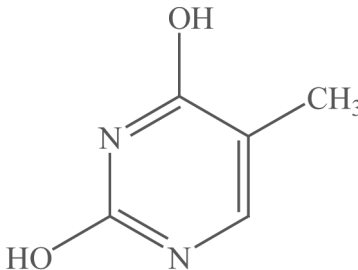
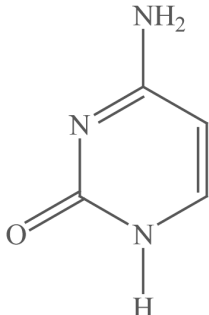
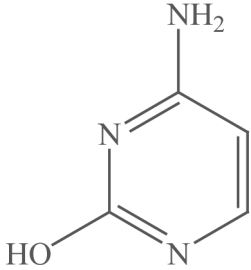
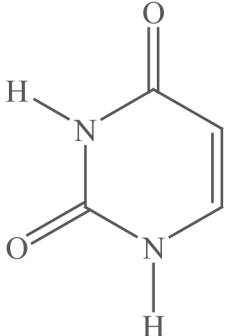
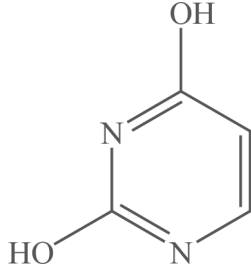


Table 1.3 Chemical structures of nitrogen bases.

S. No.	Name of base	Chemical name	Lactam form or Keto form	Lactim form or Enol form
A. Purine bases				
1	Adenine	6-Aminopurine (or) 9H-Purin-6-amine		---
2	Guanine	2-Amino-6-oxopurine (or) 2-Amino-1H-purin- 6(9H)-one		

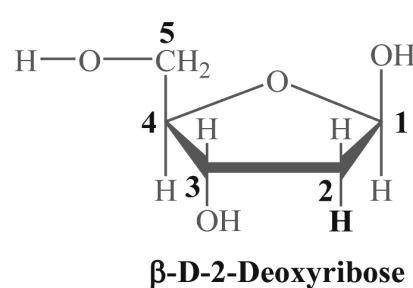
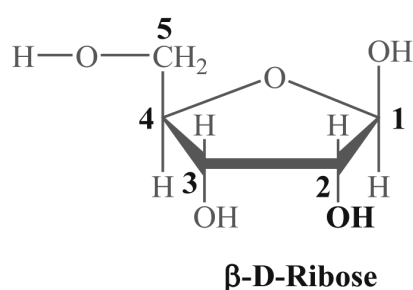
Table 1.3 contd...

S. No.	Name of base	Chemical name	Lactam form or Keto form	Lactim form or Enol form
B. Pyrimidine bases				
3	Thymine	2,4-Dioxy-5-methylpyrimidine or 5-Methyluracil		
4	Cytosine	2-Oxo-4-aminopyrimidine		
5	Uracil	2,4-Dioxypyrimidine (or) Pyrimidine – 2, 4 (1H, 3H) - dione		

Pyrimidines: Thymine, cytosine and uracil are the three pyrimidine bases present in the nucleic acids. Thymine is present only in DNA and uracil is present only in RNA. Cytosine is present in both DNA and RNA. Like purines, pyrimidines with oxo (C=O) functional groups exhibit tautomeric forms. At physiological pH lactam forms are predominantly present. Chemical structures of various purine and pyrimidine nitrogen bases are listed in Table 1.3.

Sugars

Nucleic acid contains pentose sugars (five carbon monosaccharides) such as ribose and 2'-deoxyribose. For differentiation from nitrogen base numbering, sugar molecule numbers are represented with an associated prime ('). The two sugars mentioned above are differing in their structure at C-2' only. Deoxyribose possess one less oxygen at C-2' compared to ribose. DNA contains 2'-deoxyribose and RNA contains ribose sugar.



Nomenclature of Nucleotides

Nucleosides are formed when pentose sugars are added to the nitrogen bases. If the sugar attached is ribose it is called ribonucleoside. The ribonucleosides of bases adenine, guanine, cytosine and uracil are adenosine, guanosine, cytidine and uridine, respectively. If the sugar attached is 2-deoxyribose then it is called deoxyribonucleoside. The prefix deoxy is added to the corresponding ribonucleoside name to get the deoxyribonucleoside name. The deoxyribonucleosides of bases adenine, guanine, cytosine and thymine are deoxyadenosine, deoxyguanosine, deoxycytidine and deoxythymidine, respectively.

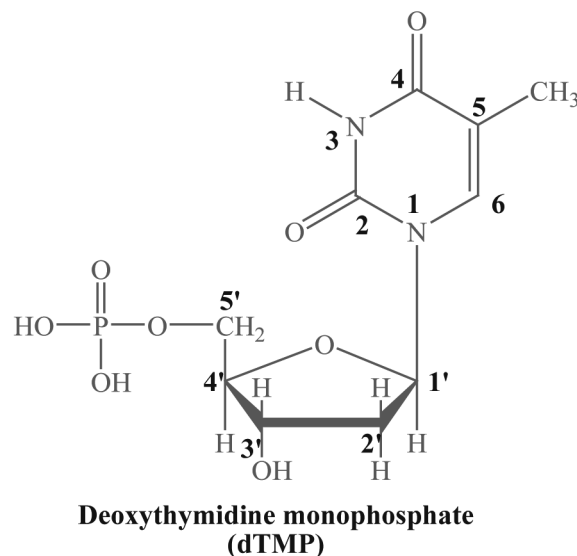
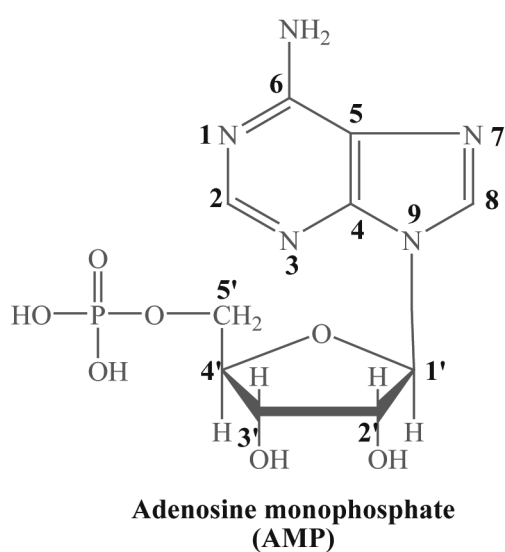
When a nucleoside is attached to a single phosphate moiety, the term mononucleotide is used. For example, adenosine attached to single phosphate moiety is named as adenosine monophosphate (AMP) which is composed of adenine, ribose and phosphate moiety. The various bases present in the nucleic acid and their corresponding nucleoside, mononucleotides and abbreviations are listed in the Table 1.4.

Table 1.4 Various bases, nucleoside, mononucleotides present in nucleic acid.

S. No.	Nitrogen base	Nucleoside	Mononucleotide	Abbreviation
A. Ribonucleotide				
1	Adenine (A)	Adenosine (Adenine + Ribose)	Adenosine-5'-monophosphate or adenylate (Adenosine + Phosphate)	AMP
2	Guanine (G)	Guanosine (Guanine + Ribose)	Guanosine-5'-monophosphate or guanylate (Guanosine + Phosphate)	GMP
3	Cytosine (C)	Cytidine (Cytosine + Ribose)	Cytidine-5'-monophosphate or cytidylate (Cytidine + Phosphate)	CMP
4	Uracil (U)	Uridine (Uracil + Ribose)	Uridine-5'-monophosphate or uridylate (Uridine + Phosphate)	UMP
B. Deoxyribonucleotide				
5	Adenine (A)	Deoxyadenosine (Adenine + 2-Deoxyribose)	Deoxyadenosine-5'-monophosphate or Deoxyadenylate (Deoxyadenosine + Phosphate)	dAMP
6	Guanine (G)	Deoxyguanosine (Guanine + 2-Deoxyribose)	Deoxyguanosine-5'-monophosphate or Deoxyguanylate (Deoxyguanosine + Phosphate)	dGMP
7	Cytosine (C)	Deoxycytidine (Cytosine + 2-Deoxyribose)	Deoxycytidine-5'-monophosphate or Deoxycytidylate (Deoxycytidine + Phosphate)	dCMP
8	Thymine (T)	Deoxythymidine (Thymine + 2-Deoxyribose)	Deoxythymidine-5'-monophosphate or Deoxythymidylate (Deoxythymidine + Phosphate)	dTMP

Binding of nucleotide components: The pentose sugars are bonded to nitrogen bases by N-glycosidic bonds. C-1' of sugars are covalently attached to the N-9 of purine bases or N-1 of pyrimidine bases to form corresponding nucleosides. In nucleosides, the hydroxyl group present at C-5' or C-3' of sugar molecules is esterified with phosphates to produce corresponding 5'- or 3'- monophosphates (i.e., nucleotide). Generally, esterification takes place at C-5', hence 5' is usually omitted while writing names of nucleotides. In case if esterification takes place at C-3' then 3' is included while writing names of nucleotides. The structures of some nucleotides such as AMP & dTMP are given below.

Nucleoside di and triphosphates: Only one phosphate moiety is present in nucleoside monophosphates like AMP, GMP, CMP, UMP, dAMP, dGMP, dCMP and dTMP. When second or third phosphates are attached to nucleoside it produced nucleoside diphosphates like ADP, GDP, CDP, UDP, dADP, dGDP, dCDP and dTDP or nucleoside triphosphates like ATP, GTP, CTP, UTP, dATP, dGTP, dCTP and dTTP, respectively. The negative charges of the phosphate groups are responsible for anionic properties of nucleotides and nucleic acids.



Biological Significance of Nucleic Acids

The various biological significance of nucleic acids are given under the following different headings.

(a) DNA

1. DNA is the chemical basis of heredity organized into genes. The fundamental unit of genetic information is gene.
2. DNA is regarded as the reserve bank of genetic information.
3. Over millions of years, identities of different species are maintained by DNA only.
4. In addition, DNA controls every aspect of cellular functions.
5. Through RNA mediation, gene controls the synthesis of proteins.
6. DNA is the precursor for the synthesis of RNA by a process called transcription.

(b) RNA

1. RNA is useful for the synthesis of protein by a process called translation.
2. To synthesize proteins, mRNA transfers genetic information from genes to ribosomes.
3. For protein synthesis, tRNA transfers amino acids to mRNA.
4. rRNA provides a structural framework for ribosomes.
5. hnRNA serves as a precursor for the synthesis of all RNAs including mRNA.
6. snRNA is involved in processing of mRNA.
7. snoRNA plays a major role in processing of rRNA.
8. scRNA is involved in the secretion of proteins for export.
9. In bacteria, tmRNA is mostly present and it facilitates the degradation of incorrectly synthesized proteins by adding short peptide tags to proteins.

(c) Ribozymes

Ribozymes are types of RNA which act as enzymes. Before the occurrence of protein enzymes during evolution, ribozymes were probably functioning as a catalyst. The following are the selected list of ribozymes and their corresponding biochemical reactions.

1. In protein synthesis rRNA is involved in peptide bond formation.
2. *Ribonuclease P (RNase P)* is a component of RNA and is a ribozyme containing protein. It is involved in cleavage of RNA particularly tRNA precursors to generate mature tRNA molecules. It is also involved in ligation.
3. Self-splicing RNA is involved in cleavage of DNA.
4. RNAs of spliceosome is involved in splicing of RNA.
5. *In vitro* selected RNAs are involved in RNA polymerization, RNA aminoacylation, RNA phosphorylation, redox reactions, glycoside bond formation and disulfide exchange.

(d) Nucleotides

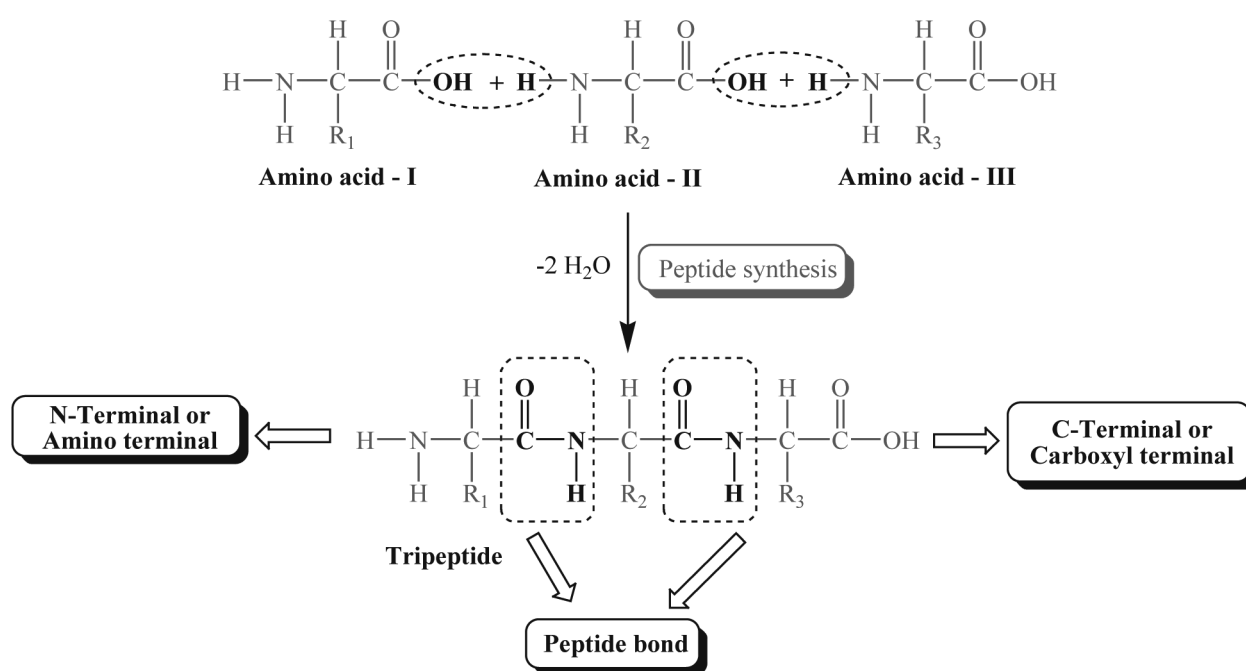
1. Nucleotides are the monomeric unit or building blocks of nucleic acid.
2. Nucleotides are the structural components of some B-complex vitamin co-enzymes like FAD, NAD⁺, etc.
3. ATP is one of the important nucleotides which is energy currency of the cell involved in energy reactions.
4. In addition, nucleotides also regulate the metabolic reactions.
5. Clinically some nucleotide analogs are used due to its pharmacological properties. They are,
 - (a) Allopurinol is used in the treatment of gout and hyperuricemia.
 - (b) Many nucleotide analogs are used in the treatment of cancers. **Example:** 6-Mercaptopurine, 5-fluorouracil, 3-deoxyuridine, 5-iodouracil, 5- or 6-azauridine, 5- or 6-azacytidine and arabinosylcytosine.
 - (c) During transplantation azathioprine is used to suppress the immunological rejection of transplanted organs.
 - (d) Neurological disease and viral encephalitis are treated by using arabinosyladenine.
 - (e) Drugs like zidovudine, 3-azido-2',3'-dideoxythymidine and didanosine are used in the treatment of AIDS.

Proteins

Proteins are the most abundant organic substances present in the living system. 50 % of the cellular dry weight is composed of proteins. Cell forms the fundamental basis of structure and functions of life. The term protein is obtained from Greek word "**proteios**" means "holding the first place (or) primary". In 1838, Dutch chemist Mulder used the term "protein" for high molecular weight nitrogen rich and most abundant substances present in plants and animals.

Proteins and peptides are polyamides composed of L- α -amino acids bonded in a head to tail manner through the carboxyl function of one amino acid with the amino function of other amino acid. The amide linkage is called a peptide bond. Hence, proteins are known as **polypeptides**. In other words, building blocks of peptides and proteins are composed of amino acids. By a variety of methods proteins undergo hydrolysis and cleaved i.e., hydrolyzed into their constituent amino acids. As proteins contain nitrogen also it acts as a major source of nitrogen to the biological system.

Peptide linkage (-CO-NH-) is formed when two or more amino acids are joined together, and a chain of many amino acids is called as polypeptide. One or more polypeptide molecules are present in proteins. Peptide bonds covalently link the amino acids. Every polypeptide contains two ends, in that one end is known as amino terminal or N-terminal which has a free amino group and conventionally it is present in the left-hand amino acid. The other end is known as carboxyl terminal or C-terminal which has a free carboxyl group and conventionally it is present in the right-hand amino acid. The above figure of tripeptide shows three amino acids linked by two peptide bonds.



Elemental composition of proteins: Five major elements are predominantly present in proteins. They are, a) Carbon (50 to 55 %), b) Hydrogen (6 to 7 %), c) Oxygen (19 to 24 %), d) Nitrogen (13 to 19 %), and e) Sulphur (0 to 4 %). The other elements such as phosphorous, iron, copper, iodine, magnesium, manganese, zinc, etc. are also present in proteins. On an average about 16 % nitrogen is present in proteins. Hence, Kjeldahl's method of nitrogen estimation in laboratory is used to estimate the amount of proteins present in biological fluids and foods.

Classification of Proteins

Proteins are classified in three different ways as follows,

1. Functional classification of proteins
2. Chemical nature and solubility classification of proteins
3. Nutritional classification of proteins

1. Functional Classification of Proteins

In this type of classification, proteins are broadly classified into nine different types according to its functions they perform. They are,

1. **Structural proteins:** These proteins are basis for cellular structure. **Example:** Keratin present in hair and nail, collagen present in bones, etc.
2. **Catalytic proteins or Enzyme proteins:** Proteins exhibit its function as enzyme comes in this category. **Example:** Almost all enzymes except ribosome, *glucokinase*, *pepsin*, etc.
3. **Transport proteins:** These proteins are useful for the transport of some compounds. **Example:** Hemoglobin used for transport of oxygen, serum albumin used for the transport of bilirubin, etc.
4. **Storage proteins:** Proteins are stored in one form in this type. **Example:** Ovalbumin is the storage form of protein in egg, glutelin is the storage form of protein in endosperm of certain seeds of the grass family, etc.
5. **Defense proteins:** These proteins perform defense function in biological system. **Example:** Snake venom is the defense protein of snake, immunoglobulin is the defense protein of human, etc.
6. **Hormonal proteins:** These proteins exhibit their function as hormones. **Example:** Insulin, growth hormone, etc.

7. **Receptor proteins:** Receptors are chemically proteins. **Example:** Receptors for hormones, receptors for viruses, etc.
8. **Genetic proteins:** These proteins involved in genetic functions. **Example:** Nucleoprotein.
9. **Contractile proteins:** This protein plays a role in muscle contraction. **Example:** Actin, myosin, etc.

2. Chemical Nature and Solubility Classification of Proteins

Proteins are classified into three major types on the basis of increasing complexity in their structure. They are,

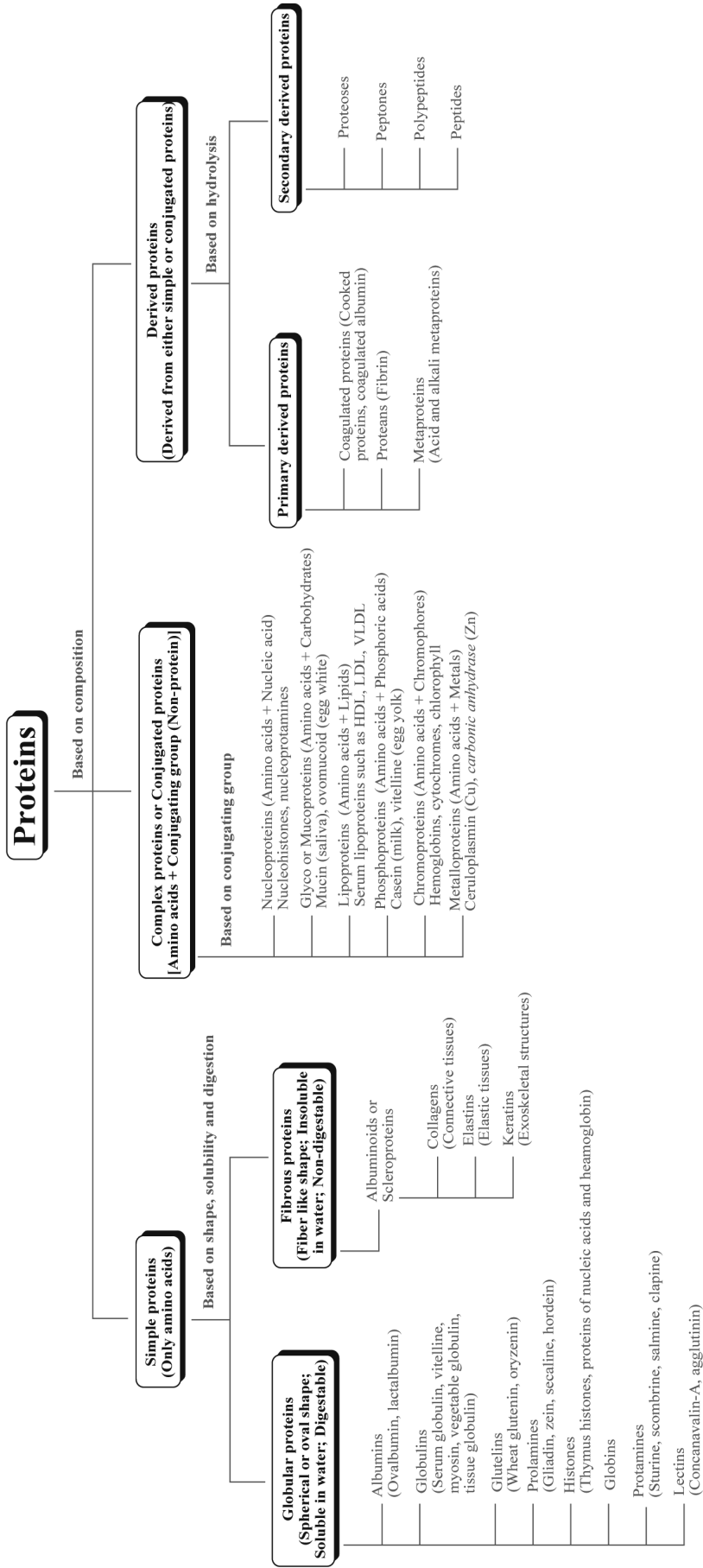
1. Simple proteins
2. Conjugated or complex proteins and
3. Derived proteins

1. **Simple proteins:** These proteins on hydrolysis yield only α -amino acids. They are further classified into two major categories based on shape, solubility and digestion.

- A. Globular proteins
- B. Fibrous proteins

- A. **Globular proteins (Spheroproteins):** They are usually spherical or oval in shape, soluble in water and easily digestible. They are more highly branched and cross-linked condensation products of basic or acidic amino acids. As the globular proteins have diamino and dicarboxylic acids, branching and cross-linking takes place by the usual peptide linkage involving the second amino group of one amino acid and the second carboxyl group of another amino acid. The peptide chain is stabilized by intramolecular hydrogen bonds. They are further classified into several types based on their solubility.

- (i) **Albumins:** They are soluble in water, acids and alkalis and are coagulated by heat and precipitated by saturated solution of ammonium sulphate. These are usually deficient in glycine. **Example:** Serum albumin (blood), ovalbumin (egg white) and lactalbumin (milk).
- (ii) **Globulins:** They are insoluble in water, but soluble in dilute solutions of salt, strong inorganic acids and alkalis. They are coagulated by heat and precipitated by half saturating their solutions with ammonium sulphate. Generally, globulins contain glycine. **Example:** Serum globulin (blood), myosin (muscle), vitelline vegetable globulin and tissue globulin.
- (iii) **Glutelins:** They are insoluble in water and dilute salt solution, but soluble in dilute acids and alkalis. They are coagulated by heat, and are comparatively rich in arginine, proline and glutamic acid. **Example:** Glutenin (wheat) and oryzenin (rice).
- (iv) **Prolamins:** They are insoluble in water or salt solutions. But soluble in dilute acids, alkalis and 70-90 % ethyl alcohol. They contain large amounts of proline and are deficient in lysine. **Example:** Gliadin (wheat and rye), zein (corn), secaline (rye) and hordein (barley).
- (v) **Histones:** They are complex chemicals in nature, soluble in water or dilute acids but insoluble in dilute ammonia. They are not coagulated by heat. These are hydrolyzed by pepsin and trypsin. **Example:** Proteins of the nucleic acids and hemoglobin and thymus histones.
- (vi) **Globins:** These are also considered along with histones generally. However, globins are not basic proteins and are not precipitated by ammonium hydroxide.
- (vii) **Protamines:** They are soluble in water, dilute acids and dilute ammonia. These are more basic than the histones and have a simpler structure and found in sperm cells of certain fish. **Example:** Sturine (sturgeon), scombrine (mackerel), salmine (salmon) and clapeine (herring).



- (viii) **Lectins:** They are carbohydrate binding proteins and are involved in the interaction between cells and proteins. They help to maintain tissue and organ structures. In the laboratory they are used to purify carbohydrates by affinity chromatography. **Example:** Concanavalin-A and agglutinin.
- B. **Fibrous proteins:** They are fiber like in shape, insoluble in water and resistant to digestion. They are formed by condensation of (neutral amino acids) monoamino monocarboxylic acids and there is a few or no branching. By intermolecular hydrogen bonds the linear protein chains are held together. Proteins that tend to be insoluble and strong play a structural role in organisms for support or protection. Scleroproteins or albuminoids are predominant group of fibrous proteins. They are insoluble in water and salt solution, but soluble in concentrated acids and alkalis. They are attacked by enzymes. **Example:** Keratin (from hair, nails, hooves, horns and feathers) and fibroin (silk). Albuminoids are sub-divided into three types.
- (i) **Collagen:** It is the most common protein in the mammalian body. Found in skin, tendons and bones. They are attacked by pepsin and trypsin. When boiled with water, they form a water-soluble protein (gelatin).
 - (ii) **Elastin:** They are found in tendons, arteries and other elastic tissues. They are attacked slowly by trypsin.
 - (iii) **Keratins:** They are present in exoskeletal structures. **Example:** Hairs, nails and horns. Human hair contains as much as 14 % cysteine.
2. **Conjugated proteins:** Upon hydrolysis they yield α -amino acids and non-proteinous substances. They contain simple protein molecules linked with a non-protein substance. The non-proteinous moiety is referred as **prosthetic group**. On the basis of prosthetic group present in it, they are subdivided as follows.
- A. **Nucleoproteins:** The prosthetic group present in nucleoprotein is a nucleic acid. **Example:** Nucleohistones and nucleoprotamines.
 - B. **Glycoproteins (mucoproteins):** They are produced by adding sugar residues through O-glycoside linkages to the hydroxyl groups of serine and threonine residues or via N-glycoside linkages to the amino group of asparagine. The prosthetic group present in glycoprotein is a carbohydrate or a derivative of carbohydrate. **Example:** Mucin of saliva and ovomucoid of egg white.
 - C. **Lipoproteins:** They have the phosphorylated hydroxyl groups of serine or threonine. The prosthetic group present in lipoprotein is phospholipid (a class of fat). **Example:** Lipoproteins of serum such as HDL, LDL and VLDL.
 - D. **Phosphoproteins:** The prosthetic group present in phosphoprotein is phosphoric acid. **Example:** Casein of milk and vitelline of egg yolk.
 - E. **Chromoproteins:** They contain colored prosthetic group, due to the presence of a metal in their structure. **Example:** Hemoglobin (in which heme is prosthetic group and globin is the protein), chlorophyll and cytochromes.
 - F. **Metalloproteins:** They contain metal ions such as Zn, Co, Fe, Mg, Cu, etc. as prosthetic group. **Example:** Copper in ceruloplasmin and zinc in *carbonic anhydrase*.
3. **Derived proteins:** These proteins are generally derived from either simple proteins or conjugated proteins. They are the products obtained by the action of heat, chemical or enzymatic agents on natural proteins. The derived proteins (intermediate hydrolysis products) are further classified on the basis of progressive cleavage into two major types.
- A. Primary derived proteins
 - B. Secondary derived proteins
- A. **Primary derived proteins:** These proteins are the first hydrolyzed products of either simple proteins or conjugated proteins. They are,
- (i) **Coagulated proteins:** These are denaturated proteins. They are insoluble proteins, formed by the action of heat on proteins. **Example:** Cooked proteins and coagulated egg white albumin.

(ii) **Proteans:** These are the earliest products of protein hydrolysis by enzymes, dilute acids, alkalis, etc. These proteins are insoluble in water. **Example:** Fibrin obtained from fibrinogen.

(iii) **Metaproteins:** These are second stage products of protein hydrolysis obtained by treatment with slightly stronger acids and alkalis. They are insoluble in water, dilute salt solution and soluble in acids or alkalis. They are precipitated by half-saturation with ammonium sulphate. **Example:** Acid and alkali metaproteins.

B. Secondary derived proteins: These proteins are the progressive hydrolytic products of protein hydrolysis. **Example:** Proteoses, peptones, polypeptides and peptides.

3. Nutritional Classification of Proteins

Proteins are broadly classified into three major types based on their nutritive value as follows,

1. Complete proteins
2. Partially incomplete proteins
3. Incomplete proteins

1. Complete proteins:

Body required proportion of all ten essential amino acids are present in complete proteins. These proteins generally promote good growth in the body. **Example:** Egg albumin and milk casein.

2. Partially incomplete proteins:

One or more essential amino acids are partially lacking in these proteins. These proteins generally promote moderate growth in the body. **Example:** Rice proteins and wheat proteins which are partially lacking essential amino acids such as lysine and threonine.

3. Incomplete proteins:

One or more essential amino acids are completely lacking in these proteins. These proteins generally do not promote growth in the body. **Example:** Gelatin which completely lacks tryptophan and zein which completely lacks tryptophan and lysine.

Biological Significance of Proteins

Proteins possess diverse specialized and essential biological functions. These functions are broadly categorized into two categories as,

1. Structural or static function
 2. Dynamic function
- #### 1. Structural or static functions of proteins:

Proteins play a major role in the structure and strength of the biological system due to their brick and mortar roles. **Example:** Some proteins like collagen and elastin in bone matrix, vascular system and other organs and keratin in epidermal tissues such as hair and nail act as biological structural materials.

2. Dynamic functions of proteins:

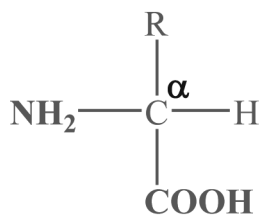
Dynamic functions of proteins are more diversified in nature. In general, the dynamic functions of proteins are approximately regarded as the working horses of the cell. The followings are the various dynamic functions performed by proteins.

1. Enzymes are made up of proteins, which catalyzes the biological reactions. **Example:** Almost all enzymes except ribosome, *glucokinase*, *pepsin*, etc.
2. Few proteins are useful for the transport of some compounds. **Example:** Hemoglobin used for transport of oxygen, serum albumin used for the transport of bilirubin, etc.
3. Proteins also performs storage function by stored in one form. **Example:** Ovalbumin is the storage form of protein in egg, glutelin is the storage form of protein in endosperm of certain seeds of the grass family, etc.
4. Some of the proteins perform defense function in biological system. **Example:** Snake venom is the defense protein of snake, immunoglobulin is the defense protein of human, etc.

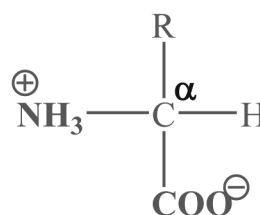
5. Hormones are proteins which regulate various metabolic processes. **Example:** Insulin maintains blood sugar level and growth hormone maintains growth.
6. Receptors are chemically proteins. **Example:** Receptors for hormone, receptors for viruses, etc.
7. During cell division, genetic message is transmitted through nucleoproteins which is an important constituent of nucleic acids. **Example:** Nucleoproteins.
8. Some protein plays a role in muscle contraction. **Example:** Actin, myosin, etc.
9. Antibodies which makes immunity of the body for resistance to diseases are formed from blood proteins.
10. Blood clotting factors are protein in nature.
11. Immunoglobulins are also protein in nature and involved in immune functions.

Amino Acids

Amino acid is defined as a group of organic compounds possessing two functional groups namely carboxylic acid (COOH) and amino (NH₂) group. The amino group is attached at α-position of carboxylic acid or both carboxyl group and amino groups are attached to the same carbon, hence it is known as **α-amino acids**. The carboxylic acid group is acidic in nature and the amino group is basic in nature. General structure of amino acid is given below.



**General structure
of L-α-amino acid**



**Amino acid
exist as ion**

Where α indicates position of amino group and L indicates configuration of amino acids [amino group present on left side]. If it is present on right side it is known as D-amino acid.

Classification of Amino Acids

Amino acids are classified in four different ways as follows,

1. Structural or chemical classification of amino acids
 2. Nutritional classification of amino acids
 3. Polarity classification of amino acids
 4. Metabolic fate classification of amino acids
- 1. Structural or Chemical Classification of Amino Acids**

It is one of the important classification method of amino acids. In this method twenty amino acids present in proteins are classified into seven different types based on its structure and chemical nature. A three letter or one letter symbol is assigned for each and every twenty amino acids present in proteins. In protein structure, these symbols are generally used to denote the amino acids (Table 1.5).

- I. Aliphatic amino acids:** These amino acids are chemically monoamino mono carboxylic acids. They are further divided into two types based on the presence of branching as follows.
 - (a) **Un-branched aliphatic amino acids:** No branch is present in aliphatic chain. **Example:** Glycine and alanine.
 - (b) **Branched aliphatic amino acids:** These amino acids contain branches in aliphatic chain. Leucine, isoleucine, and valine are sometimes called “branched-chain amino acids” (BCAA)


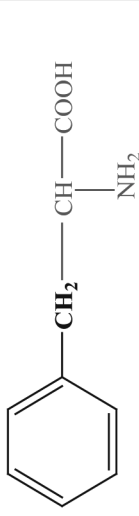
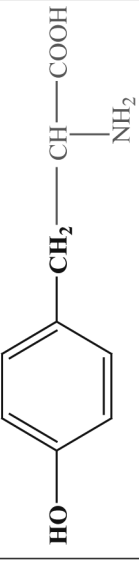
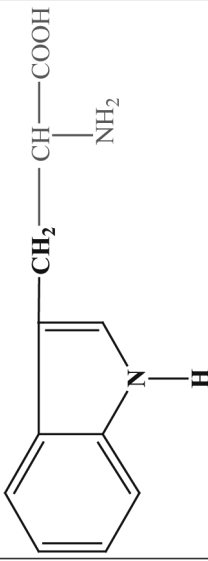
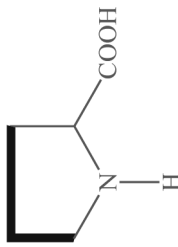
Table 1.5 Structural or chemical classification of amino acids.

S. No.	Name	Additional structural features present	Chemical structure	Reasoning for name	Three letters symbols	One letter symbol
I. Aliphatic amino acids						
1	Glycine	Un-branched aliphatic chain	$\begin{array}{c} \text{H} - \text{CH} - \text{COOH} \\ \\ \text{NH}_2 \end{array}$	From the Greek word "Glukus" meaning sweet, because it was first isolated from gelatin	Gly	G
2	Alanine		$\begin{array}{c} \text{CH}_3 - \text{CH} - \text{COOH} \\ \\ \text{NH}_2 \end{array}$	"Al" is a shortening of aldehyde. The infix "an" was added to make it easier to pronounce	Ala	A
3	Valine	Branched aliphatic chain	$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH} - \text{CH} - \text{COOH} \\ \quad \\ \text{CH}_3 \quad \text{NH}_2 \end{array}$	Named in 1906 after a type of acid that occurs in the roots of the "valerian" plant	Val	V
4	Leucine		$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH} - \text{CH}_2 - \text{CH} - \text{COOH} \\ \quad \\ \text{CH}_3 \quad \text{NH}_2 \end{array}$	First used in 1826 by chemist William Henry comes from the Greek word "leukos" meaning "white"	Leu	L
5	Isoleucine		$\begin{array}{c} \text{CH}_3 - \text{CH}_2 - \text{CH} - \text{CH} - \text{COOH} \\ \quad \quad \\ \text{CH}_3 \quad \text{NH}_2 \end{array}$	Named in 1904 by Felix Ehrlich, who observed that it was similar but not identical to leucine	Ile	I
II. Hydroxyl group containing amino acids						
6	Serine	Hydroxyl group	$\begin{array}{c} \text{CH}_2 - \text{CH} - \text{COOH} \\ \quad \\ \text{OH} \quad \text{NH}_2 \end{array}$	From the Latin word "sericum" meaning "silk", because it was first obtained from silk protein	Ser	S
7	Threonine		$\begin{array}{c} \text{CH}_3 - \text{CH}_2 - \text{CH} - \text{CH} - \text{COOH} \\ \quad \quad \\ \text{OH} \quad \text{NH}_2 \end{array}$	Named in 1936 after threose, a type of monosaccharide that it was thought to resemble	Thr	T
	Tyrosine		$\begin{array}{c} \text{HO} - \text{C}_6\text{H}_4 - \text{CH}_2 - \text{CH} - \text{COOH} \\ \\ \text{NH}_2 \end{array}$	From Greek "tyros" meaning "cheese", because it was obtained from old cheese	Tyr	Y

Table 1.5 Contd...

S. No.	Name	Additional structural features present	Chemical structure	Reasoning for name	Three letters symbols	One letter symbol
III. Sulphur group containing amino acids						
8	Cysteine	Sulphydryl group	$\begin{array}{c} \text{CH}_2 - \text{CH} - \text{COOH} \\ \\ \text{SH} \\ \\ \text{NH}_2 \end{array}$	Had an earlier spelling of cystine. That comes from the ancient Greek word for "bladder", "kustis"	Cys	C
	Cystine	Disulfide group	$\begin{array}{c} \text{CH}_2 - \text{CH} - \text{COOH} \\ \\ \text{S} \\ \\ \text{S} \\ \\ \text{CH}_2 - \text{CH} - \text{COOH} \\ \\ \text{NH}_2 \end{array}$		-	-
9	Methionine	Thioether linkage	$\begin{array}{c} \text{CH}_2 - \text{CH}_2 - \text{CH} - \text{COOH} \\ \\ \text{S} - \text{CH}_3 \\ \\ \text{NH}_2 \end{array}$	Coined in 1926 by Barger and Coyne as a contraction of γ -methylol- α -aminobutyric acid	Met	M
IV. Acidic amino acids and their amides						
10	Aspartic acid	β -Carboxyl group	$\begin{array}{c} \beta \\ \text{CH}_2 - \text{CH} - \text{COOH} \\ \\ \text{COOH} \\ \\ \text{NH}_2 \end{array}$	Named after asparagine, because it was first isolated from it by hydrolysis in 1827	Asp	D
11	Glutamic acid	γ -Carboxyl group	$\begin{array}{c} \gamma \\ \text{CH}_2 - \text{CH}_2 - \text{CH} - \text{COOH} \\ \quad \\ \text{COOH} \quad \text{NH}_2 \\ \alpha \end{array}$	"Glu" refers how the compound was first isolated from gluten in 1866 by chemist Karl Rithausen	Glu	E
12	Asparagine	Amide group	$\begin{array}{c} \text{CH}_2 - \text{CH} - \text{COOH} \\ \\ \text{CONH}_2 \\ \\ \text{NH}_2 \end{array}$	First extracted in 1806 from a sample of "asparagus" juice, after which it was named	Asn	N
13	Glutamine		$\begin{array}{c} \text{CH}_2 - \text{CH}_2 - \text{CH} - \text{COOH} \\ \\ \text{CONH}_2 \\ \\ \text{NH}_2 \end{array}$	Named before it was isolated, because it was hypothesized to be similar to glutamic acid	Gln	Q

Table 1.5 Contd...

S. No.	Name	Additional structural features present	Chemical structure	Reasoning for name	Three letters symbols	One letter symbol
V. Basic amino acids						
14	Lysine	ε-Amino group	$ \begin{array}{c} \epsilon \\ \text{CH}_2 \\ \\ \text{NH}_2 \\ \delta, \gamma, \beta \\ \text{---} (\text{CH}_2)_3 \text{---} \text{CH} \text{---} \text{COOH} \\ \\ \alpha \\ \text{NH}_2 \end{array} $	Named in 1889 from the ancient Greek word "luisis" meaning "loosening"	Lys	K
15	Arginine	Guanidino group	$ \begin{array}{c} \text{NH} \\ \\ \text{C}=\text{NH} \\ \\ \text{NH}_2 \\ \text{---} (\text{CH}_2)_3 \text{---} \text{CH} \text{---} \text{COOH} \\ \\ \text{NH}_2 \end{array} $	From the Greek word "arginoeis" meaning "silver", due to the appearance of silver nitrate	Arg	R
16	Histidine	Imidazole ring		From Greek "histos" meaning "tissue", because it was thought to be important to tissue function	His	H
VI. Aromatic amino acids						
17	Phenylalanine	Phenyl ring		Named by Erlenmeyer and Lipp in 1883 because it looks like alanine with a phenyl group	Phe	F
18	Tyrosine	Phenol analog		From Greek "tyros" meaning "cheese", because it was obtained from old cheese	Tyr	Y
19	Tryptophan	Indole ring		Traces to the Greek roots "tripsis" meaning "rubbing", and "phainein" meaning "to show"	Trp	W
VII. Imino acids						
20	Proline	Pyrrolidine ring		The name is a contraction of pyrrolidine, which makes up a side chain of the compound	Pro	P

because human beings cannot survive unless these amino acids are present in the diet. The combination of these three amino acids makes up approximately one-third of skeletal muscle in the human body. **Example:** Valine, leucine and isoleucine.

- II. **Hydroxyl group containing amino acids:** These amino acids contain hydroxyl group in their structure. **Example:** Serine, threonine and tyrosine. In general, aromatic ring is present in tyrosine. Hence tyrosine is usually considered as aromatic amino acid and not as hydroxyl group containing amino acid.
- III. **Sulphur containing amino acids:** These amino acids contain sulphur atom in their structure. **Example:** Cysteine (contain sulfhydryl group), cystine (formed by condensation of two molecules of cysteine and contain disulfide group) and methionine (contain thioether group).
- IV. **Acidic amino acids and their amides:** These amino acids are generally dicarboxylic mono amino acids. They are highly acidic in character. These amino acids in general possess different codons for their incorporation into proteins. **Example:** Aspartic acid & glutamic acid are acidic amino acids and asparagine and glutamine are their corresponding amides.
- V. **Basic amino acids:** These amino acids are generally dibasic monocarboxylic acids. They are highly basic in character. **Example:** Lysine and arginine (possess guanidine group) and histidine (possess imidazole ring).
- VI. **Aromatic amino acids:** These amino acids are generally contains aromatic ring in their structure. **Example:** Phenylalanine and tyrosine (contain phenyl ring), tryptophan (contain indole ring) and histidine (contain imidazole ring).
- VII. **Imino acids:** These amino acids generally contain imino group i.e., =NH instead of amino (NH_2) group in their structure. **Example:** Proline. Histidine, tryptophan and proline are considered as heterocyclic amino acids also as they have heterocyclic ring in their structure.

2. Nutritional Classification of Amino Acids

More than two hundred amino acids have been isolated and identified but only twenty-five are obtained from typical proteins, in turn only twenty amino acids are generally found in all proteins. Except other biological functions these twenty amino acids are needed for the synthesis of many proteins. But it is not necessary to take all these twenty amino acids in diet because some of the amino acids are biosynthesized in the biological system. Based on the dietary requirements of amino acids it is broadly classified into two major types as follows.

- (a) **Essential amino acids:** Among the twenty amino acids, ten are called as essential amino acids. These amino acids **cannot be synthesized by the body** and must be supplied by dietary sources. They are also called as **indispensable amino acids**. Deficiency in any one of the essential amino acid prevents growth and may even cause death. Although there are ten essential amino acids to man, eight are more important, viz methionine, tryptophan, threonine, valine, isoleucine, leucine, phenylalanine and lysine. Two amino acids are less important namely arginine and histidine because it is partly synthesized by the body (To remember these ten essential amino acids, it can be mentioned as **MATT VIL PHL Y** which corresponds to **M**ethionine, **A**rginine, **T**ryptophan, **T**heronine, **V**aline, **I**soleucine, **L**eucine, **P**henylalanine, **H**istidine and **L**Ysine).
- (b) **Non-essential amino acids:** The other ten amino acids are called as **non-essential amino acids** or **dispensable amino acids** and are **synthesized by the body**. Hence no need to take by dietary sources. The non-essential amino acids are alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, proline, serine and tyrosine.

3. Polarity Classification of Amino Acids

Based on their polarity, amino acids are broadly classified into four major types.

- (a) **Non-polar amino acids:** Also known as hydrophobic amino acids because of its water hating property. These amino acids don't have any charge on "R" group. **Example:** Alanine, leucine, isoleucine, valine, methionine, phenylalanine, tryptophan and proline.
- (b) **Polar amino acids with no charge on "R" group:** These amino acids don't have any charge on "R" group but having other polar groups such as hydroxyl, sulfhydryl and amide group leads

to hydrogen bonding. **Example:** Glycine, serine, threonine, cysteine, glutamine, asparagine and tyrosine.

(c) **Polar amino acids with positive charge on "R" group:** These amino acids have positive charge on "R" group which makes them as polar. **Example:** Lysine, arginine and histidine.

(d) **Polar amino acids with negative charge on "R" group:** These amino acids have negative charge on "R" group which makes them as polar. **Example:** Aspartic acid and glutamic acid.

4. Fate of Metabolism of Amino Acids Classification

Amino acids are broadly classified into three types based on their fate of metabolism because the carbon skeleton of amino acids can serve as a precursor for the synthesis of carbohydrates (glucogenic) or fat (ketogenic) or both.

(a) **Glucogenic amino acids:** The amino acids serve as a precursor for the synthesis of carbohydrates such as glucose or glycogen are called as glucogenic amino acids. **Example:** Alanine, glycine, valine, serine, cysteine, methionine, arginine, threonine, histidine, aspartic acid, asparagine, glutamic acid, glutamine and proline.

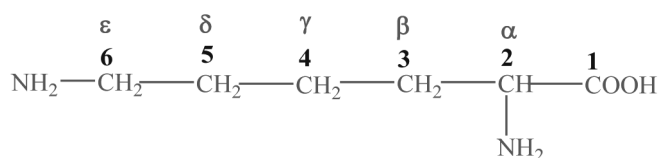
(b) **Ketogenic amino acids:** The amino acids which serve especially as a precursor for the synthesis of fat are called as ketogenic amino acids. **Example:** Leucine and lysine.

(c) **Glucogenic and ketogenic amino acids:** The amino acids which serve as a precursor for the synthesis of both carbohydrates and fat are called as glucogenic and ketogenic amino acids. **Example:** Isoleucine, phenylalanine, tryptophan and tyrosine.

Nomenclature of Amino Acids

Trivial or common names are available for all the amino acids. These names are given some times based on the source from which they were first isolated. **Example:** Asparagine was first found in asparagus, glutamate in wheat gluten; tyrosine in cheese (In Greek *tyros*, means "cheese"). Sometime the names are given based on their taste. **Example:** Glycine (In Greek "*glykos*", means "sweet") was so named because of its sweet taste.

The amino acids are named in the IUPAC system, as amino derivatives of the corresponding acid with the position of the amino group defined by an appropriate number. The C-1 would be carboxyl carbon of an amino acid and the C-2 would be α -carbon, the C-3, C-4, C-5 and C-6 would be β , γ , δ and ϵ -carbon, respectively. The Greek lettering system is confusing in some cases, such as amino acids with heterocyclic R groups. Hence, generally the numbering system is used.



2, 6-Diamino heptanoic acid

Biological Significance of Amino Acids

Biological significance of amino acids explained under two sub divisions as follows.

(a) Standard amino acids:

The 20 amino acids present in proteins are known as standard amino acids which performs several biological functions as follows.

1. 4-Hydroxyproline and 5-hydroxylysine are the major constituents of the most abundant protein in mammals i.e., collagen.
2. Many methylated or acetylated or phosphorylated amino acids are present in the histones in association with DNA.
3. γ -Carboxyglutamic acid present in certain plasma protein is participated in blood clotting process.

(b) Non-standard amino acids:

There are several amino acids present in nature beyond 20 standard amino acids which are present in proteins. These amino acids are commonly known as non-standard amino acids or non-protein amino acids which performs some biologically important functions. They are,

1. Creatinine is derived from muscle and excreted in urine.
2. In biological system methyl group is donated by S-adenosylmethionine (SAM).
3. Thyroxine and triiodothyronine are thyroid hormones derived from tyrosine.
4. In the metabolism of threonine, aspartate and methionine, homoserine is the intermediate.
5. DOPA is a neurotransmitter which serves as a precursor for the synthesis of melanin pigment.
6. Ornithine, citrulline and arginosuccinate are intermediates in the urea biosynthesis.
7. Ovothiol is the sulphur containing amino acids found in fertilized eggs which acts as an antioxidant.
8. In methionine metabolism, homocysteine is the intermediate which is a risk factor for coronary heart diseases.
9. Azaserine is used as anticancer agent and cycloserine is used as antitubercular drug.
10. β -Alanine is the component of vitamins such as pantothenic acid and co-enzyme A.
11. The end product of pyrimidine metabolism is β -aminoisobutyric acid.
12. Taurine is found in association with bile acids.
13. From glutamic acid the neuro transmitter GABA is biosynthesized.
14. In the synthesis of porphyrin and heme, δ -aminolevulinic acid (ALA) is the intermediate.
15. D-Penicillamine effectively chelates copper and is chemically D-dimethylglycine. It is a metabolite of penicillin and is used in the chelation therapy of Wilson's disease.
16. N-Acetylcysteine is used in cystic fibrosis and chronic renal insufficiency due to its antioxidant property.
17. Gabapentin is chemically γ -aminobutyrate linked to cyclohexane used in the treatment of convulsion.

Bioenergetics (or) Biochemical Thermodynamics

Role of high energy compounds in biological process and basic knowledge of bioenergetics is very useful for better understanding of biological oxidation.

Study of energy changes (utilization and transfer) in biochemical reaction is termed as bioenergetics or biochemical thermodynamics. In bioenergetics mechanism of chemical reaction is not concerned but it concerned about the initial and final states of energy components of reactants. Based on energy released or consumed in biochemical reaction it was broadly classified into two types. They are,

1. **Exergonic reaction:** In this type biochemical reaction energy is released. ΔG° value of this reaction is negative and the reactions will take place spontaneously. Almost all catabolic reactions are exergonic reactions. **Example:** Breakdown of ATP into ADP and inorganic phosphate liberates 7.3 Cal/mol energy.



2. **Endergonic reaction:** In this biochemical reaction energy is consumed or utilized by the reactants. It needs energy; hence, energy must be supplied. ΔG° value of this reaction is positive and the reactions will not take place spontaneously. Almost all anabolic reactions, muscle contraction, nervous excitation, etc. are good examples for endergonic reactions. **Example:** Synthesis of ATP from ADP and inorganic phosphate. This reaction occurs only when 7.3 Cal/mol energy is supplied at least.



Terms used in Bioenergetics

To understand the bioenergetics reactions, it is necessary to know about the following terms

1. Free energy
2. Enthalpy
3. Entropy
1. **Free energy:** It is defined as the energy actually available for utilization or to do work. The feasibility of chemical reaction is predicted valuably using changes in free energy and is represented by the symbol " ΔG ". If the reaction is accompanied by decrease in free energy then the reaction can occur spontaneously.

Standard free energy change: It is defined as the free energy change when the reactants or products are at a concentration of 1 mol/l at pH 7.0. This standard free energy is denoted by the symbol " ΔG° ".

The free energy change (ΔG) may be either,

- (a) **Negative free energy change:** In a chemical reaction if there is a loss of free energy then ΔG is represented by negative sign and the reaction is called as exergonic reaction and the reaction proceeds spontaneously. Free energy changes of almost all catabolic reactions possess negative sign only. **Example:** Breakdown of ATP into ADP and inorganic phosphate liberates 7.3 Cal/mol energy.



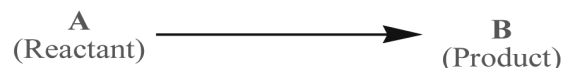
- (b) **Positive free energy change:** In a chemical reaction if free energy is supplied then the ΔG is represented by positive sign and the reaction is called as endergonic reaction and the reaction does not proceed spontaneously. Free energy changes of almost all anabolic reactions possess positive sign only. **Example:** Synthesis of ATP from ADP and inorganic phosphate and the reaction occurs only when 7.3 Cal/mol energy is supplied at least.



- (c) **Zero free energy change:** In a chemical reaction ΔG becomes zero when it is at equilibrium.



The free energy change (ΔG) is generally dependent on the actual concentrations of reactants and products at a constant temperature and pressure. Consider the below reaction in which reactant "A" is converted to product "B".



The following mathematical relationship can be derived when the reactant "A" is converted to product "B".

$$\Delta G = \Delta G^\circ + RT \ln \frac{[B]}{[A]}$$

Where,

ΔG = Free energy change

ΔG° = Standard free energy change

R = 1.987 Cal / mol (Gas constant)

T = Absolute temperature in Kelvin (273 + °C)

\ln = Natural logarithm

$[B]$ = Concentration of product

$[A]$ = Concentration of reactant

When reaction is at equilibrium then the free energy change is zero i.e., $\Delta G = 0$. Substitute the value of ΔG in above equation.

$$0 = \Delta G^\circ + RT \ln \frac{[B]_{eq}}{[A]_{eq}}$$

Therefore,
$$\Delta G^\circ = -RT \ln \frac{[B]_{eq}}{[A]_{eq}}$$

Where, K_{eq} = Equilibrium constant

The free energy change (ΔG) is an additive value for pathways. A series of reactions are often involved in biochemical pathways. In such reaction the free energy change (ΔG) is an additive value. Whether the particular pathway will proceed or not is crucially determined by the sum of the free energy change (ΔG). The pathway can operate when the sum of the free energy change (ΔG) is negative even though some of the individual reactions may have positive free energy change (ΔG).

2. **Enthalpy:** It is a measure of the change in the heat content of the reactants compared to products. It is denoted by the symbol " ΔH ". During the thermodynamic reaction either the heat may be released or absorbed. Based on this the chemical reactions are broadly classified into two major types as,
 - (a) **Exothermic reaction:** During a chemical reaction if the heat is released then the reaction is said to be exothermic reaction. **Example:** Sodium hydroxide dissolved in water.
 - (b) **Endothermic reaction:** During a chemical reaction if the heat is absorbed then the reaction is said to be endothermic reaction. **Example:** Benedict's test, Fehling's test, etc.
3. **Entropy:** It is the change in the randomness or disorder of reactants and products. It is usually represented by " ΔS ". When the reaction attains equilibrium, entropy attains a maximum. In general, temporary decrease in entropy was observed in the reactions of biological systems.

Relationship between the change of Free Energy, Enthalpy and Entropy

The relationship between the change of free energy, enthalpy and entropy is expressed in the below mentioned equation.

$$\Delta G = \Delta H - T\Delta S$$

Where,

ΔG = Free energy change

ΔH = Enthalpy

T = Absolute temperature in Kelvin (273 + °C)

ΔS = Entropy

Redox Potential

Redox potential is otherwise known as oxidation–reduction potential. A quantitative measure of the tendency of a redox pair to lose or gain electrons is known as redox potential. Specific standard redox potential (E_o , Volts) is assigned to each redox pair based on their tendency to lose or gain electrons at 25 °C and pH 7.0. The redox potential (E_o) is directly related to the change in the free energy (ΔG°).

The specific standard redox potential (E_o) may be either positive or negative. More negative redox potential (E_o , Volts) indicates greater tendency of reductant to lose electrons and a more positive redox

potential (E_0 Volts) indicates greater tendency of oxidant to accept electrons. Generally, the electrons flow from a redox pair with more negative redox potential (E_0 Volts) to another redox pair with more positive redox potential (E_0 Volts). Specific standard redox potential (E_0 volts) of various redox pair system is summarized in Table 1.6.

Table 1.6 Specific standard redox potential (E_0 Volts) of various redox pair system.

S. No	Redox pair	E_0 in Volts
1	Succinate / α -ketoglutarate	- 0.67
2	$2H^+$ / H_2	- 0.42
3	$NADH + H^+$ / NAD^+	- 0.32
4	$NADP^+$ / $NADP + H^+$	- 0.32
5	FMN / $FMNH_2$ (Enzyme bound)	- 0.30
6	Lipoate (ox / red)	- 0.29
7	FAD / $FADH_2$	- 0.22
8	Pyruvate / Lactate	- 0.19
9	Fumarate / succinate	+ 0.03
10	Cytochrome b (Fe^{3+} / Fe^{2+})	+ 0.07
11	Coenzyme Q (ox / red)	+ 0.10
12	Cytochrome c_1 (Fe^{3+} / Fe^{2+})	+ 0.23
13	Cytochrome c (Fe^{3+} / Fe^{2+})	+ 0.25
14	Cytochrome a (Fe^{3+} / Fe^{2+})	+ 0.29
15	$\frac{1}{2} O_2$ / H_2O	+ 0.82

Energy Rich Compounds

It is otherwise known as high energy compounds or high energy phosphates. In the biological systems certain compounds on hydrolysis yield energy. Energy rich compounds or high energy compounds are substances which possess sufficient free energy to liberate at least 7 Cal/mol at pH 7.0. Energy rich compounds are otherwise known as high energy compounds. Compared to hydrolysis of ATP into ADP and inorganic phosphates, all the high energy compounds liberate more energy when undergo hydrolysis. High energy compounds except acetyl CoA generally contains phosphate group in their structure, hence it is also known as high energy phosphates. **Example:** Phosphoenol pyruvate, carbamoyl phosphate, cAMP, 1,3-bisphosphoglycerate, phosphocreatine, acetyl phosphate, S-adenosylmethionine (SAM), pyrophosphate (PPi), acetyl CoA and ATP.

Table 1.7 The standard free energy (ΔG°) liberated during hydrolysis of some important compounds.

S. No	Compounds Name	ΔG° (in Cal / mol)
High energy phosphates or High energy compounds		
1	Phosphoenol pyruvate	- 14.8
2	Carbamoyl phosphate	- 12.3
3	cAMP	- 12.0
4	1,3-Bisphosphoglycerate	- 11.8
5	Phosphocreatine	- 10.3
6	Acetyl phosphate	- 10.3
7	S-Adenosylmethionine (SAM; Sulfonium compound)	- 10.0
8	Pyrophosphate (PPi)	- 8.0
9	Acetyl CoA (Thioester)	- 7.7
10	ATP (Breakdown into ADP & inorganic phosphate)	- 7.3

Table 1.7 Contd...

S. No	Compounds Name	ΔG° (in Cal / mol)
Low energy phosphates or Low energy compounds		
11	ADP (Breakdown into AMP & inorganic phosphate)	- 6.6
12	Glucose-1-phosphate	- 5.0
13	Fructose-1-phosphate	- 3.8
14	Glucose-6-phosphate	- 3.3
15	Glycerol-3-phosphate	- 2.2

Compounds which liberate less than 7.0 Cal/mol (which is lower than hydrolysis of ATP into ADP and inorganic phosphate) are referred as low energy phosphates or low energy compounds. **Example:** ADP, glucose-1-phosphate, fructose-1-phosphate, glucose-6-phosphate and glycerol-3-phosphate. The standard free energy liberated during hydrolysis of some important compounds is summarized in Table 1.7.

Classification of High Energy Compounds

High energy compounds are broadly classified into five major types according to type of bonds present in their structure. They are,

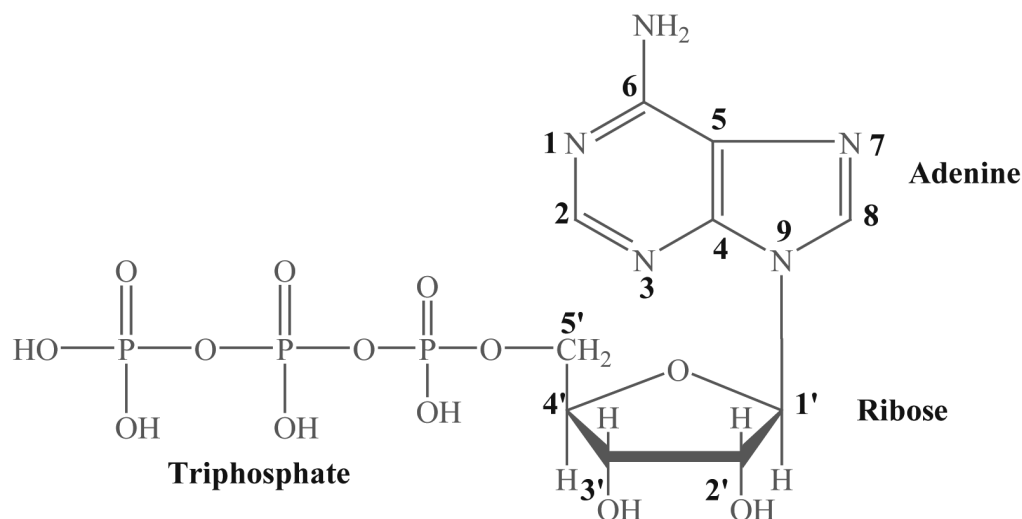
1. Pyrophosphate
2. Acyl phosphate
3. Enol phosphate
4. Thioester or thiol ester
5. Phosphagens or guanidino phosphate

Acid anhydride bonds particularly phospho anhydride bonds are high energy bonds which are usually present in all high energy compounds. Condensation of two acidic groups or related compounds generally produces this acid anhydride bonds. These bonds liberate free energy when it undergoes hydrolysis; hence it is known as high energy bonds. The symbol '~' is used by Lipmann to represent high energy bonds. ATP is instantly written as AMP-P-P. The various examples and bonds present in different classes of high energy compounds are summarized in Table 1.8.

Table 1.8 High energy compounds.

S. No	Class	Type of bond present	Example
1	Pyrophosphate		Pyrophosphate, ATP
2	Acyl phosphate		Carbamoyl phosphate, 1,3-bisphosphoglycerate, acetyl phosphate
3	Enol phosphate		Phosphoenol pyruvate
4	Thioester or thiol ester		Acetyl CoA, acyl CoA
5	Phosphagens or guanidino phosphate		Phosphocreatine, phosphoarginine

Adenosine Triphosphate (ATP)



Adenosine triphosphate (ATP)

In living cells, the most important high energy molecule present is adenosine triphosphate (ATP). It is a nucleotide and composed of

1. Adenine (nitrogen base)
2. Ribose (sugar) and
3. A triphosphate groups.

In the triphosphate moiety of ATP, it contains two phospho anhydride bonds, hence ATP is a high energy compounds. ATP-ADP cycle evidences that ATP is the energy currency of the cell.

ATP-ADP Cycle

Large amount of energy (7.3 Cal/mol) is released when ATP is hydrolyzed to ADP and inorganic phosphate.



Several processes in the biological systems such as muscle contraction, active transport, biosynthesis, etc. utilizes the energy liberated from the ATP when it breaks. In addition, energy rich compounds are biosynthesized from low energy compounds by reacting with high energy phosphates which is donated by ATP. Whilst, the compounds possessing higher free energy content donates high energy phosphates to ADP in order to produce ATP. ATP-ADP cycle is represented in Figure 1.1.

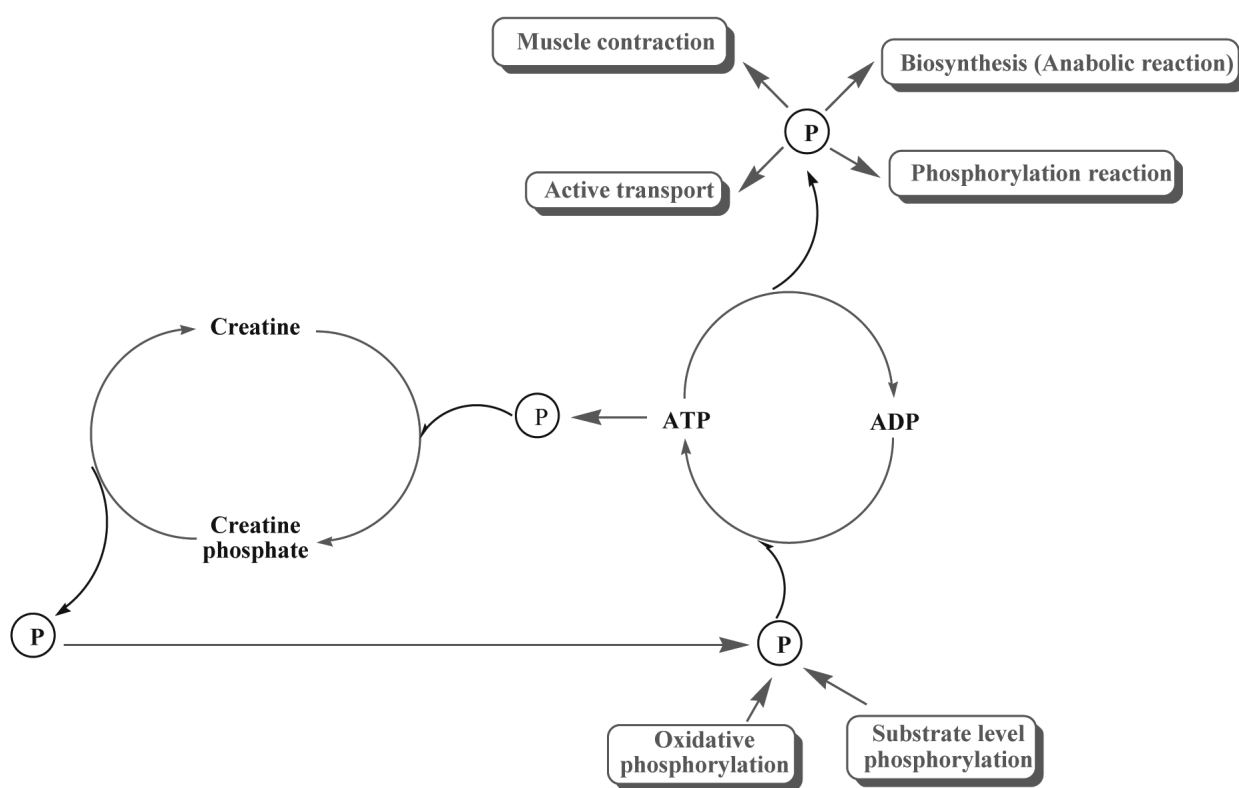
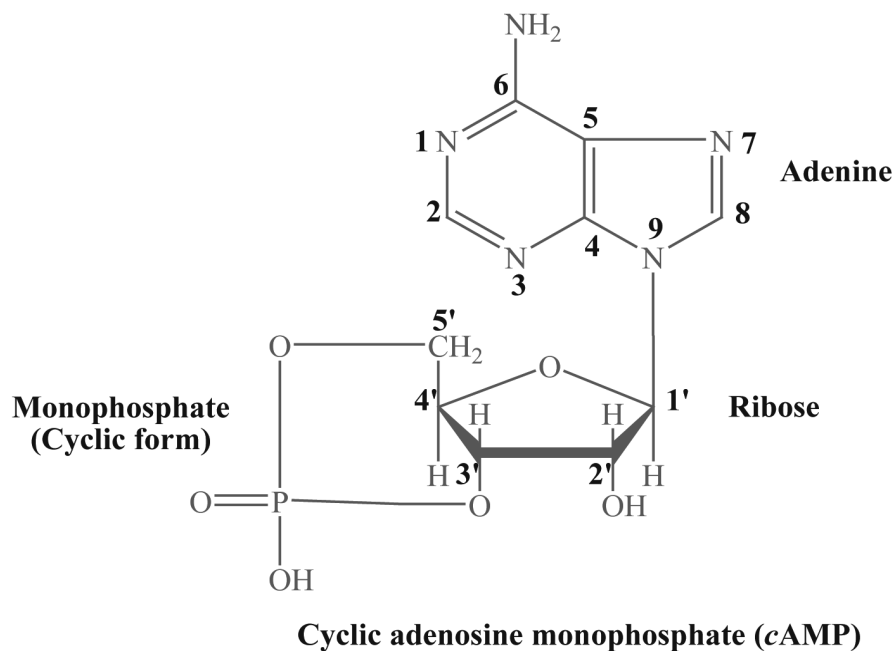


Figure 1.1 ATP-ADP cycle along with formation and breakdown of ATP (Phosphate will not exist free in biological system. It is only transferred).

Biological Significance of ATP

1. ATP is the short-term energy store of the cell.
2. Universally for all living things ATP is the energy currency of cell.
3. ATP is the source of phosphate moiety for phosphorylation reaction.
4. In addition, ATP can also donate pyrophosphate (PPi) and adenosine monophosphate (AMP) to other suitable acceptor for the formation of important biological compounds.
5. It easily participates in many biological reactions.
6. ATP is necessary for muscle contraction.
7. ATP is useful for nerve impulse transmission.
8. ATP is important for normal growth and development.
9. ATP is necessary for active transport.
10. ATP is also useful for homeostasis.
11. ATP is needed for all anabolic reactions.
12. ATP is helpful for intracellular signaling.
13. ATP is useful for the synthesis of nucleic acid.
14. ATP also plays a role in synthesis of proteins for the activation of amino acids.

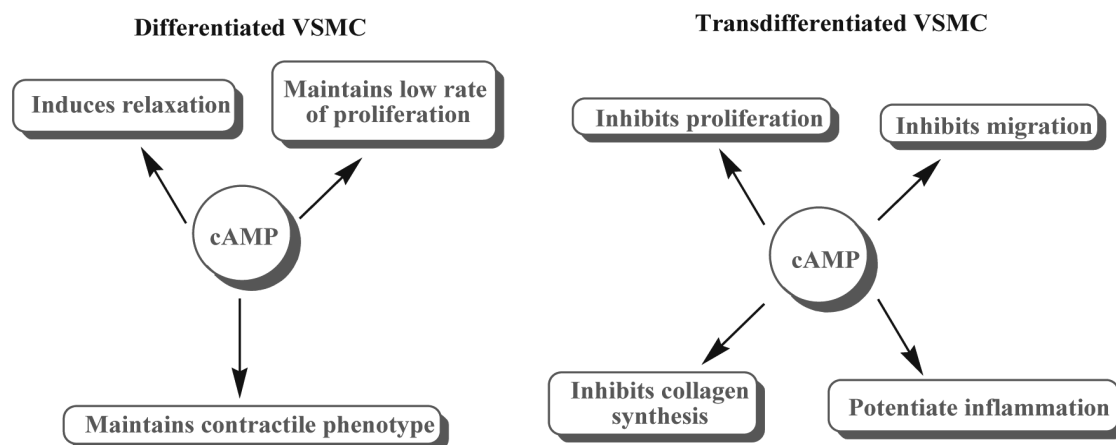
Cyclic Adenosine Monophosphate (cAMP)



In living cells, another important high energy molecule present is cyclic adenosine monophosphate (cAMP). The prefix 'cyclic' indicates the cyclic structure formed between phosphate moiety present at C-5 of ribose and hydroxyl group present at C-3 of ribose molecule.

It is a nucleotide and composed of

1. Adenine (nitrogen base)
2. Ribose (sugar) and
3. A monophosphate group.



Biological Significance of cAMP

1. It is the intracellular secondary messenger present in many biological processes.
2. It is used for signal transduction intracellularly.
3. cAMP plays an important key regulatory role in most type of cells.
4. *Adenyl cyclase* particularly alters cAMP and this cAMP regulates the enzyme called *phosphodiesterases*.
5. cAMP mediates some short-term aspects of synaptic transmission. In addition, some rapid actions of certain neurotransmitter on ion channels that do not involve ligand gated channels are mediated through cAMP.
6. Along with other intracellular messenger, cAMP plays a central role in mediating other aspects of synaptic transmission.
7. Virtually all other effects of neurotransmitter on target neuron functioning both short and long term are achieved through intracellular messengers.

PROBABLE QUESTIONS

PART - A: Multiple Choice Questions

1. _____ are the building blocks of lipids.
(a) Fatty acid (b) Glycerol
(c) Both a & b (d) None of the above
2. If enthalpy change for a reaction is zero, then ΔG° equals to _____.
(a) $-T\Delta S^\circ$ (b) $T\Delta S^\circ$
(c) $-\Delta H^\circ$ (d) $\ln k_{eq}$
3. ΔG° is defined as the _____.
(a) Residual energy present in the reactants at equilibrium
(b) Residual energy present in the products at equilibrium
(c) Difference in the residual energy of reactants and products at equilibrium
(d) Energy required in converting one mole of reactants to one mole of products
4. For a reaction if ΔG° is positive, then _____.
(a) The products will be favored
(b) The reactants will be favored
(c) The concentration of the reactants and products will be equal
(d) All of the reactant will be converted to products
5. The study of energy relationships and conversions in biological systems is called as _____.
(a) Biophysics (b) Biotechnology
(c) Bioenergetics (d) Microbiology
6. Which of the following statement is false?
(a) The reaction tends to go in the forward direction if ΔG is large and positive
(b) The reaction tends to move in the backward direction if ΔG is large and negative
(c) The system is at equilibrium if $\Delta G = 0$
(d) The reaction tends to move in the backward direction if ΔG is large and positive
7. Anabolism and catabolism are chemically linked in the form of _____.
(a) ADP (b) ATP
(c) Phosphodiester linkage (d) ASP

8. Which of the following statements is false about ATP hydrolysis?
- (a) It is highly exergonic
(b) Activation energy is relatively high
(c) $\Delta G^\circ = -30.5 \text{ kJ/mol}$
(d) $\Delta G^\circ = 30.5 \text{ kJ/mol}$
9. An endergonic reaction _____
- (a) Proceeds spontaneously
(b) Does not require activation energy
(c) Releases energy
(d) Requires energy
10. An exergonic reaction _____
- (a) Proceeds spontaneously
(b) Does not require activation energy
(c) Releases energy
(d) Requires energy
11. Phosphoryl groups are derivatives of _____
- (a) Phosphorous acid
(b) Phosphoric acid
(c) Acetic acid
(d) Citric acid
12. Water does a nucleophilic attack on phosphate monoester by producing _____
- (a) Phosphorous chloride
(b) Phosphorous sulfide
(c) Inorganic phosphate
(d) Organic phosphate
13. Which is an example of chemical to osmotic energy conversion that occurs in living organisms?
- (a) ATP-driven muscle contraction
(b) ATP-dependent photon emission in fireflies
(c) Light-induced electron flow in chloroplasts
(d) ATP-driven active transport across a membrane
14. Which of the following statements about redox potential is false?
- (a) NADH/NAD⁺ redox pair has the least redox potential
(b) Oxygen/H₂O redox pair has the highest redox potential
(c) The components of the electron transport chain are organized in terms of their redox potential
(d) The redox potential of a system is usually compared with the potential of the hydrogen electrode
15. Which out of the following has the highest redox potential?
- (a) NAD⁺
(b) FMN
(c) FAD
(d) O₂
16. Which one out of the following is not a NAD⁺ requiring enzyme?
- (a) *Lactate dehydrogenase*
(b) *Pyruvate dehydrogenase complex*
(c) *Malate dehydrogenase*
(d) *Acyl CoA dehydrogenase*
17. Which of the following enzyme catalyzes the direct transfer and incorporation of O₂ into a substrate molecule is
- (a) *Reductase*
(b) *Oxidase*
(c) *Oxygenase*
(d) *Peroxidase*
18. Loss of electrons can be termed as _____
- (a) Metabolism
(b) Anabolism
(c) Oxidation
(d) Reduction
19. Gain of electrons can be termed as _____
- (a) Metabolism
(b) Anabolism
(c) Oxidation
(d) Reduction

20. Name the compound with the greatest free energy
- (a) ATP (b) Phosphocreatine
(c) Cyclic AMP (d) Phosphoenolpyruvate
21. 1,3-Bisphosphoglycerate is an example for which type of high energy compound?
- (a) Acyl phosphate (b) Enol phosphate
(c) Pyrophosphate (d) Guanidino phosphate
22. In general, high energy compounds contain which type bond in its structure?
- (a) Peptide (b) Glycoside
(c) Acid anhydride (d) Covalent
23. What happens to free energy changes when a reaction is at equilibrium?
- (a) Maximum (b) Minimum
(c) Average (d) Zero
24. Standard redox potential of NAD^+/NADH pair is _____ volts.
- (a) - 0.67 (b) - 0.22
(c) +0.29 (d) - 0.32
25. Which of the following is the general formula for polysaccharides?
- (a) $(\text{C}_6\text{H}_{10}\text{O}_5)_n$ (b) $(\text{C}_6\text{H}_{12}\text{O}_5)_n$
(c) $(\text{C}_6\text{H}_{10}\text{O}_6)_n$ (d) $(\text{C}_6\text{H}_{12}\text{O}_6)_n$
26. Out of the following polysaccharide which one is homopolysaccharide?
- (a) Inulin (b) Heparin
(c) Hyaluronic acid (d) Keratan sulfate
27. Which of the following one is aldose sugar?
- (a) Glycerose (b) Ribulose
(c) Erythrulose (d) Dihydroxyacetone
28. Which of the following one is a triose sugar?
- (a) Glycerose (b) Ribose
(c) Erythrose (d) Fructose
29. Which of the following one is a pentose sugar?
- (a) Dihydroxyacetone (b) Ribulose
(c) Erythrose (d) Glucose
30. How many isomers are possible for glucose?
- (a) 2 (b) 4
(c) 8 (d) 16
31. _____ are compounds having the same structural formula but differing in spatial configuration.
- (a) Stereoisomers (b) Anomers
(c) Optical isomers (d) Epimers
32. In semen which sugar is present abundant?
- (a) Glucose (b) Lactose
(c) Galactose (d) Fructose
33. In solution, glucose is present predominantly in which form.
- (a) Acyclic form (b) Glucopyranose
(c) Glucofuranose (d) Hydrated acyclic form

34. Which of the following sugars are not an oligosaccharide?
(P) Raffinose (Q) Stachyose
(R) Glucoheptose (S) Sedoheptulose.
Choose the correct option.
(a) P and Q (b) R and S
(c) P and S (d) Q and S
35. Which of the following sugar does not form osazone?
(a) Maltose (b) Sucrose
(c) Lactose (d) Glucose
36. Which is a sweetener used in sugarless gums and candies?
(a) Sorbitol (b) Ribitol
(c) Myoinositol (d) Xylitol
37. Esters of fatty acids with alcohols other than glycerol are commonly known by which of the following name? P) Fats Q) Oils R) Waxes S) Phospholipids. Choose the correct option.
(a) P & Q (b) R & S
(c) P only (d) R only
38. Which of the following fatty acids are hydroxy fatty acids? P) β -Hydroxy butyric acid Q) Cerebronic acid R) Recinoleic acid S) Linolenic acid. Choose the correct option.
(a) Both P, Q & R (b) Both Q, R & S
(c) Both R, S & P (d) Both S, P & Q
39. Which of the following are glycolipids? P) Lecithin Q) Cephalin R) Cerebrosides S) Gangliosides.
Choose the correct option.
(a) Both P & Q (b) Both R & S
(c) Both Q & R only (d) Both P & S
40. Spingomyelin is comes under which of the following class of complex lipid? P) Phospholipid Q) Glycolipid R) Lipoprotein S) Sulpholipid. Choose the correct option.
(a) Only P (b) Only S
(c) Both Q & R only (d) Both P & S
41. In short hand representation of fatty acids, second digit indicates what?
(a) Number of carbons (b) Number of double bonds
(c) Position of double bonds (d) Number of oxygens
42. Which of the following fatty acids are known as essential fatty acids? P) Palmitic acid Q) Linoleic acid R) Oleic acid S) Linolenic acid. Choose the correct option.
(a) Both P & Q (b) Both R & S
(c) Both P & R (d) Both Q & S
43. Which of the following is important for the synthesis & transport of lipoproteins and reverse transport of cholesterol?
(a) Phospholipid (b) Glycolipid
(c) Lipoprotein (d) Sulpholipid
44. The following substance(s) is(are) ketogenic
(a) Fatty acids (b) Leucine
(c) Lysine (d) All of them

45. Which of the following compounds possessing characteristics of lipids? P) Carotenoids Q) Squalene R) Pentacosane S) Alkaloids. Choose the correct option.
- (a) Both P & Q (b) Both R & S
(c) Both P, Q & R (d) Both Q, R & S
46. Which lipoprotein possess the highest quantity of phospholipid.
- (a) HDL (b) LDL
(c) VLDL (d) Chylomicrons
47. Which of the following is not a non-drying oil?
- (a) Almond oil (b) Peanut oil
(c) Olive oil (d) Castor oil
48. Which of the following is example for semi-drying oil?
- (a) Olive oil (b) Mustard oil
(c) Poppy seed oil (d) Almond oil
49. Which of the following is not on drying oil?
- (a) Linseed oil (b) Poppy seed oil
(c) Cotton seed oil (d) Hemp oil
50. Cocoa butter is an example for what type of lipids?
- (a) Simple lipid (b) Complex lipid
(c) Derived lipid (d) Miscellaneous lipid
51. Which of the following statement is not correct with respect to lipid functions?
- (a) It is as a concentrated fuel reserve of the body
(b) It acts as an insulating material
(c) It serve as a source of fat-soluble vitamins
(d) It is not responsible for the shape and smooth appearance to the body
52. Which of the following fatty acid is not an even carbon fatty acid?
- (a) Valeric acid (b) Oleic acid
(c) Palmitic acid (d) Stearic acid
53. Which of the following fatty acids are not an essential fatty acid?
- (a) Linoleic acid (b) Linolenic acid
(c) Palmitic acid (d) Arachidonic acid
54. Proteins are the polymer of which of the following?
- (P) D- α -Amino acids (Q) D- β -Amino acids
(R) L- α -Amino acids (S) L- β -Amino acids
- Choose the correct option.
- (a) Only R (b) Only S
(c) Both R & S (d) Both P & Q
55. Which of the following function of a protein is regarded as "The working horses" of the cell?
- (a) Structural functions (b) Dynamic functions
(c) Both a & b (d) None of the above
56. Which of the following amino acids are essential amino acids?
- (P) Alanine (Q) Methionine
(R) Tyrosine (S) Lysine

Choose the correct option.

- (a) P & S (b) Q & R
(c) P & R (d) Q & S

57. Which of the following one is wrong with respect to peptide bond?

- (P) Rigid & planar (Q) Partial double bond character
(R) Covalent bond (S) Weak bond.

Choose the correct option.

- (a) P, Q & R is correct; S is wrong (b) Q, R & S is correct; P is wrong
(c) P, Q & S is correct; R is wrong (d) P, R & S is correct; Q is wrong

58. Which of the following is true in peptide chain?

- (P) C-terminal residue at the left (Q) N-terminal residue at the left
(R) N-terminal residue at the right (S) C-terminal residue at the right.

Choose the correct option.

- (a) Both P & Q (b) Both P & R
(c) Both P & S (d) Both Q & S

59. For naming peptides which of the following suffix is added by replacing existing suffix with the exception of C-terminal amino acid?

- (a) -ine (b) -yl
(c) -ane (d) -ate

60. Which of the following bond is not present in the protein structure?

- (a) Covalent bond (b) Non-covalent bond
(c) Hydrogen bond (d) Co-ordinate covalent bond

61. Which of the followings are not globular proteins?

- (P) Collagens (Q) Prolamines
(R) Histones (S) Keratins

Choose the correct option.

- (a) Both Q & R (b) Both P & S
(c) Both R & S (d) Both P & Q

62. Casein present in milk & vitelline present in egg yolk are comes under which of the following category?

- (a) Glycoprotein (b) Nucleoprotein
(c) Phosphoprotein (d) Lipoprotein

63. Hydroxyl group is not present in which of the following amino acid?

- (a) Proline (b) Tyrosine
(c) Threonine (d) Serine

64. Which of the following amino acids are both glucogenic and ketogenic in nature?

- (P) Phenylalanine (Q) Isoleucine
(R) Tryptophan (S) Tyrosine

Choose the correct option.

- (a) P, Q & R (b) Q, R & S
(c) P, R & S (d) P, Q, R & S

65. Which of the following amino acids is not a polar with positive R group in structure?
(a) Arginine (b) Lysine
(c) Alanine (d) Histidine
66. Which of the following amino acid was first identified as essential amino acid.
(a) Valine (b) Cystine
(c) Cysteine (d) Tryptophan
67. Which of the following sulphur containing amino acid is participated in transmethylation reactions?
(a) Methionine (b) Cysteine
(c) Cystine (d) Glutathione
68. Which of the following amino acid is not a branched chain amino acid?
(a) Leucine (b) Isoleucine
(c) Alanine (d) Valine
69. Nucleotide contains which of the following?
(a) Nitrogen base (b) Sugar
(c) Phosphate group (d) All of them
70. Numbering of purine follows which pattern?
(a) Anti-clockwise (b) Clockwise
(c) Either (a) or (b) (d) Both (a) and (b)
71. Which of the following is not a pyrimidine base?
(a) Uracil (b) Guanine
(c) Orotate (d) Thymine
72. Which of the following is not a purine base?
(a) Orotate (b) Guanine
(c) Xanthine (d) Uric acid

Key for Multiple Choice Questions

- | | | | | |
|--------|--------|--------|--------|--------|
| 1 (c) | 2 (a) | 3 (d) | 4 (b) | 5 (c) |
| 6 (d) | 7 (b) | 8 (d) | 9 (d) | 10 (c) |
| 11 (b) | 12 (c) | 13 (d) | 14 (a) | 15 (d) |
| 16 (d) | 17 (c) | 18 (c) | 19 (d) | 20 (d) |
| 21 (a) | 22 (c) | 23 (d) | 24 (d) | 25 (a) |
| 26 (a) | 27 (a) | 28 (a) | 29 (b) | 30 (d) |
| 31 (a) | 32 (d) | 33 (b) | 34 (b) | 35 (b) |
| 36 (d) | 37 (d) | 38 (a) | 39 (b) | 40 (a) |
| 41 (b) | 42 (d) | 43 (a) | 44 (d) | 45 (c) |
| 46 (a) | 47 (d) | 48 (b) | 49 (c) | 50 (a) |
| 51 (d) | 52 (a) | 53 (c) | 54 (a) | 55 (b) |
| 56 (d) | 57 (a) | 58 (d) | 59 (b) | 60 (d) |
| 61 (b) | 62 (c) | 63 (a) | 64 (d) | 65 (c) |
| 66 (d) | 67 (a) | 68 (c) | 69 (d) | 70 (a) |
| 71 (b) | 72 (a) | | | |

PART – B: Short Answers

1. What is free energy and free energy change?
2. What is energy rich compounds?
3. What are the main reasons for the ATP acts as universal energy currency molecule?
4. Write a brief account on ATP cycle.
5. Write about the biological significance of ATP & cAMP.
6. Explain redox potential & free energy constant.
7. Explain the biological significance of ATP.
8. Define and classify carbohydrates with suitable examples.
9. Write a note on structural aspects of carbohydrates.
10. Write a note on chemical nature of carbohydrates.
11. Write a note on biological significance of carbohydrates.
12. Write short notes on a) Epimer, b) Anomer.
13. Explain optical activity and D- & L-isomer of monosaccharides.
14. Define and classify lipids with suitable examples.
15. Define and classify fatty acid with suitable examples.
16. List out various biological significance of cholesterol.
17. Note on biological functions of lipids.
18. Explain the various biological importance of fatty acids.
19. What is the difference between glucogenic and ketogenic amino acids?
20. Explain about complete proteins.
21. What is conjugated protein?
22. List out the biological importance of amino acids.
23. List out nitrogen bases present in nucleic acid and draw the chemical structure of any one nitrogen base.
24. Write a note on nomenclature of nucleotides.
25. What is the importance of DNA & RNA?
26. What is nucleotide?
27. What are nucleosides?

PART – C: Long Answers

1. Write a detailed note on bioenergetics.
2. Define free energy, enthalpy and entropy. Explain the relationship between free energy, enthalpy and entropy.
3. Define and classify energy rich compounds. Explain any one compound in detail with chemical structure.
4. Write short notes on cyclic AMP.
5. Write briefly on: a) biological significance of ATP, b) Free energy, c) Energy rich compounds.
6. Write an account of high energy compounds metabolism.
7. Define carbohydrates and explain its various structural aspects with special emphasize on anomer and mutarotation.
8. Define and list out various types of protein classification. Explain any one classification in detail with suitable examples?
9. Write a detailed note on chemical nature and solubility classification of proteins.
10. Explain the biological significance of proteins.

11. Define and list out various types of amino acid classification. Explain any one classification in detail with suitable examples?
12. How amino acids are classified based on their chemical structure? Explain with suitable structure of amino acids.
13. Explain the biological significance of amino acids.
14. Explain the composition of nucleic acid.