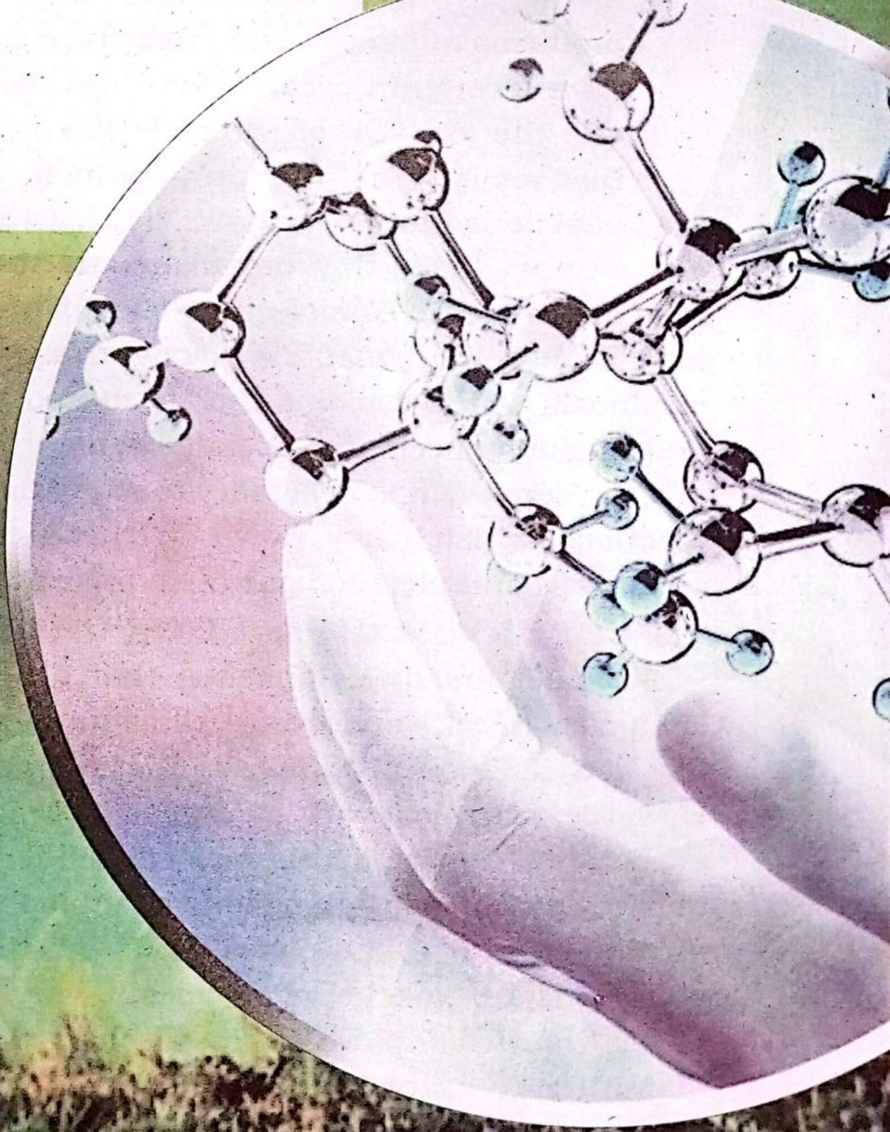
BIOLOGICAL MOLECULES

Chapter 1

Major Concept

In this Unit you will learn:

- Introduction of Biological Molecules
- Importance of water molecules
- Carbohydrates
- Proteins
- Lipids
- Nucleic acids
- Conjugated molecules



Introduction of Biochemistry:

The branch of biology which explains the biochemical basis of life is called **Biochemistry**. It is one of the most important branch of biology due some reasons given below:

- It provides information about all the processes carried-out in the living organisms from construction of body structures to flow of information from nucleus, especially DNA for enzyme/ protein synthesis and control of all the mechanisms.
- It provides information about abnormal mechanisms which lead to diseases. It ultimately open doors to the development of medicines and medical equipment to elucidate these abnormalities.
- The recent concept and technologies of biochemistry enabled us to investigate and understand most challenging and fundamental problems of biology and medicine e.g. how does cells find each other to form a complex organ? How does the growth of cells controlled? What are the causes of cancer? What is the mechanism of memory? Biochemistry is the only branch of science which answer these questions properly.

As we know that organisms are made up to tissues and cells while cells are made up of molecules, molecules are chemically bonded atoms. It means that fundamentally living things or organisms are made up to chemicals which explains the second postulate of cell theory i.e. structure and function of cell are dependent upon their chemical composition.

Therefore it is necessary to study the chemical composition of cell and reactions which carry down in these cells to understand the different structures and metabolisms of an organism.

1.1 CHEMICAL COMPOSITION OF CELL:

It is already established that all living organisms are structurally composed of cells and living cell contains a living matter called Protoplasm. The actual chemical composition of protoplasm is still not known perfectly. However, chemically it contains 70% to 90% of H_2O. If the water is evaporated, the remaining mass of cell is called **Dry Weight** of cell, consist of many carbon containing long chain molecules called **Biomolecules** which are the types of organic molecules. So, the compounds produced by living organisms are called biomolecules.

The elements which are involved in the synthesis of biomolecules are mainly six i.e. carbon, hydrogen, oxygen, nitrogen, phosphorus and sulphur.

The form approximately 98% of the biomolecules.

1.1.2 Fundamental types of Biomolecules:

Biomolecules can be divided into following groups according to variability in their structures and functions in cells and organisms i.e.

1. Carbohydrates
2. Proteins
3. Lipids
4. Nucleic Acids
5. Conjugated Molecules

Table 1.1 Biomolecules their units and linkages

Biomolecules	Units	Linkages
Carbohydrates (oligo & Polysaccharide)	Monosaccharides	Glycoside linkage
Proteins	Amino Acids	Peptide linkage
Lipids		
Fats & Oils	Glycerol & Fatty Acids	Ester linkages
Phospholipids	Glycerol, Fatty acids, Phosphate & Choline.	Ester & c-c linkages
Terpenoids	Isoprenoids units	c-c linkages
Nucleic Acids		
DNA	Deoxyribonucleotides	Phosphoester linkages
RNA	Ribonucleotides	Phosphoester linkages
Conjugated molecules	Different biomolecules	Different linkages

There is a variation found in literature about the percentage of biomolecules present in the cell. It is because, different cells within the same body have different amount of biomolecules. Therefore, these values are always taken as average values. Approximate percentage of chemical composition of a typical bacterial and a typical mammalian cell is given in table 1.2.

Table 1.2 Chemical compositions of cells (in %)

Molecules	Bacterial Cell	Mammalian Cell
Water	70	70
Protein	15	18
Carbohydrates	3	4
Lipids	2	3
DNA	1	0.25
RNA	6	1.10
Other Organic Compounds	2	2
Inorganic Ions	1	1

1.1.3 Synthesis and Breakdown of macromolecules (Polymers):

(a) Synthesis of macromolecules (polymers) by Condensation:

Molecules which form the structure and carry out activities of the cells are large in size and highly organized molecules called **macromolecules** which are made up of large numbers of low molecular weight, small molecules the subunits called **monomers** or building block. Therefore the macromolecules are also called **polymers** (poly = many, mers = parts). Biomolecules which are mentioned above are all macromolecules or polymers.

Macromolecules are constructed from monomers by a process that resembles coupling of rail cars onto a train. The basic structure of each group of macromolecule is very similar in all organisms from bacteria to human beings. In this process monomers are joined together by removing -OH from one monomer and +H from another monomer so both monomers form a new covalent bond between them, this process of joining two monomers by removing water molecule is called **condensation** or **dehydration synthesis**. Condensation always takes place by proper enzymes and energy expense.

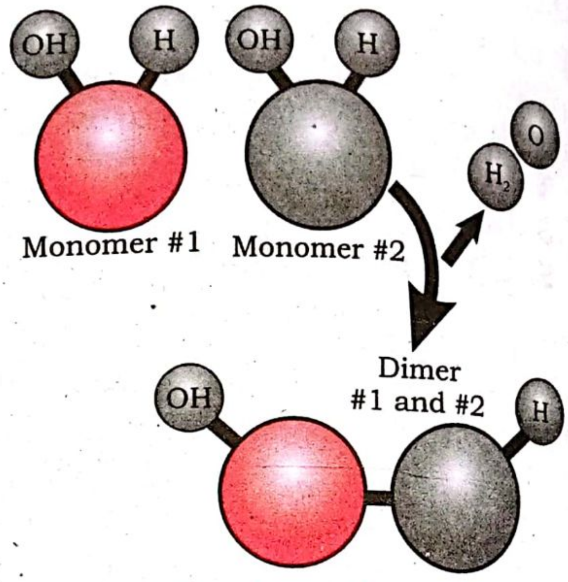


Fig 1.1 Condensation reaction

(b) Break down of macromolecule by hydrolysis:

Process where macromolecule (polymer) are broken down into their subunits (monomers) by addition of H_2O molecule is called **hydrolysis**. It is just revers of condensation, during this process a water molecule breaks into H^+ and OH^- ions with the help of enzyme, whereas OH group to one monomer and H attaches to the other by breaking linkage bond between two monomers. During this bond breaking energy is released and made available for other metabolic processes.

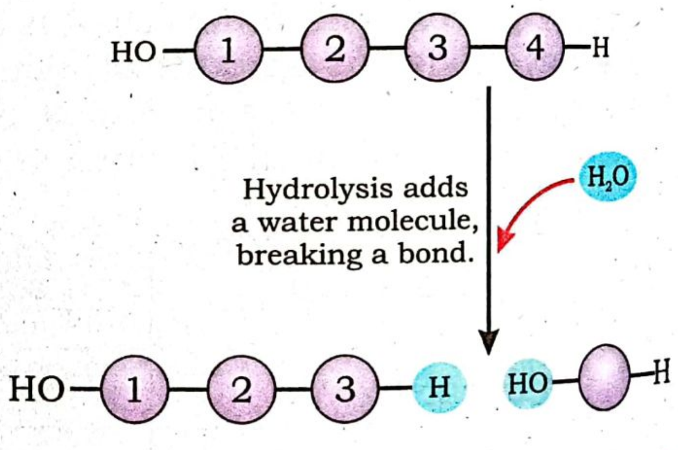


Fig 1.2 Hydrolysis: breaking down a polymer

During metabolism, macromolecules are either formed or broken down in the cell, when cell rebuild many of its structures. In heterotrophs, during digestion macromolecules broken into monomers by hydrolysis with the help of hydrolytic enzymes, these monomers when reach to cell again form macromolecules by the process of condensation. In autotrophs, cell produce monomers from inorganic molecules like CO_2, H_2O, NO_3^{-1}, SO_4^{-2} etc. These monomers latter on assembled to form macromolecules in source or sink tissues by the process of condensation, while the other cell when require these molecules either for building purpose or to produce energy, these molecules break into monomers by the process of hydrolysis.

1.2 IMPORTANCE OF WATER:

Water is the most abundant component in living cell. Its amount varies approximately from 70% to 90%. It is the medium of life. Almost all reactions of a cell occur in the presence of water. It also takes part in many **biochemical** reactions such as hydrolysis, also provides raw material for photosynthesis.

The ability of water to play its wide variety of roles and the reasons for its importance in biological systems is due to the chemistry of H_2O molecule. The chemical formula of water is H_2O, which means that the two atoms of hydrogen are joined to one atom of oxygen.

Water is a polar molecule. It means that it has partial negative charge (δ^-) on oxygen and partial positive charge (δ^+) on hydrogen atoms due to difference in electronegativities of hydrogen and oxygen atoms. This separation of electrical charges is called Dipole, which give the water molecule very important properties i.e. high polarity, formation of hydrogen bond, cohesion, adhesion, high specific heat, high heat of vaporization, hydrophobic exclusion, ionization and low density of ice. These properties make it best solvent and cradle of life.

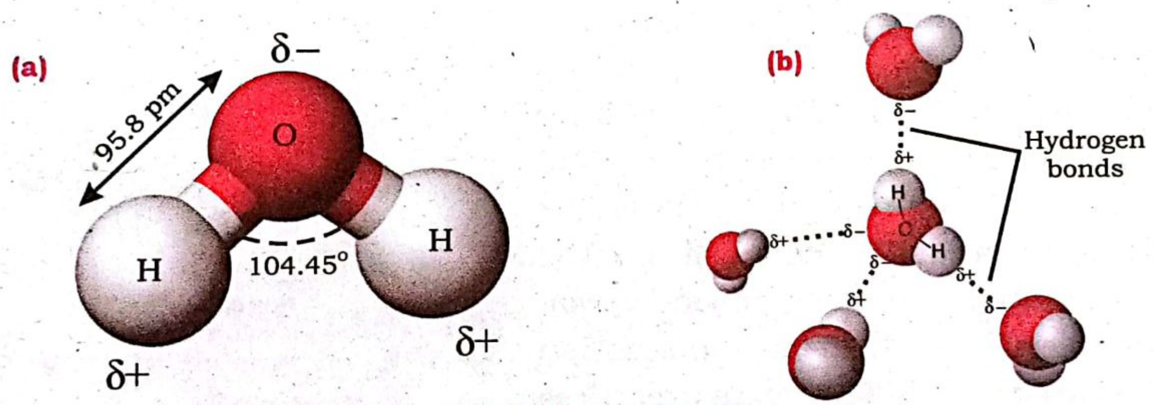


Fig 1.3 Hydrogen bonding

1.2.1 Hydrogen bond:

It is an intermolecular force of attraction formed between two molecule one of which contain partially charge $H^{+\delta}$ and other contain partial $O^{-\delta}$ charge as present in water. These charges attract two molecules, this force of attraction due to $H^{+\delta}$ and $O^{-\delta}$ is called Hydrogen bond. Due to this Hydrogen bonding two molecules have following two types of characters.

(a) Cohesion or Cohesive force of attraction:

The attractive force between similar molecules is called cohesive force of attraction. Due to polar nature water molecules attract each other and form H-bonds between them to form a long chain of water molecule, which help it in flowing freely. It flows as protoplasm in cell, as blood in blood vessels, as transporting fluid in the conducting tissues of plants.

(b) Adhesive force of attraction or Adhesion:

The attractive force between dissimilar molecules is called Adhesive force of attraction. Due to polar nature, water molecule attracts other charged molecules and attached with them. It can hold the water molecules in the vessels and prevent them from backward flow.

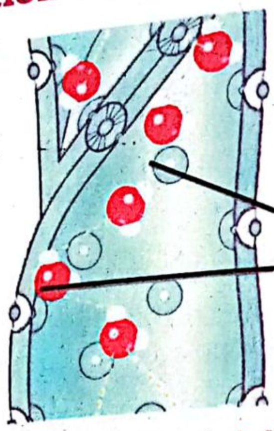


Fig 1.4 Adhesion and cohesion

1.2.2 High specific heat:

Specific heat of a substance is the amount of heat energy required to raise the temperature of 1gm of that substance by 1C° (e.g. 15C° to 16C°). The specific heat of water is high due to its polar nature and hydrogen bonding between their molecules. It means water required high amount of heat to make changes in its temperature or warm up. It works as temperature stabilizer for organism and hence protect protoplasm against sudden thermal charges.

1.2.3 High heat of vaporization:

The amount of heat required to change liquid state of water to vapor state is called heat of vaporization. Greater the heat of vaporization higher will be the chances of stability in state or vice versa. Water has very high heat of vaporization i.e. 574 kcal/kg, therefore water requires to absorb high heat to change its state from liquid to vapors. It gives stability to water molecules and its state in cell. It plays an important role in thermoregulation. It also provides cooling effect when evaporate during transpiration are perspiration.

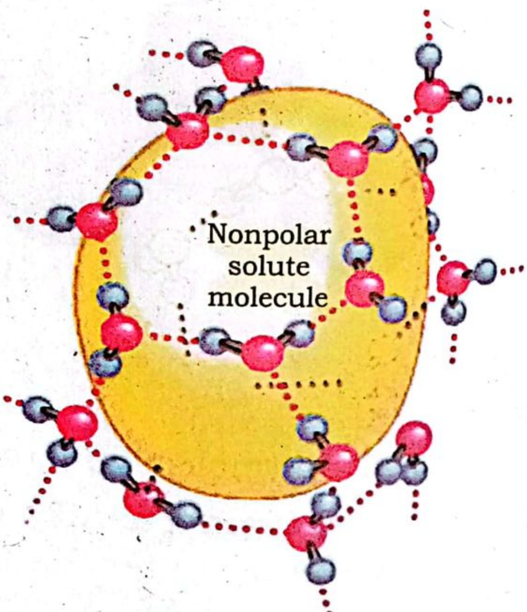


Fig 1.5 Vaporization

1.2.4 Hydrophobic exclusion:

It is the tendency of water to coalesce oil drop into large droplet. The water molecules have hydrogen bonding between them which are destroyed by the presence of hydrophobic oil and form new bonds. The water molecules then form more hydrogen bonds with themselves and the nonpolar molecules clump together. This excludes hydrophobic substance (oil) from water.

1.2.5 Ionization of water:

The water molecules ionize into H^+ and OH^-. This reaction is reversible and also maintain equilibrium. Due to ionization property water may behave as acid or base i.e. **Amphoteric** in nature. It also behaves as **buffer** due to this nature. It maintains pH for enzymatic activities in cells and organs.

1.2.6 Anomalous behavior of water:

Water shows different behavior below 4°C. Usually matter contract at low temperature but due to hydrogen bond below 4°C, water expands which decreases its density so at 0°C water expands maximally in ice condition. The low density water in ice become lighter, comes above the surface of high density water of liquid. It makes the life possible under frozen water.

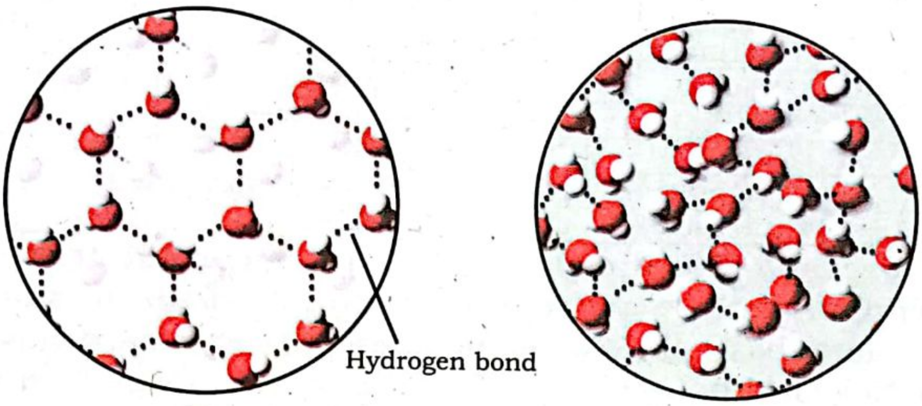


Fig 1.6 Behavior of water

1.3 CARBOHYDRATE (CARBO = CARBON, HYDRATE = WATER):

The literal meaning of word carbohydrate is hydrated carbon i.e. water containing carbon. Thus biomolecule contain C, H and O as element where the hydrogen and oxygen are present in the simple ration of 2:1 as present in water. The general formula of carbohydrate molecules is $C_nH_{2n}O_n$, whereas 'n' is the whole number. According to I.U.P.A.C carbohydrates are defined as "the polyhydroxy carbonyl compounds", carbonyls are aldehydes or Ketones.

Main source of carbohydrates are plants because they synthesize carbohydrate molecules as primary product during photosynthesis, other bio-molecules are produced from carbohydrate during different metabolic pathways.

They are sweet in taste if feels therefore called sacchrum or Saccharide. They are also called sugars.

Carbohydrate found abundantly in all organism, like cellulose in cell wall of plant, paper, starch is stored in cereal grains, tubers, sugar cane, etc. It plays both structural and functional role.

1.3.1 Classification of Carbohydrates

As we have discussed earlier that carbohydrate molecules are also called 'Saccharides' these Saccharides are classified into three group.

(i) Monosaccharide (ii) Oligosaccharide (iii) Polysaccharide

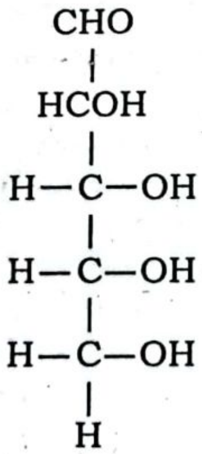
(i) Monosaccharide: (Mono = one; Saccharide = Sugar)

The group of carbohydrate molecules which contain only one sugar molecule. They cannot hydrolyses due to this reason. The empirical formula of their molecules is $C_nH_{2n}O_n$ e.g. Ribose ($C_5H_{10}O_5$). Fructose $C_6H_{12}O_6$, etc; all are found in white crystalline solid with sweet taste and soluble in water. Monosaccharide can further classified on the basis of C atoms present in them, the suffix 'Ose' use with no: of C atoms present in them as given in following table.

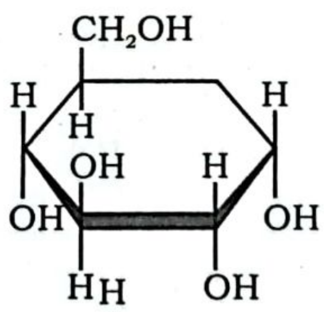
Table 1.3 Classification of monosaccharides

Class	Formula	Example
Triose	$C_3H_6O_3$	Glycerose (Glyceraldehyde) Dihydroxy acetone etc.
Tetrose	$C_4H_8O_4$	Erythrose, Erythrulose etc.
Pentose	$C_5H_{10}O_5$	Ribose, Ribulose etc
Hexose	$C_6H_{12}O_6$	Glucose, Fructose, Galactose etc
Heptose	$C_7H_{14}O_7$	Glucoheptose.

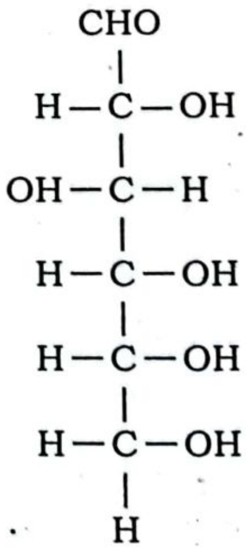
Glycerose and Dihydroxy acetone are important triose, produced during respiration. Tetrose are rare in nature, it occurs in some bacteria, pentose sugar form basic skeleton of nucleic acid. Hexose are most important sugars from biological point of view. Glucose found in ripe fruit, sweet corn and honey. It is also found in all known polysaccharide in combined state. Fructose another hexose present in fruit so called fruit sugar usually they are found in ring structures but we can also draw their structure in open chain form:



Ribose

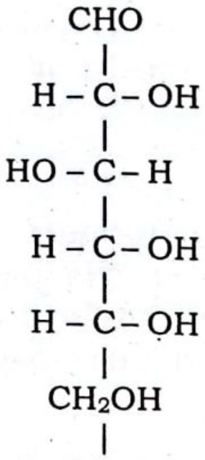


Glucose

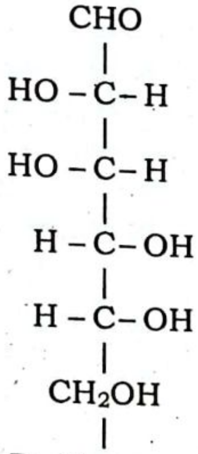


Glucose

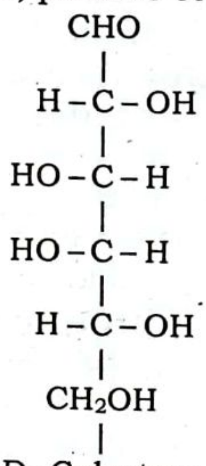
The hexose are further divided into aldohexose isomers (having same molecular formula but different structural formula) like glucose, galactose, mannos etc and ketohexose isomers like fructose, sorbose, psicose etc.



D- Glucose



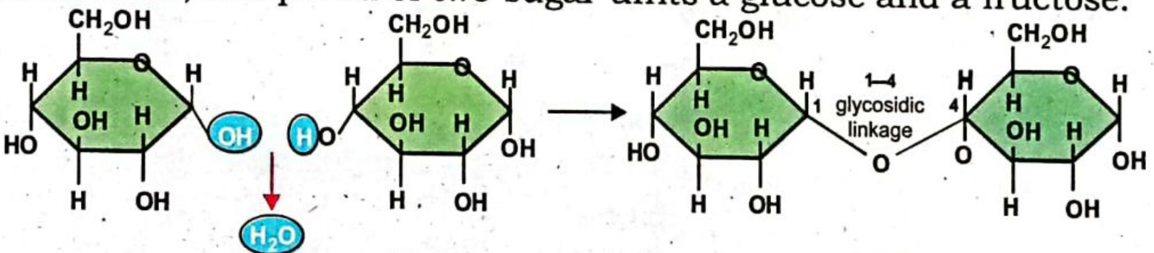
D- Mannose



D- Galactose

(ii) Oligosaccharides:

The type of carbohydrate which are made up to 2 to 10 monosaccharides. These are comparatively less sweet in taste and less soluble in water. They can hydrolyze. The most common type is disaccharide, on hydrolysis yield two monosaccharides. The covalent bond between these two monosaccharides is **Glycosidic bond** or linkage. A glycoside is simply a ring shaped sugar molecule that is attach to another molecule, the sugar ring may be either 5 membered ring or a six membered ring. For example sucrose is a disaccharide, composed of two sugar units a glucose and a fructose.



The disaccharide may be reducing or non-reducing sugar. The reducing sugar is any carbohydrate which is capable of being oxidized and causes the reduction of other substances without hydrolysis. It is due to the presence of free aldehyde or free ketone group. Examples are maltose, lactose etc. The non-reducing sugars are carbohydrate which are unable to be oxidized and do not reduce other substance. It is due to absence of free aldehyde or ketone groups, e.g. sucrose or refinose etc.

Living organisms especially plants transport their sugar from source (leaf) to sink (fruit) tissues in the form of non-reducing sugar where glycosidic bonds are formed between 'carbonyl' groups of both sugars. Sucrose is the sugar which is non-reducing. It contains more energy i.e, it is energy efficient in transport and storage. During transport it is not oxidized and react with other substance so no intermediate reaction with other molecules occur.

(iii) Polysaccharide:

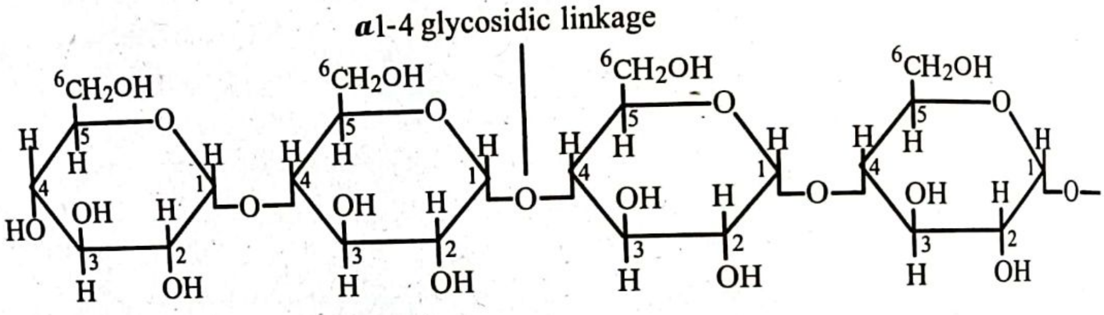
These are high molecular weight carbohydrates which on hydrolysi yield many monosaccharides. These are formed by the condensation o hundreds or thousands of Monosaccharide units, e.g. starch, glycogen, cellulose and chitin.

1.3.2 Starch:

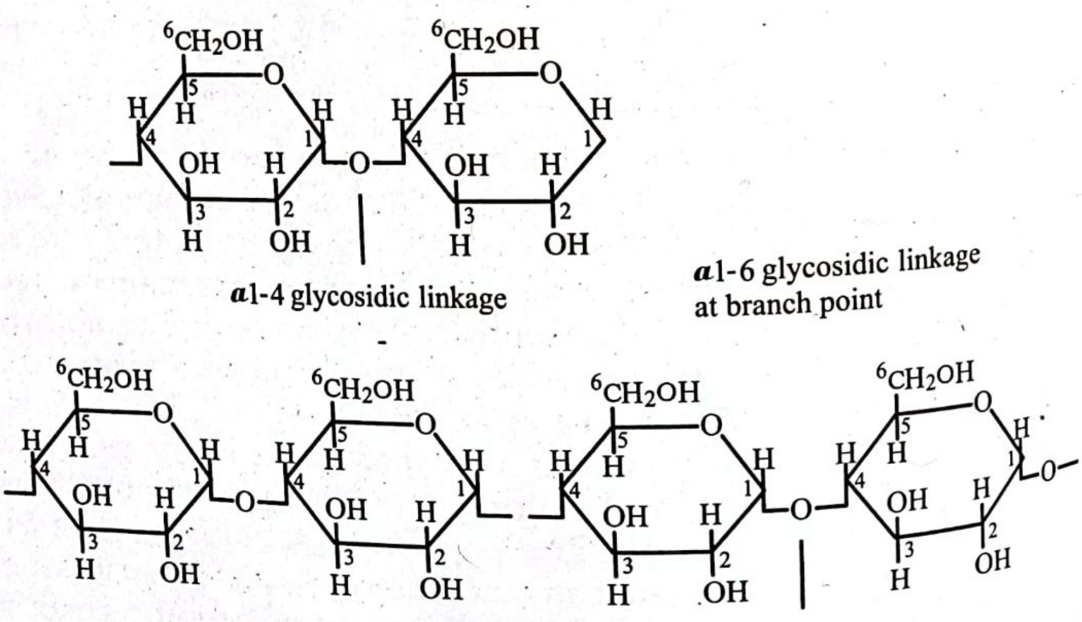
It is the most important and abundant reserve food material of highe plants, found in cereals, legumes, tubers and other vegetables. It is made up of many glucose molecules joined together in straight chain **amylose** which is soluble in hot water and a branched chain **amylopectin**, which is insolubl in hot and cold water. It gives blue color to iodine.

1.3.3 Glycogen:

It is also a polymer of glucose. Its molecular structure is similar to starch but found in animal therefore it is commonly called animal starch. I is mainly found in bacteria, fungi, in animals abundantly found in liver and muscles. It gives red color with Iodine.



Amylose



Amylopectin

1.3.4 Cellulose:

It is also a polymer of glucose, most abundant carbohydrate found in nature. It is highly insoluble in water. It is not digested in human body. In cellulose the glucose units are joined in straight chain and no branch chain present in it. This straight chain become spirally coiled and condensed to form tubes. These tubes of cellulose form cell-wall of plant cells. Cellulose give no colour to iodine.

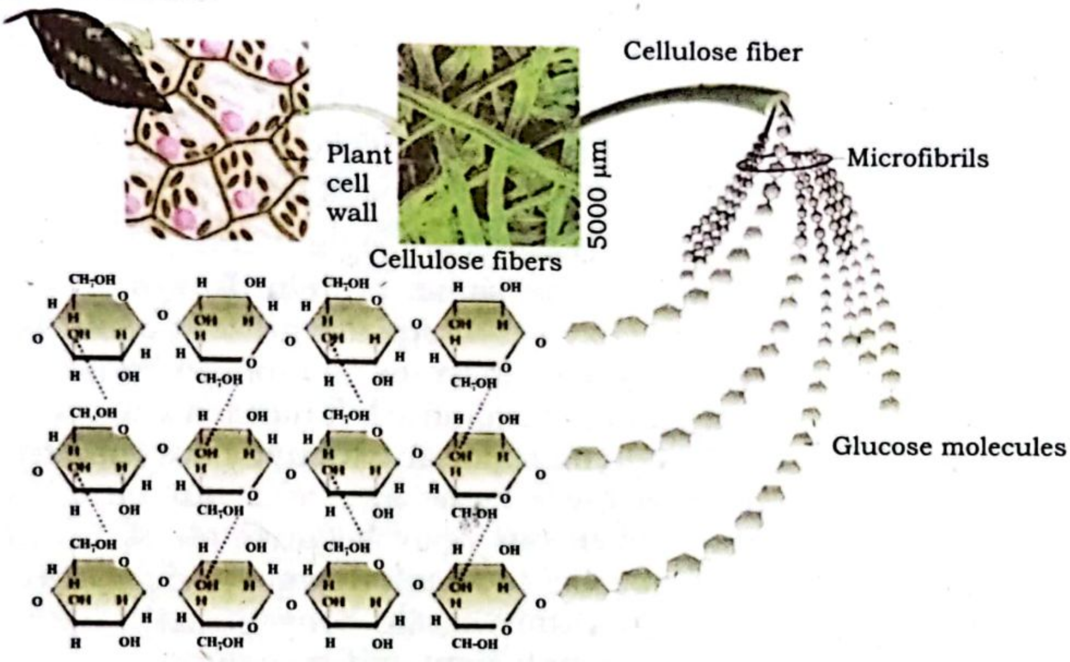


Fig 1.7 Structure of cellulose

1.3.5 Chitin ($C_8H_{13}O_5N)_n$:

It is a long chain polymer of N-acetyl glucosamine, an amide derivative of glucose. The structure of chitin is similar to cellulose, forming crystalline Nano fibrils. Functionally, it is comparable to Keratin protein. Chitin is modified polysaccharide contains Nitrogen which allows for increased hydrogen bonding between adjacent polymers, giving it more strength.

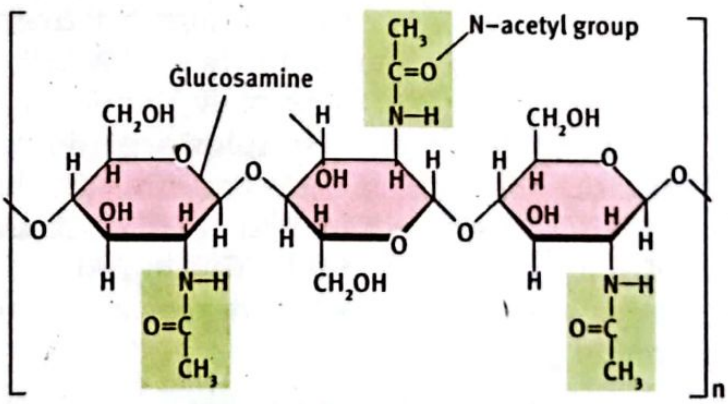


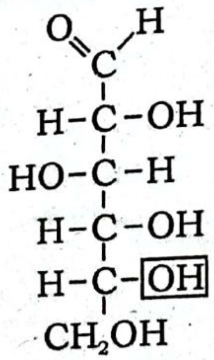
Fig 1.8 Structure of chitin

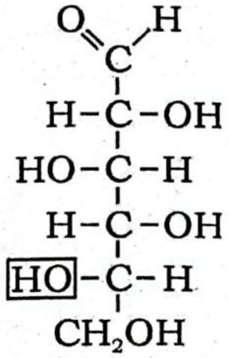
In its pure and unmodified form chitin is translucent, pliable, resilient and quite tough in most arthropods but it is mostly found in modified form such as proteineceous matrix form exoskeleton of insects, with $CaCO_3$ in the shells of mollusks and crustaceans, composite material is much harder and stiffer than pure chitin.

Stereoisomers in Carbohydrates and its role in artificial sweetness:

Many sugar molecules have stereoisomers i.e. the molecules are mirror images of each other.

D-Glucose
Right handed sugar





L- Glucose
Left handed sugar

Most of the sugars in our body are right handed. The taste of right handed and left handed sugars are same, protein (Enzymes) are also right handed and left handed. The enzymes which are present in our body are also right handed therefore right handed enzymes metabolize right handed sugars only. They are unable to digest or metabolize left handed sugars. The artificial sweetener which are used by diabetic patients usually are left handed sugars, these sugars have same mass and same sweetens but have zero calories. These sugars are not digested in our body because all of our enzymes are right handed and they are specific to break down the right handed sugars. The left handed won't fit into catalytic site consequently there will be no breakdown of these sugar, no metabolism and no calories.

1.4 PROTEIN: (GR: PROTEIOS MEANS 'FIRST RANK')

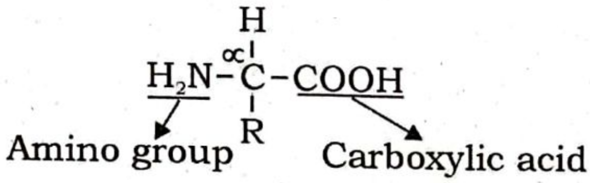
Proteins can be defined as the polymers of specific amino acid arrange in a particular manner which perform definite function. Proteins are the most important organic compounds of the cell which carry out virtually all of the cell's activities. They constitute major part of the dry weight of a cell.

Proteins are the complex organic compounds having C, H, O and N as elements, sometimes they contains S also. Due to presence of N in large proportion they are called **nitrogenous compounds**. Proteins are the building blocks of tissues. Many parts of the body such as hair, nails and feathers are also protein. Whereas meat, fish, milk and pulses are the major source of protein.

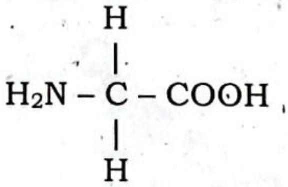
1.4.1 Amino acid as a building block of protein

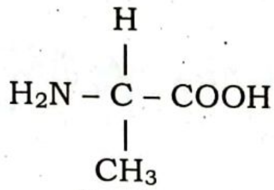
Proteins are macromolecule or polymers of amino acids. These amino acids are monomers and linked with each other by a covalent bond called **peptide bond or peptide linkage**. As we have defined above that each protein has a unique sequence of amino acids that gives the unique properties to these molecules. There are twenty basic amino acids which constitute each type of protein, found in viruses to human beings.

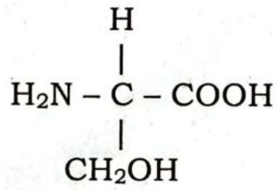
Amino acids are organic compounds which contain at least one amino group (–NH_2) which work as base and one carboxylic acid, work as acid, both are chemically bonded to an asymmetric carbon, this carbon is also called ∝ Carbon. The general structure (empirical formula) of amino acid is



All 20 amino acids have same formula except R group i.e. Radical group, which is variable, the types of 20 amino acids based on the variability of R as shown in following simple amino acids.

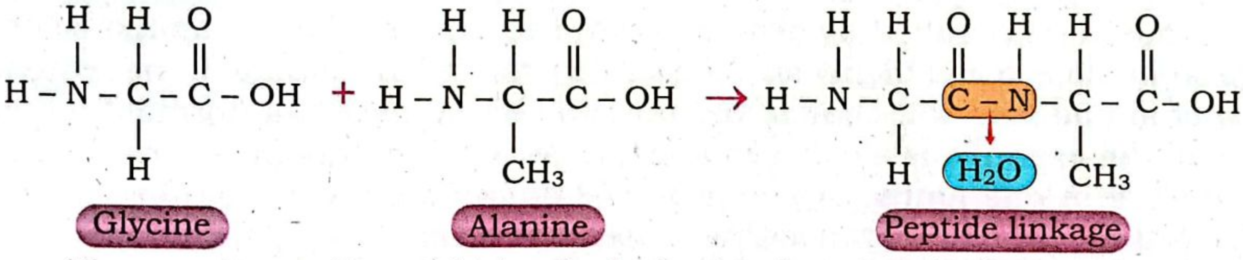

Glycine


Alanine

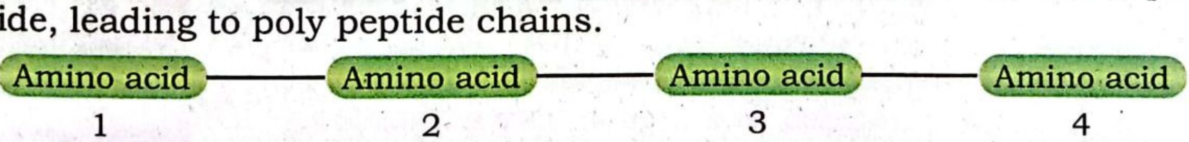

Serine

1.4.1.1 Formation and Breakdown of peptide linkage

The protein or polypeptide chain is formed by linking amino acids by peptide bond. The peptide bonds are formed by linking amino group of one amino acid with carboxylic acid of another amino acid by releasing one water molecule as given below



The resultant dipeptide is glyclyalanine has two amino acid subunit called **dipeptide**. A dipeptide has an amino group of one end and a carboxylic acid group at the other end of the molecule. In this way both reactive parts are again available for further peptide linkage to produce tri, tetra, penta peptide, leading to poly peptide chains.



The polypeptide chain can be broken by breaking peptide bonds by the process of hydrolysis with the help of hydrolytic enzymes. The protein chain can be broken into small chain of more than 10 amino acids called **peptone**, whereas peptone can be hydrolysis further into small units of few amino acid called **peptide** which are further hydrolysis into amino acids.

1.4.1.2 Significance of the sequence of amino acids

F. Sanger was the first scientist who determined the sequenc amino acids in a protein molecule. He found that Insulin is composed o amino acid in two chains. One had 21 amino acid and other had 30 am acids they held together by disulphide bonds. Same is found in Hemoglol which is composed of 4 chains, two alpha (α) and two Beta (β) chains. E alpha chain has 141 amino acids, while each beta chain contain 146 am acids.

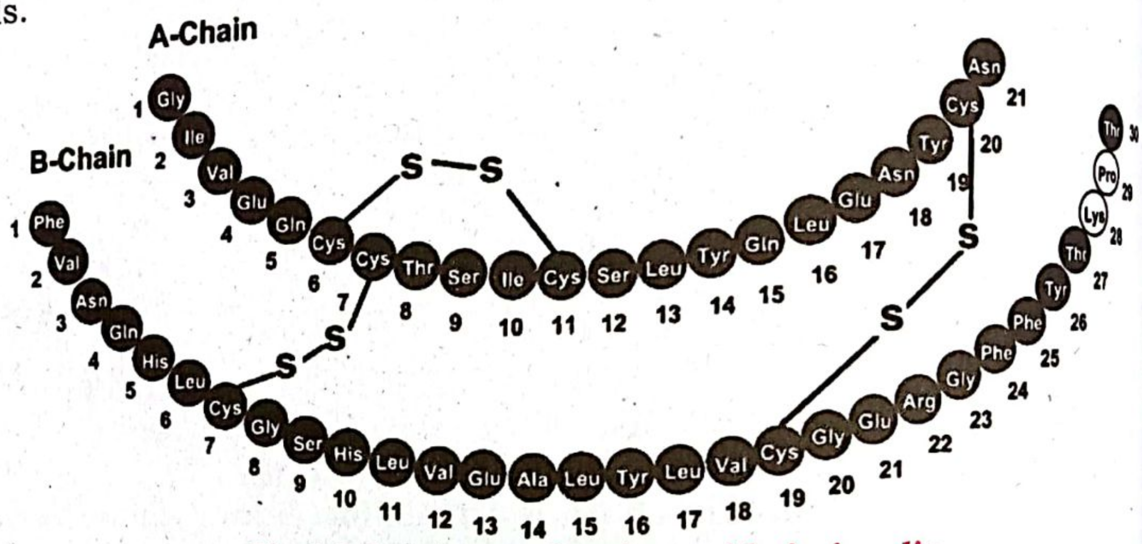


Fig 1.9 Sequence of amino acids in insulin

Human body has more than 10,000 protein. These protein composed of unique and specific arrangement of 20 amino acids. T sequence is determined by gene as DNA, the arrangement of amino acids a protein molecule is highly specific for its proper functioning. If the sequen of any amino acid will change the protein fails to carry its normal functio One of the example is sickle cell anemia i.e. abnormality in hemoglobin d to change in one amino acid out of 574 amino acid. Only glutamic acid replaced by valine at 6th position. Due to this little change the hemoglob fails to carry sufficient O_2 which leads to death of the person.

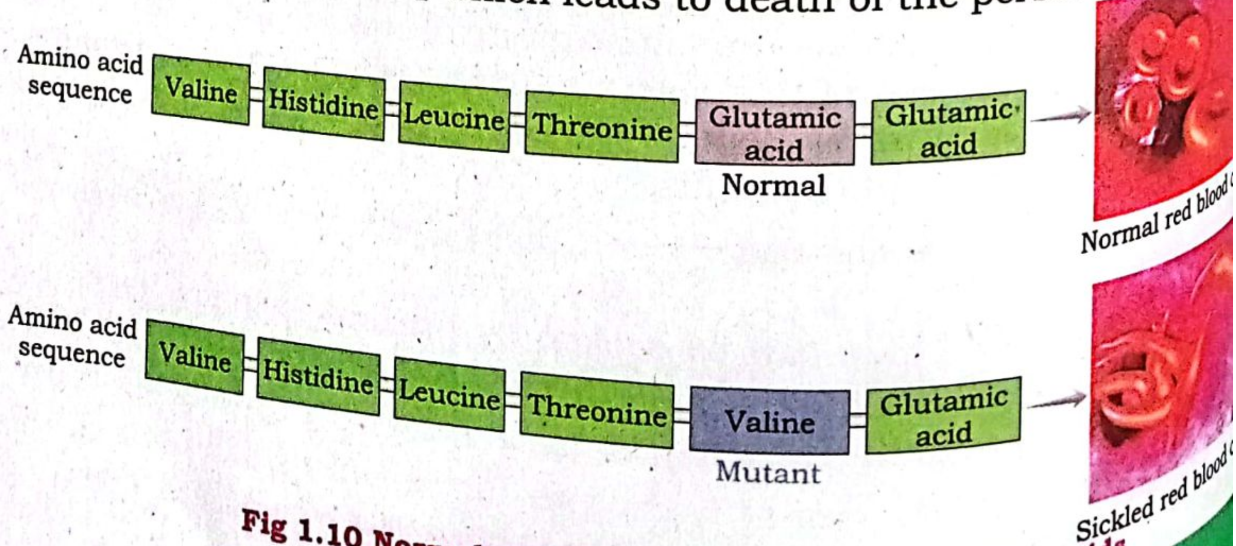


Fig 1.10 Normal and abnormal sequence of amino acids

1.4.2 Classification of Protein

Protein can be classified in many ways i.e. on the basis of structure or on the basis of function etc. Proteins can also be classified on the basis of shape in two following groups.

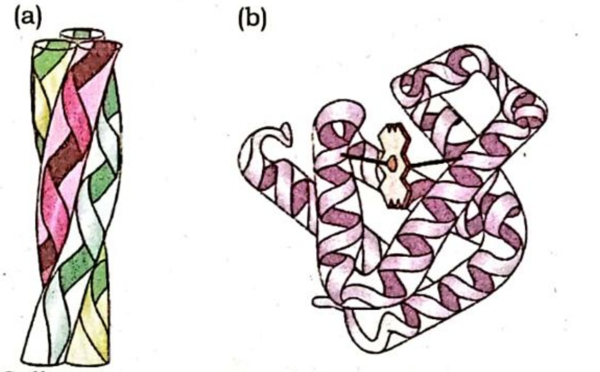
(i) Fibrous Protein (ii) Globular Proteins

(i) Fibrous Protein:

These are long fibers of proteins. The secondary protein (spiral) chains intertwine with each other's they are consist of more polypeptide chains in the form of fibrils these proteins are insoluble in water, non-crystalline and elastic in nature. They perform structural role in cells and organism e.g. silk, spider web, myosin in muscles, fibers and clothing, Keratin of nails and hairs etc.

(ii) Globular Proteins:

These are spherical or ellipsoidal due to three dimensional fold of secondary protein. These are either tertiary or quaternary in structure. They are soluble in salt, acid or base containing aqueous medium or alcohol. They can be crystalized. These proteins work as enzyme, antibodies, hormones and hemoglobin.



Collagen, a fibrous protein

Myoglobin, a globular protein

Fig 1.11 Structure of Proteins

Table 1.4 List of structural proteins

Actin	Muscle forming protein
Amyloid	Work as cell surface protein
Caddisfly (Fibroin)	Used to bind debris like rocks sticks twigs and shells for net of prey.
Condrocalein	Form extra cellular matrix
Collagen	Give strength, turned elasticity to skin main component of cartilage, ligaments, tendon, bone and teeth.
Elastin	Provide resilience and elasticity to tissues and organs.
Fibrillin	Glycoprotein provide force bearing structural support in elastic and non-elastic connective tissues.
Gelatin	Nutritious protein derived from collagen of skin and bones.
Sclera protein	Include Keratin, collage, elastin and fibrin
Titin	Provide elastic stabilization of myosin and action filament
Tubulin	Microtubules farming protein
Keratin	Nails and hairs farming protein

Table 1.5 List of Functional Proteins

Type	Examples	Function
Digestive enzymes	Amylase, lipase, pepsin, trypsin	Help in digestion of food by hydrolysi into simple monomers.
Transport	Hemoglobin, albumin	Carry O_2 and CO_2 other substance i the blood or lymph throughout th body.
Hormones	Insulin, thyroxin	Co-ordinate different functions of bod
Defenses	Immunoglobulin, interferon	Protect the body from foreign pathoge
Contractile	Actin, myosin	Muscle contraction
Storage	Legume storage protein, egg white (albumin)	Provide nourishment at the time development of embryo.

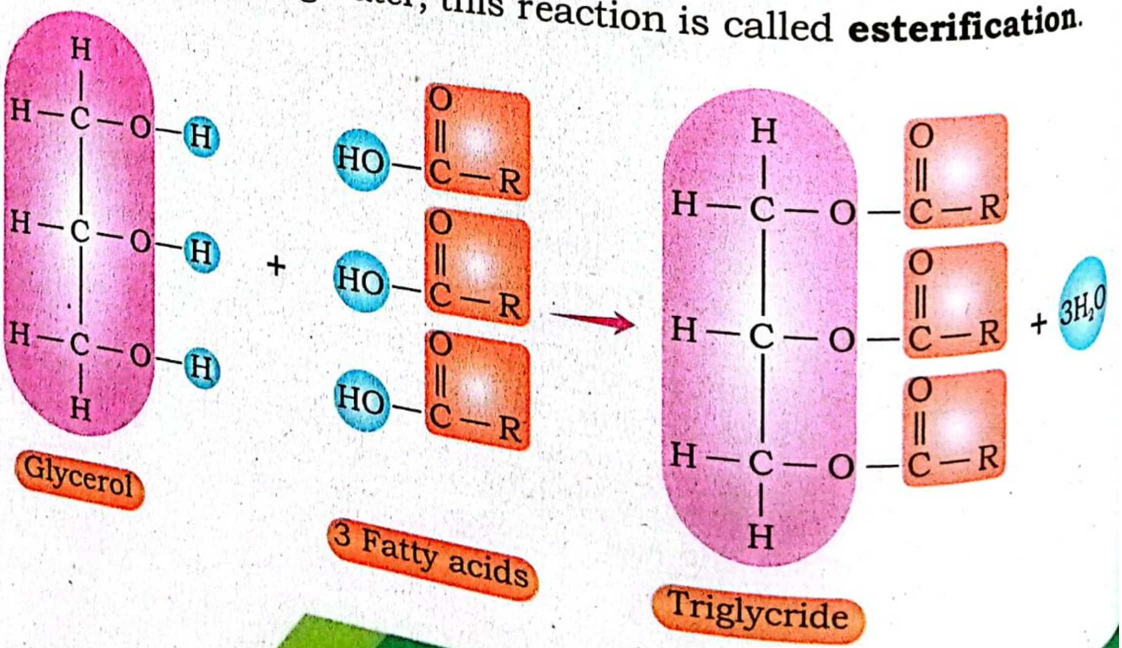
1.5 LIPIDS:

Lipids are the important diverse group of biological molecules, wid distributed among plants and animals. The term lipid is proposed by Blo in 1943, for those biomolecules which are insoluble in water and soluble organic solvents like ether and alcohol etc. These compounds are made of C, H, O like carbohydrates but contain much lesser ratio of oxygen tha carbohydrates e.g. stearin is a fat, has molecular formula ($C_{57}H_{110}O_6$). Due high quantity of carbon and hydrogen, they contain almost double amou of energy than carbohydrates.

Following are some common groups of lipids.

1.5.1 Acylglycerol (Fats and oil):

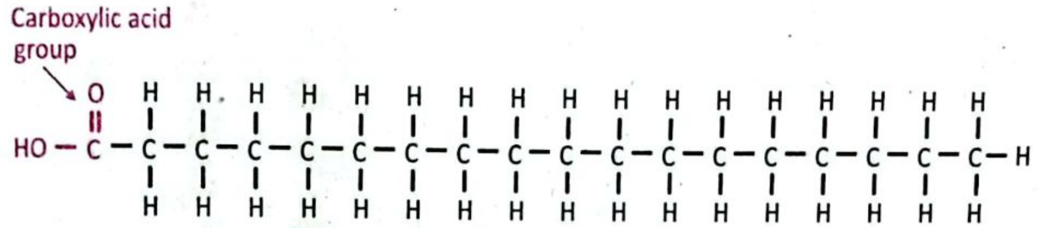
These are the condensation product of glycerol and three fatty aci commonly called **fats** and **oils**. They can be defined as the esters of glycer and fatty acid. Ester is the bond or linkage formed between alcohol an organic acid by removing water, this reaction is called **esterification**.



Glycerol is a trihydroxy alcohol, made of three carbon atom each contain on OH- group, while a fatty acid is a type of organic acid containing one carboxylic acid group with long hydrocarbon chain. When three fatty acid combine with glycerol each at one -OH, they form three ester bonds. A compound called **Triglycerol** (triglyceride) is formed. There triglycerol are neutral in nature because all three OH group of glycerol become bonded with fatty acids and no charge bearing OH is left. There are two types of acylglycerol.

(a) Saturated acylglycerol (Fats):

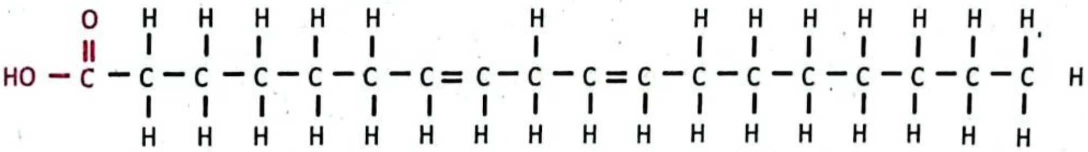
They contain saturated fatty acid i.e. do not contain any double bond between carbon atoms of hydrocarbon chain e.g. stearin.



Structure of stearic acid

(b) Unsaturated acylglycerol (oils):

They contain unsaturated fatty acids i.e. contain one or more than one double bond between carbon atoms of hydrocarbon chain. They have stable physical state, usually found at liquid state at ordinary temperature, found in plants, also called oil e.g. linolin found in seed.



Structure of linoleic acid

Acylglycerol provide energy for different metabolic activities and are very rich in chemical energy, twice in amount of energy content than carbohydrate. It is estimated that a person of average size contains approx: 16 kg of fats which contain 144×10^3 KCal of energy.

1.5.2 Phospholipids:

Type of lipids which is condensation product of Glycerol, two fatty acids one choline and one phosphate.

Phospholipid is the most important group of lipids from biological point of view. A phospholipid is similar to acylglycerol, except that one fatty acid is replaced by phosphate which is attached with a nitrogenous compound **choline**. It contains two ends, one which is made up of fatty acid, which form non-polar part therefore behave as water repellant so called hydrophobic. The phosphate and choline form another end, which form polar part, therefore attract water molecule so behave as water loving i.e. hydrophilic. Phospholipids are present in all living cells and form membrane. They are related to vital functions such as regulation of cell permeability and transport processes. Properties of cell membrane depend on it phospholipid component.

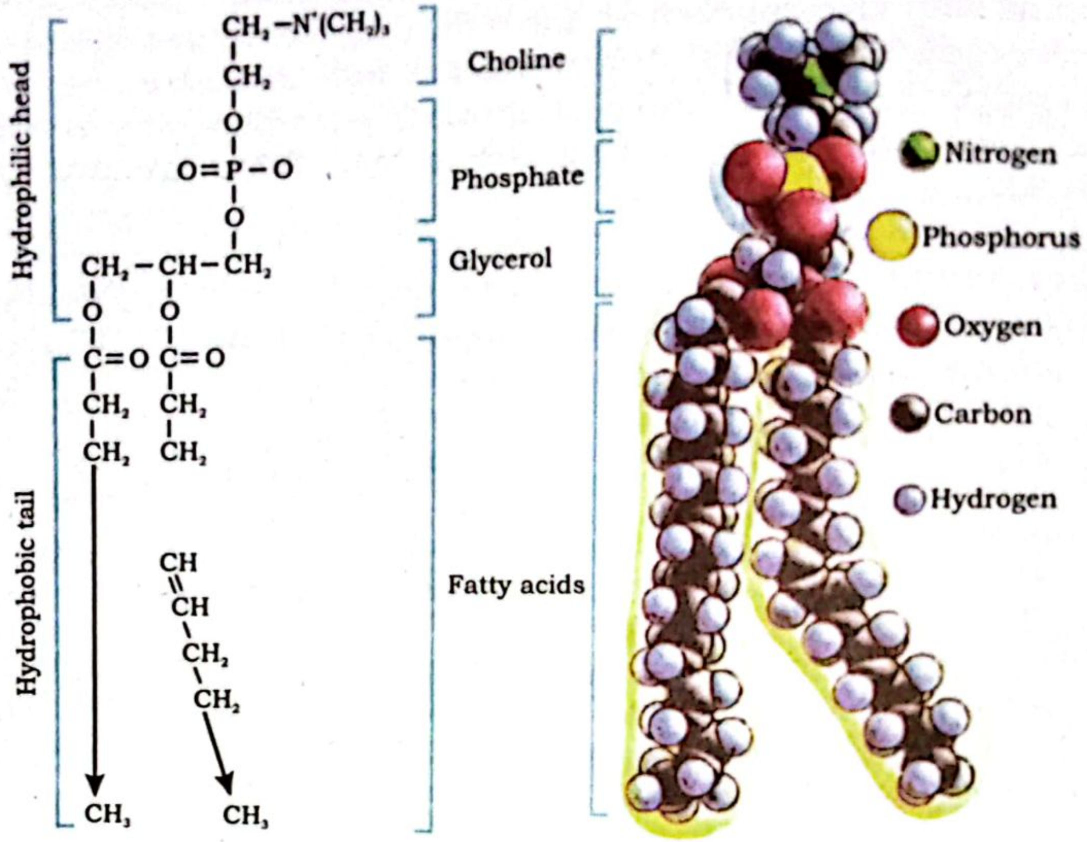


Fig 1.12 Phospholipid

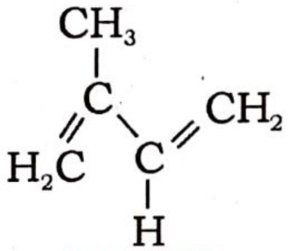
1.5.3 Waxes:

They are esters of long chain mono-alcohol and long chain fatty acids. These are simple lipid and found as protective coating on stem, stalks, leaves, petals, fruits skin, animal skin, fur and feathers etc, these are water repellant and non-reactive due to its non-polar nature i.e. hydrophobic compounds. These are chemically inert and resistant to atmospheric oxidation. There are two types of waxes i.e. Natural, like bee's wax and cutin form cuticle of leaves and synthetic waxes, generally derived from petroleum or polyethylene.

Waxes are of considerable commercial importance because they act as superior machine lubricants. Sperm whales were the principle source of these wax.

$$\underbrace{CH_3(CH_2)_{14}-\overset{\overset{O}{\|}}{C}}_{\text{Palmitic acid}}-\underbrace{O-CH_2-(CH_2)_{28}-CH_3}_{\text{Triacontanol}}$$

1.5.4 Terpenoids:



Isoprenoid

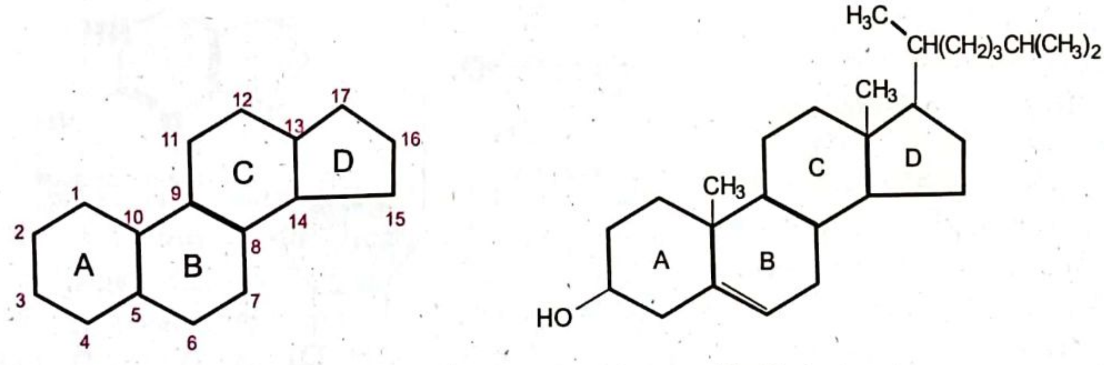
Terpenoid is a large and important class of lipids, made up of isoprenoid units (C_5H_8). Terpenes, steroids, carotenoids and prostaglandins are type of Terpenoids. These are found in cell membrane as cholesterol, as pigment like chlorophyll, fragrance as menthol etc.

1.5.4.1 Terpenes:

Terpens are the type of terpenoids which contain few isoprenoid units like diterpens, Triterpens. These small size terpens are volatile in nature and produce special fragrance. Some of these are used in perfume e.g. Myrcens from oil of bay, Geranoil from rose, Limonene from lemon oil, Menthol from peppermint oil. Some component of vitamin A_1, and A_2, chlorophyll molecules as well as some other molecules which utilized in the synthesis of rubber and latex.

1.5.4.2 Steroids:

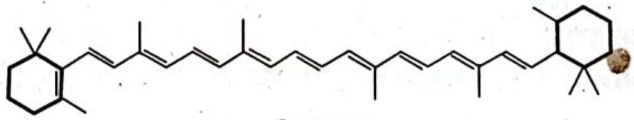
Steroids is a type of Terpenoid which form steroid nucleus made up isoprenoid units contain 17 Carbon atoms arranged in four attached rings, three of them are hexagonal and one is pentagonal in shape. The radical attached with them as side chains distinguish them from one another cholesterol is one of the type of steroid. Cholesterol is the precursor for the synthesis of a number of steroids i.e. testosterone, progesterone and estrogens.



(a) Steroid skeleton (b) Cholesterol

1.5.3 Carotenoids:

It is polyterpenes, consist of long chain of isoprenoid unit which contain isoprenoid rings at both or at one terminal. These compounds are pigments producing red, orange, yellow and brown color in plants. Some important carotenoids are plant pigments, like chlorophyll, cytochromes, phytochromes, latex, rubber etc.


β-carotene

1.5.4 Prostaglandins:

Prostaglandins is a group of lipids made by mammalian tissues at the sites of tissues damage or infection that are involved in dealing with injury and illness. They control different physiological process such as inflammation, intensity of sensation of pain, blood flow, and formation of blood clots, Immunity and the induction of labour. We use aspirin to reduce fever and decrease pain depend on the inhibition of prostaglandin synthesis.

1.6 NUCLEIC ACIDS:

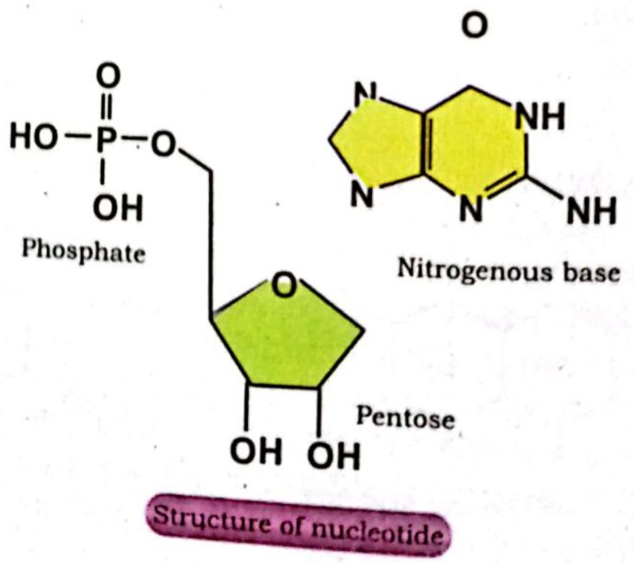
Friedrich Miescher a Swiss physician isolated a new compound from the nucleus of pus cells, which was quite different from other biomolecule therefore named "Nuclein" it was found that the nuclein had acidic properties and hence it was renamed **nucleic acid**.

The nucleic acids are polymers of five sugar based compound called **nucleotide**. These polymers have high molecular weight. These are present in all living things from virus to man.

There are two kinds of nucleic acids i.e. **Deoxyribonucleic Acid (DNA)** and **Ribonucleic Acid (RNA)**. Both nucleic acids are liner unbranched polymers. DNA is the polymer of Deoxyribonucleotide and RNA is the polymer of Ribonucleotide.

1.6.1 Composition of Nucleotide:

Nucleotide are the monomers of Nucleic acid, which is Pentose sugar based where a nitrogenous base molecule is attached at its first carbon and a phosphate is attached at 5th carbon of pentose sugar as shown below. The nucleotide without phosphate called Nucleoside.

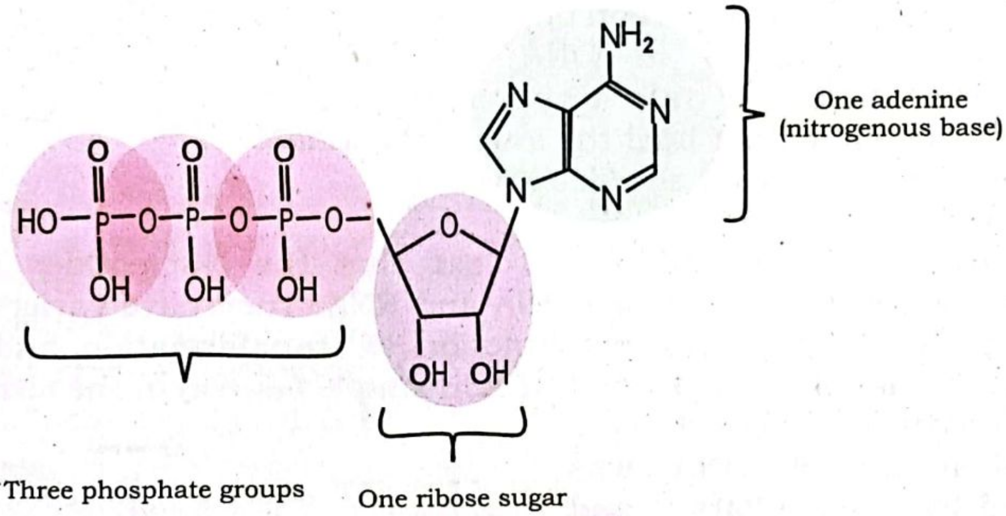


Structure of nucleotide

The DNA and RNA are made up four types of nucleotides, which are variable on the basis of nitrogenous basis. There are two groups of nitrogenous bases i.e. Purine and Pyrimidine. Purines are of two types i.e. Adenine (A) and Guanine (G) while Pyrimidine includes three nitrogenous bases Cytosine(C), thymine (T) and Uracil (U). The structures are given below.

1.6.2 Mononucleotide:

Generally, nucleotides are found in the nucleic acids as polynucleotide but sometime a single nucleotide also work independently as mono nucleotide, these mononucleotide have extra phosphate group as ADP (Adenosine phosphate) or ATP as (Adenosine Tri Phosphate). ATP work as energy storing, carrying and energy providing molecules to metabolic reactions. This energy is utilized to derive energy demanding reactions such as synthesis of proteins, lipids, carbohydrates, mechanical energy for cyclosis, contractility, cell-divisions, movement of flagella, active transport etc. During conversion of ATP into ADP, 7.3 Kcal/ mole or 31.81 kj/ mole energy is released.



Structure of ATP

1.6.3 Dinucleotide:

Sometimes two nucleotides are covalently bonded together to form a compound called **dinucleotide** one of the well-known dinucleotide is NAD **(Nicotineamide Adenosine Dinucleotide)**. A vitamin Nicotine is attached with these two nucleotides in NAD. It works as co-enzyme for Redox reaction. It carries 2e- (electron), 2H+ (proton) and energy e.g. $NADH_2$, $FADH_2$ etc.

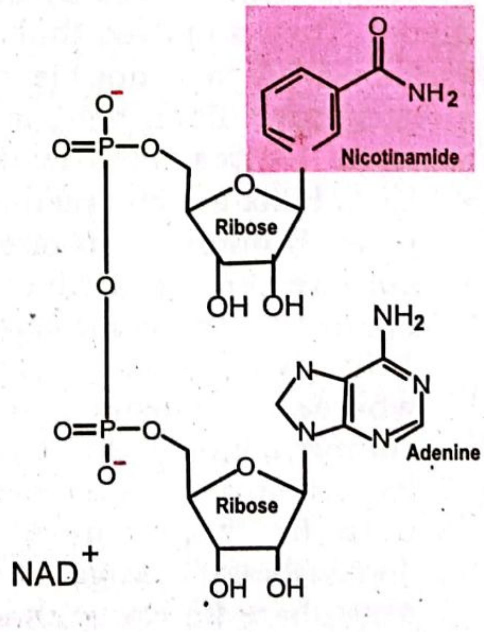


Fig 1.13 Dinucleotide

Formation of phosphodiester bond

The two nucleotides are linked together by a bond in nucleic acid i.e. DNA or RNA, this linkage or bond is called phosphodiester bond. It is considered as the backbone of the nucleic acid strands. It is a bond which is formed as a result of the condensation reaction between phosphate group (PO_4^{-3}) group of pentose sugar. So it is defined as a chemical bond that forms when exactly two hydroxyl group in a phosphoric acid reacts with a hydroxyl another molecules of sugar forming ester bond. In this bond the 3'-carbon of pentose sugar is linked with 5' carbon in DNA or RNA via phosphoester bond and thus it acts as backbone. These are the bonds that hold the sugar phosphate components of the DNA molecule together.

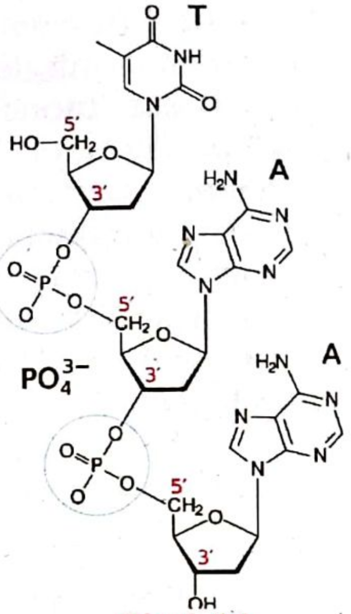


Fig 1.14
Formation of phosphodiester bond

1.6.4 Polynucleotide:

Earlier discussion made it clear that the Nucleotides are joined together and form polymers like DNA and RNA. They have variety of role in living organism. DNA performs function of transformation and heredity. Genetic information is encoded in DNA in simple fashion in the form of codes.

1.6.5 Structure of DNA:

Structure of DNA was explained by James Watson and Francis Crick in 1953 by making model. They proposed that.

- The DNA is a double helical structure. Each helix is made up of 4 types of Nucleotides.
- Both helix are complementary to each other i.e. if one helix contain A (Adenine) the opposite or complimentary helix will contain thymine whereas cytosine (C) is complementary to Guanine (G). Each helix is consist of 2 parts (i) Upright: made up of deoxyribose sugars and phosphate (ii) Rung: made up of Nitrogenous bases.

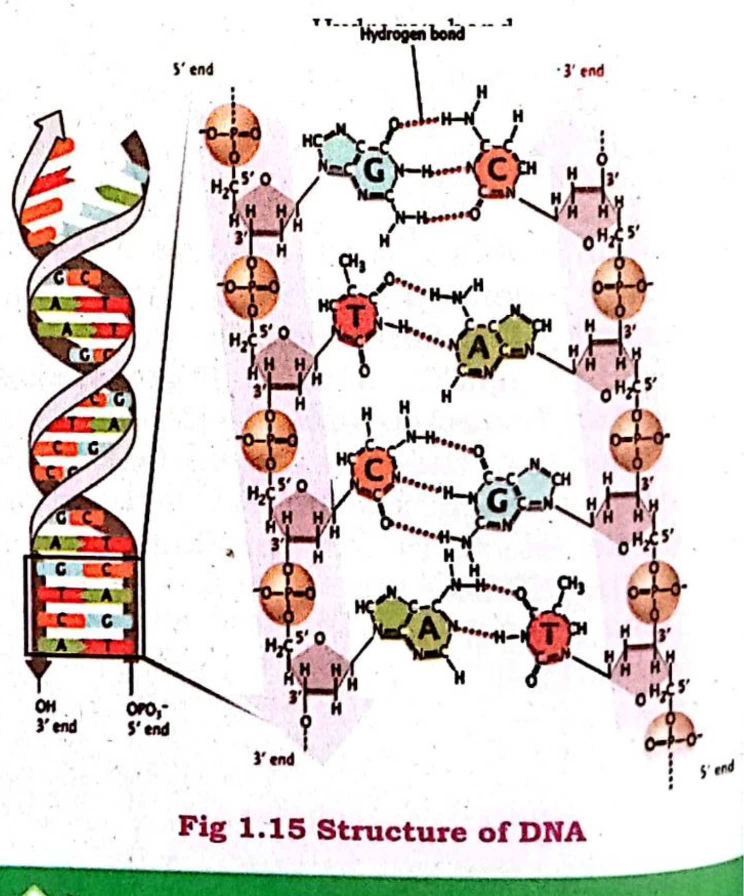


Fig 1.15 Structure of DNA

- Both helix are held together by H-bond due to which zipping and unzipping of both helix occur by making and breaking of there H bonds.
- Both helix are opposite in direction i.e. one chain run from 5' to 3' end (downward) whereas the other chain runs from 3' to 5' end (upward) direction.
- Distance between two helix remain same from one end to another end i.e. 20 A^{0}.
- Each turn of the duplex consist of 10 base pairs.

1.6.6 What is Gene?

We know now that DNA is a heredity material it carries genetic information from parent to offspring in the form of **Genes**. A gene is a part of DNA which has information to synthesis a protein, which will work as enzyme. It is a functional unit of heredity material. The gene gives instructions for developing characters like eye and hair color by producing enzymes.

Genetic information flow in a cell from DNA to *m* RNA than to cytoplasm in two steps for protein synthesis.

1. Transcription **2. Translation**

1. Transcription:

In this step the information of gene is copied into the form of RNA i.e. mRNA, which carries information from nucleus to the ribosome in the form of genetic code.

2. Translation:

In this step mRNA attach to ribosome. Two other types of RNAs i.e tRNA (transfer) and rRNA (ribosomal) translate the information of mRNA into specific sequence of amino acids which help to synthesize the protein.

1.6.7 Ribonucleic Acid (RNA):

RNA is also a polymer of nucleotides. We have already discussed it that it is a polymer of ribonucleotide i.e. the nucleotide contain ribose sugar and one of the nitrogenous bases i.e. A, G, C and U. It means instead of Thymine it contains the nucleotide of uracil.

DNA is a heredity material while RNA helps in protein synthesis. There are three types of RNA.

(i) Messenger RNA (mRNA)

It consists of single strand. Its length depends on the size of gene. It contains information in the form of Genetic codes, **CODON**. These codons are basically triplets of Nucleotides of mRNA which encode one amino acid. It is about 3 to 4 % of total RNA in the cell.

(ii) Transfer RNA (tRNA)

The smallest sized RNA consists of only 70 to 90 nucleotides. Basically it is single stranded RNA but it shows duplex at some regions where complementary bases are present. It has anticodons of genetic codes as its complementary form. It transfers related amino acid from cytosol to ribosome, they are sixty in numbers, while human cell contains only 45 different types of tRNA. It is about 10 to 20% of total RNA.

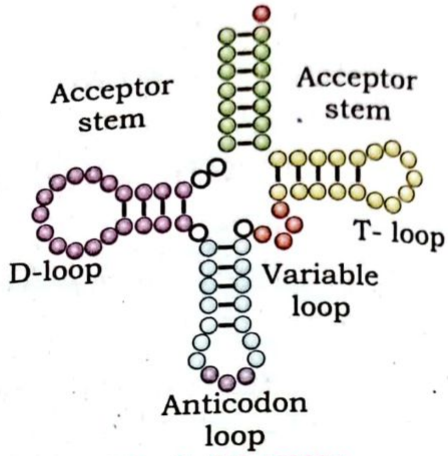


Fig 1.16 tRNA

(iii) Ribosomal RNA (rRNA)

Ribosomal RNA is present in ribosome. It has largest size among all three RNA i.e. 80% of total of RNA in a cell is rRNA. It is involved in peptide linkages during protein synthesis.

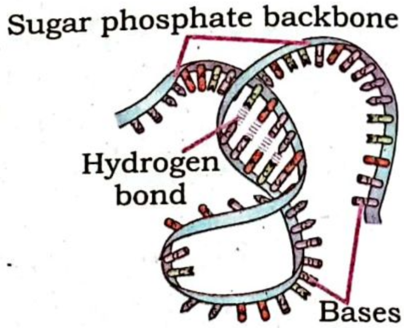


Fig 1.17 rRNA

1.7 CONJUGATED MOLECULES:

Conjugated molecules are formed when biomolecules of two different groups combine chemically with each other, acting as one unit. These are glycolipids, glycoproteins, lipoproteins and Nucleoproteins.

(i) Glycolipids or Cerebrosides:

These are conjugates of lipids and carbohydrates. They are also called cerebrosides because they are present in white matter of brain and myelin sheath of nerve fiber. They are also found in the inner membrane of chloroplast.

(ii) Glycoproteins or Mucoids:

Glycoproteins are formed by combining a molecule of carbohydrate with a protein molecule. Most of the oligo and polysaccharide in animal and plant cells are linked covalently to protein molecules. They perform function as, transport proteins, receptors, antigens of blood group etc. It is one of the part of egg albumin and gonadotropins.

(iii) Lipoprotein:

They are conjugate of lipids and proteins. They help in the transportation of lipids in blood plasma. They also occur as component of membrane of mitochondria, endoplasmic reticulum, nucleus, egg yolk and chloroplast membrane.

(iv) Nucleoprotein:

Nucleoprotein are formed by simple basic protein and nucleic acid. They are the main component of chromatin material, chromosomes and ribosomes.

SUMMARY

- The branch of biology which explains the biochemical basis of life is called biochemistry.
- Molecules which form the structure and carry out activities of the cells are large in size and highly organized molecules called macromolecules.
- Macromolecules are broken down into their subunits by addition of H_2O molecule is called hydrolysis
- Water is most abundant component in living cell.
- The attractive force between similar molecules is called cohesive force of attraction.
- Due to ionization property water may behave as acid and base.
- Carbohydrates are polyhydroxy aldehyde or polyhydroxy ketones.
- Carbohydrates which are made up to 2 to 10 monosaccharides are called oligosaccharides.
- Cellulose is polymer of glucose, most abundant carbohydrate found in nature.
- Amino acids are organic compounds which contain at least one amino group and one carboxylic acid both are chemically bonded to an asymmetric carbon.
- The protein and polypeptide chain is formed by linking amino acids by peptide bond.
- Human body has more than 10,000 proteins.
- Lipids are the important diverse group of biological molecules, widely distributed among plants and animals.
- A phospholipid is similar to acylglycerol except that one of fatty acid is replaced with phosphate and choline.
- Terpenoid is a large and important class of lipids, made up of isoprenoid units (C_5H_8).
- Prostaglandins is a group of lipids made by mammalian tissues at the sites of tissue damage or infection.
- The nucleic acids are polymers of five carbon sugar based compound called nucleotide.
- The DNA is a double helical structure. Each helix is made up of 4 types of nucleotides.
- DNA is a heredity material while RNA helps in protein synthesis.
- Conjugated molecules are formed when biomolecules of two different groups combine chemically with each other acting as one unit.

EXERCISE

1. Encircle the correct choice

(i) The slight negative charge at one end of one water molecule is attracted to the slight positive charge of another water molecule. What is this attraction called?
(a) Covalent bond (b) Hydrogen bond
(c) Ionic bond (d) Hydrophilic bond

(ii) Tendency of water to coalesce oil drop into large droplet called
(a) Hydrophilic force (b) Hydrophobic exclusion
(c) Hydrophilic exclusion (d) Hydrogen bonding

(iii) The covalent bond between two monosaccharides is called
(a) Peptide bond (b) Ester bond
(c) Phosphodiester bond (d) Glycosidic bond

(iv) Most abundant carbohydrate found in nature?
(a) Glucose (b) Maltose
(c) Cellulose (d) Glycogen

(v) Most important organic compound of the cell which carry out virtually all of the cell's activities.
(a) Protein (b) Carbohydrates
(c) Nucleic acid (d) Lipids

(vi) All amino acids have same formula except
(a) Alpha carbon (b) Hydroxyl group
(c) Radical group (d) Amino group

(vii) A trihydroxy alcohol, made of three carbon atoms called
(a) Glucose (b) Glycerol
(c) Maltose (d) Ribose

(viii) Large and important class of lipid made up of isoprenoid unit called
(a) Phospholipid (b) Terpenoids
(c) Waxes (d) Acylglycerol

(ix) How many molecules of water are needed to completely hydrolyze a polymer that is 21 monomers long?
(a) 10 (b) 20
(c) 21 (d) 2

(x) Which of the following is true of both starch and cellulose?
(a) They are both polymers of glucose
(b) They are geometric isomers of each other.
(c) They can both be digested by humans
(d) They are both used for energy storage in plants.

2. **Write short answers of the following questions:**

1. Why water molecules are called amphoteric in nature?
2. Why amino acids are named so?
3. How monosaccharides are classified?
4. Enlist bio-elements make 98 % of living system?
5. Why fats provide more energy than carbohydrates?
6. How many steps involve in nucleotide formation?
7. Distinguish between saturated acylglycerol and unsaturated acylglycerols.

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

1. Describe the properties and roles of starch, glycogen, cellulose and chitin.
2. What is nucleic acid? Describe structure of a mononucleotide (ATP) and a dinucleotide (NAD).
3. What is amino acid? Explain peptide linkage formation.
4. Explain classification of protein and list structural and functional protein.
5. What are lipids? Explain acylglycerol and waxes
6. Explain terpenoids and its types.
7. What are conjugated molecules? Explain types of conjugated molecules.