

Chapter 14: Biomolecules

Biomolecules: Macromolecules which are naturally occurring in biological system are called Biomolecules.

Carbohydrates

1. Classification of Carbohydrates:

(i) **Monosaccharide:** Simplest carbohydrates, it cannot be hydrolysed in to simpler compounds. Examples- Glucose, fructose, ribose, mannose etc.

(ii) **Oligosaccharides:** Carbohydrates which gives 2 to 10 monosaccharide units on hydrolysis. Examples- Sucrose, Lactose, Maltose, Raffinose etc.

(iii) **Polysaccharides:** Carbohydrates which gives large number of monosaccharide units on hydrolysis. Monosaccharides unit joined together by glycosidic linkage. Examples- Starch, Cellulose etc.

2. Reducing sugars: Sugars which contain free aldehyde group or sugars in which hemiacetal - OH group do not involve in glycosidic linkage formation those reduces Fehling's solution and Tollen's reagent are known as reducing sugars. Examples are all monosaccharides, maltose, lactose etc.

3. Non –reducing sugars: Due to absence of free aldehyde group or due to involvement of hemiacetal – OH group in glycosidic linkage formation, those sugars do not reduce Fehling's solution and Tollen's reagent are known as non-reducing sugars. Ex. Sucrose.

4. Importance of Carbohydrates:

- Carbohydrates are used as storage molecules as starch in plants and glycogen in animals.
- Cell wall of bacteria and plants is made up of cellulose.
- D-ribose and 2-deoxy-D-ribose are present in RNA and DNA.

Monosaccharide

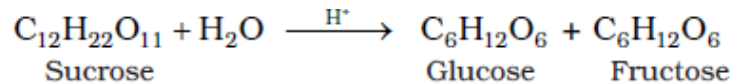
Monosaccharide is classified on the basis of number of carbon atoms and the functional group present in them. If a monosaccharide contains an aldehyde group, it is known as an aldose and if it contains a keto group, it is known as a ketose.

Carbon atoms	General term	Aldehyde	Ketone
3	Triose	Aldotriose	Ketotriose
4	Tetrose	Aldotetrose	Ketotetrose
5	Pentose	Aldopentose	Ketopentose
6	Hexose	Aldohexose	Ketohexose
7	Heptose	Aldoheptose	Ketoheptose

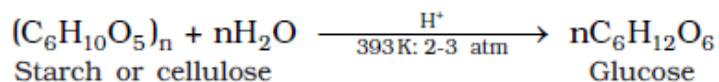
1. Glucose: Glucose is an aldohexose and is also known as dextrose. The molecular formula of glucose is $C_6H_{12}O_6$ and it is the monomer of many of the larger carbohydrates, namely starch, cellulose.

1) Preparation of Glucose:

(i) **From Sucrose:**

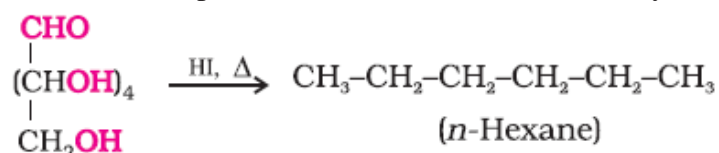


(ii) **From Starch:**

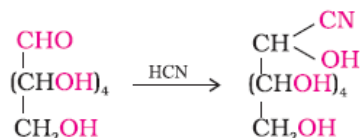


2) Reactions of Glucose:

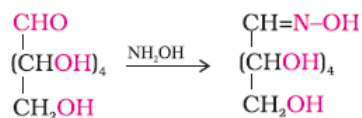
(i) **D- Glucose with HI:** Shows the presence of 6 carbons linked linearly.



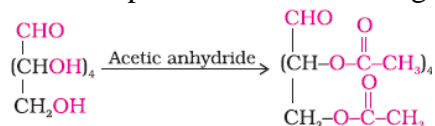
(ii) **D- Glucose with HCN:** It forms glucose cyanohydrin which shows the presence of -CHO group (open chain structure).



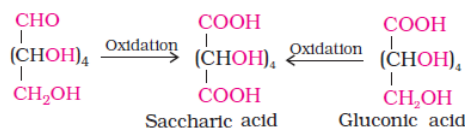
(iii) **D- Glucose with NH_2OH :** It forms glucose oxime which shows the presence of -CHO group (open chain structure).



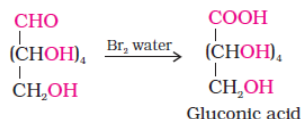
(iv) **D- Glucose with Acetic anhydride:** Acetylation of glucose with acetic anhydride gives glucose penta acetate which confirms the presence of five -OH groups.



(v) **D- Glucose with Nitric Acid:** This indicates the presence of a primary alcoholic (-OH) group in glucose.

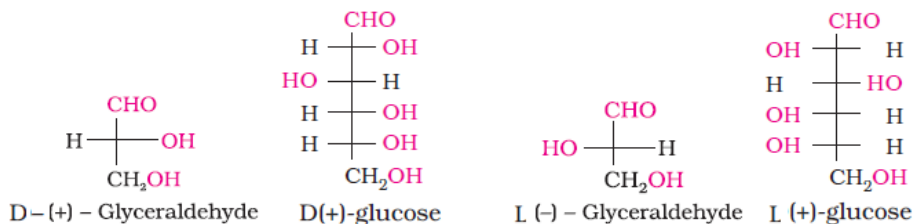


(vi) **D- Glucose with Bromine water:** This indicates that the carbonyl group is present as an aldehydic group.



3) Structure of Glucose:

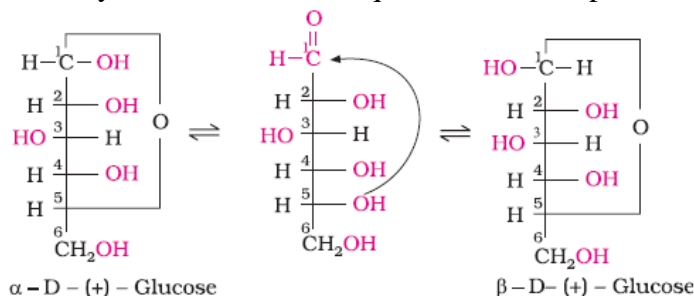
(i) Fischer projection formula for open chain structure of Glucose:



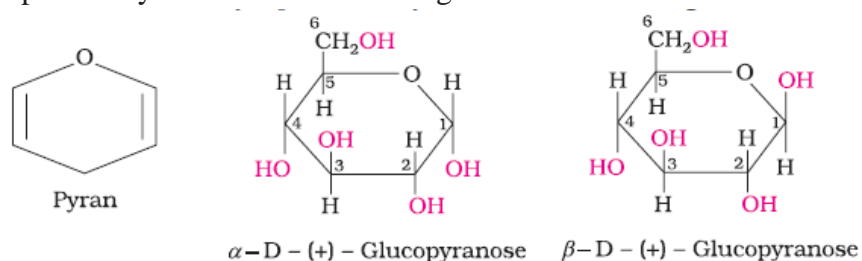
(ii) **Fischer projection formula for two cyclic structures (anomers) of Glucose:** Following reactions and facts could not be explained by the open chain structure of glucose-

- Glucose doesn't give Schiff's test and doesn't react with sodium bisulphate and NH_3 .
- The Penta acetate glucose doesn't react with hydroxyl amine.

So justify those properties of glucose, Fischer proposed the ring (cyclic) structure of glucose. Here one of the —OH group at C-5 may add to the —CHO group and form a cyclic **hemiacetal structure**. This explains the absence of —CHO group and also existence of glucose in two forms as shown below. These two cyclic forms exist in equilibrium with open chain structure.



(iii) **Haworth (Pyranose ring) structure for anomers of Glucose:** Cyclic structure of glucose is more correctly represent by Haworth structure as given below-

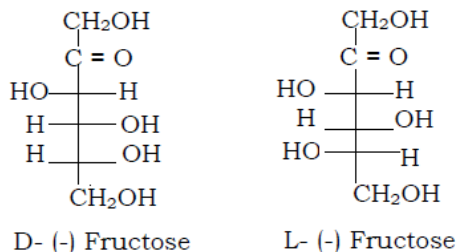


Pair of optical isomers which differ in configuration only around C1 atom are called **Anomers** and that type of carbon is called **Anomeric carbon**. Examples, α - D-glucopyranose and β - D-glucopyranose.

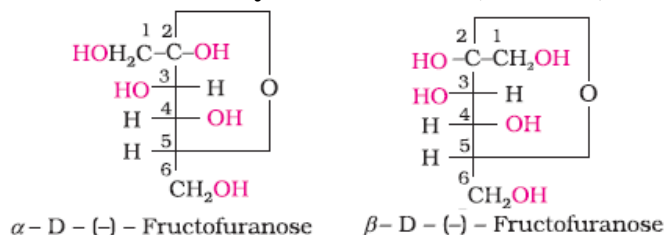
2. Fructose: Fructose is a ketohexose and has the molecular formula $\text{C}_6\text{H}_{12}\text{O}_6$. It belongs to D-series and is a laevorotatory compound.

1) Structure of Fructose:

(i) Fischer projection formula for open chain structure of fructose:

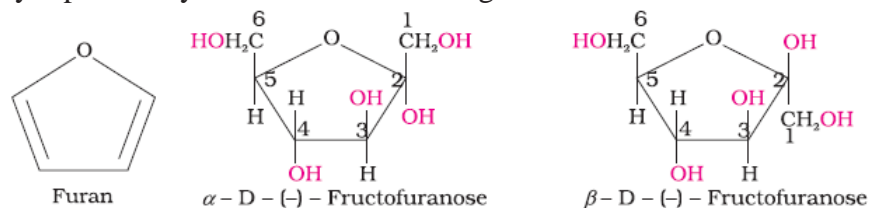


(ii) Fischer projection formula for two cyclic structures (anomers) of fructose:



Pair of optical isomers which differ in configuration around any carbon atom than C1 atom are called *Epimers*. Examples- D-glucose and D-mannose are C2 epimers, α -D-fructopyranose and β -D-fructopyranose.

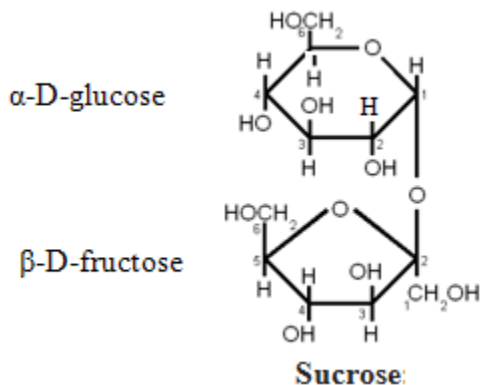
(iii) **Haworth (Furanose ring) structure for anomers of Fructose:** Cyclic structure of fructose is more correctly represented by Haworth structure as given below



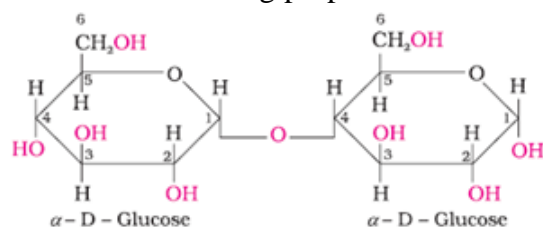
Disaccharides

Glycosidic linkage: The oxide linkage formed by the loss of a water molecule when two monosaccharides are joined together through oxygen atom is called glycosidic linkage.

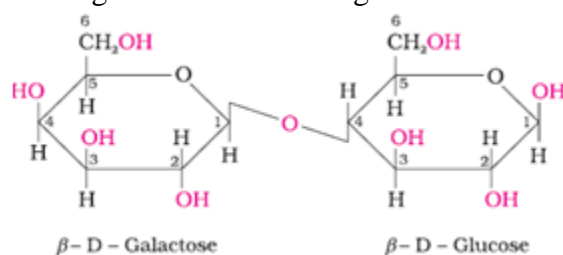
1. Sucrose: It is composed by holding two monosaccharides together by a glycosidic linkage between C1 of α -D-glucose and C2 of β -D-fructose. Since the reducing groups of glucose and fructose are involved in glycosidic bond formation, sucrose is a non-reducing sugar.



2. Maltose: Another disaccharide, maltose is composed of two α -D-glucose units in which C1 of one glucose is linked to C4 of another glucose. The free aldehyde group can be produced at C1 of second glucose in solution and it shows reducing properties so it is a reducing sugar.



3. Lactose: Commonly it is known as milk sugar. It is composed of β -D-galactose and β -D-glucose. The linkage is b/w C1 of galactose and C4 of glucose. Hence it is also a reducing sugar.



Polysaccharides

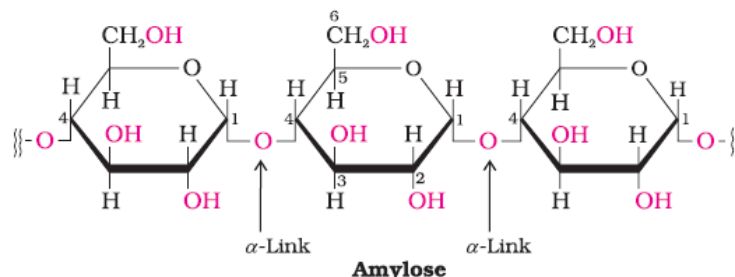
1. Starch: It is a polymer of α -glucose and consists of two components– Amylose and Amylopectine.

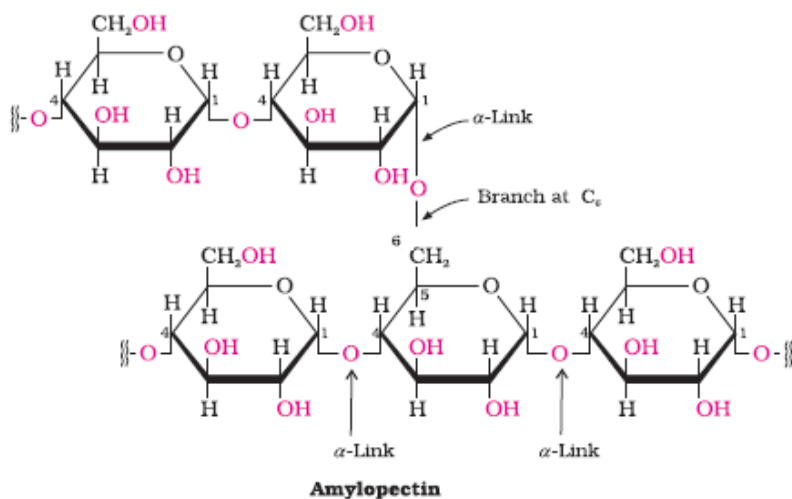
Amylose:

- It is water soluble part of starch.
- It is a long unbranched chain polymer.
- It contains 200- 1000 α - D (+) Glucose units held by C1 – C4 α -glycosidic linkage.
- It constitute about 15-20% of starch.

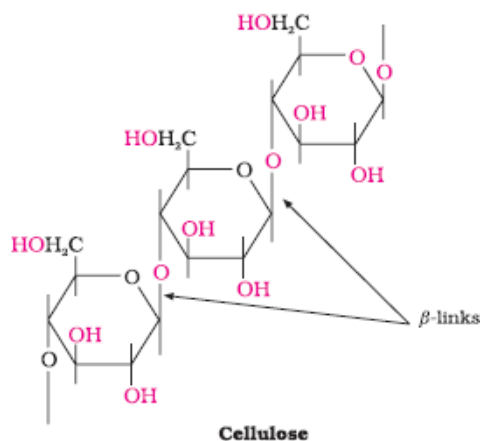
Amylopectine:

- It is water insoluble part of starch.
- It is a long branched chain polymer.
- α - D (+) Glucose units held by C1 – C4 α -glycosidic linkage and branching occurs by C1 - C6 glycosidic linkage.
- It constitute about 80-85% of starch.





2. Cellulose: Cellulose occurs exclusively in plants. It is a straight chain polysaccharide composed only of β -D-glucose units which are joined by glycosidic linkage between C1 of one glucose unit and C4 of the next glucose unit.

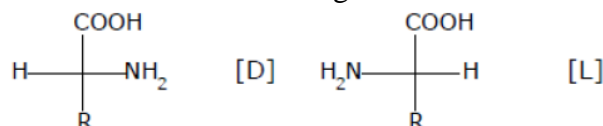


3. Glycogen: The carbohydrates are stored in animal body as glycogen. It is also known as animal starch because its structure is similar to amylopectin and is rather more highly branched.

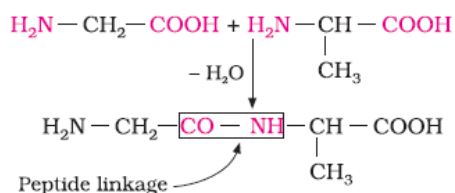
Protein

1. Protein: Proteins are the polymers of α -amino acids and they are connected to each other by peptide bond or peptide linkage. A polypeptide with more than hundred amino acid residues, having molecular mass higher than 10,000u is called a protein.

2. Amino acids: Amino acids contain amino ($-\text{NH}_2$) and carboxyl ($-\text{COOH}$) functional groups. Most naturally occurring amino acids have L- configuration.



3. Peptide linkage: Peptide linkage is an amide linkage formed by condensation reaction between $-\text{COOH}$ group of one amino acid and $-\text{NH}_2$ group of another amino acid.

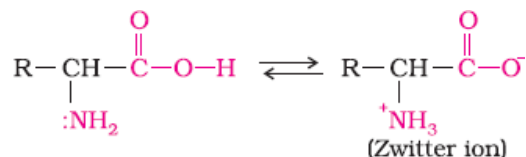


4. Classification of Amino Acids:

- **Essential amino acids:** The amino acids which cannot be synthesized in the body and must be obtained through diet are known as essential amino acids. Examples- Valine, Leucine.
- **Non-essential amino acids:** The amino acids which can be synthesized in the body are known as non-essential amino acids. Examples- Glycine, Alanine.
- Amino acids are also classified as acidic, basic or neutral depending upon the relative number of amino and carboxyl groups in their molecule.
- Equal number of amino and carboxyl groups makes it neutral; more number of amino than carboxyl groups makes it basic and more carboxyl groups as compared to amino groups makes it acidic.

5. Zwitter ion and amphoteric nature of Amino acids:

- Amino acids behave like salts rather than simple amines or carboxylic acids. This behaviour is due to the presence of both acidic (carboxyl group) and basic (amino group) groups in the same molecule.
- In aqueous solution, the carboxyl group can lose a proton and amino group can accept a proton, giving rise to a dipolar ion known as *zwitter ion*.
- Zwitter ion is neutral but contains both positive and negative charges hence amino acids show amphoteric behaviour as they react both with acids and bases.



6. Types (shapes) of Proteins: Proteins can be classified into two types on the basis of their molecular shape- (i) Fibrous proteins (ii) Globular proteins

	fibrous proteins		globular
1	Linear condensation product	1	Cross linked condensation polymers of acidic and basic amino acids
2	Insoluble in water and common solvents but soluble in strong acidic or basic solutions	2	Soluble in water or an aqueous solution of a base, acid or salt
3	have rigid rod like shape	3	have spherical or spheroidal shape
4	parallel polypeptide chains are held together by H-bond and disulphide bond to form a fibre like structure.	4	coiling of polypeptide chain takes place to give a spherical shape.
5	Ex. Keratin(hair,wool,silk) myosin (muscles)	5	Insulin,albumin

7. Structure of Protein:

(i) Primary structure of proteins: Specific sequence of amino acids in proteins refers to primary structure. Any change in the primary structure (i.e. sequence of amino acids) creates a different protein.

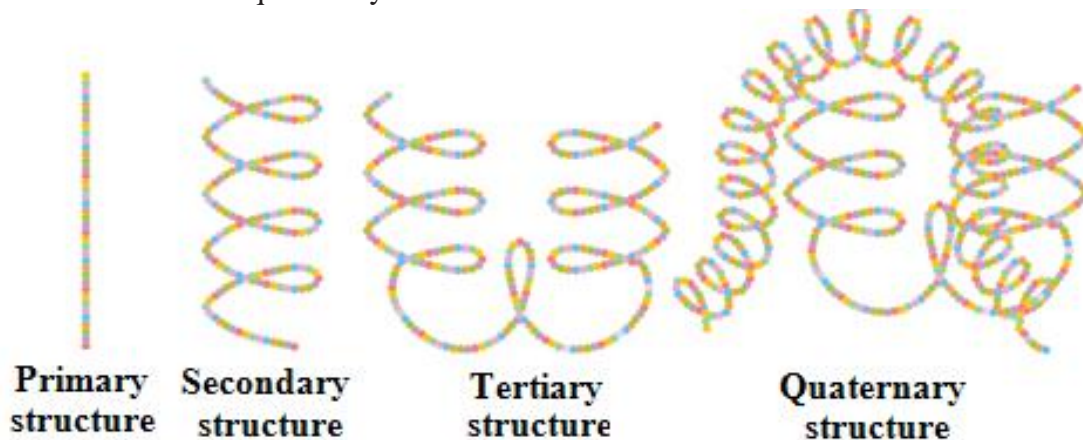
(ii) Secondary structure of proteins: It refers to the shape in which a long polypeptide chain can exist. They are found to exist in two different types of structures, α -helix and β -pleated sheet structure.

(a) α -helix: These structures arise due to the regular folding of the backbone of the polypeptide chain due to hydrogen bonding between $-\text{CO}$ and $-\text{NH}-$ groups of the peptide bond. Keratin and myosin protein have α -helix structure.

(b) β -pleated sheet structure: In β -structure all peptide chains are stretched out to nearly maximum extension and then laid side by side which are held together by intermolecular hydrogen bonds. The structure resembles the pleated folds of drapery and therefore is known as β -pleated sheet. Silk has β -pleated sheet structure.

(iii) Tertiary structure of proteins: The tertiary structure of proteins represents overall folding of the polypeptide chains i.e., further folding of the secondary structure. It gives rise to two major molecular shapes viz. fibrous and globular. The main forces which stabilise the 2° and 3° structures of proteins are hydrogen bonds, disulphide linkages, van der Waals and electrostatic forces of attraction.

(iv) Quaternary structure of proteins: Some of the proteins are composed of two or more polypeptide chains referred to as sub-units. The spatial arrangement of these subunits with respect to each other is known as quaternary structure.



8. Denaturation:

- When a protein in its native form, is subjected to physical change like change in temperature or chemical change like change in pH, the hydrogen bonds are disturbed. Due to this, globules unfold and helix gets uncoiled and protein loses its biological activity. This is called denaturation of protein.
- During denaturation 2° and 3° structures are destroyed but 1° structure remains intact.
- Example, coagulation of egg white on boiling, curdling of milk (lactose to lactic acid).

Enzymes

1. Enzymes: Enzymes are essential biological catalysts which are required to catalyse biological reactions. Almost all the enzymes are globular proteins. Examples are maltase, sucrase, lactase, invertase etc.

2. Mechanism of Enzyme action: Enzymes are needed only in small quantities for the progress of a reaction. Similar to the action of chemical catalysts, enzymes are said to reduce the magnitude of activation energy.

Vitamins

1. Vitamins: Vitamins are organic compounds required in the diet in small amounts to perform specific biological functions for normal maintenance of optimum growth and health of the organism.

2. Classification of Vitamins: Vitamins are classified into two groups depending upon their solubility in water or fat.

(i) Fat soluble vitamins: Vitamins (A, D, E and K) which are soluble in fat and oils but insoluble in water are kept in this group. They are stored in liver and adipose (fat storing) tissues.

(ii) Water soluble vitamins: Vitamins belonging to group B and vitamin C are soluble in water. They must be supplied regularly in diet because they are readily excreted in urine and cannot be stored (except vitamin B₁₂) in our body.

Some important vitamins, their sources and diseases caused by their deficiency are listed in below table-

Sl. No.	Name of Vitamins	Sources	Deficiency diseases
1.	Vitamin A	Fish liver oil, carrots, butter and milk	Xerophthalmia (hardening of cornea of eye) Night blindness
2.	Vitamin B ₁ (Thiamine)	Yeast, milk, green vegetables and cereals	Beri beri (loss of appetite, retarded growth)
3.	Vitamin B ₂ (Riboflavin)	Milk, eggwhite, liver, kidney	Cheilosis (fissuring at corners of mouth and lips), digestive disorders and burning sensation of the skin.
4.	Vitamin B ₆ (Pyridoxine)	Yeast, milk, egg yolk, cereals and grams	Convulsions
5.	Vitamin B ₁₂	Meat, fish, egg and curd	Pernicious anaemia (RBC deficient in haemoglobin)
6.	Vitamin C (Ascorbic acid)	Citrus fruits, amla and green leafy vegetables	Scurvy (bleeding gums)
7.	Vitamin D	Exposure to sunlight, fish and egg yolk	Rickets (bone deformities in children) and osteomalacia (soft bones and joint pain in adults)
8.	Vitamin E	Vegetable oils like wheat germ oil, sunflower oil, etc.	Increased fragility of RBCs and muscular weakness
9.	Vitamin K	Green leafy vegetables	Increased blood clotting time

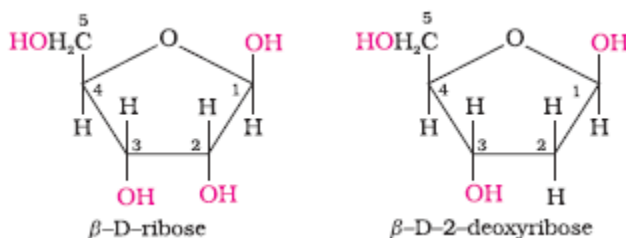
Nucleic Acid (Polynucleotides)

1. Nucleic Acid (Polynucleotides): Nucleic acids are long chain polymers of nucleotides. Nucleotides are joined by phosphodiester linkage b/w 5' and 3' C atoms of a pentose sugar.

2. Chemical composition of nucleic acid: Following are the constituents of nucleic acids-

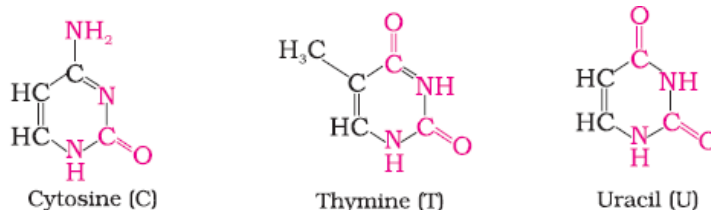
- (i) Phosphoric acid
- (ii) Pentose sugar
- (iii) Nitrogenous bases

(ii) Pentose sugar: In DNA molecules, the sugar moiety is β -d-2-deoxyribose whereas in RNA molecules it is β -d-ribose.

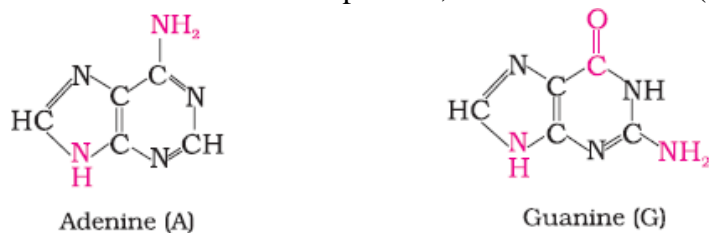


(iii) Nitrogenous bases: There are two types of nitrogenous bases found in nucleic acids-

(a) Pyrimidine: These are three bases derived from pyrimidines, which are cytosine (C), thymine (T) and uracil (U).



(b) Purine: These are two bases derived from purine, which are adenine (A) and guanine (G).

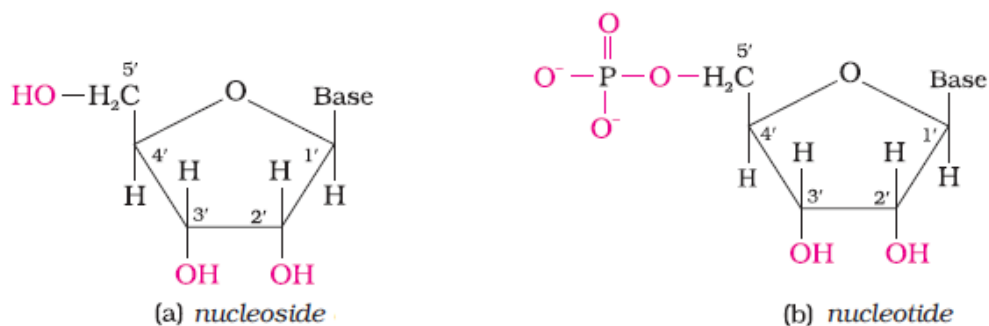


Note: DNA contains four bases viz. adenine (A), guanine (G), cytosine (C) and thymine (T) while RNA contains four bases, the first three bases are same as in DNA but the fourth one is uracil (U).

3. Structure of Nucleic Acids:

(i) Nucleoside: A unit formed by the attachment of a base to 1' position of sugar is known as nucleoside.

(ii) Nucleotide: When nucleoside is linked to phosphoric acid at 5'-position of sugar moiety, we get a nucleotide.



Nucleotides are joined together by phosphodiester linkage between 5' and 3' carbon atoms of the pentose sugar. The formation of a typical dinucleotide is shown as following figure-

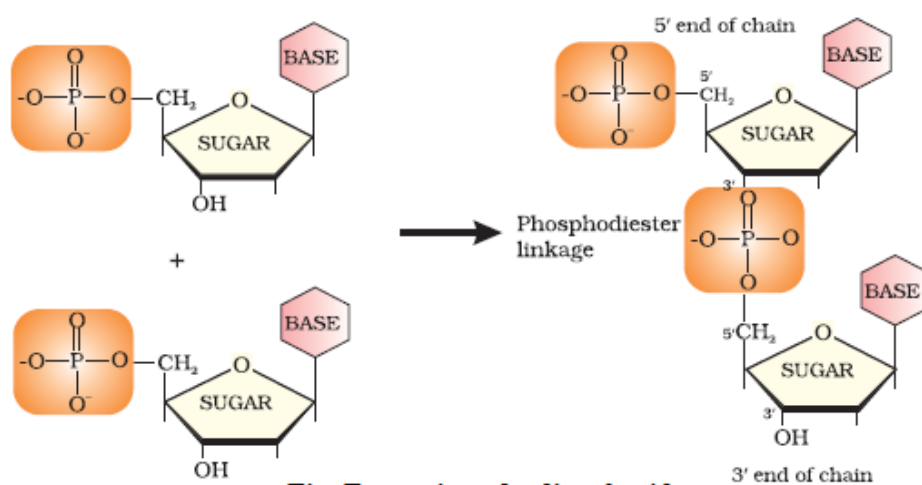
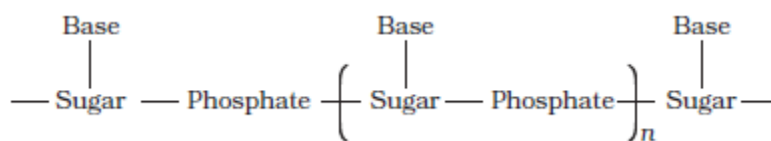


Fig: Formation of a dinucleotide

A simplified version of nucleic acid chain is can be shown as below-



4. Types of Nucleic Acids: There are two types of nucleic acids- DNA and RNA.

(i) DNA:

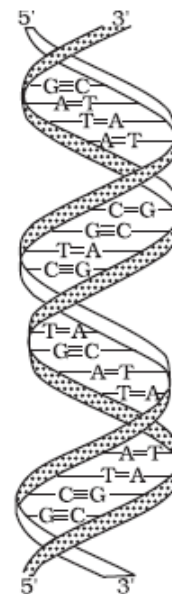
- James Watson and Francis Crick gave a double strand helix structure for DNA.
- Two nucleic acid chains are wound about each other and held together by hydrogen bonds between pairs of bases.
- Diameter of double helix is 2 nm.
- Adenine forms hydrogen bonds with thymine (A=T) whereas cytosine forms hydrogen bonds with guanine (G=C).
- Total amount of Purine (A+G) = Total amount of pyrimidine (C+T).

(ii) **RNA:** RNA molecules are of three types and they perform different functions. They are named as messenger RNA (m-RNA), ribosomal RNA (r-RNA) and transfer RNA (t-RNA).

5. Difference b/w DNA and RNA:

S.No.	DNA	RNA
1	Sugar moiety is 2-Deoxy -D(-) - ribose	Sugar moiety is D(-) ribose
2	Contains thymine and cytosine as pyrimidine bases and guanine and adenine as purine bases	Contains cytosine and uracil as pyrimidine bases and guanine and adenine as purine bases
3	Has double stranded helix structure	Has single stranded helix structure
4	Chiefly occurs in nucleus of cell	Mainly occurs in the cytoplasm of the cell
5	Very large molecules - molecular mass may vary from 6 million to 16 million	Smaller than DNA - molecular mass varies from 20000 to 40000
6	Has unique property of replication	Does not replicate
7	Controls transmission of hereditary effects	Controls synthesis of protein

(a) Difference b/w DNA and RNA



(b) Structure for DNA