

BIOMOLECULES

Living systems are made up of various complex molecules like carbohydrates, proteins, nucleic acids, lipids, vitamins etc. these are called bio-molecules. Such molecules of organic compounds build up life system and required for the growth and the maintenance .

CARBOHYDRATES

Carbohydrates are optically active polyhydroxy aldehydes or ketones or the compounds which produce such units on hydrolysis.

e.g. glucose, fructose, sucrose, starch etc.

On the basis of the products of hydrolysis, carbohydrates are classified into three groups:

Monosaccharides - A carbohydrate that cannot be hydrolysed further to give simpler unit of polyhydroxy aldehyde or ketone . Examples- Glucose, fructose ,ribose.

Oligosaccharides -Carbohydrates that yield 2 to 10 monosaccharide units on hydrolysis. They are further subdivided as disaccharides, trisaccharides, tetrasaccharides, pentasaccharides etc., depending upon whether 2,3,4,5 units of monosaccharide units are obtained on their hydrolysis. e.g.

Sucrose \longrightarrow Glucose + fructose ; disaccharide (hydrolysis)

Lactose \longrightarrow Galactose + Glucose ; disaccharide hydrolysis)

Polysaccharides -Carbohydrates that yield a large number of monosaccharide units on hydrolysis. Examples- Starch, cellulose, glycogen.

CALSSIFICATION OF CARBOHYDRATES ON THE BASIS OF TASTE:-

They are classified as Sugars and non-Sugars

Sugars: - which are sweet in taste and dissolve in water are called sugars. All mono and disaccharides are sweet in taste.

Examples: - Glucose, fructose, Sucrose, Lactose are sugars.

Non-Sugars:- Tasteless polysaccharides which are insoluble in water. They are generally amorphous in nature.

Examples: - Cellulose and Starch

MONOSACCHARIDES

Monosaccharides can be classified on the basis of no. of carbon atoms and functional group(aldehyde / ketone) present in the molecule.

Different types of monosaccharides

No. of carbon atoms	General terms	aldehyde	Ketones
3	triose	aldotriose	Ketotriose
4	tetrose	aldotetrose	Ketotetrose
5	pentose	aldopentose	Ketopentose
6	hexose	aldohexose	Ketohexose
7	heptose	aldoheptose	Ketoheptose

Properties :

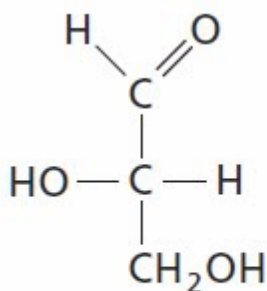
1. sweet in taste
2. water soluble
3. when heated they get charred

Note : Except dihydroxyacetone all monosaccharides contain chiral carbon.

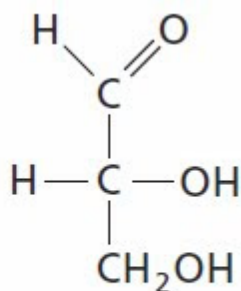
Each species of monosaccharides exist in two isomeric forms. The enantiomer which rotates the plane polarized light to the right is written as (+) and that rotates to the left is written as (-).

D-sugars – The sugars having the same configuration as of D-glyceraldehyde at the chiral carbon most distant from the carbonyl group are designated as D-sugars.

L-sugars - The sugars having the same configuration as of L-glyceraldehyde at the chiral carbon most distant from the carbonyl group are designated as L-sugars.



L-Glyceraldehyde



D-Glyceraldehyde

- Naturally occurring glucose and fructose are D-forms.

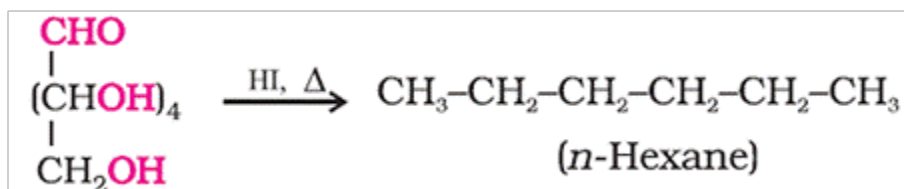
GLUCOSE

Glucose is an aldohexose and is also known as dextrose. It is the monomer of many of the larger carbohydrates, namely starch, cellulose. It is probably the most abundant organic compound on earth.

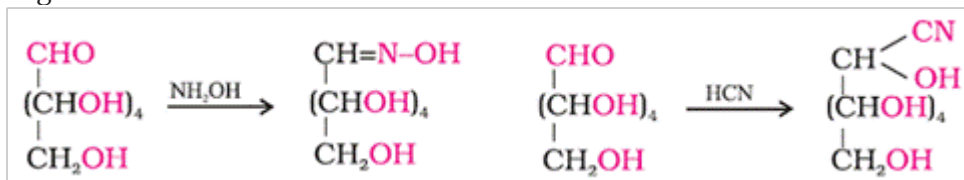
Structure of glucose :

It was assigned the structure given below on the basis of the following evidences:

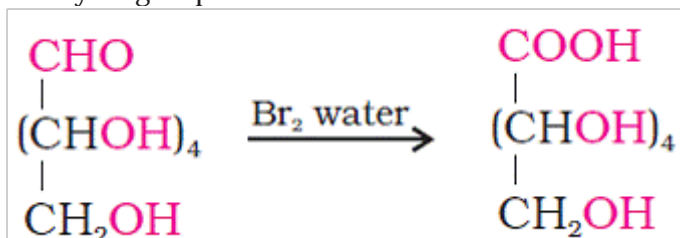
1. Its molecular formula was found to be $C_6H_{12}O_6$.
2. On prolonged heating with HI, it forms n-hexane, suggesting that all the six carbon atoms are linked in a straight chain.



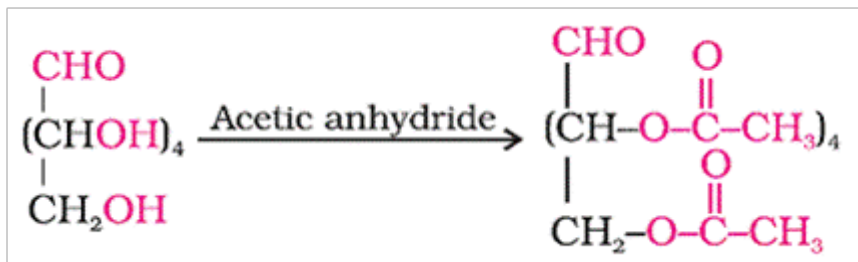
3. Glucose reacts with hydroxylamine to form an oxime and adds a molecule of hydrogen cyanide to give cyanohydrin. These reactions confirm the presence of a carbonyl group ($>C=O$) in glucose.



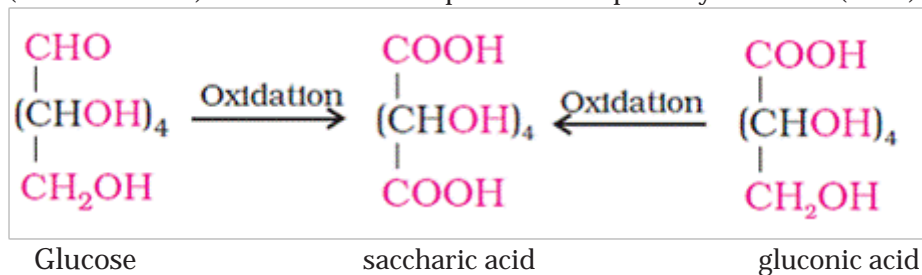
4. Glucose gets oxidised to six carbon carboxylic acid (gluconic acid) on reaction with a mild oxidising agent like bromine water. This indicates that the carbonyl group is present as an aldehydic group.



5. Acetylation of glucose with acetic anhydride gives glucose pentaacetate which confirms the presence of five $-OH$ groups. Since it exists as a stable compound, five $-OH$ groups should be attached to different carbon atoms.



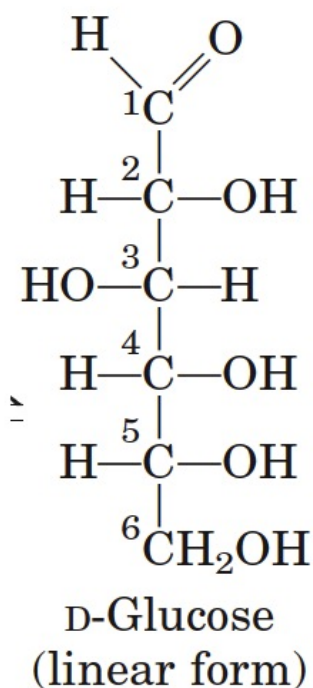
6. On oxidation with nitric acid, glucose as well as gluconic acid both yield a dicarboxylic acid, (saccharic acid). This indicates the presence of a primary alcoholic (-OH) group in glucose.



Glucose is correctly named as D(+)-glucose. 'D' before the name of glucose represents the configuration whereas '(+)' represents dextrorotatory nature of the molecule.

Notes : It may be remembered that 'D' and 'L' have no relation with the optical activity of the compound.

Open chain structure



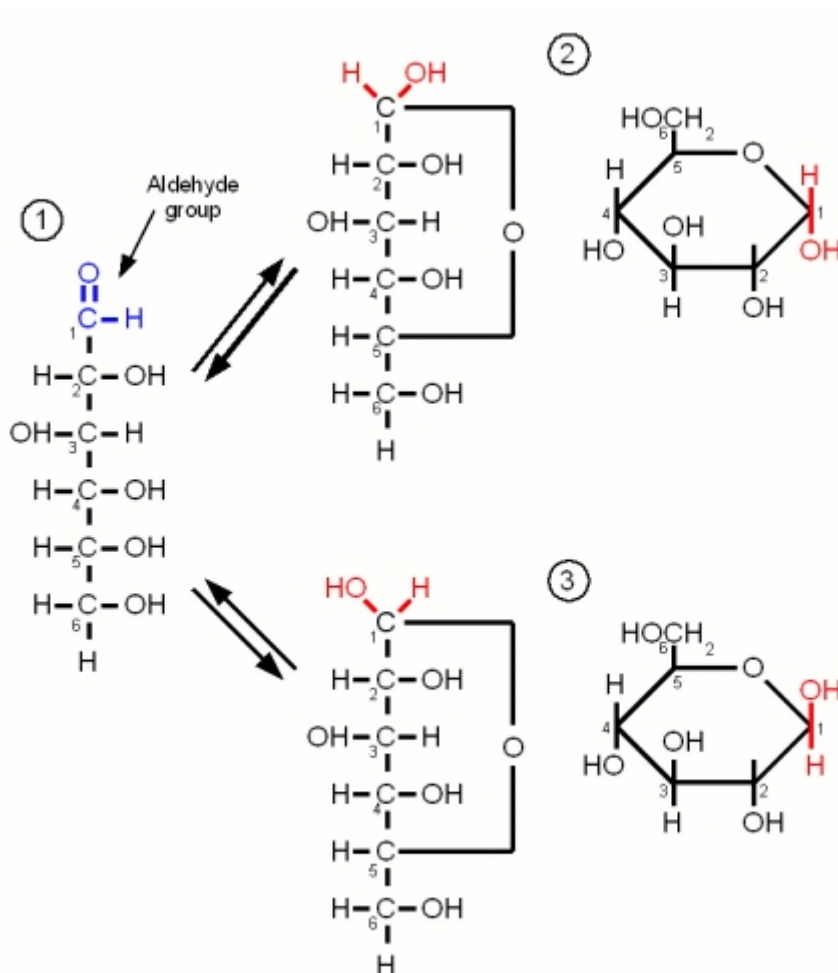
This structure of glucose explained most of its properties but the following reactions and facts could not be explained by this structure.

1. Despite having the aldehyde group, glucose does not give Schiff's test and it does not form the hydrogensulphite addition product with NaHSO₃.
2. The penta acetate of glucose does not react with hydroxylamine indicating the absence of free -CHO group.

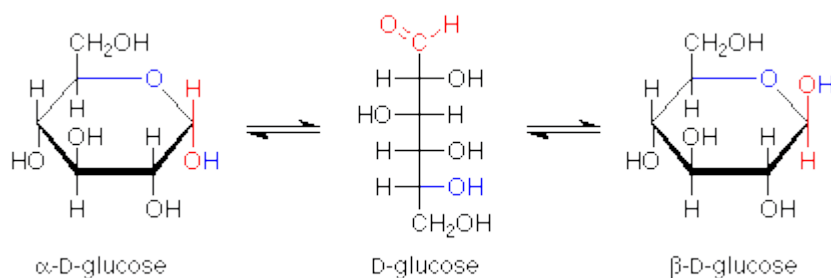
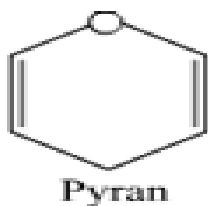
3. Glucose is found to exist in two different crystalline forms which are named as α and β . The α -form of glucose (m.p. 419 K) is obtained by crystallisation from concentrated solution of glucose at 303 K while the β -form (m.p. 423 K) is obtained by crystallisation from hot and saturated aqueous solution at 371 K .

Cyclic structure of glucose :

It was proposed that one of the —OH groups may add to the —CHO group and form a cyclic hemiacetal structure. It was found that glucose forms a six-membered ring in which —OH at C-5 is involved in ring formation. 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.
- The two cyclic hemiacetal forms of glucose differ only in the configuration of the hydroxyl group at C1, called **anomeric carbon**.
- The six membered cyclic structure of glucose is called **pyranose structure** (α - or β -), in analogy with pyran .



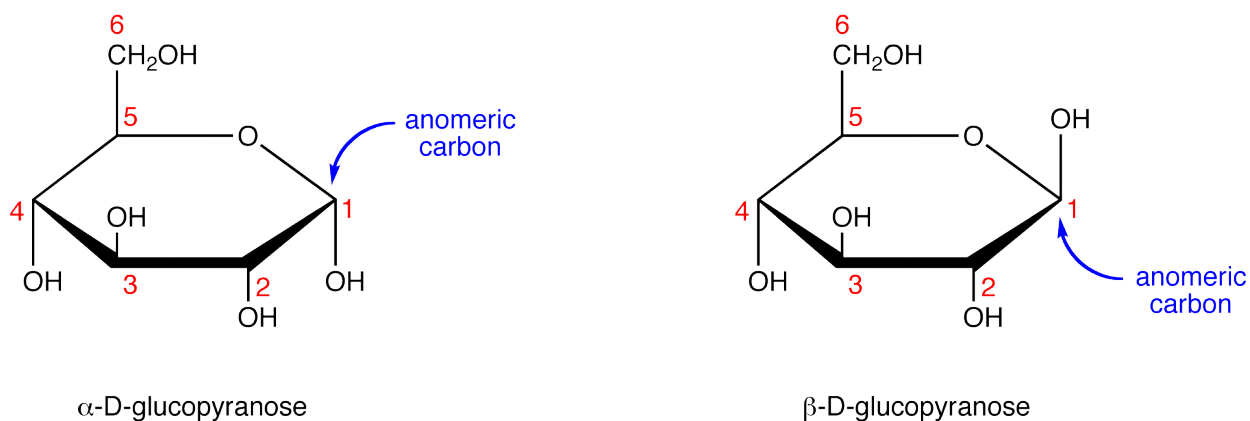
• These forms are called **Haworth structure** of glucose.

Epimers – Epimers are those special type of distereomers which have difference in configuration around just one chiral carbon.

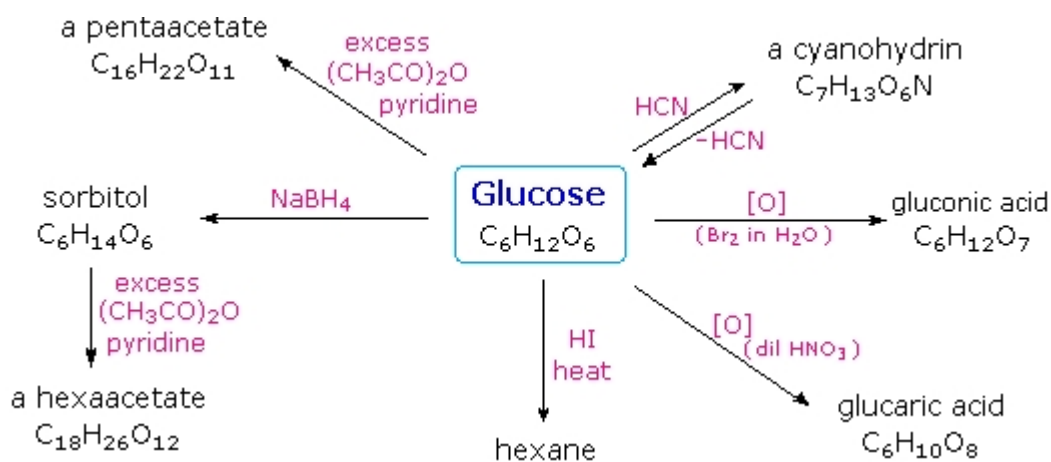
Anomers - Anomers are cyclic [monosaccharides](#) that are [epimers](#), differing from each other in the configuration of C-1 if they are [aldoses](#) or in the configuration at C-2 if they are [ketoses](#).

The [epimeric carbon](#) in anomers are known as anomeric carbon or anomeric center.

eg. 1: α -D-Glucopyranose and β -D-glucopyranose are anomers.

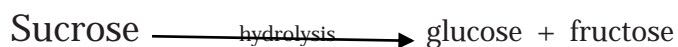


Reactions of glucose –



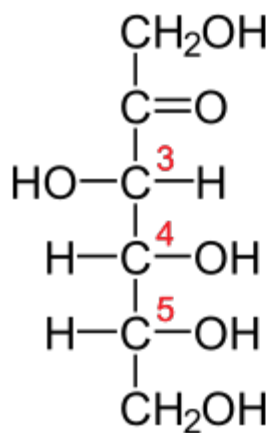
Fructose

Fructose is an important ketohexose. It is obtained along with glucose by the hydrolysis of disaccharide, sucrose.

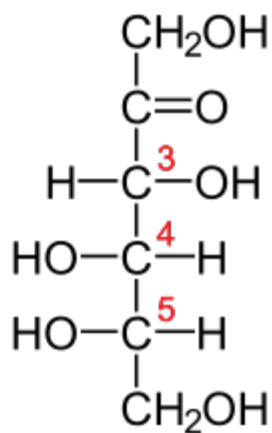


Structure of fructose

Fructose also has the molecular formula $\text{C}_6\text{H}_{12}\text{O}_6$ and on the basis of its reactions it was found to contain a ketonic functional group at carbon number 2 and six carbons in straight chain as in the case of glucose. It belongs to D-series and is a laevorotatory compound. It is appropriately written as D-(−)-fructose. Its open chain structure is as shown.



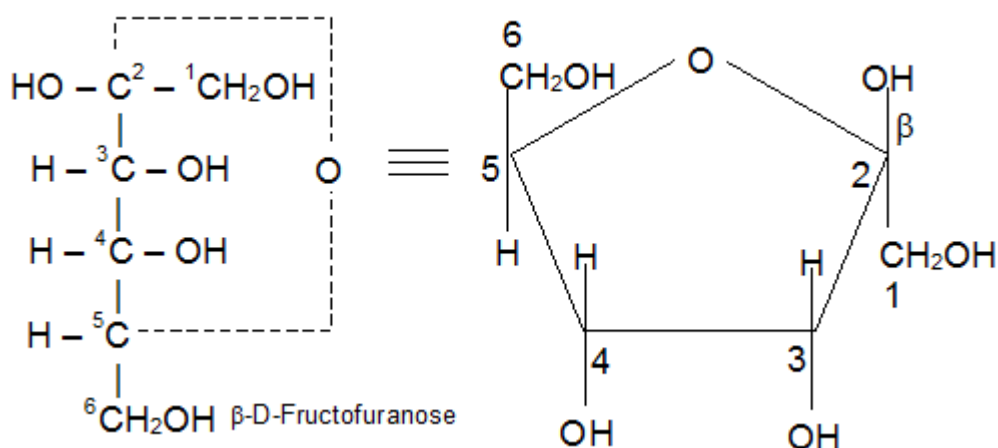
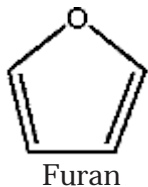
D-Fructose



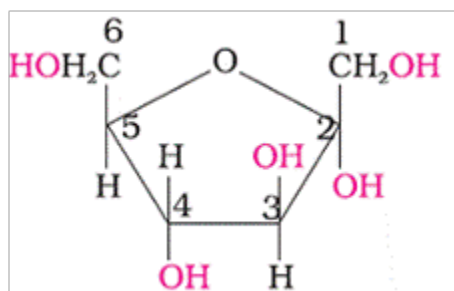
L-Fructose

Cyclic structure of fructose

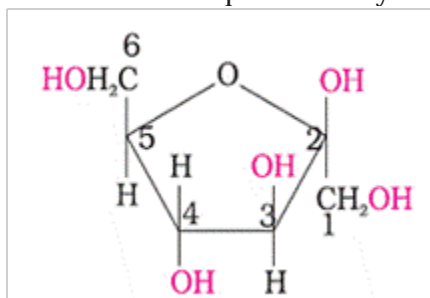
It also exists in two cyclic forms which are obtained by the addition of -OH at C5 to the $(\text{C}=\text{O})$ group. The ring, thus formed is a five membered ring and is named as furanose with analogy to the compound furan.



The cyclic structures of two anomers of fructose are represented by Haworth structures as given.



α -D (-)-fructofuranose



β -D (-)-fructofuranose

Disaccharides

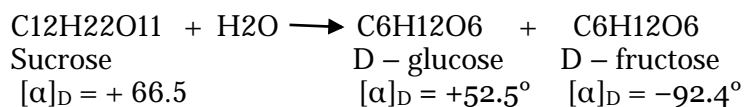
Two monosaccharides are joined together by an oxide linkage formed by the loss of a water molecule to form disaccharides. Such a linkage between two monosaccharide units through oxygen atom is called *glycosidic linkage*.

Glycosidic linkage

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

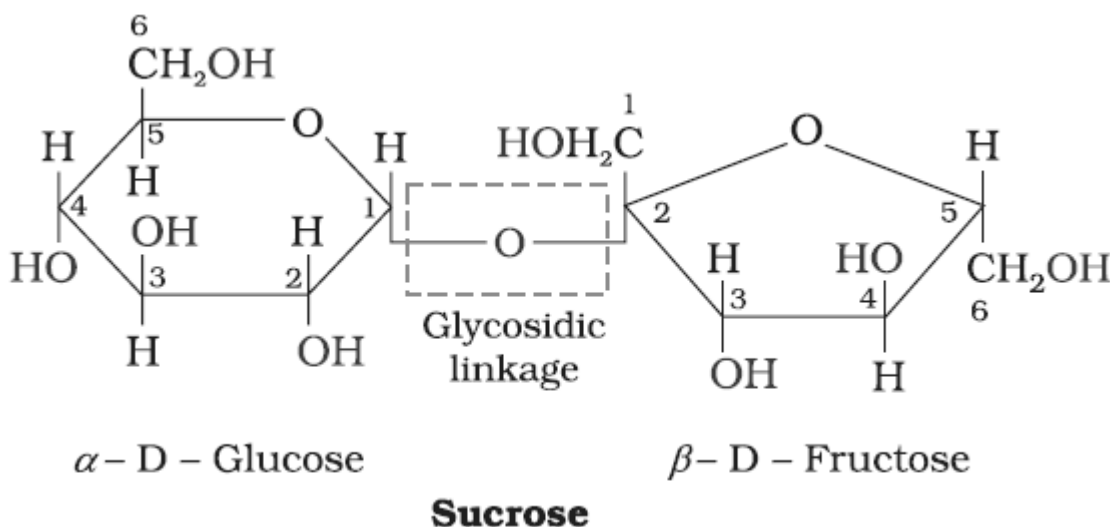
Sucrose —It is One of the common disaccharides is sucrose which on hydrolysis gives equimolar mixture of D-(+)-glucose and D-(-) fructose.

Sucrose is dextrorotatory, but on hydrolysis, it gives dextrorotatory and laevorotatory forms, and the mixture is laevorotatory. this property is called inverting of sugar, hence sucrose is an invert sugar



Sucrose is a non-reducing sugar because the two monosaccharide units are held together by a glycosidic linkage between C1 of α -glucose and C2 of β -fructose. Because the reducing groups of glucose and fructose are involved in glycosidic bond formation, sucrose is a non-reducing sugar.

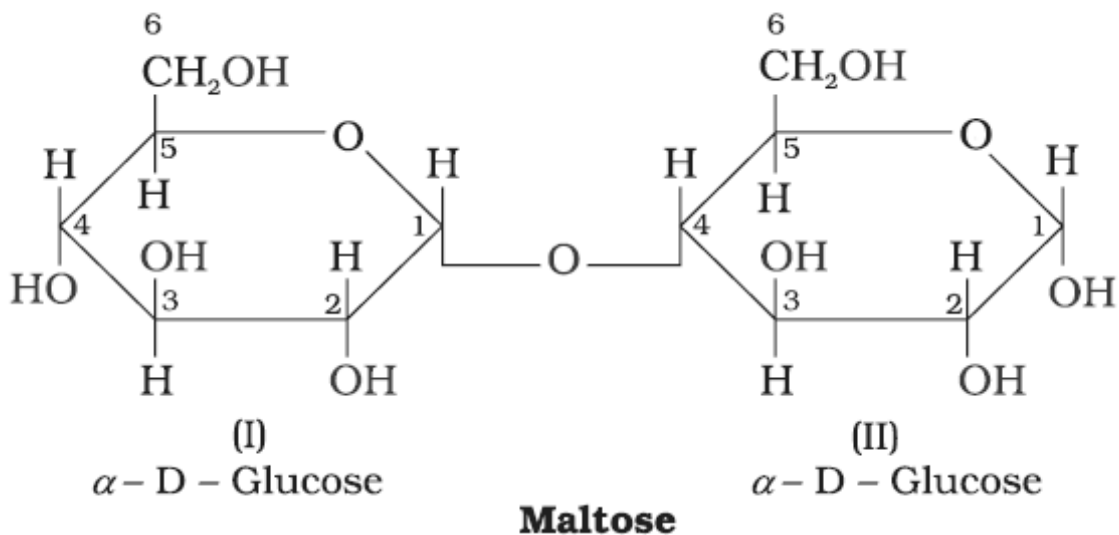
Haworth Projection of Sucrose:



Mutarotation – when α -glucose is dissolved in water the optical rotation decreases from 110° to a constant value 52.7° . similarly when β -glucose is dissolved in water the optical rotation increases from 20° to 52.7° . this change in optical rotation with time is called mutarotation. the reason of mutarotation is conversion of α - form to β - form in aqueous solution.

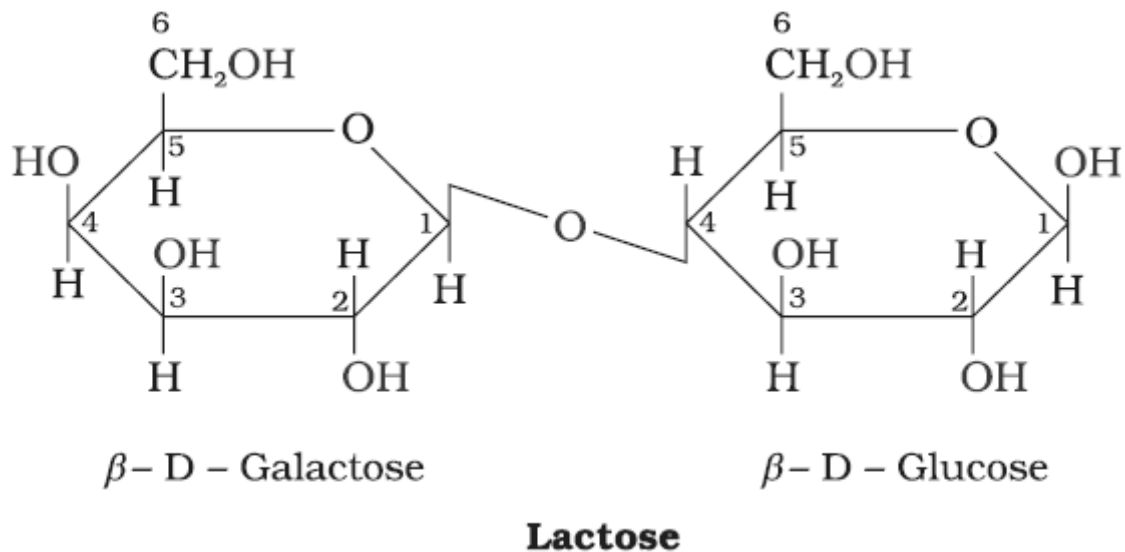
Maltose - Maltose is composed of two α -D-glucose units in which C1 of one glucose is linked to C4 of another glucose unit. The free aldehyde group can be produced at C1 of second glucose in solution and it shows reducing properties so it is a reducing sugar

Haworth projection of maltose:



Lactose (Milk sugar) -It is composed of β -D-galactose and β -D-glucose. The linkage is between C1 of galactose and C4 of glucose. Hence, it is also a reducing sugar.

Haworth projection of lactose:



Polysaccharides

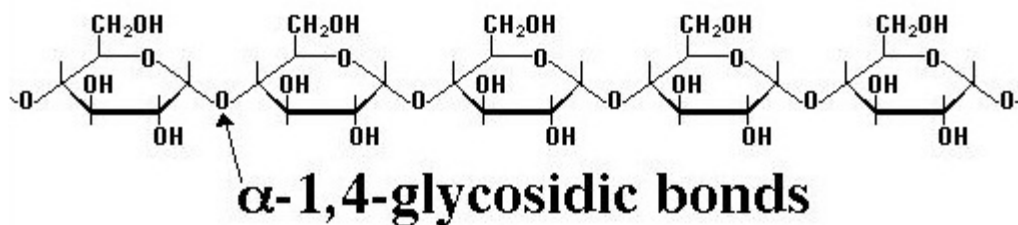
Polysaccharides contain a large number of monosaccharide units joined together by glycosidic linkages. These are the most commonly encountered carbohydrates in nature. They mainly act as the food storage or structural materials.

Starch

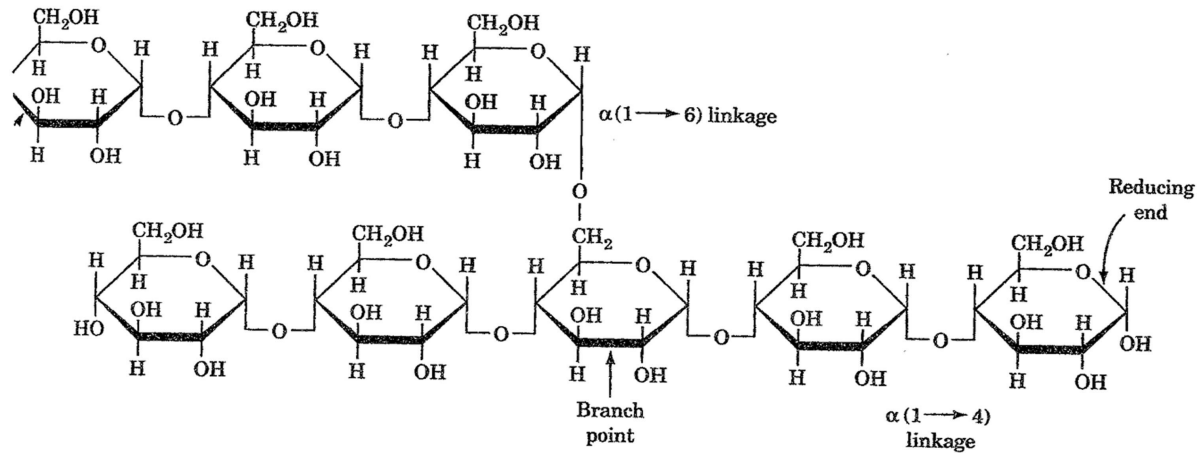
It is a polymer of α -glucose and consists of two components—Amylose and Amylopectin.

Amylose	Amylopectin
Water-soluble component.	Water-insoluble component.
Contains 200–1000 α -D-(+)-glucose units held by α -glycosidic linkages involving C1–C4 glycosidic linkage.	It is a branched chain polymer of α -D-glucose units in which chain is formed by C1–C4 glycosidic linkage, whereas branching occurs by C1–C6 glycosidic linkage.
Constitutes about 15–20% of starch.	Constitutes about 80–85% of starch.
It is a linear polymer.	It is a branched chain polymer.

Amylose

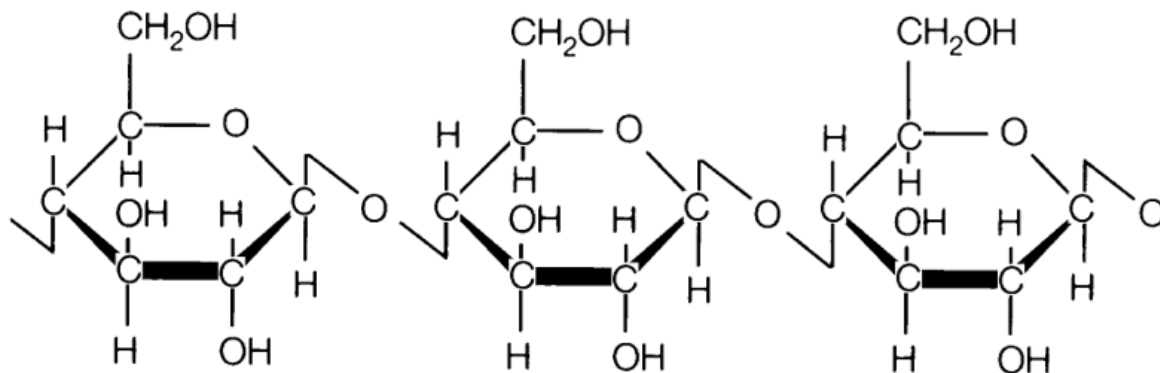


Amylopectin



Cellulose

Cellulose occurs exclusively in plants and it is the most abundant organic substance in plant kingdom. It is a predominant constituent of cell wall of plant cells. Cellulose 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.



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. It is present in liver, muscles and brain. When the body needs glucose, enzymes break the glycogen down to glucose. Glycogen is also found in yeast and fungi.

Reducing sugars- All sugars that can reduce Tollen's reagent and Fehling's solution are called reducing sugars. eg- all monosaccharides and those disaccharides in which the aldehydic or ketonic group are free like maltose and lactose.

Non-reducing sugars - Disaccharides in which the aldehydic or ketonic groups are bonded and cannot reduce either Tollen's or Fehling's reagent are called non-reducing sugars. eg-Sucrose .

Proteins

The word protein is derived from Greek word, "**proteios**" which means primary or of prime importance. All proteins are polymers of α -amino acids.

Amino acids

Amino acids contain amino ($-\text{NH}_2$) and carboxyl ($-\text{COOH}$) functional groups.

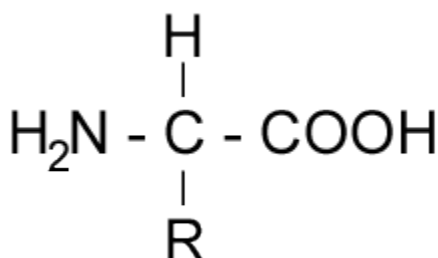
Depending upon the relative position of amino group with respect to carboxyl group, the amino acids can be classified as –

α -amino acid

β -amino acid

γ -amino acid and so on.

Only α -amino acid are found on the hydrolysis of proteins.



α -amino acid

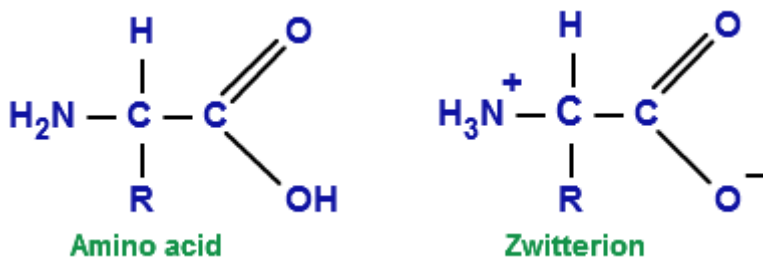
Classification-

Essential and non-essential amino acids –

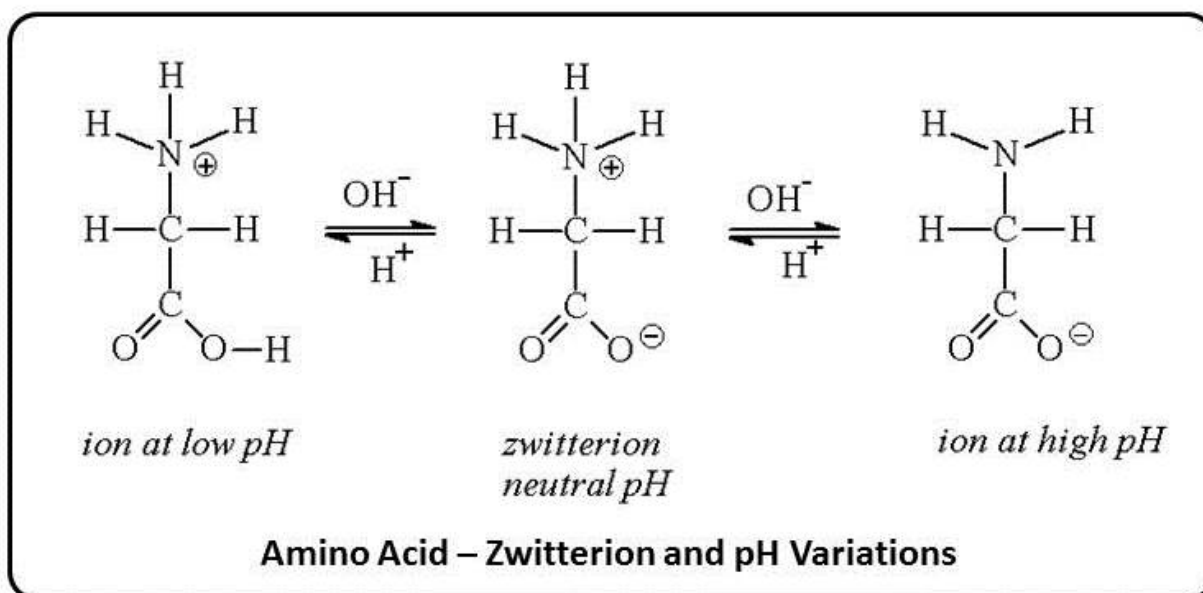
The amino acids that can be synthesized by the body are called **non-essential** amino acids. eg- Glycine, Alanine etc.

The amino acids that cannot be synthesized in the body and must be obtained through diet are called **essential** amino acids. eg- Valine, Leucine etc .

Zwitter ion - Amino acids contain both acidic(-COOH) and basic(-NH₂) groups in the same molecule. In aqueous solution, the carboxyl group loses a proton and amino group accepts a proton to form a dipolar ion called zwitter ion. It is amphoteric in nature.



These two forms exist in equilibrium.



Isoelectric point

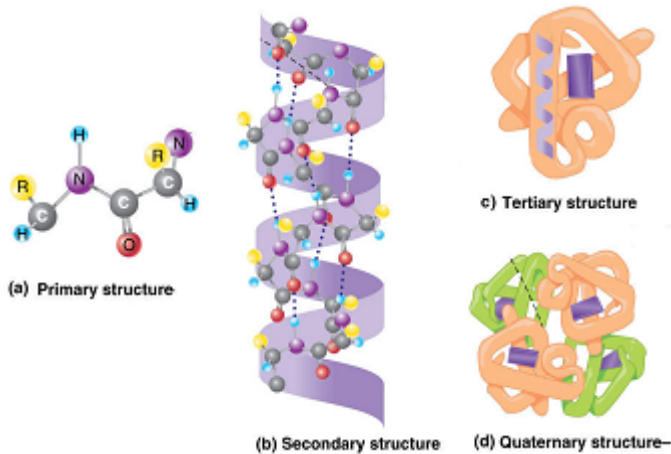
The pH at which the dipolar ion exists as a neutral ion and does not migrate to either electrode cathode or anode is called the isoelectronic point.

Structure of Proteins

Proteins are the polymer of α-amino acid connected by the peptide linkages. peptide linkage is an amide linkage formed by a condensation reaction between the -COOH group of one amino acid and the -NH₂ group of another amino acid.

Tertiary structure of protein It represents the overall folding of the polypeptide chains due to H-bonds, disulphide linkages, van der Waals and electrostatic forces of attraction to acquire fibrous and globular shapes.

Quaternary structure of proteins: Some 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 of proteins.



Denaturation of proteins - When a native protein is subjected to change in pH, temperature or chemicals, the tertiary structure of protein gets unfolded, the protein gets denatured. This causes the protein to lose its biological activity. eg- Boiled egg, curdling of milk.

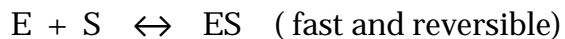
Enzymes

Enzymes are globular proteins that catalyse specific biochemical reactions.
eg-lipase, maltase

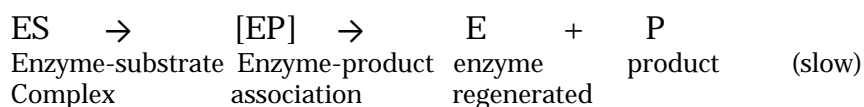
Enzymes which catalyse the oxidation of one substrate with simultaneous reduction of another substrate are called oxidoreductase enzymes.

Mechanism of enzyme catalysis. Enzyme catalysed reactions take place in two steps as follows-

Step1. Formation of enzyme-substrate complex.



Step2. dissociation of enzyme-substrate complex into products



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.

Vitamins are classified into two groups-

- A) Fat soluble vitamins- Vitamins A,D, E and K
- B) Water soluble vitamins-Vitamin B-Complex and C.

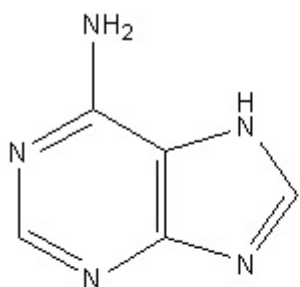
Nucleic acids

Nucleic acids are long chain polymers of nucleotides. They are mainly of two types- Deoxyribonucleic acid(DNA) and Ribonucleic acid(RNA).

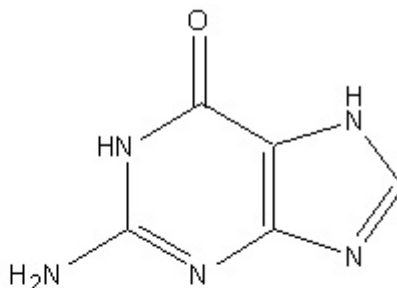
Nucleotide- A nucleotide is formed by the combination of a nitrogenous base, pentose sugar and phosphoric acid.

Nitrogenous bases are of two kinds-

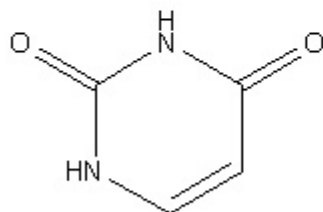
- a) Purines –Adenine and Guanine
- b) Pyrimidines–Cytosine, thymine and Uracil



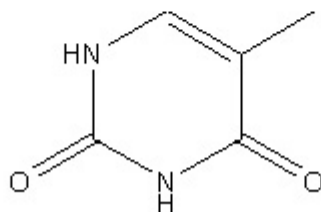
adenine



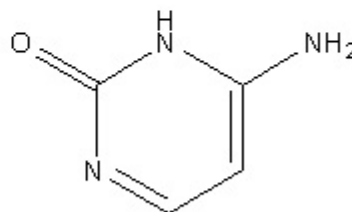
guanine



uracil



thymine



cytosine

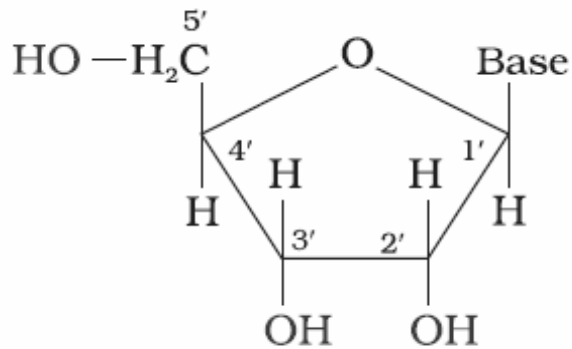
H-bonds between the nitrogenous bases-

Adenine and thymine are paired through two H-bonds i.e A= T
Cytosine and guanine pair through three H-bond i.e C ≡ G

Structure of Nucleic Acids

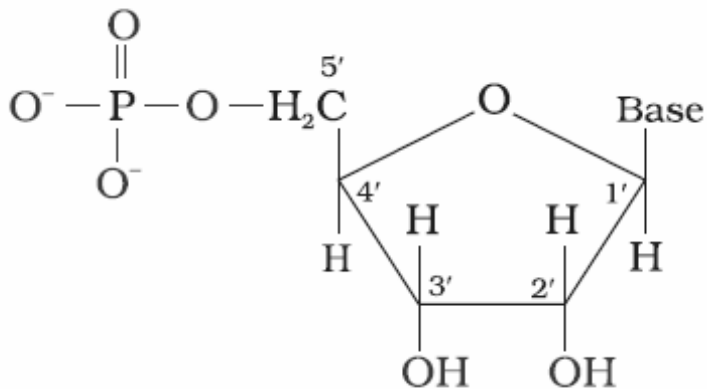
Nucleoside - A nucleoside is formed when a pyrimidine or purine base is attached to C-1 of sugar (ribose or deoxyribose) by a β -linkage.

Base + sugar



Nucleotide

Base + sugar + phosphate group



Nucleic acids (or polynucleotides)

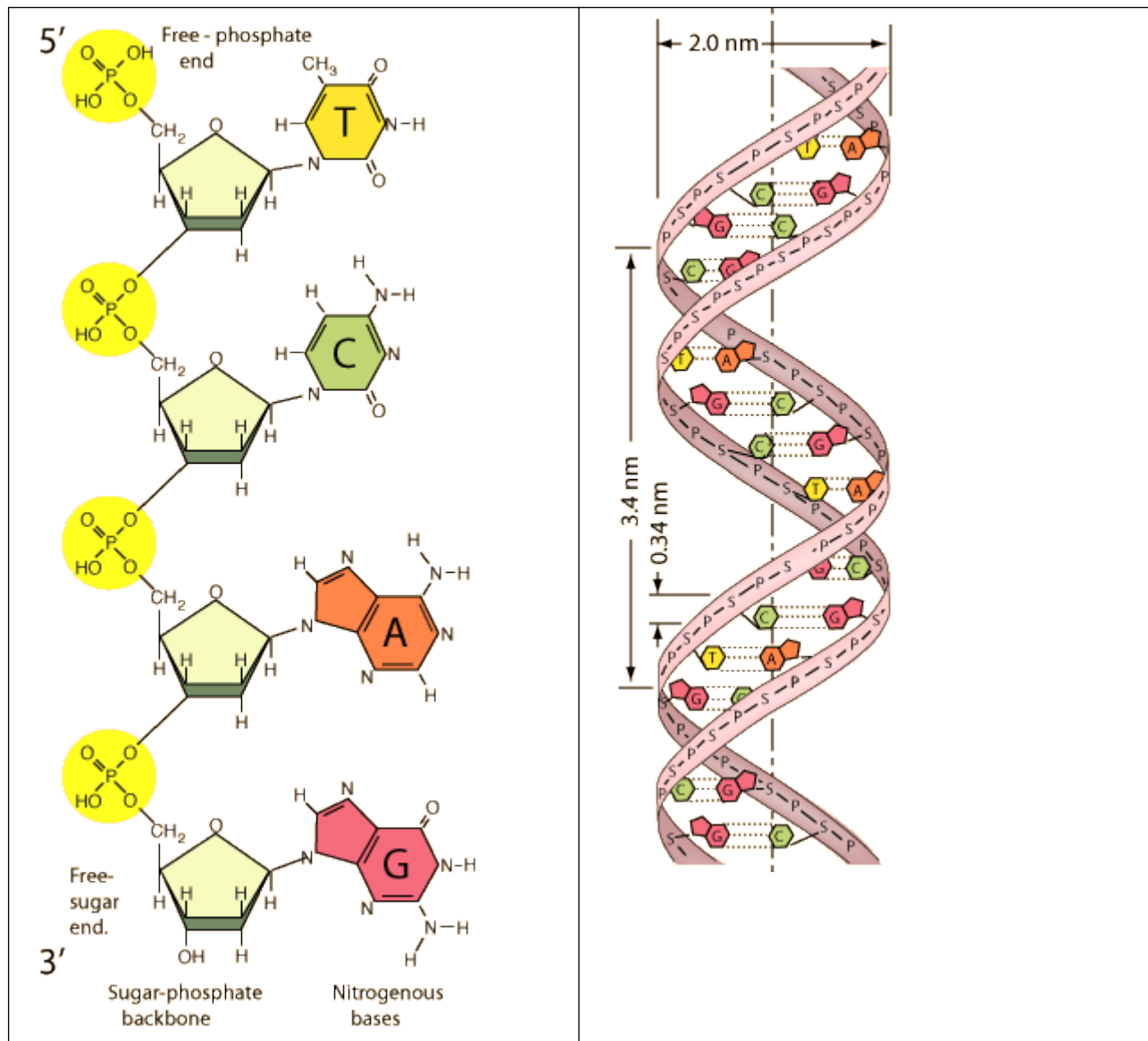
Long-chain polymers of nucleotides. Nucleotides are joined by phosphodiester linkage between 5' and 3' C atoms of a pentose sugar.

There are two types of nucleic acid

1. Deoxyribonucleic Acid (DNA)

2. Ribonucleic Acid (RNA)

Structure



Differences between DNA and RNA

DNA	RNA
It has a double-stranded α -helix structure in which two strands are coiled spirally in opposite directions.	It has a single-stranded α -helix structure
Sugar present is β -D-2-deoxyribose	Sugar present is β -D-ribose
Bases: Purine bases: Adenine (A) and guanine (G) Pyrimidine bases: Thymine (T) and cytosine (C)	Bases: Purine bases: Adenine (A) and guanine (G) Pyrimidine bases: Uracil (U) and cytosine (C)
It occurs mainly in the nucleus of the cell	It occurs mainly in the cytoplasm of the cell.
It is responsible for transmission for heredity character	It helps in protein synthesis