Biomolecules

Living systems are made up of various complex biomolecules like carbohydrates, proteins, nucleic acids, lipids, etc.

These biomolecules interact with each other and constitute the molecular logic of life processes.

CARBOHYDRATES

Most of them have a general formula, $C_x(H_2O)_y$, and were considered as hydrates of carbonfrom where the name carbohydrate was derived.

Chemically, the carbohydrates may be defined as optically active polyhydroxy aldehydes or ketones or the compounds which produce such units on hydrolysis.

Carbohydrates are also called **Saccharides**.

Carbohydrates are classified on the basis of their behaviour on hydrolysis.

Monosaccharides : A carbohydrate that cannot be hydrolysed further to give simpler unit of polyhydroxy aldehyde or ketone is called a monosaccharide.

Oligosaccharides: Carbohydrates that yield two to ten monosaccharide units, on hydrolysis, are called oligosaccharides. They are further classified as disaccharides, trisaccharides, tetrasaccharides, etc., depending upon the number of monosaccharides, they provide on hydrolysis.

Polysaccharides: Carbohydrates which yield a large number of monosaccharide units on hydrolysis are called polysaccharides.

All those carbohydrates which reduce Fehling's solution and Tollens' reagent are referred to as reducing sugars. All monosaccharides whether aldose or ketose are *reducing sugars.*

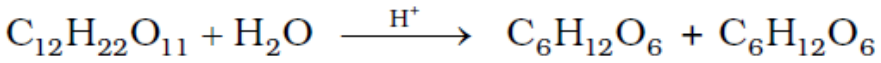
Monosaccharides are further classified on the basis of number of carbon atoms and the functional group present in them.

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

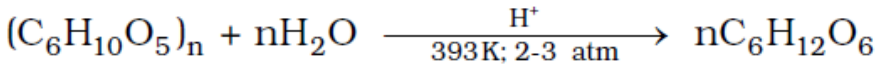
GLUCOSE

Preparation of Glucose

1. **From sucrose :** If sucrose is boiled with dilute HCl or H_2SO_4 in alcoholic solution, glucose and fructose are obtained in equal amounts.



2. **From starch :** Commercially glucose is obtained by hydrolysis of starch by boiling it with dilute H2SO4 at 393 K under pressure.

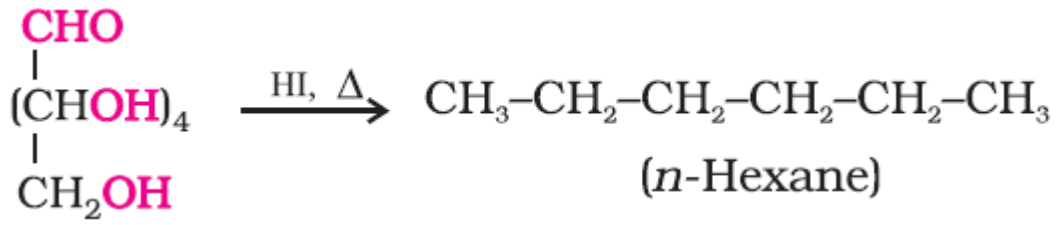


STRUCTURE OF GLUCOSE

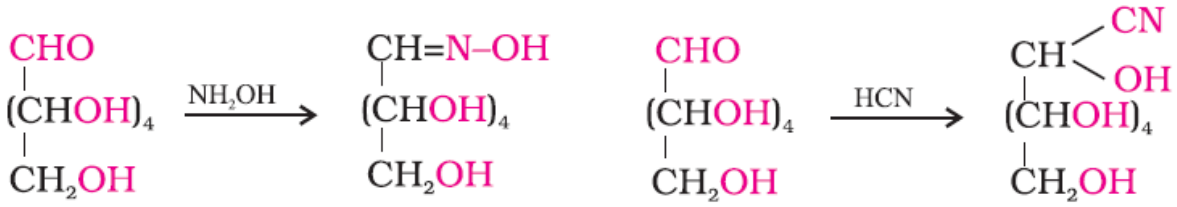
Glucose is an aldohexose and is also known as dextrose. It is the monomer of many of the larger carbohydrates, namely starch, cellulose.

It has the molecular formula $C_6H_{12}O_6$.

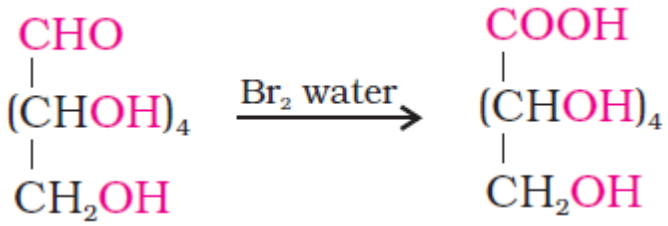
On prolonged heating with HI, it forms n-hexane, suggesting that all the six carbon atoms are linked in a straight chain.



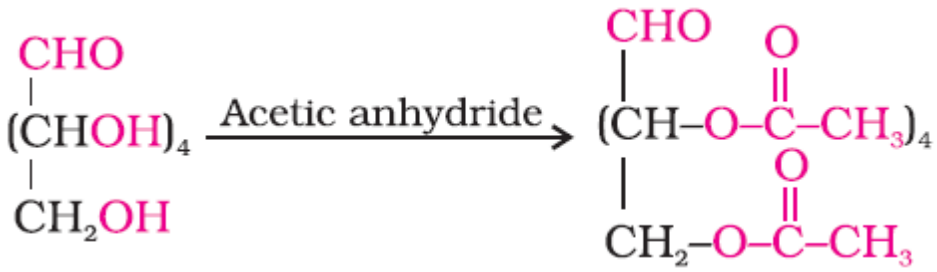
Glucose reacts with hydroxylamine to form an oxime and adds a molecule of hydrogen cyanide to give cyanohydrin. This confirm the presence of a carbonyl group (>C = 0) in glucose.



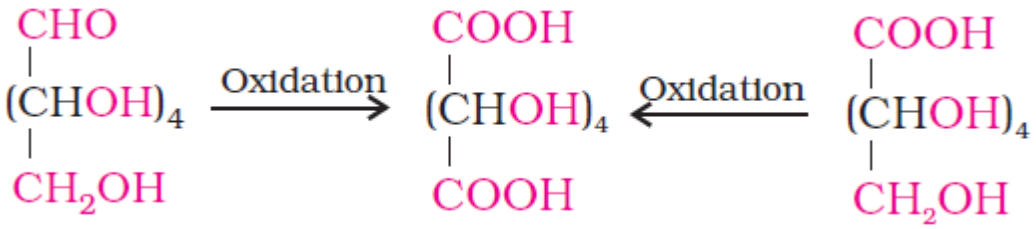
Glucose gets oxidised to six carbon carboxylic acid (gluconic acid) on reaction with a mild oxidising agent like bromine water. This indicates that the carbonyl group is present as an aldehydic group.



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.



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. The letters ‘D’ or ‘L’ before the name of any compound indicate the relative configuration of a particular stereoisomer.

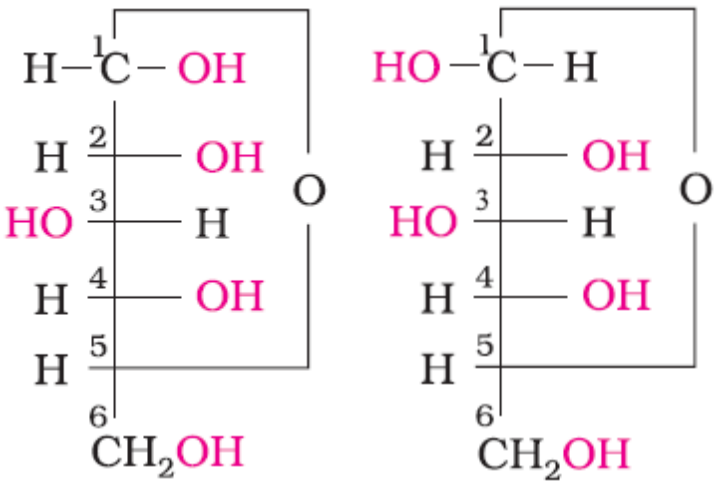
This refers to their relation with a particular isomer of glyceraldehyde. Glyceraldehyde contains one asymmetric carbon atom and exists in twoenantiomeric forms.

All those compounds which can be chemically correlated to (+) isomer of glyceraldehyde are said to have D-configuration whereas those which can be correlated to (–) isomer of glyceraldehyde are said to have L— configuration. For this comparison, the structure is written in a way that most oxidised carbon is at the top.

CYCLIC STRUCTURE OF GLUCOSE

1. Despite having the aldehyde group, glucose does not give 2, 4-DNP test, Schiff's test and it does not form the hydrogensulphite addition product with NaHSO3.
2. Glucose is found to exist in two different crystalline forms which are named as αand β.

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-5is involved in ring formation.



The two cyclic hemiacetal forms of glucose differ only in the configuration of the hydroxyl group at C1, called **anomeric** *carbon*. Such isomers, i.e., α –form and β -form, are called **anomers**.

FRUCTOSE

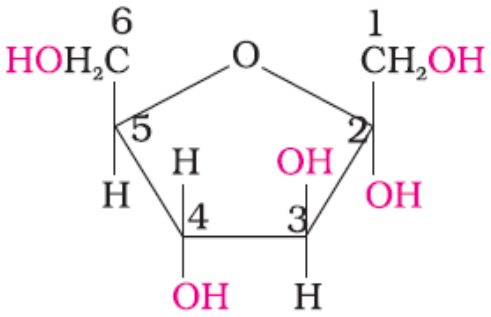
It is obtained along with glucose by the hydrolysis of disaccharide, sucrose.

STRUCTURE OF FRUCTOSE

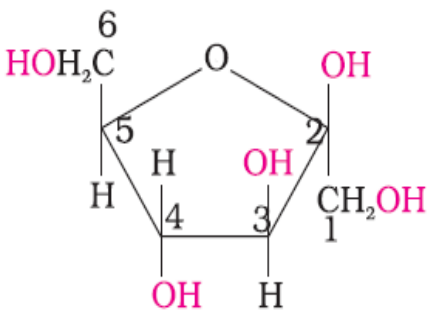
Fructose also has the molecular formula $C_6H_{12}O_6$ and on the basis of its reactions it was found to contain a ketonic functional group at carbon number 2 and six carbons in straight chain as in the case of glucose.

It belongs to D-series and is a laevorotatory compound. It is appropriately written as D-(–)-fructose.

It also exists in two cyclic forms which are obtained by the addition of —OH at C5. The cyclic structures of two anomers of fructose are represented by Haworth structures.



α – D- (-) – Fructofuranose



β- D – (-) – Fructofuranose

DISSACHARIDES AND POLYSACCHARIDES

Disaccharides on hydrolysis with dilute acids or enzymes yield two molecules of either the same or different monosaccharides. The two monosaccharides are joined together by an oxide linkage formed by the loss of a water molecule.

Such a linkage between two monosaccharide units through oxygen atom is called **glycosidic** *linkage.*

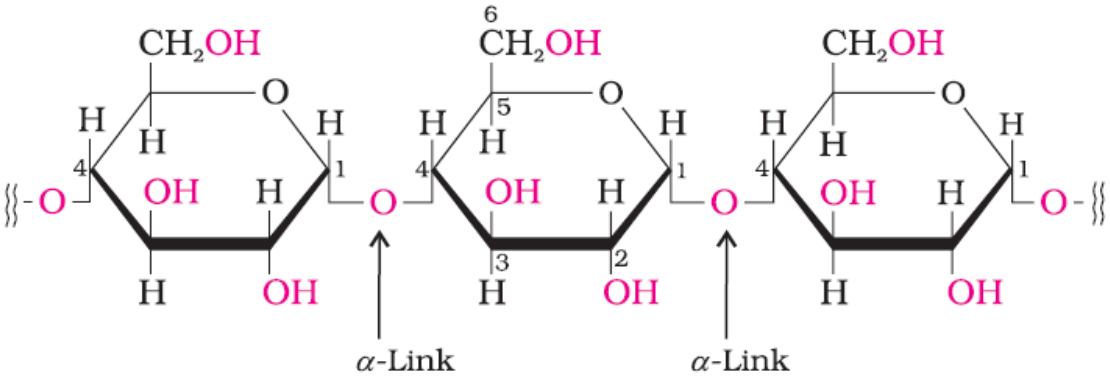
Polysaccharides contain a large number of monosaccharide units joined together by ***glycosidic*** linkages. These are the most commonly encountered carbohydrates in nature. They mainly act as the food storage or structural materials.

1. **Starch**: Starch is the main storage polysaccharide of plants. It is the most important dietary source for human beings. High content of starch is found in cereals, roots, tubers and some vegetables. It is a polymer of α-glucose and consists of two components—

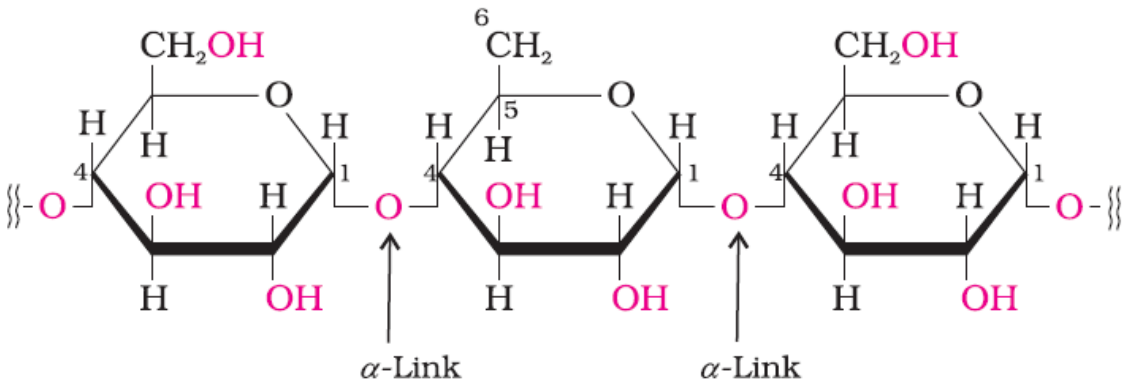
Amylose and **Amylopectin**.

Amylose is water soluble component which constitutes about 15-20% of starch. Chemically amylose is a long unbranched chain with 200-1000 α-D-(+)-glucose units held by C1– C4 glycosidic linkage.

Amylopectin is insoluble in water and constitutes about 80-85% of starch. It is a branched chain polymer of α-D-glucose.



Amylose



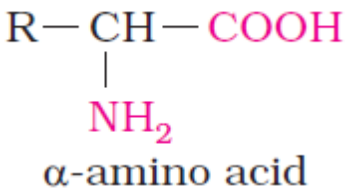
Amylopectin

PROTEINS

Proteins are the most abundant biomolecules of the living system. All proteins are polymers of α - amino acids.

1. AMINO ACIDS

Amino acids contain amino (–NH2) and carboxyl (–COOH) functional groups. Depending upon the relative position of amino group with respect to carboxyl group, the amino acids can be classified as α, β, γ,δ and so on. Only α-amino acids are obtained on hydrolysis of proteins. They may contain other functional groups also.



α-amino acid

CLASSIFICATION OF AMINO ACIDS

Amino acids are 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.

The amino acids, which can be synthesised in the body, are known as **nonessential amino acids.** On the other hand, those which cannot be synthesised in the body and must be obtained through diet, are known as **essential amino acids.**

Proteins can also be classified into two types on the basis of their molecular shape.

(a)***Fibrous proteins***

When the polypeptide chains run parallel and are held together by hydrogen and disulphide bonds, then fibre – like structure is formed

(b) ***Globular proteins***

This structure results when the chains of polypeptides coil around to give a spherical shape. Insulin and albumins are the common examples of globular proteins.

STRUCTURE OF PROTEINS

Proteins are the polymers of α-amino acids and they are connected to each other by peptide bond or peptide linkage. Chemically, peptide linkage is an amide formed between –COOH group and –NH2 group.

Structure and shape of proteins can be studied at four different levels, i.e., primary, secondary, tertiary and quaternary, each level being more complex than the previous one.

1. Primary structure of proteins:

Proteins may have one or more polypeptide chains. Each polypeptide in a protein has amino acids linked with each other in a specific sequence and it is this sequence of amino acids that is said to be the primary structure of that protein.

2. Secondary structure of proteins:

The secondary structure of protein refers to the shape in which a long polypeptide chain can exist. They are found to exist in two different types of structures viz. α-helix and β-pleated sheet structure. These structures arise due to the regular folding of the backbone of the polypeptide chain.

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.

3. 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.

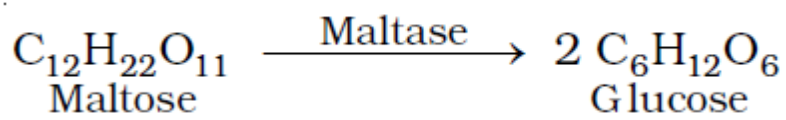
4. Quaternary structure of proteins:

Some of the proteins are composed of two or more polypeptide chains referred to as sub-units.

ENZYMES

Life is possible due to the coordination of various chemical reactions in living organisms. An example is the digestion of food, absorption of appropriate molecules and ultimately production of energy. This occurs with the help of certain biocatalysts called **enzymes.**

Almost all the enzymes are globular proteins. Enzymes are very specific for a particular reaction and for a particular substrate. They are generally named after the compound or class of compounds upon which they work.



VITAMINS

Vitamins are **organic compounds required in the diet in small amounts to perform specificbiological functions for normal maintenance of optimum growth and health of the organism.** Vitamins are designated by alphabets A, B, C, D, etc. Some of them are further named as sub-groups e.g. B1, B2, B6, B12, etc.

CLASSIFICATION OF VITAMINS

Vitamins are classified into two groups depending upon their solubility

in water or fat.

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

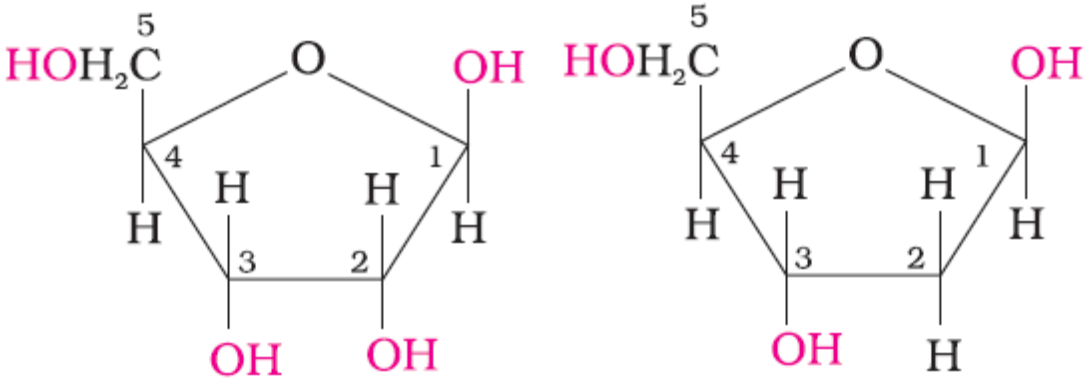
(ii) *Water soluble vitamin*s: B group vitamins and vitamin C are solublein water so they are grouped together. Water soluble vitamins mustbe supplied regularly in diet because they are readily excreted inurine and cannot be stored (except vitamin B12) in our body.

NUCLIEC ACID

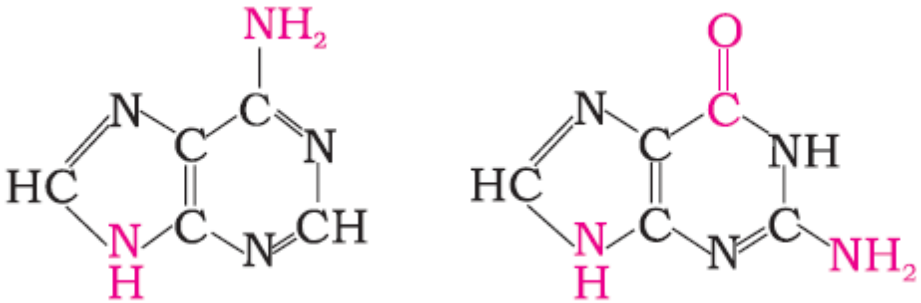
It has been observed that nucleus of a living cell is responsible for the transmission of inherent characters, also called **heredity**. The particles in nucleus of the cell, responsible for heredity, are called chromosomes which are made up of proteins and another type of biomolecules called **nucleic acids.** These are mainly of two types, the **deoxyribonucleic acid (DNA) and ribonucleic acid(RNA).** Since nucleic acids are long chain polymers of **nucleotides,** so they are also called **polynucleotides.**

CHEMICAL COMPOSITION OF NUCLEIC ACIDS

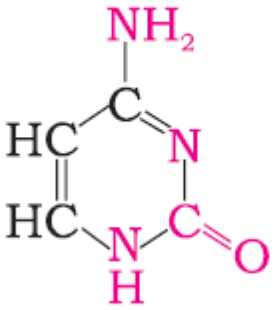
Complete hydrolysis of DNA (or RNA) yields a pentose sugar, phosphoric acid and nitrogen containing heterocyclic compounds (called bases). In DNA molecules, the sugar moiety is β-D-2-deoxyribose whereas in RNA molecule, it is β-D-ribose.



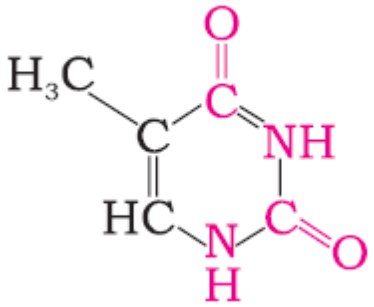
DNA contains four bases viz. adenine (A), guanine (G), cytosine (C)and thymine (T). RNA also contains four bases, the first three bases aresame as in DNA but the fourth one is uracil (U).



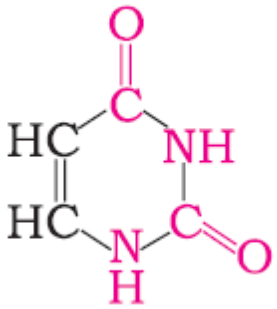
Adenine Guanine



Cyatosine



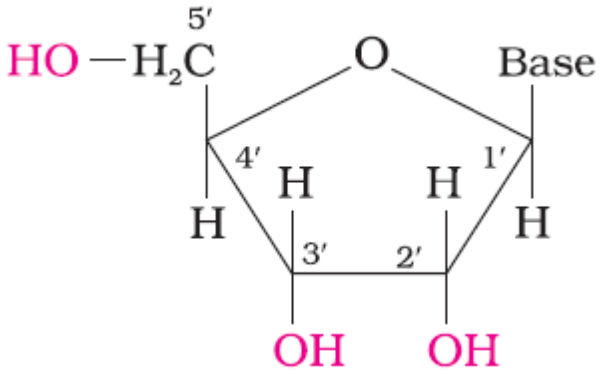
Thymine



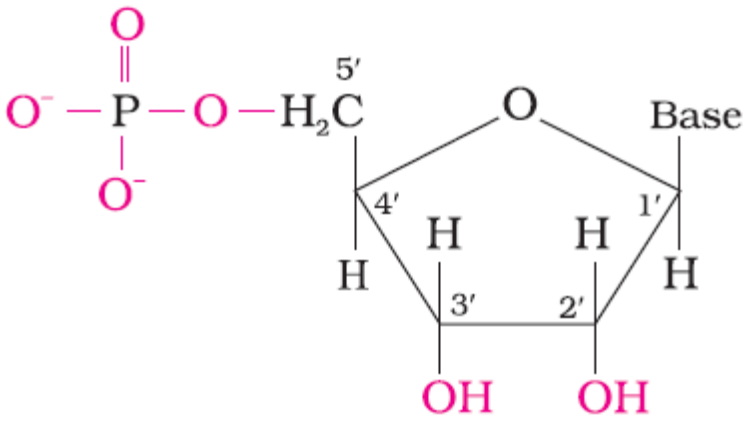
Uracil

STRUCTURE OF NUCLEIC ACIDS

A unit formed by the attachment of a base to 1′position of sugar is known as **nucleoside.** In nucleosides, the sugar carbons are numbered as 1□ , 2 □ , 3 □ etc. in order to distinguish these from the bases. When nucleoside is linked to phosphoric acid at 5′-position of sugar moiety, we get a nucleotide.

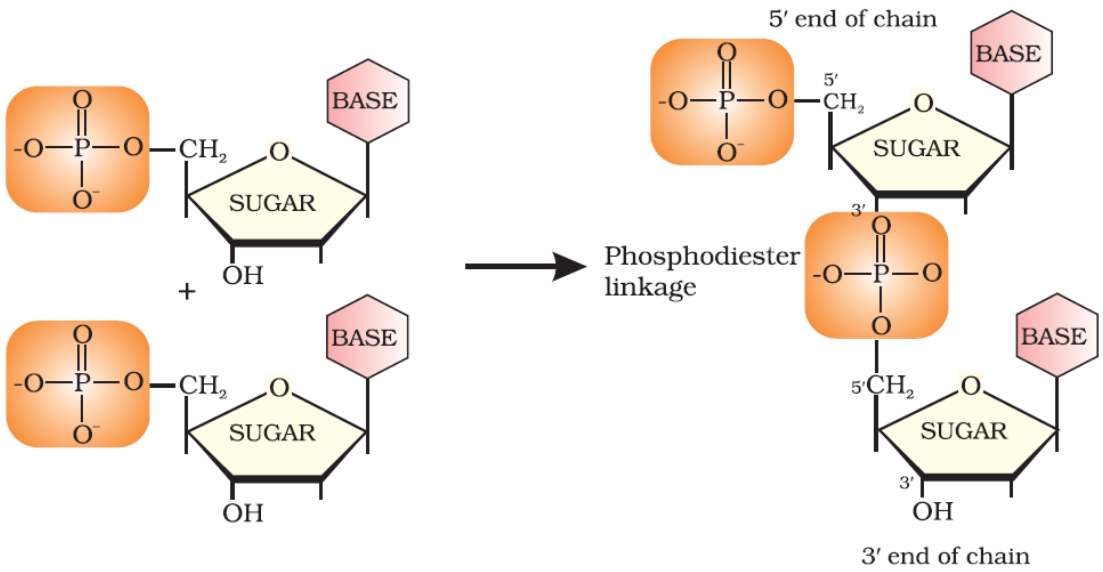


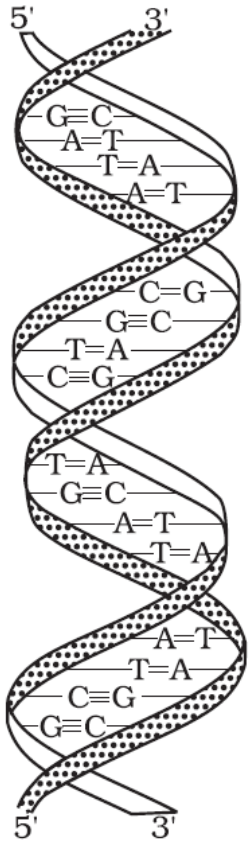
A nucleoside



A nucleotide

FORMATION OF DINUCLEOITIDE





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. The two strands are complementary to each other because the hydrogen bonds areformed between specific pairs of bases. Adenine forms hydrogenbonds

with thymine whereas cytosine forms hydrogen bondswith guanine.