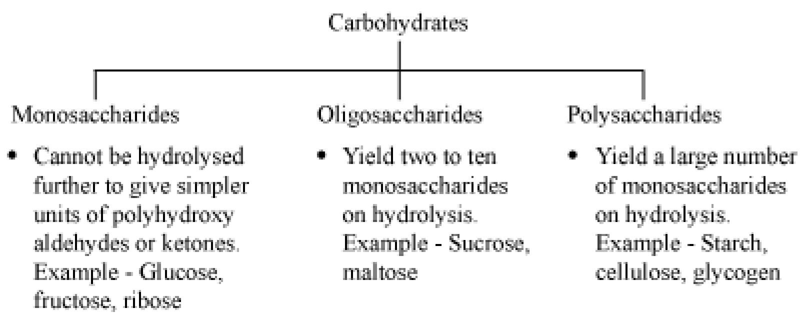
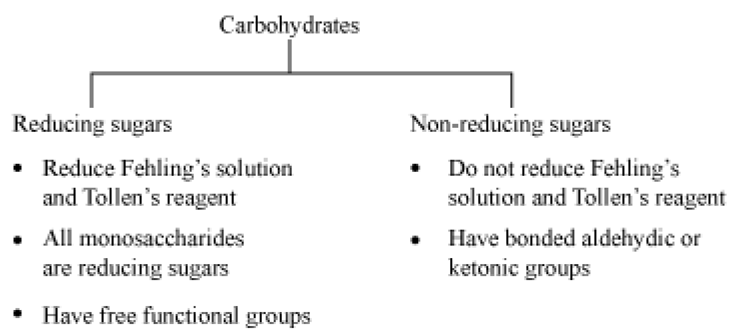
Biomolecules

Classification of Carbohydrates & Glucose - Preparation and Structure

- Carbohydrates are called saccharides.
- **Classification**





Classification of Monosaccharides

- Monosaccharides are classified based on the number of carbon atoms and the functional group present in them.
- Different types of monosaccharides arelisted in the given table.

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**
- By boiling sucrose with dilute HCl or H_2SO_4 in alcoholic solution

$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{H^+} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Fructose}}{C_6H_{12}O_6}$$

- By boiling starch with dilute H_2SO_4, at 393 K, under pressure

$$\underset{\text{Starch or cellulose}}{(C_6H_{10}O_5)_n} + nH_2O \xrightarrow[393K,\ 2-3\,atoms]{H^+} \underset{\text{Glucose}}{nC_6H_{12}O_6}$$

- **Structure**

$$\begin{array}{l} CHO \\ | \\ (CHOH)_4 \\ | \\ CH_2OH \end{array}$$

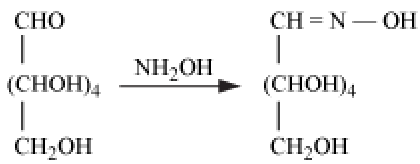
- Glucose has been assigned the above structure based on the following evidences.

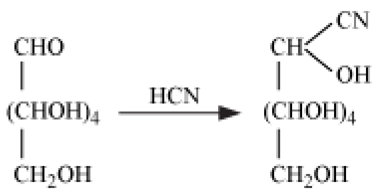
(i) Molecular formula – $C_6H_{12}O_6$

(ii) Suggestion of straight chain

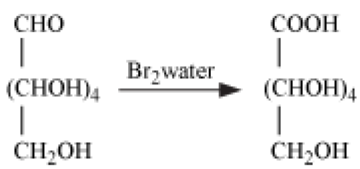
$$\begin{array}{l} CHO \\ | \\ (CHOH)_4 \\ | \\ CH_2OH \end{array} \xrightarrow{HI,\ \Delta} \underset{n\text{-Hexane}}{CH_3-CH_2-CH_2-CH_2-CH_2-CH_3}$$

(iii) Confirmation of carbonyl (> C = O) group



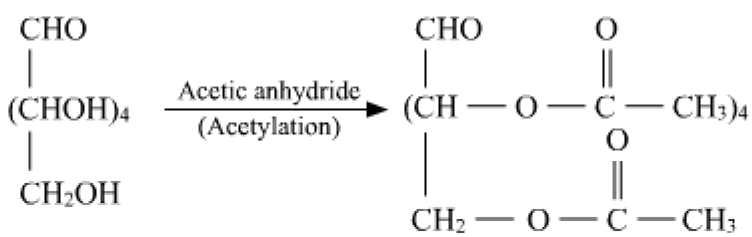


(iv) Confirmation of the presence of carbonyl group as aldehydic group



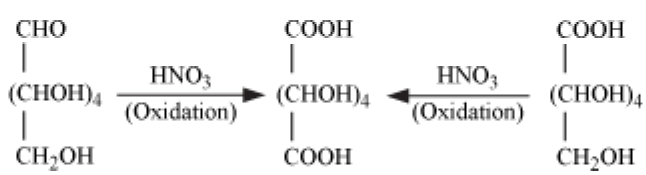
Gluconic acid

(v) Confirmation of the presence of five –OH groups



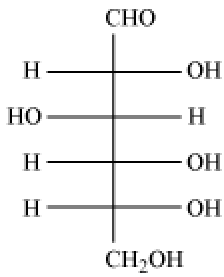
Glucose pentaacetate

(vi) Indication of the presence of a primary alcohol



Saccharic acid Gluconic acid

- The correct configuration of glucose is given by



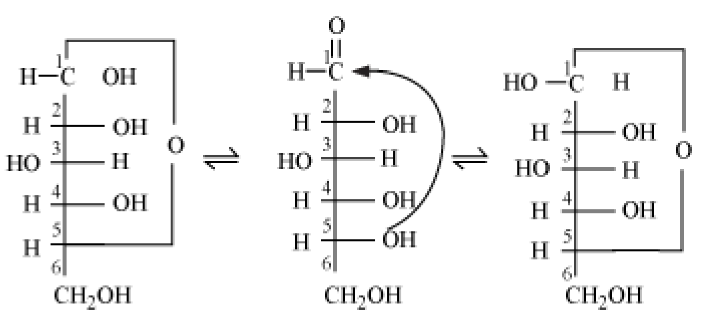
- Glucose is correctly named as D (+) − Glucose
- To understand **the concept** of configuration further, let us go through the following puzzle.

  Cyclic Structure of Glucose

- The following reactions of glucose cannot be explained by its open-chain structure.
- Aldehydes give 2, 4-DNP test, Schiff's test, and react with $NaHSO_3$ to form the hydrogen sulphite addition product. However, glucose does not undergo these reactions.
- The penta-acetate of glucose does not react with hydroxylamine. This indicates that a free −CHO group is absent from glucose.
- Glucose exists in two crystalline forms, α and β.

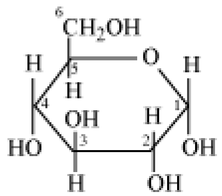
  The α-form (m.p = 419 K) crystallises from a concentrated solution of glucose at 303 K and the β-form (m.p = 423 K) crystallises from a hot and saturated aqueous solution at 371 K. This behaviour cannot be explained by the open-chain structure of glucose.

- Glucose exists in two cyclic forms, which exist in equilibrium with the open- chain structure.

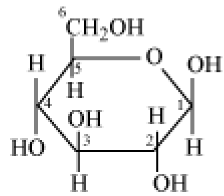


α – D – (+) – Glucose β – D – (+) – Glucose

- Representation of the cyclic structure of glucose by Haworth structure:



α – D – (+) – Glucopyranose

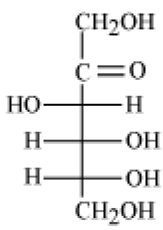


β – D – (+) – Glucopyranose

Structure of Fructose, Disaccharides & Polysaccharides

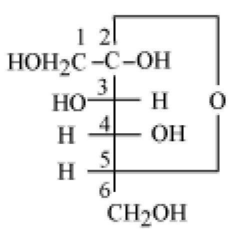
Structure of Fructose

- Open-chain structure:

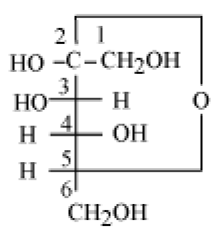


D – (–) – Fructose

- Cyclic structure:

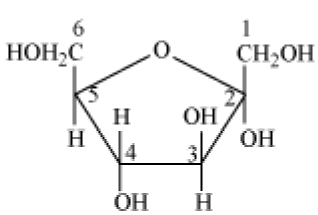


α – D – (–) – Fructofuranose

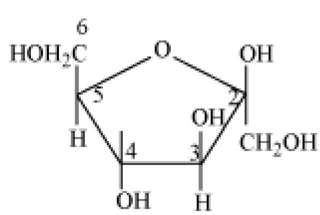


β – D – (–) – Fructofuranose

- Representation of the structure of fructose by Haworth structures



α – D – (–) – Fructofuranose



β – D – (–) – Fructofuranose

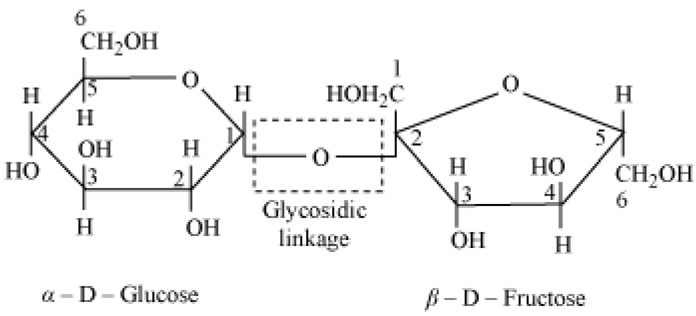
Disaccharides

Glycosidic linkage – Linkage between two monosaccharide units through oxygen atom

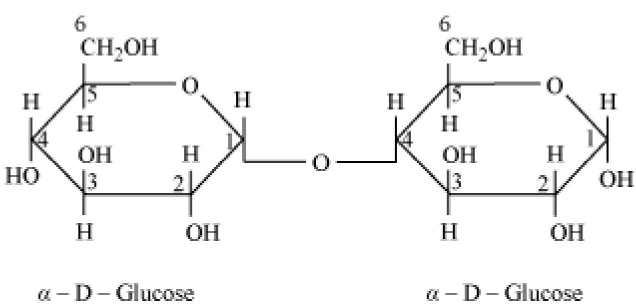
- **Sucrose**
- Hydrolysis of sucrose:

$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + H_2O \longrightarrow \underset{\text{D}-(+)-\text{glucose}}{C_6H_{12}O_6} + \underset{\text{D}-(-)-\text{fructose}}{C_6H_{12}O_6}$$

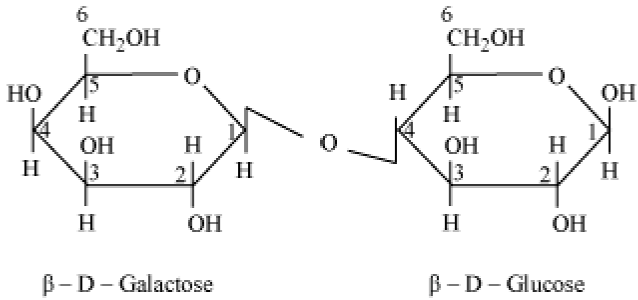
- Structure:



- The product formed on the hydrolysis of sucrose is called invert sugar as the sign of rotation changes from dextro (+) of sucrose to laevo (−) of the product.
- Non-reducing sugar
- **Maltose**
- Structure:



- Reducing sugar
- **Lactose**
- Commonly known as milk sugar
- Structure:

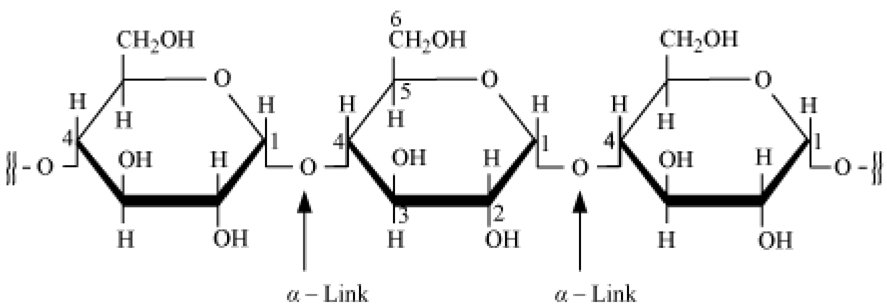


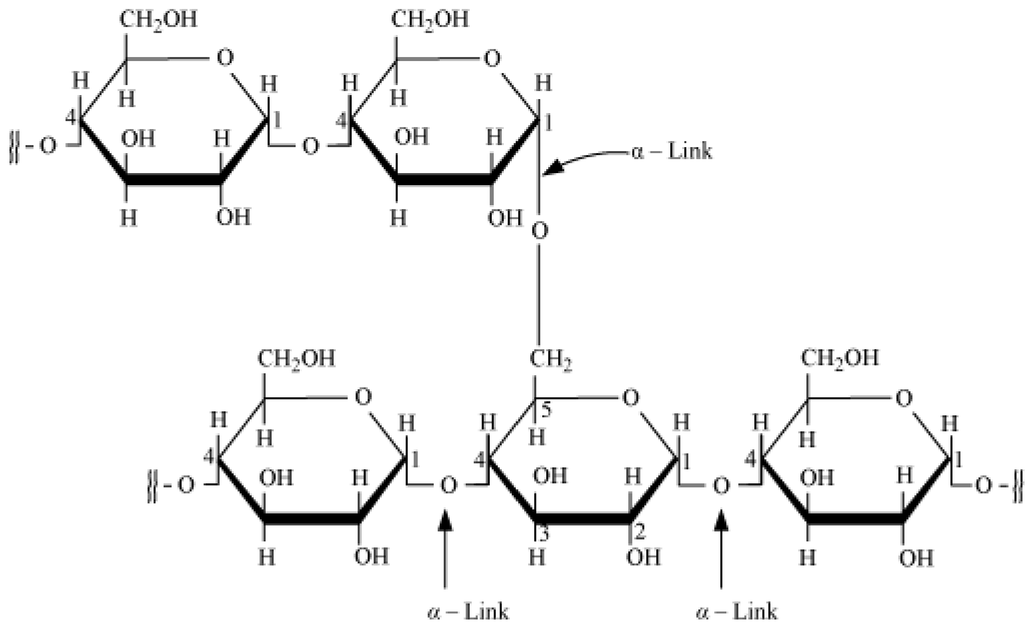
- Reducing sugar

Polysaccharides

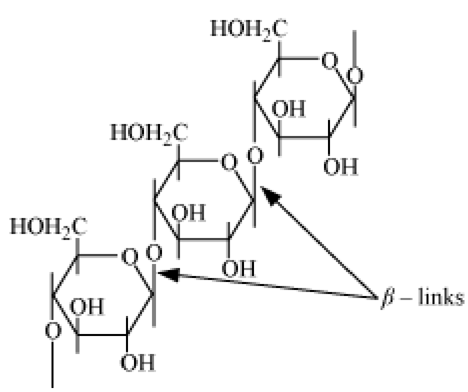
They mainly act as food storage or structural materials.

- **Starch**
- Main storage-polysaccharide of plants
- Polymer of α-glucose; consists of two components – amylase and amylopectin





- **Cellulose**
- Predominant constituent of the cell wall of plant cells.
- Straight-chain polysaccharide, composed of only β-D-Glucose

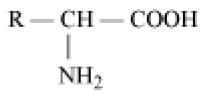


- **Glycogen**
- Storage-polysaccharide in animal body
- Also known as *animal starch* because its structure is similar to amylopectin.

Proteins

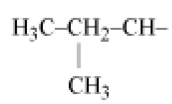
- Proteins are polymers of α – amino acids.

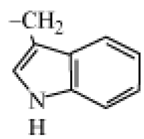
Amino Acids



α-Amino acid
(R= side chain)

- Some amino acids with their symbols are listed in the given table.

Name	Side chain, R	Three-letter symbol	One-letter code
1. Glycine	H	Gly	G
2. Alanine	$-CH_3$	Ala	A
3. Valine	$(H_3C)_2CH-$	Val	V
4. Leucine	$(H_3C)_2CH-CH_2-$	Leu	L
5. Isoleucine		Ile	I
6. Lysine	$H_2N-(CH_2)_4-$	Lys	K
7. Glutamic acid	$HOOC-CH_2-CH_2-$	Glu	E
8. Aspartic acid	$HOOC-CH_2-$	Asp	D

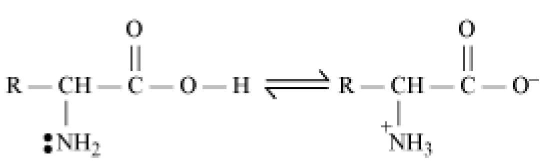
9. Cysteine	HS−CH_2−	Cys	C
10. Methionine	H_3C−S−CH_2−CH_2−	Met	M
11. Phenylalanine	C_6H_5−CH_2−	Phe	F
12. Tryptophan		Trp	W

Classification of Amino Acids

- Based on the relative number of amino and carboxyl groups, they are classified as acidic, basic and neutral.
- Amino acids are also classified as essential and non-essential amino acids.
- Non-essential amino acids: Amino acids that can be synthesised in the body. Example − Glycine, alanine, glutamic acid etc.
- Essential amino acids: Amino acids that cannot be synthesised in the body, and must be obtained through diet. Example − Valine, leucine, isolecuine etc.

Properties of Amino Acids

- Colourless and crystalline solids
- Exist as dipolar ions, known as zwitter ions, in aqueous solution



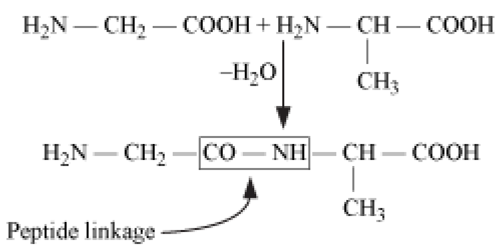
(Zwitter ion)

- In zwitter form, amino acids show amphoteric behaviour.

- All naturally occurring α-amino acids (except glycine) are optically active.

Structure of Proteins

- Proteins are polymers of α-amino acids, joined to each other by peptide linkage or peptide bond.
- Peptide linkage: Amide formed between −COOH group and $-NH_2$ group of two amino acid molecules.



Glycylalanine (Gly-Ala)

- Dipeptide − Contains two amino acid molecules

  Tripeptide − Contains three amino acid molecules

  Polypeptide − Contains more than ten amino acid molecules

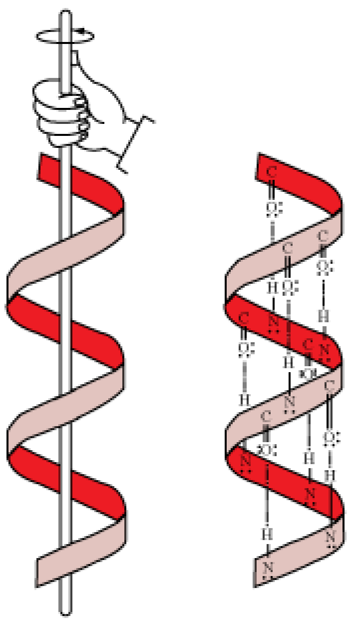
- Based on the molecular shape, proteins are classified into two types −

- Fibrous proteins
- Globular proteins

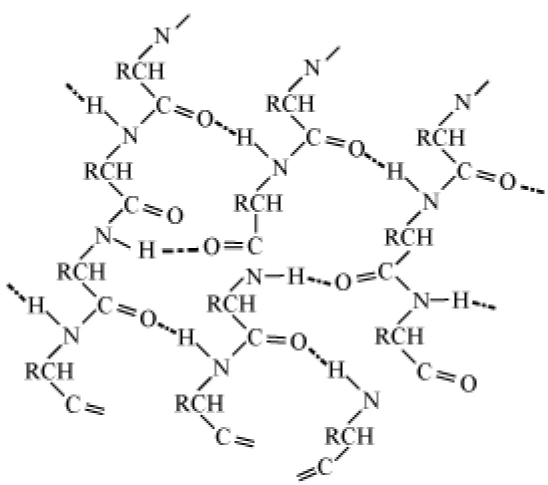
- **Fibrous Proteins**: In fibrous proteins, polypeptide chains run parallel and are held together by hydrogen and disulphide bonds. Example: keratin and myosin.
- **Globular Proteins**: Polypeptide chains coil around, giving a spherical shape. Example: Insulin.
- Structures and shapes of proteins are studied at four different levels: primary, secondary, tertiary and quaternary.
- Primary structure of proteins: Contains one or more polypeptide chains, and each chain has amino acids linked with each other in a specific sequence. This sequence of amino acids represents the primary structure of proteins.

- Secondary structure of proteins: Shape in which a long polypeptide chain can exist; two types of secondary structures: α-helix, β-pleated sheet

- α-helix structure of protein is as follows:



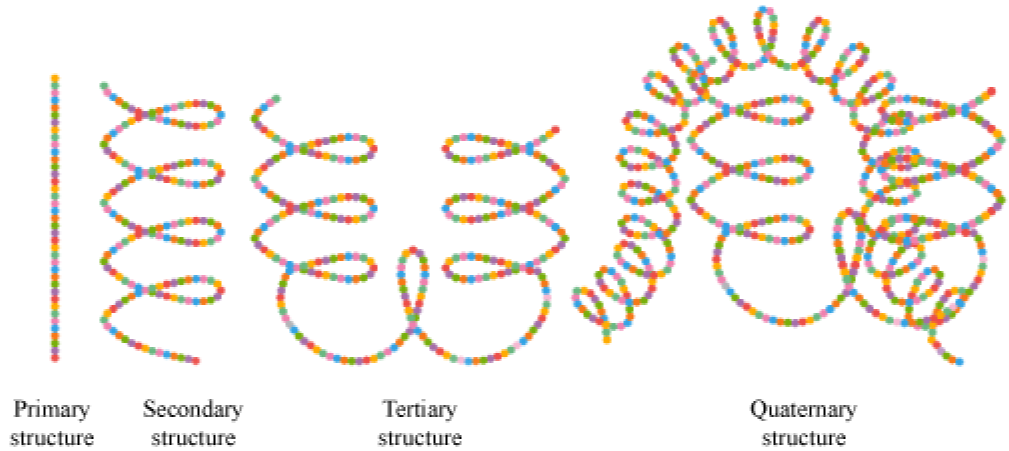
- β-pleated sheet structure of proteins is as follows:



- Tertiary structure of proteins: Overall folding of the polypeptide chains; results in fibrous and globular proteins; secondary and tertiary structures of proteins are stabilised by hydrogen bonds, disulphide linkages, van der Waals forces and electrostatic forces.

- Quaternary structure of proteins: Spatial arrangement of subunits (two or more polypeptide chains forming some proteins) with respect to each other is known as quaternary structure.

- The diagrammatic representations of the four structures of proteins are given below



Denaturation of Proteins

- Loss of biological activity of proteins due to the unfolding of globules and uncoiling of helix.
- Example – Coagulation of egg white on boiling, curdling of milk

- Enzymes, Vitamins & Nucleic Acids

Enzymes

- Enzymes are biocatalysts.
- Specific for a particular reaction and for a particular substrate
- For example, maltase catalyses hydrolysis of maltose

$$\underset{\text{Maltose}}{C_{12}H_{22}O_{11}} \xrightarrow{\text{Maltase}} \underset{\text{Glucose}}{2C_6H_{12}O_6}$$

- The name of an enzyme ends with '–ase'.
- Reduce the magnitude of activation energy

Vitamins

- Organic compounds required in the diet in small amounts to maintain normal health, growth and nutrition
- Classified into groups –
    - Water-soluble vitamins: Vitamin C, B-group vitamins (B_1, B_2, B_6, B_{12} etc)

- Fat-soluble vitamins: Vitamins A, D, E and K

Some vitamins with their functions, sources and the diseases caused by their deficiency are given in the following table.

Name of Vitamin	Function	Source	Deficiency Diseases
Vitamin A	Maintenance of normal vision and healthy epithelial tissue	Fish liver oil, carrots, butter and milk	Xerophthalmia and night blindness
Vitamin B_1	It plays a key role in the production of energy	Yeast, milk, green vegetables and cereals	Beriberi
Vitamin B_2	Conversion of carbohydrates into glucose Protection of the cells and DNA from free radicals	Milk, egg-white, liver, kidney	Cheilosis, digestive disorders and burning sensation of the skin
Vitamin B_6	Synthesis of antibodies and haemoglobin Maintenance of normal nerve function Breakdown of proteins Regulation of blood sugar	Yeast, milk, egg yolk, cereals and gram	Convulsions
Vitamin B_{12}	Formation of RBC and maintenance of CNS	Meat, fish, egg and curd	Pernicious anaemia
Vitamin C	Maintenance of teeth and gums Repairing of tissues in the body Inhibition of histamine Improvement of body defence mechanism	Citrus fruits, *amla* and green leafy vegetables	Scurvy
Vitamin D	Absorption of calcium required for the growth of	Exposure to	Rickets and osteomalacia

	bones	sunlight, fish and egg yolk	
Vitamin E	Improvement of the immune system Formation of RBC To prevent the blood clotting inside blood vessels	Vegetable oils like wheat germ oil, sunflower oil	Increased fragility of RBC and muscular weakness
Vitamin K	Required for normal blood clotting and synthesis of proteins found in plasma	Green leafy vegetables	Delay of blood clotting

Nucleic Acids

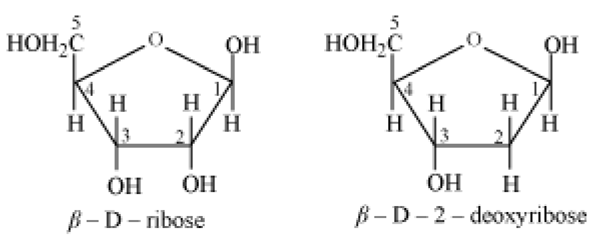
- Two types:

- Deoxyribonucleic acid (DNA)
- Ribonucleic acid (RNA)

- Nucleic acids are polymers of nucleotides. Hence, they are also known as polynucleotides.

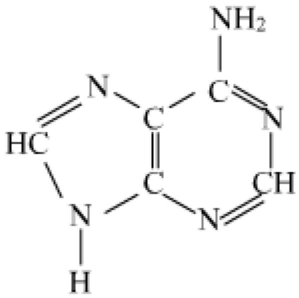
- Each nucleic acid contains a pentose sugar, phosphate moeity and a nitrogenous base (heterocyclic compound containing nitrogen).

- In DNA, sugar is β-D-2-deoxyribose; in RNA, sugar is β-D-ribose

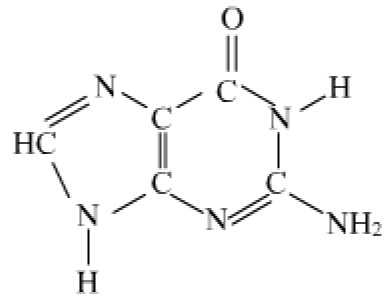


- Bases in DNA: Adenine (A), guanine (G), cytosine (C) and thymine (T)

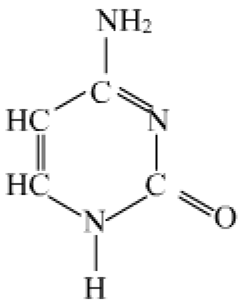
- Bases in RNA: Adenine (A), guanine (G), cytosine (C) and uracil (U)



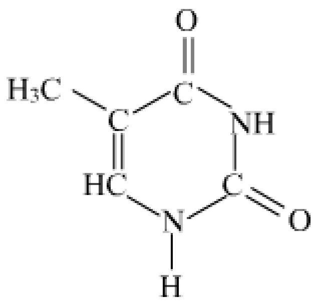
Adenine (A)



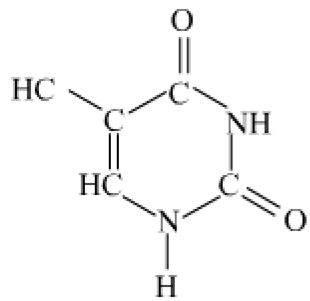
Guanine (G)



Cytosine (C)

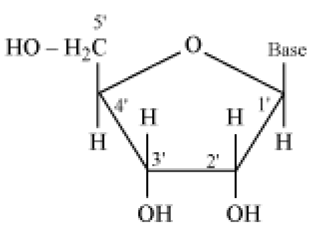


Thymine (T)

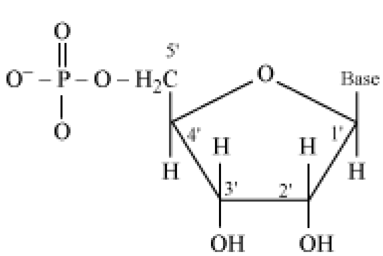


Uracil (U)

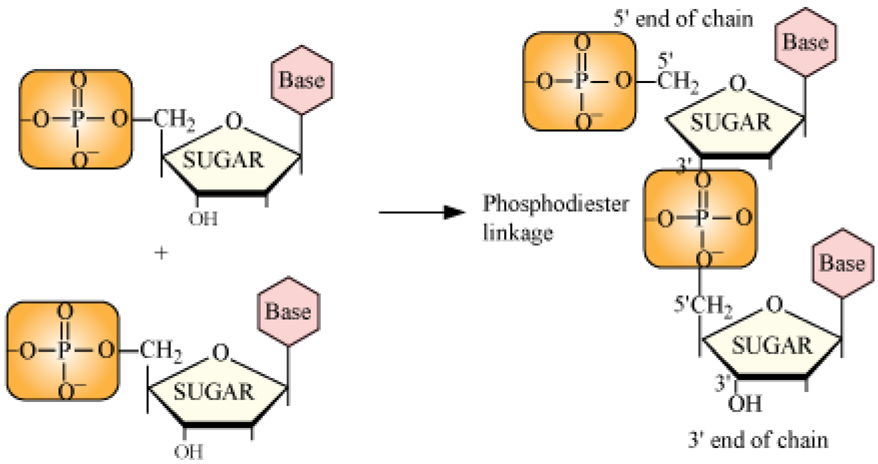
- **Structure of nucleic acids**
- Structure of a nucleoside:



- Structure of a nucleotide:



- Formation of a di-nucleotide:



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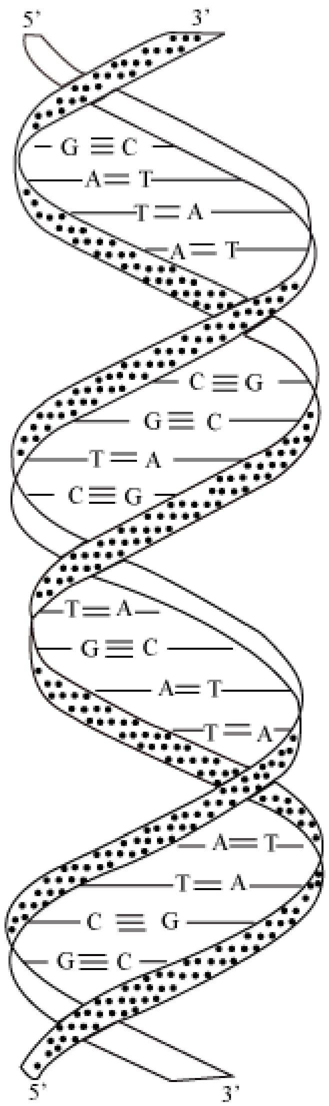
- In secondary structure, the helices of DNA are double-stranded while those of RNA are single-stranded.

- The two strands of DNA are complementary to each other.

  Reason: H-bonds are formed between specific pairs of bases.

- Double-strand helix structure of DNA:



- Types of RNA:
- Messenger RNA (m-RNA)
- Ribosomal RNA (r-RNA)
- Transfer RNA (t-RNA)
- Functional differences between RNA and DNA:

-	RNA	DNA

1.	RNA is not responsible for heredity.	DNA is the chemical basis of heredity.
2.	Proteins are synthesised by RNA molecules in the cells.	DNA molecules do not synthesise proteins, but transfer coded messages for the synthesis of proteins in the cells.