Biomolecules

Biomolecules are naturally occuring organic compounds present as essential constituent of living organism in different cells.

Carbohydrates :-

Carbohydrates may be defined as optically active polyhydroxy aldehydes or ketones or the compounds which produces such units on hydrolysis.

eg. cellulose, glycogen, starch, glucose etc.

Classification of carbohydrates:

↓

saccharides → Greek: sakchron means sugar.

i). Monosaccharides :

- non-hydralysable
- Soluble in water
- can't give polyhydroxy aldehyde or ketone

eg. Glucose, fructose, galactose, ribose etc.

- 20 are known.

(ii) Disaccharides :

- On hydrolysis yields two molecules of monosaccha-rides.
- Crystalline
- Soluble in water
- Sweet in taste.

eg. Canesugar (sucrose), maltose, lactose etc.

(iii) Oligosaccharides :-

- yeilds 2 to 10 monosaccharide on hydrolysis.
- soluble in water.

eg. Raffinose (trisaccharide).

↓ hydrolysis

Glucose + fructose + Galactose.

(iv) Polysaccharides :-

produce 'n' number of monosaccharides. formed by linking of large number of monosaccharides through glycosidic linkage. * Non-sugar include all polysaccharides.

eg. Starch, amylose, cellulose etc.

Sugar (monosaccharides and oligo.)

Reducing Sugar	Non-reducing sugar.
↓	↓
contain free aldehydic or ketonic group, and reduce Fehling's solution and tollens reagent	donot have free aldehydic or ketonic group and do not reduce Fehling's solution or tollen's reagent are known as non-reducing sugars.
eg. all monosaccharides maltose Lactose.	eg. Sucrose.

Glucose :-

Preparation of glucose :

(1). From sucrose (canesugar) :

$$\underset{\text{(sucrose)}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{H^+} \underset{\text{(glucose)}}{C_6H_{12}O_6} + \underset{\text{(fructose)}}{C_6H_{12}O_6}$$

(2). From Starch :
commercial method.

$$\underset{\substack{\text{starch} \\ \text{or cellulose}}}{(C_6H_{10}O_5)_n} + n\,H_2O \xrightarrow[393K-2-3atm]{H^+} n\,C_6H_{12}O_6$$

Structure of glucose :

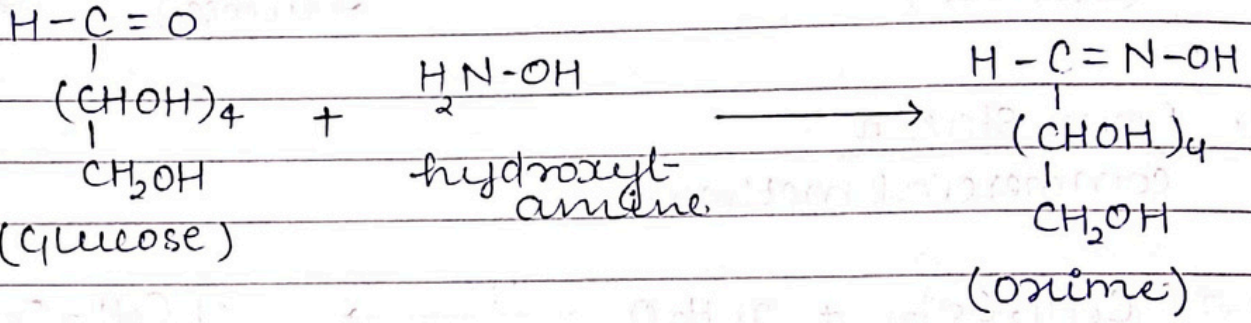
Aldohexose
Dextose.
Most abundant organic compounds on earth.

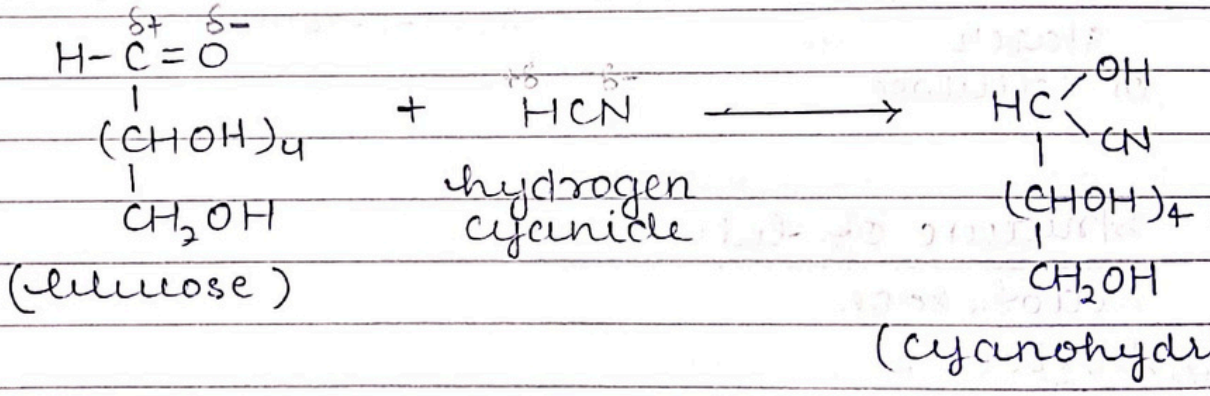
1. Molecular formula → $C_6H_{12}O_6$ and M.mass = 180 u.
2. $$\underset{\text{glucose}}{\begin{matrix}CHO\\|\\(CHOH)_4\\|\\CH_2OH\end{matrix}} \xrightarrow[HI]{\Delta} \underset{n\text{-hexane}}{CH_3-CH_2-CH_2-CH_2-CH_2-CH_3}$$

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

3. Glucose reacts with hydroxylamine to form an oxime and adds a molecule of hydrogen cyanide to give cyanohydrin.

This reaction confirms the presence of a carbonyl group (>C=O) in glucose.





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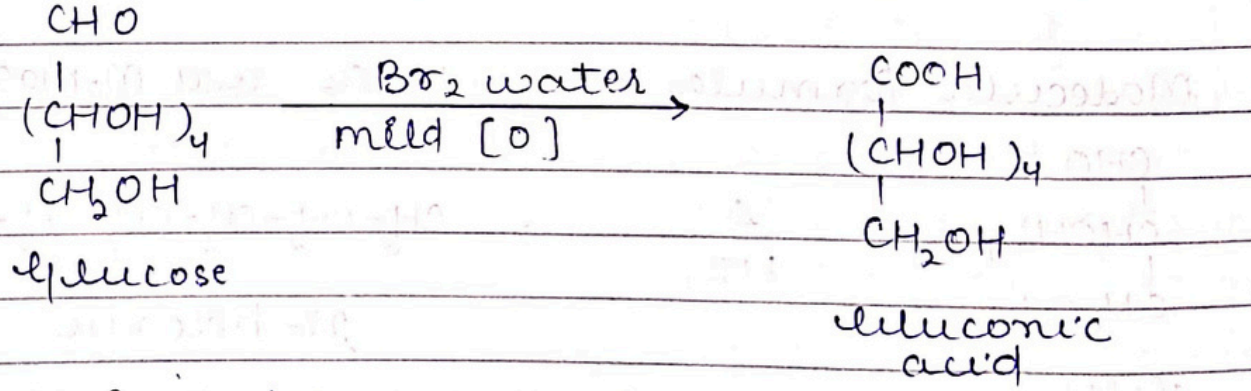
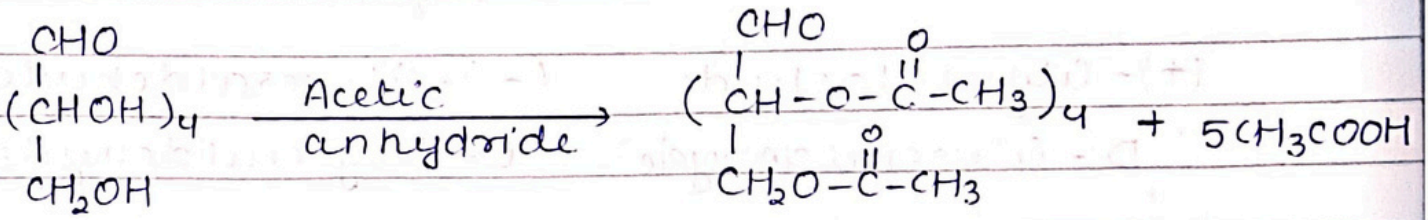


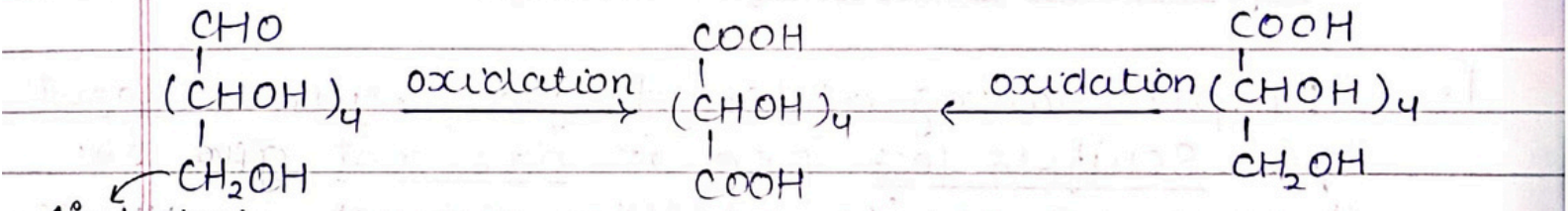
This indicates that the carbonyl group present is an aldehydic group.

5. Acetylation of glucose with acetic anhydride gives glucose pentaacetate which confirm the presence of five -OH groups.



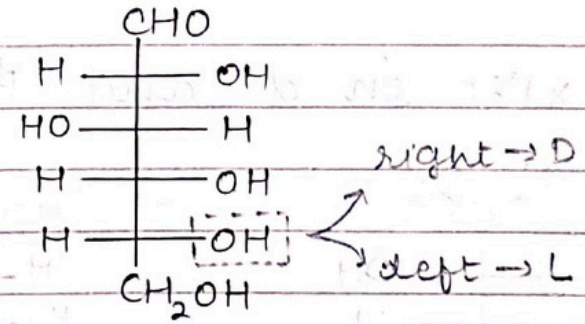
(glucose) (pentacetate)

6. On oxidation with nitric acid (HNO_3), 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 saccharic acid gluconic acid

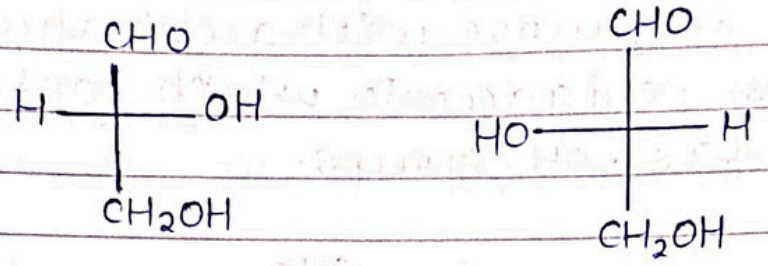
Fischer projection of glucose :-



(+)/d → dextro-rotatory

l/(-) → laevo-rotatory

D-(+)-glucose



(+)- Glyceraldehyde (−)- Glyceraldehyde

D- Glyceraldehyde L- Glyceraldehyde

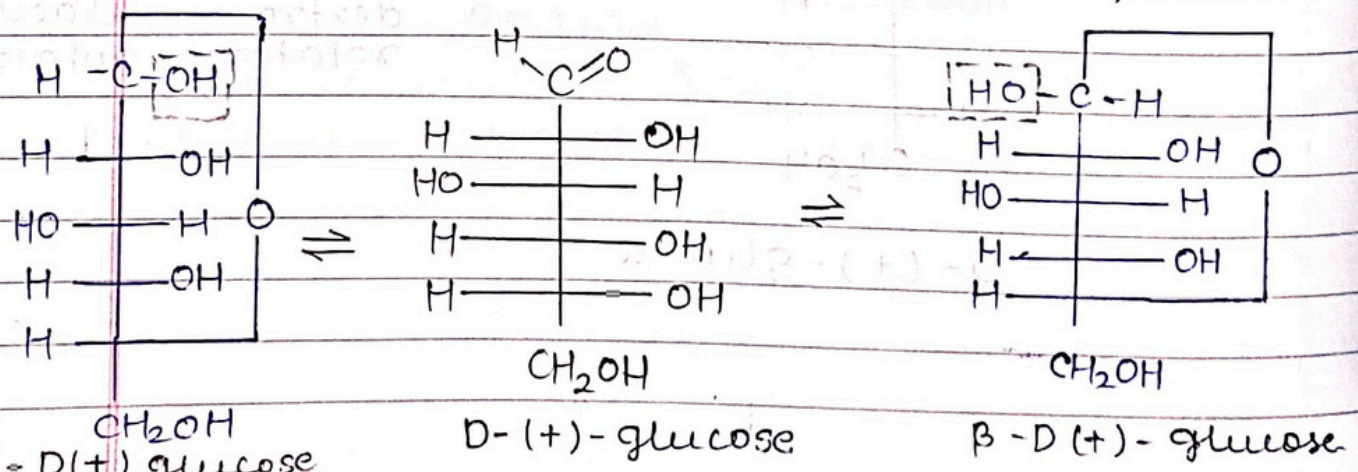
All those compound which can be chemically correlated to D(+) isomer of glyceraldehyde are said to have D- configuration whereas those which can be correlated to 'L' (−) isomer of glyceraldehyde are said to have L- configuration.

Cyclic Structure of Glucose:

1. Despite having aldehyde group, glucose do not give Schiff's test and it does not form the hydrogensulphite addition product with $NaHSO_3$.

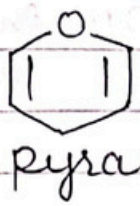
2. The pentaacetate of glucose do not react with hydroxylamine indicating the absence of free -CHO group.

3. Glucose exist in α and β form.

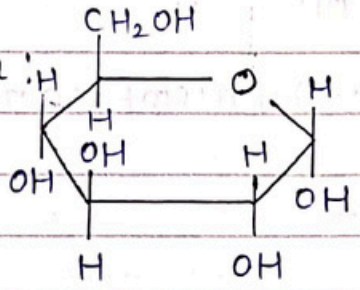


This two cyclic forms exist in equilibrium with open chain structure and differ only in the configuration of hydroxyl group at C_1, called anomeric carbon. Such isomers i.e α-form and β-form are called anomers.

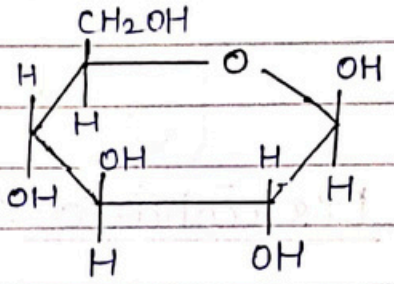
Haworth projection:



Pyran



α-D-(+) Glucopyranose

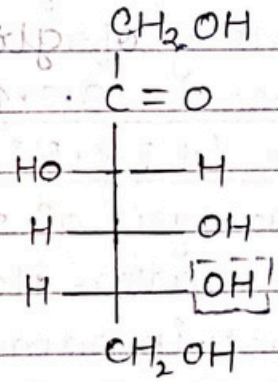


β-D-(+)-Glucopyranose

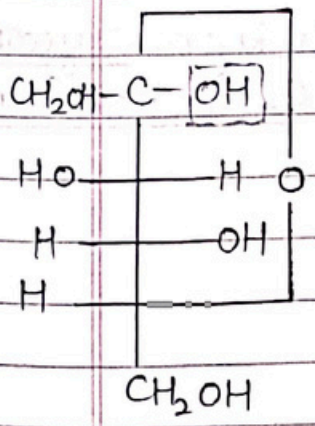
Anomers

Fructose: → (sweetest sugar)

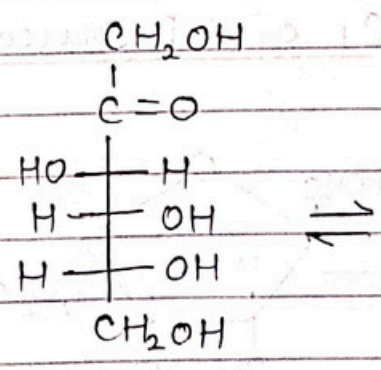
- Ketohexose.
- Fruit sugar.
- Laevorotatory
- belong to D-series.



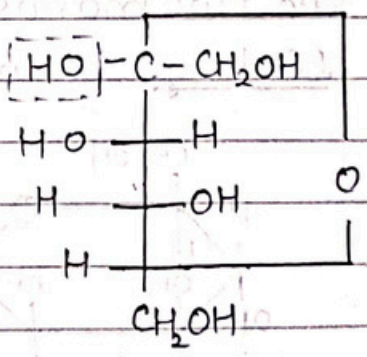
D-(−)-fructose.



α-D(−) fructose



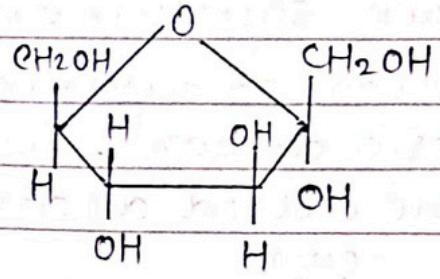
D-(−)-fructose.



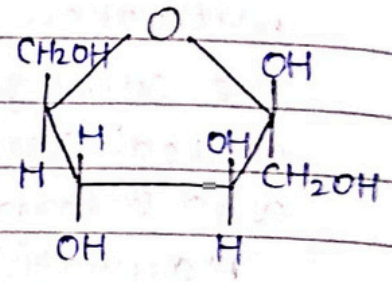
β-D(−)-fructose.

Haworth structure :

furan



α - D(-)-fructofuranose



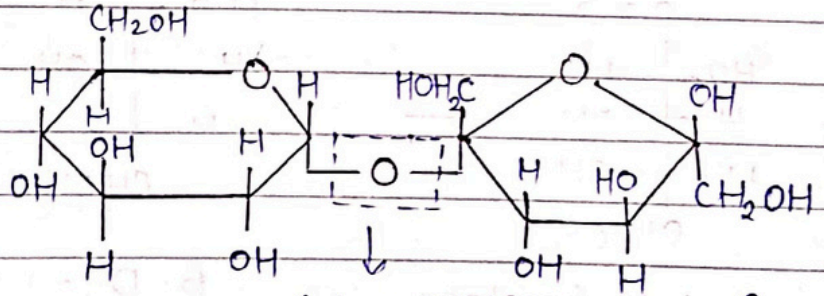
β - D(-) fructo furanose

Disaccharides :-

Sucrose :

- non-reducing sugar.
- INVERT Sugar : Sucrose is dextrorotatory but after hydralysis gives dextrorotatory glucose and laevorotatory fructose. Since the laevarotation of fructose (- 92.4°) is more than dextrorotation of glucose (+ 52.5°), the mixture is laevoratatory. Thus, hydrolysis of sucrose brings about a change in sign of rotation, from dextro (+) to laevo (-) and the product is named as invert sugar.

- The two monosaccharide are held together by a glycosidic linkage between C_1 of α D-glucose and C_2 of β-D fructose

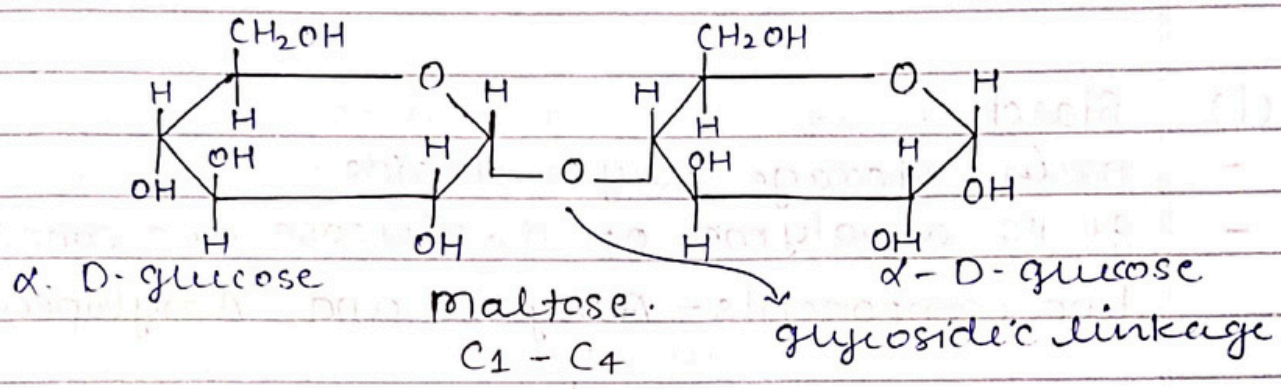


α-D-Glucose — glycosidic linkage — β-D-fructose

$C_1 - C_2$

Maltose :

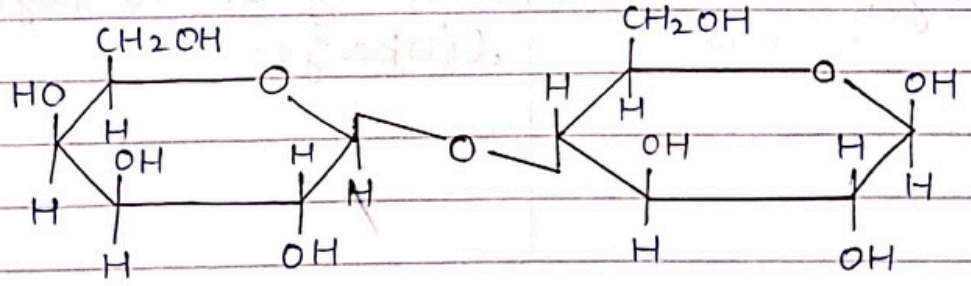
Maltose is composed of two α-D-glucose units in which C_1 of one glucose (I) linked to C_4 of another glucose unit (II).



- Maltose is reducing sugar.

Lactose :

- known as milk sugar.
- composed of β-D-galactose and β-D-glucose.
- linkage is between C-1 of galactose and C-4 of glucose. Free aldehyde group may be produced at C-1 of glucose unit, hence it is reducing sugar.



Polysaccharides :

Polysaccharides contain a large number of monosaccharides units joints together by glycosidic linkages.

(i) Starch :

- main storage polysaccharide.
- It is a polymer of α-glucose and consists of two components - Amylose and Amylopectine.

Amylose	Amylopectin
• water soluble component	• Insaluble in water.
• 15-20% of starch.	• 80-85% of starch.
• long unbranched chain with 200-1000 α-D-(+)-glucose units held together by C_1-C_4 glycosidic linkage.	• branced chain polymer of α-D-glucose units in which chain formed by C_1-C_4 glycosidic linkage whereas branching occur by C_1-C_6 glycosidic linkage.

(ii) Cellulose :

- exclusively in plants.
- most abundant organic substance in plant kingdom
- constitute cell wall of plant.

- Straight chain polysaccharide composed only of β-D-glucose units which are joined by glycosidic linkage between C_1 of one and C_4 of next.

(iii) Glycogen:

- Stored in animal body as glycogen.
- Animal starch because its structure is
- similar to amylopectin.
- highly branched.
- present in liver, muscles and brain.
- on need enzyme break glycogen down to glucose
- Glycogen is found in yeast and fungi.

Importance of carbohydrates:

- essential for plant and animals as a source of energy.
- structural material of cells.
- raw material for textile, paper and alcohol inds.
- monosaccharides are also present in nucleic acids.
- which controls transmission of heredity effects from one generation to another.
- Biosynthesis of proteins as well.

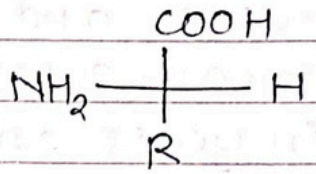
↳ Greek: Proteios → primary or of prime imp.

Proteins :

- most abundant biomolecules of the living system.
- required for growth and maintenance of body.
- All proteins are polymers of α-amino acids.

Amino acids :

- It contain amino ($-NH_2$) and carboxyl ($-COOH$) functional groups
- only α amino acids are obtained on hydrolysis of proteins.



α- amino acids

Classification of Amino acids :-

→ depending upon relative number of amino and (acid) carboxyl groups in their molecule –

(i) Neutral Amino acid [amino group = carboxyl group]
(ii) Basic Amino acid [amino group > carboxyl group]
(iii) Acidic Amino acid [amino group < carboxylic group]

→ Essential Amino acid :

can be synthesised in the body are known as essential amino acid and must be obtained by the body.-

Non-Essential Amino acid :

can be synthesised in the body. and ~~must be~~ o

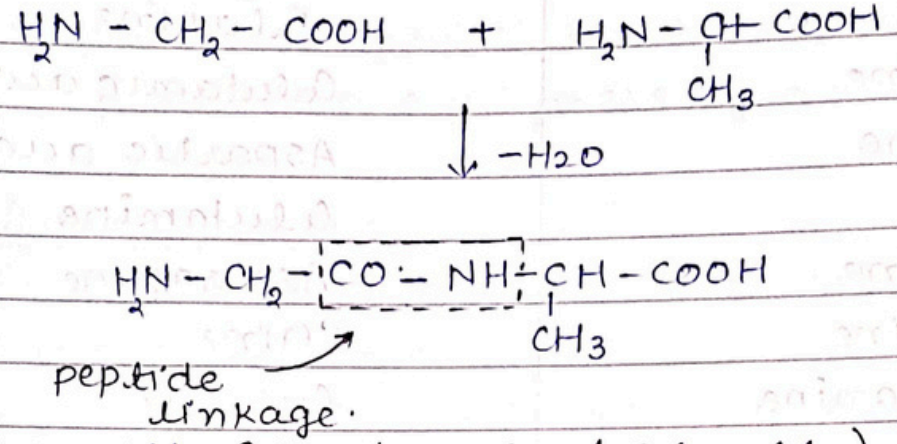
Essential amino acid	Non-essential amino acid
Leucine	Glycine
Valine	Alanine
Isoleucine	Glutamic acid
Arginine	Asparlic acid
Lysine	Glutamine
Threonine	Asparagine
Methromine	Serine
Phenylalanine	Cystcine
Tryptophan	Tyrosine
Histidine	Proline

Properties :

- colourless
- crystalline solids.
- water soluble.
- High melting solids
- Behaves like salt.
- Zwitter ions : In aqueos 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. This is neutral but contains both positive and negative charges.
- This is behaves as amphoteric behaviour as they react with both acid and bases.

- Except Glycine (R = H), all α amino acid are optically active.
- Most naturally occuring amino acids have L-configuration and represented by writing the $-NH_2$ group on left hand side.

Structure of Proteins :



dipeptide - Glycylalanine (Gly-Ala)

↓

1 peptide linkage

Note : Dipeptide have two amino acid and 1 peptide linkage.

When number of amino acid is more than ~~hundred~~ ten ⟶ Polypeptide.

A polypeptide with more than hundred amino acid residues, having molecular mass higher than 10,000 u is called a protein.

Classification of Proteins :

@ Based on molecular shape :

(i) Fibrous proteins : when polypeptide chains run parallel and are held together by hydrogen and disulphide bonds, then fibre - like structure is formed.

- Insoluble in water

eg. Keratin, myosin, collagen etc.

(ii) Globular protein :

This structure result when the chain of polypeptides chain coil around to give a spherical shaped.

- Soluble in water.

eg. Insulin albumin, haemoglobin etc.

(b) Based on structure and shape :

(1) Primary structure : Each amino acids linked with each other in a specific sequence. This sequence of amino acids is called as primary structure of protein.

(2) Secondary structure :

α - helix

polypeptide chain forms intramolecular hydrogen bonds by twisting into a right handed helix with the -NH group of each amino acid residue hydrogen bonded to >C=O of an adjacent turn of the helix.

eg. keratin in hair nails

β - pleated sheet.

has all peptide chains stretched to nearly minimum extension and then arranged side by side held together with intermolecular hydrogen bonding.

eg. Silk

(iii) Tertiary structure of proteins :

It represents the overall folding of polypeptide chains by H-bond disulphide linkage, van der waals and electro-static forces of attraction.

eg. Fibrous and globular proteins.

(iv) Quaternary structure :

The spatial arrangement of two or more polypeptide chain w.r.to each other is known as quaternary structure.

Denaturation of Proteins :

Denaturation of the proteins is a condition when the unique three dimensional structure of protein is exposed to changes. Due to changes in temperature, pH or other chemical activities, the hydrogen bond present in proteins get disturbed.

eg. Coagulation of egg white on boiling.
curding of milk.

Note: During denaturation, only primary structure remain intact

Enzymes :

- Biological catalyst which are needed to catalyse biochemical reaction.
- Almost all enzyme are globular protein.
- Specific in nature.
- ending with the name -ase
- lowers activation energy.
- works at particular temp. and pH range.

eg. Matase : Maltose → Glucose
Lactase : Lactose → Glucose + Galactose
Invertase : Sucrose → Glucose + fructose
Trypsin : Protein → Amino acid.

Vitamins : Vitamins are group of organic compounds which are required in a very small amount for healthy growth and functioning of animals organism. They can not be made by organism and so have to be part of our diet.

Types of vitamins :

Fat soluble vitamins	water soluble vitamins
- soluble in fat and oils but insoluble in water	- water soluble vitamins are readily excreted in urine and cannot be stored (except Vit. B12) in our body so regularly included in diet.
- Stored in liver and adipose.	
- Vitamin A, D, E and K	- Vitamin B (B1, B2, B6, B12 etc) and C.

	Name of Vitamins	source	Deficiency disease
1.	Vitamin A	Fish liver oil carrat, butter and milk	Xerophthalmia, Night blindness.
2.	Vitamin B_1 (Thiamine)	Yeast, milk, green veg. cereals.	Beri beri
3.	Vitamin B_2 (Riboflavin)	milk, egg white liver, kidney	Cheilosis, digestive disorder burning sensation of skin
4.	Vitamin B_6 (Pyridoxine)	Yeast, milk, egg yolk, grams.	Convulsions
5.	Vitamin B_{12}	Meat, fish, egg curd	Pernicious anemia
6.	Vitamin C (ascorbic acid)	Citrus fruit leafy veg.	Scurvy
7	Vitamin D	Sunlight fish and yolk	Rickets, Osteomalacia
8.	Vitamin E	vegetable oils	Fragile RBCs and muscular weakness
9.	Vitamin K	Green leafy veg.	increased blood Clotting time

Nucleic Acids :

Nucleic acids are long chain polymers of nucleotides, so they are also called as polynucleotides.

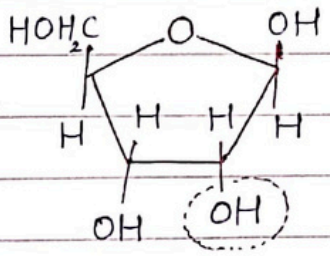
Types -

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

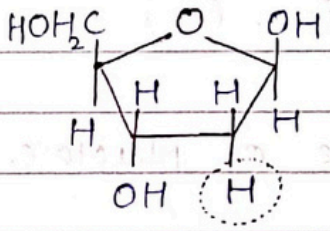
Chemical composition of Nucleic Acids :

Hydrolysis of DNA (or RNA) yields a pentose sugar, phosphoric acid and nitrogen containing heterocyclic compound (bases).

In DNA molecules, sugar moiety is β-D-2-deoxyribose where in RNA, it is β-D-ribose.



β-D-ribose

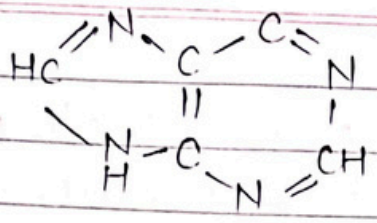


β-D-2-deoxyribose

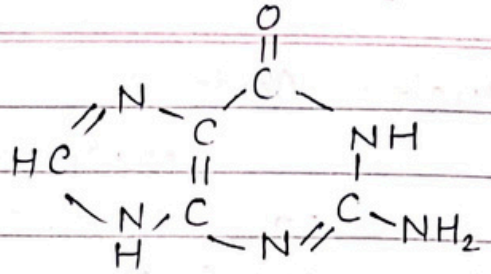
DNA contains four bases - Adenine(A), guanine (G), cytosine (C) and thymine (T) but RNA contains uracil (U) at the place of thymine.

Nitrogen containing bases :

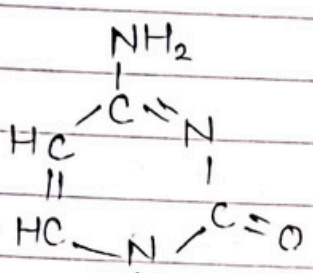
- Pyrimidines : Cytosine, thymine and uracil.
- Purines : Adenine and guanine



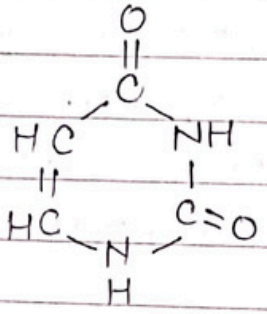
Adenine (A)



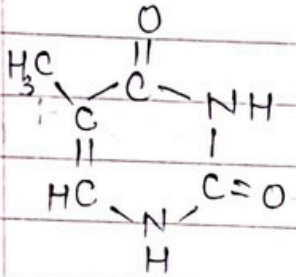
Guanine (G).



Cytosine (C.)



Uracil (U)

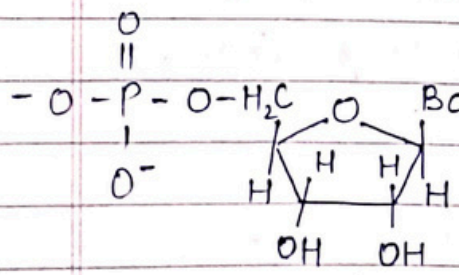


Thymine (T)

Structure of Nucleic acid:

- Nucleoside: sugar + Base
  Base join at 1'-position of sugar.

- Nucleotide: sugar + Base + phosphate group
  ↓
  at 5'-position of sugar.



Nucleotide.

Nucleotide joint together by phosphodiester linkage between 5' and 3' C-atom of pentose sugar.

→ James watson and Francis Crick gave a double strand helix structure for DNA.

* Two nucleic acid chain are wound together by hydrogen bonds between pairs of bases.
* Both straind are complementary to each other.
* A forms H-bond with T
* C forms H-bond with G.

→ RNA is single stranded helix.

Three types of RNA -
Messenger RNA.
Ribosomal RNA
Transfer RNA

DNA fingerprinting :

- A sequence of bases on DNA is also unique for a person and information regarding this is called
- DNA fingerprinting.

same for every cell and can't be altered.

Uses -

(a) identification of criminals
(b) paternity issue determination.
(c) identification of dead body.
(d) identify radial groups to rewrite biological evolution.

Biological Function of Nucleic Acids:

→ DNA is chemical basis of heredity and may be regarded as reserve of genetic information

→ DNA is responsible for maintaining the identity.

→ DNA molecule is capable of self replication during cell division and identical DNA strands are transferred to daughter cells.

→ Protein synthesis in cell. the message for the synthesis of a particular protein is present in DNA.

Hormones:

- Chemicals produced by endocrine gland which find their way into blood stream and influence and regulate the functions.

- Some of these are steroids, palypeptide (insuline and endorphins), amino acid derivatives (epinephrine and norepinephrine).

- acts as intracellular messengers.

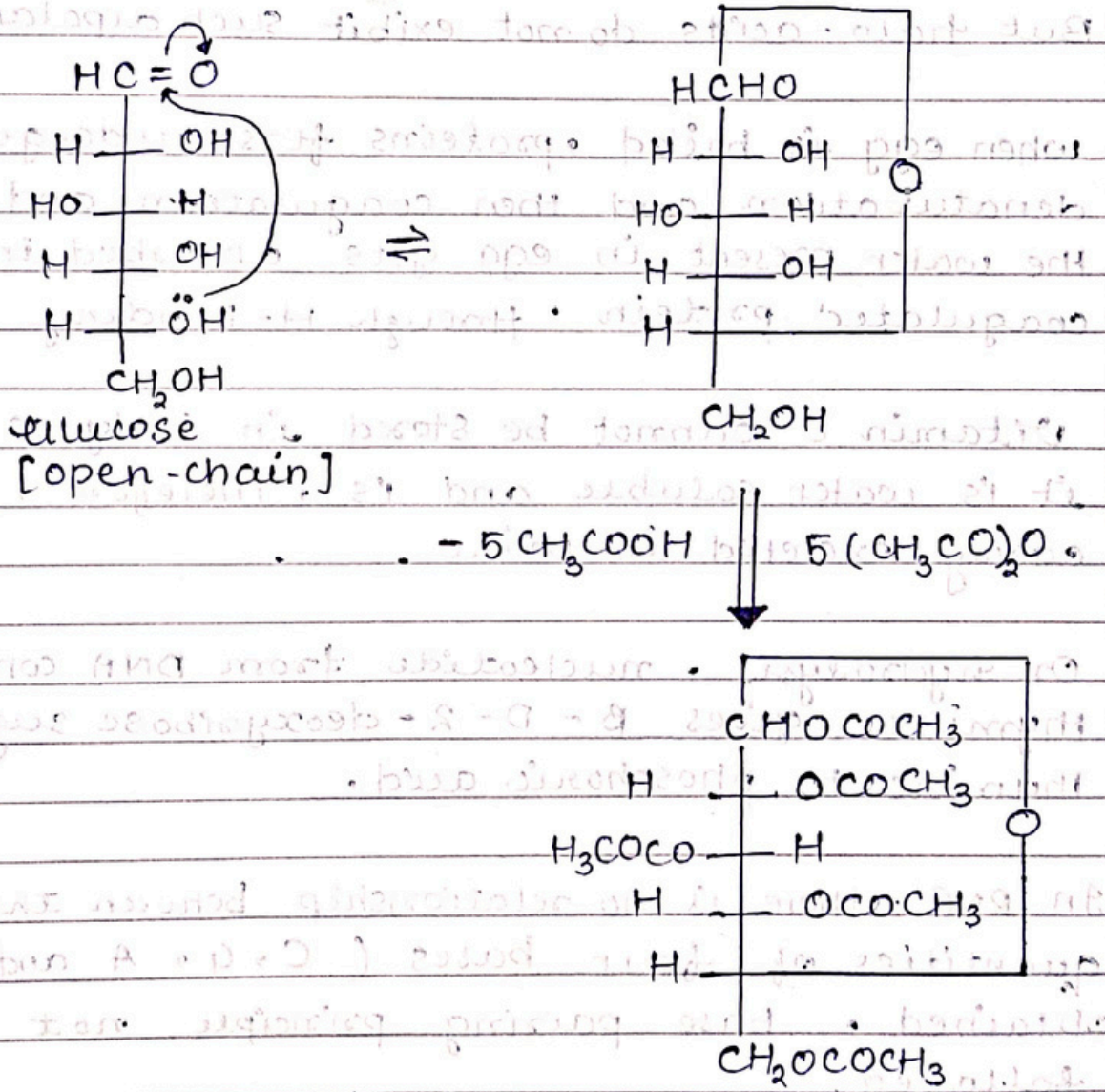
Biomolecules

Intext Questions

14.1 The solubility of a solute in a given solvent follows the rule 'Like dissolves like'. Also, due to extensive intermolecular H-bonding, glucose or sucrose are soluble in water. On the other side, benzene and cyclohexane do not form H-bond with H_2O and they are non-polar.

14.2 Lactose $\xrightarrow{H_2O}$ β-D-glucose + β-D-galactose

14.3



This shows that aldehyde group is not free.

14.4 Both acidic and basic groups are present in same molecule of amino acids. In aqueous soln, carboxyl group can lose a proton and the amino group can accept proton, thus giving rise to a dipolar ion known as zwitter ion.

Due to this dipolar behaviour, they have strong electrostatic interaction within them and water. But halo-acids do not exibit such dipolar nature.

14.5 When egg is boiled, proteins first undergo denaturation and then coagulation and the water present in egg gets absorbed in coagulated protein through H-bonding.

14.6 Vitamin C cannot be stored in body as it is water soluble and is, therefore, easily excreted in urine.

14.7 On hydrolysis, nucleotide from DNA containing thymine gives β-D-2-deoxyribose sugar + Thymine + phosphoric acid.

14.8 In RNA, there is no relationship between the quantities of four bases (C, G, A and U) obtained, base pairing principle not followed.