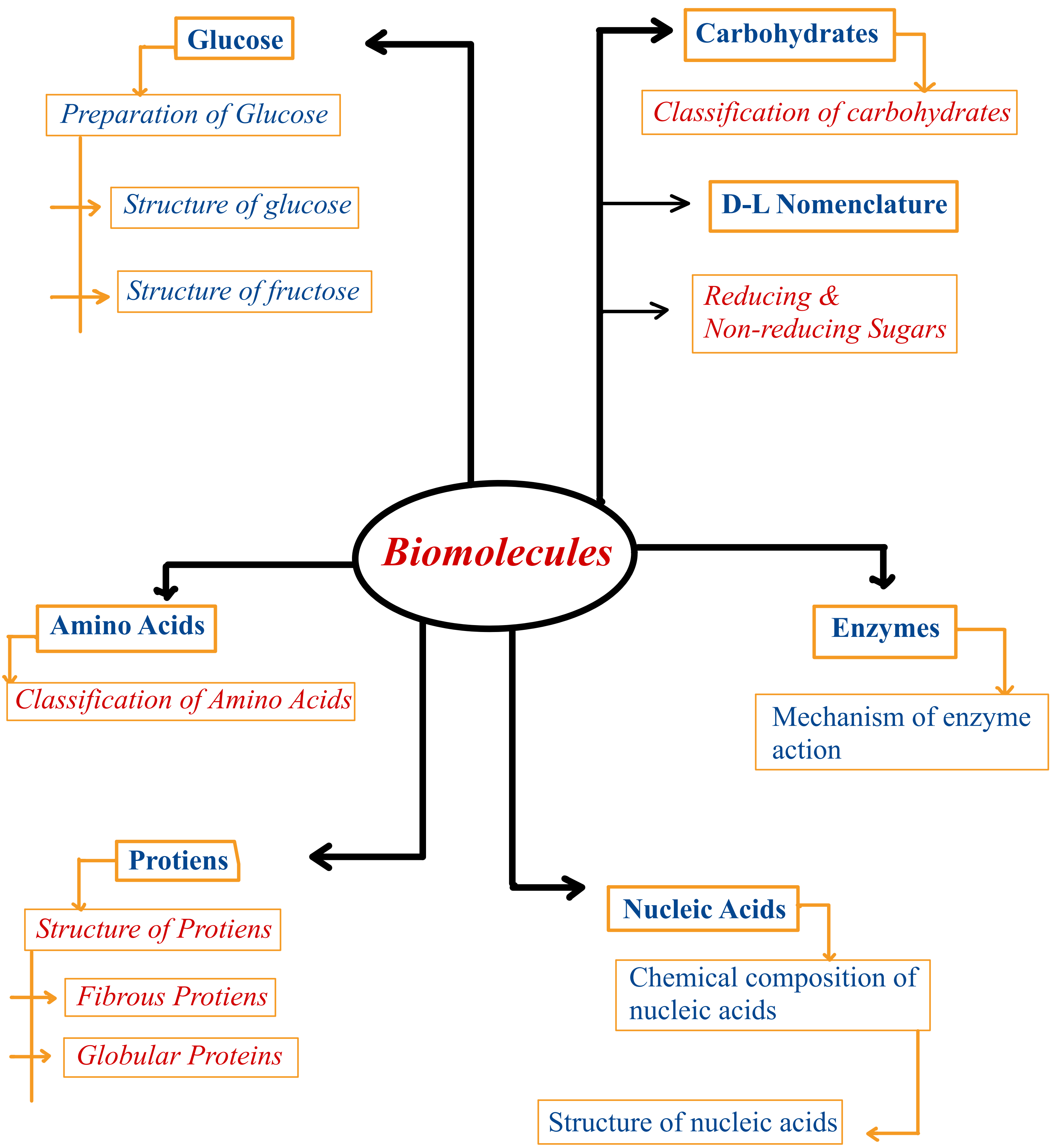
Biomolecules

Flow Chart Of Biomolecules



Biomolecules

→ The branch of chemistry that deals with the molecules involved in living system, is called Biochemistry.

→ Carbohydrates, proteins, vitamins and nucleic acids are some of the major components of our body. These are collectively called Biomolecules.

Carbohydrates :- Carbohydrates are optically active polyhydroxy aldehydes or ketones or substances that will yield these types of compounds on hydrolysis.

↓

Hydrates of Carbon

$C_x(H_2O)_y$: General Formula.

Example -: $C_6(H_2O)_6 \Rightarrow C_6O_6H_{12}$ ($C_6H_{12}O_6$: Glucose | Fructose)

Classification of Carbohydrates :-

→ This classification is based on hydrolysis.

a.] **Monosaccharides :-** A carbohydrate that can not be hydrolysed further to give simpler unit of polyhydroxy aldehyde or ketones is called a monosaccharide.

[CBSE 2010] → (1M)

For example -: Glucose | Fructose | Ribose

b.] **Oligosaccharides :-** Carbohydrates that produce 2 to 10 monosaccharide units on hydrolysis, are called oligosaccharide.

→ **Disaccharide** : It produce 2 unit of monosaccharide.

[CBSE 2019] (1M) Example → Sucrose, Lactose [Sucrose $\xrightarrow{\text{Hydrolysis}}$ Glucose + Fructose]

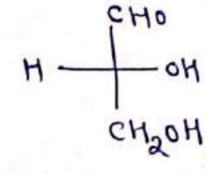
c.] **Polysaccharides -:** Carbohydrates that produce a large no. of monosaccharide units on hydrolysis are called polysaccharide.

Example -: Starch | Cellulose | Glycogen.

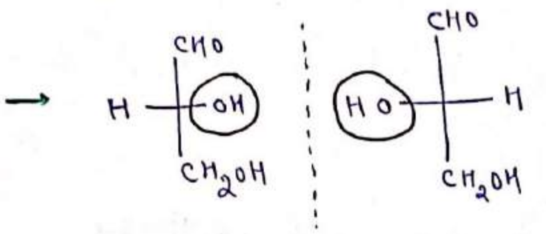
→ Polysaccharides are not sweet in taste. Hence they are also called non-sugars.

D-L Nomenclature :-

Standered for this Nomenclature :



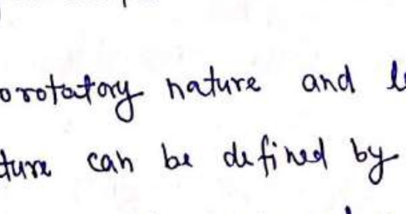
Glyceraldehyde

→ 

D-Glyceraldehyde Mirror L-Glyceraldehyde

→ (+) and (-) represents dextrorotatory nature and leavorotatory nature of a compound, means that optical active nature can be defined by ⊕ or ⊖. But remember that D and L have no relation with optical activity of a compound, they represents only configuration of a compound.

→ Structure of Glucose -:



At, last chiral carbon -OH group is present at right side ⇒ D-Glucose.

Reducing and Non-reducing Sugars :- [Delhi 2010C] (1M)

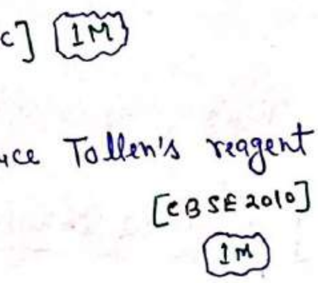
→ Reducing Sugars -: All those carbohydrates which reduce Tollen's reagent and fehling reagent are called reducing sugars. [CBSE 2010] (1M)

→ All monosaccharides are reducing sugars. (Example → Glucose and fructose)

→ Non-reducing Sugars -: Carbohydrates which can not reduce Tollen's reagent and Fehling solution are called non-reducing sugars.

For example → Sucrose

Classification of monosaccharides :-



D-Fructose

Aldose -: Monosaccharide containing aldehyde group.

Ketose -: Monosaccharide containing keto group.

→ Glucose is an example of Aldose, while fructose is an example of Ketose.

Different Types of Monosaccharides

Carbon atoms	Aldehyde	Ketone
3	Aldotriose	Ketotriose
4	Aldotetrose	Ketotetrose
5	Aldopentose	Ketopentose
6	Aldohexose	Ketohexose

Glucose

→ It occurs freely in nature as well as combined form. It is present in sweet fruits, honey and ripe grapes.

Preparation of glucose

(1M) [CBSE 2010/2013 and Delhi 2014]

(i) from Sucrose [Cane Sugar]

$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} \xrightarrow[\text{Acidic Hydrolysis}]{H_3O^+} \underset{\text{Glucose + Fructose}}{C_6H_{12}O_6 + C_6H_{12}O_6}$$

(ii) from Starch :- $[C_6H_{10}O_5]_n$

$$[C_6H_{10}O_5]_n \xrightarrow{H_3O^+} \underset{\text{Glucose.}}{n\ C_6H_{12}O_6}$$

Linear Structure of glucose -:

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

Molecular formula : $C_6H_{12}O_6$

Supporting Evidence for this structure -:

a.] Six Carbon in straight chain -:

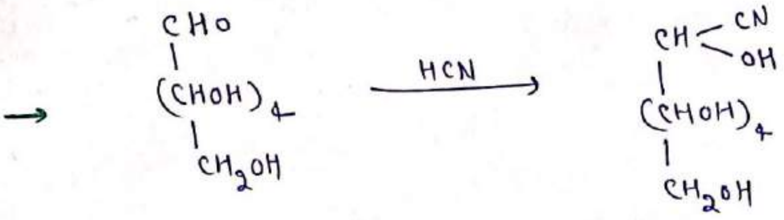
[CBSE 2012] (1M)

$$\begin{array}{c} CHO \\ | \\ (CHOH)_4 \\ | \\ CH_2OH \end{array} \xrightarrow[\text{HI}]{\text{Prolonged Heating with}} \underset{\text{n-Hexane}}{\begin{array}{c} CH_3 \\ | \\ CH_2 \\ | \\ CH_2 \\ | \\ CH_2 \\ | \\ CH_2 \\ | \\ CH_3 \end{array}}$$

b.] Presence of carbonyl group -:

$$\begin{array}{c} H \diagdown \\ C=O \quad H_2N-OH \\ | \\ (CHOH)_4 \\ | \\ CH_2OH \end{array} \xrightarrow[\text{Hydroxyl amine}]{NH_2-OH} \begin{array}{c} H \diagdown \\ C=N-OH \\ | \\ (CHOH)_4 \\ | \\ CH_2OH \end{array}$$

CBSE 2015 (1M)



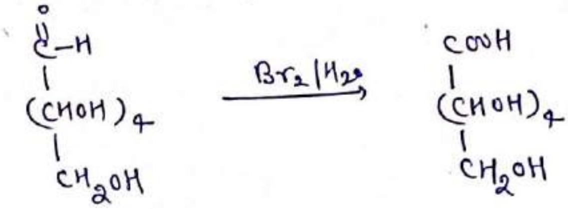
[CBSE 2019]

(1M)

c.] Presence of aldehyde group —:

[CBSE 2019 / 2018]

(1M)

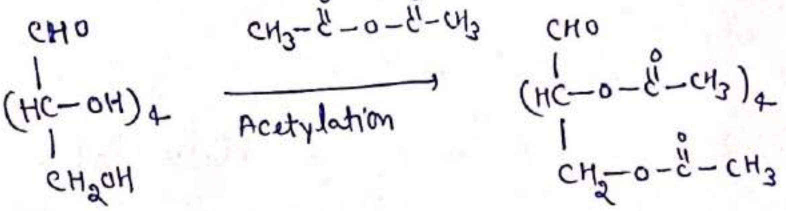


Gluconic Acid

d.] Presence of 5 OH groups —:

[CBSE 2019]

(1M)

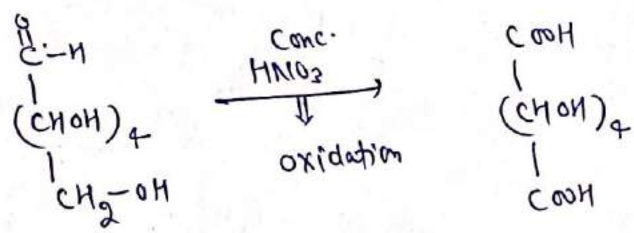


Glucose Pentaacetate

e.] Presence of 1° alcoholic group (—OH) :—

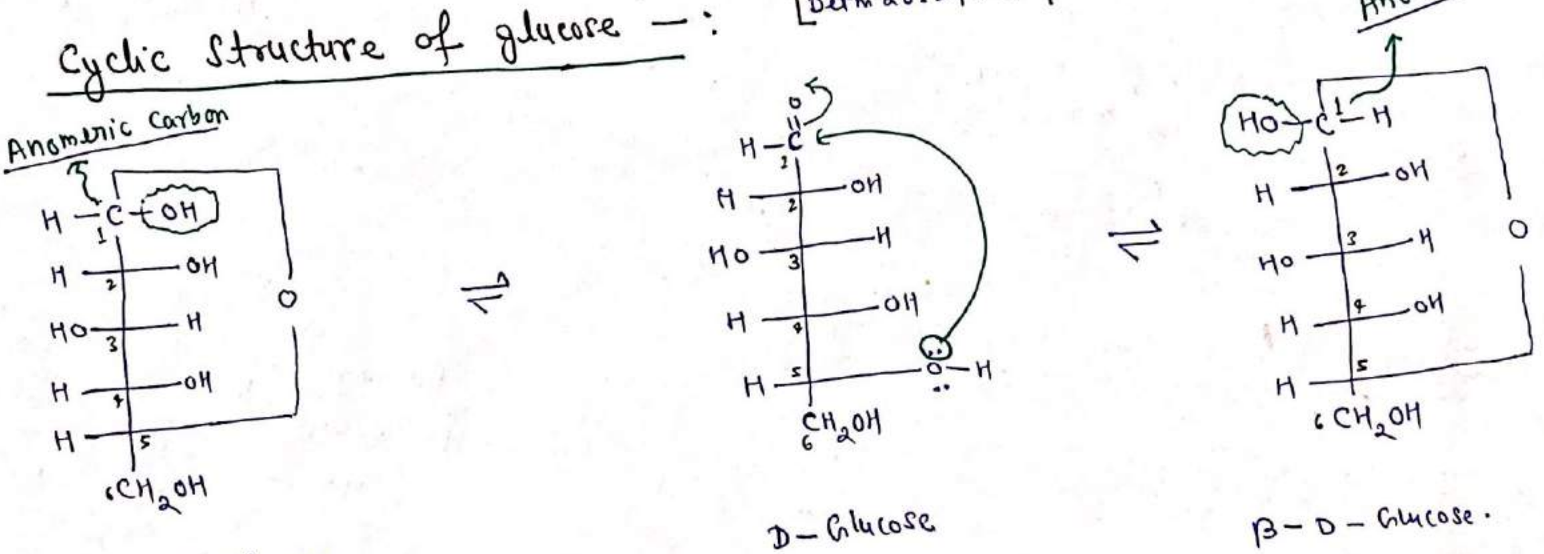
[CBSE 2018] (1M)

Con. HNO_3 oxidises only aldehyde and 1° alcohol.

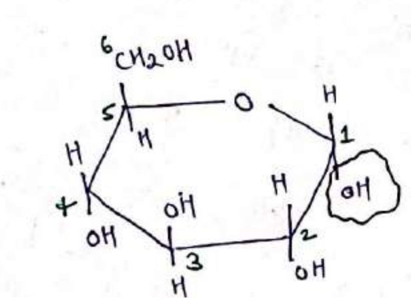


Cyclic Structure of glucose —:

[Delhi 2012 / 2011 / CBSE 2018] (1M)

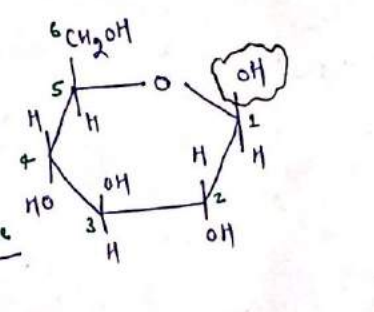


α - D - Glucose D - Glucose β - D - Glucose.



Haworth Projection

α - D - Glucopyranose β - D - Glucopyranose



→ In Haworth Projection, the six membered cyclic structure of glucose is called Pyranose structure. (In analogy with Pyran ).

→ <u>Anomers</u>-: Anomers are isomers that differ in the configuration at the acetal or hemiacetal carbon atom of a sugar in its cyclic form.

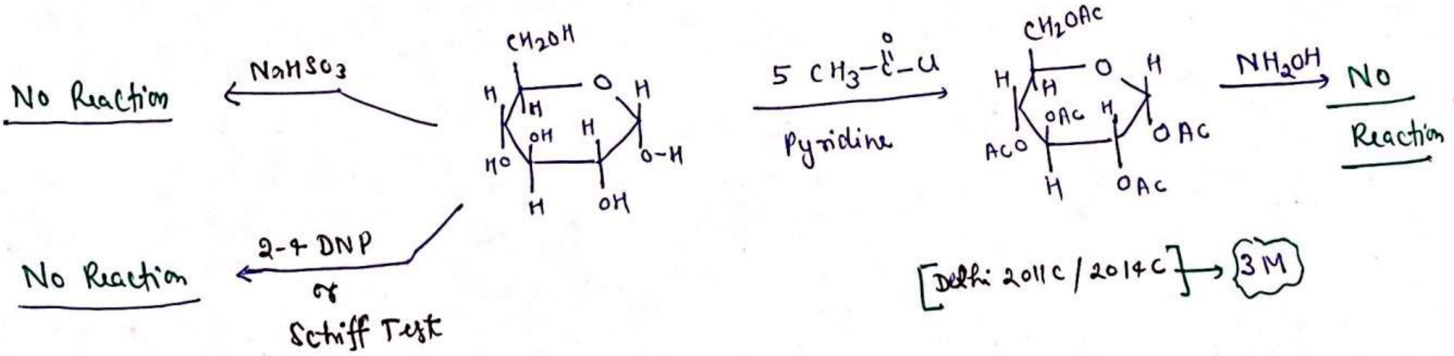
<u>CBSE 2014</u> ↓ 1M

<u>For example</u> -: α-D-Glucose and β-D-Glucose <u>are Anomers</u>.

<u>Cyclic structure of glucose</u> : <u>Supporting Evidence</u> :- [CBSE 2010C/2011/2011C] ↳ 2M

(i) Despite having aldehyde group, glucose does not give 2,4-DNP test, Schiff test and it does not form adduct with $NaHSO_3$.

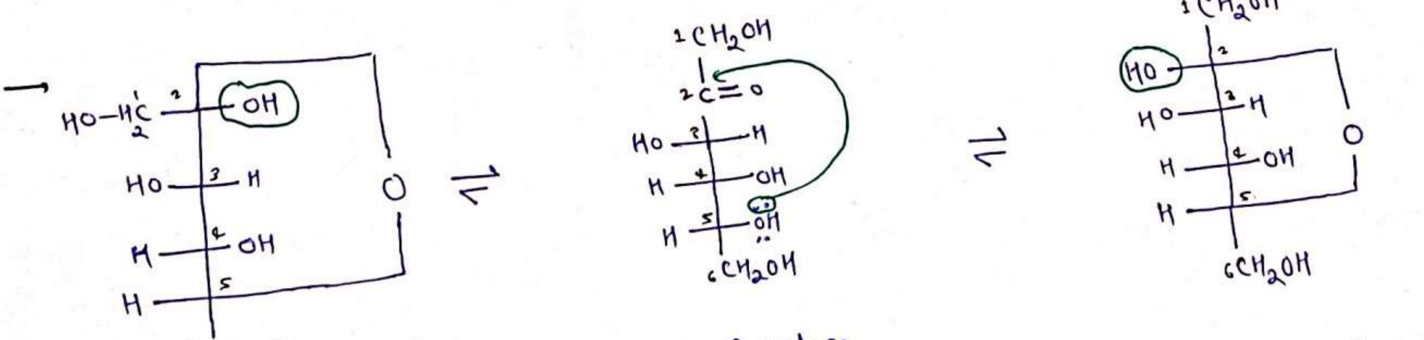
(ii) Pentaacetate of glucose does not react with NH_2-OH inticating the absence of free $-CHO$ group.



[Delhi 2011C/2014C] → 3M

(iii) Glucose is found to exist in two different crystalline forms which are named as α and β. They both have different melting point and different temperature for crystallisation.

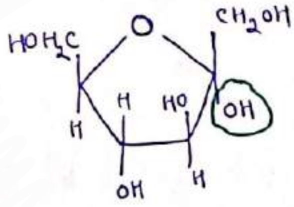
<u>Structure of fructose</u> -:



D-fructose

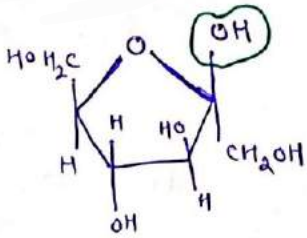
β-D-fructose

α-D-Froctose



α- D - fructofuranose

furan



β - D - fructofuranose

Amino Acids

Amino group ($-NH_2$) ← Amino Acids → Carboxyl group ($-\overset{O}{\overset{\|}{C}}-OH$)

→ α - Amino Acid -: $R-\overset{\alpha}{C}H_2-COOH$ with NH_2 on the α carbon R → Side chain

20 Amino Acids ↓

- Glycine
- Alanine
- Valine
- Leucine
- Isoleucine
- Arginine
- Lysine
- Glutamic Acid
- Aspartic Acid
- Glutamine
- Asparagine
- Threonine
- Serine
- Cysteine
- Methionine
- Phenylalanine
- Tyrosine
- Tryptophan
- Histidine
- Proline

Classification of amino acids -:

(2M)

(i) Depending on nature of synthesis -: [CBSE 2010 / Delhi 2010] [CBSE 2014C] → (3M)

a.) Non - Essential Amino acids → The amino acids which can be synthesised in body are known as non-essential amino acids.

→ 10 amino acids are non-essential.

For example → alanine, Glycine, Asparagine

b.) Essential Amino acids -: Those amino acids which can not be synthesised in our body and must be obtained through diet.

For example → PVT - TIM HALL

P → Phenyl alanine
V → Tryptophan
T → Threonine
L → Arginine

(ii) On the basis of functional group -:

a.) Neutral Amino Acids :- One $-NH_2$ and one $-\overset{O}{\overset{\|}{C}}-OH$ group.

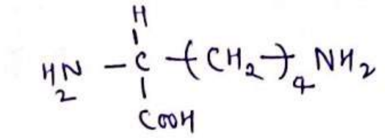
For Example → Glycine $H-\underset{NH_2}{\underset{|}{CH}}-\overset{O}{\overset{\|}{C}}-OH$

b.) Acidic Amino Acids -: One $-NH_2$ and 2 $-\overset{O}{\overset{\|}{C}}-OH$ group.

For example → Aspartic acid $\underset{COOH}{\underset{|}{H_2C}}-\underset{NH_2}{\underset{|}{HC}}-COOH$

c.) <u>Basic Amino Acid</u> –: More no. of amino group than carboxyl group.

<u>For example</u> → Lysine



<u>NOTE</u> –: Amino acids are crystalline solids. These are water soluble and behave like salts rather than simple amines or carboxylic acids.

<u>Zwitter Ion</u> –: Due to presence of both acidic (Carboxyl group - COOH) and basic ($-NH_2$ group) in the same molecule, in aqueous solution $-\overset{O}{\overset{\|}{C}}-OH$ group can lose a proton and $-NH_2$ group can accept a proton giving rise to a dipolar ion. This dipolar ion is known as zwitter ion. [CBSE 2011C] (1M)

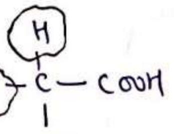
Amino Acid

<u>Zwitter Ion</u>

→ This is neutral but contain both ⊕ and ⊖ charge.

→ This can react with both acid and base. So, has amphoteric character. [CBSE 2015 / 2019] (1M)

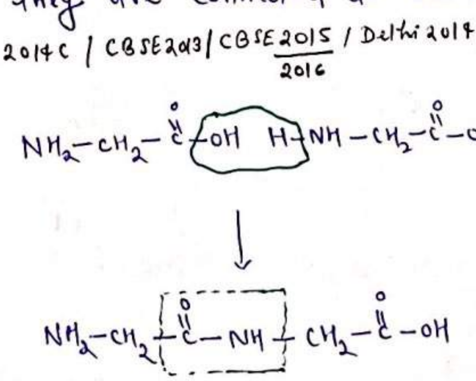
→ All α-amino acids are optically active except Glycine. Because there is no chiral Carbon in glycine.

Glycine → 

Proteins

→ Proteins are most abundant biomolecules of the living system.

→ Proteins are the polymers of α-amino groups and they are connected to each other by <u>peptide bond</u> or <u>peptide linkage</u>. (1M) [CBSE 2014C / CBSE 2013 / CBSE 2015 / 2016 / Delhi 2017]



Peptide linkage

chemically, peptide linkange is an amide linkage formed between $-\overset{O}{\overset{\|}{C}}-OH$ group of one α-amino acid and $-NH_2$ group of other α-amino acid formed by the loss of water molecule.

→ Dipeptide –: Combination of 2 amino acid by peptide bond is know as dipeptide.

→ Similarly, a tripeptide contains 3 amino acids linked by 2 peptide linkages.

→ Polypeptide –: Combination of 10 or more than 10 amino acids by peptide bonds, is known as poly peptide. (1M) [Delhi 2010]

→ Protein is a polypeptide.

Proteins $\xrightarrow{\text{Hydrolysis}}$ Peptides $\xrightarrow{\text{Hydrolysis}}$ α– Amino Acids.

[CBSE 2010 / 2016 / Delhi 2013] → (1M)

Classification of Proteins :– Two types on the basis of their molecular shape.

a.) **Fibrous Proteins** :– When polypeptide chains run parallel and are held together by hydrogen and disulphide bonds, then fibre like structure is formed.

→ Such proteins are insoluble in water.

→ Example –: Keratin [hair | wool | silk] and myosin [present in muscles].

b.) **Globular Proteins** –: The chains of polypeptides coil around to give a spherical shape. These are usually soluble in water.

→ Example :– Insulin and albumins.

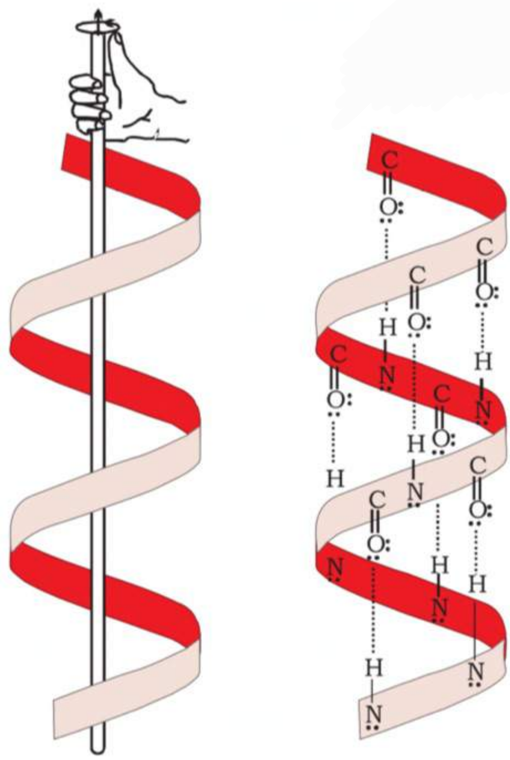
→ Structure and shape of proteins can be studied at four different levels

→ Primary, secondary, tertiary and quaternary, each level being more complex than previous one.

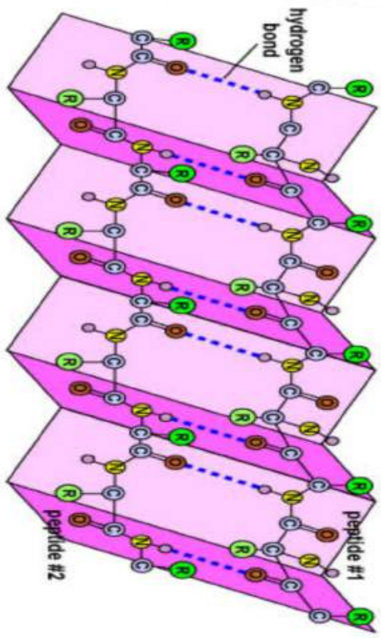
a.) **Primary Structure of proteins** :– In a protein molecule, one or more polypeptide chains may be present. Each polypeptide chain in a protein is linked together in a specific sequence of amino acids. This sequence of amino acids is termed as primary structure of proteins. [CBSE 2015] (1M)

b.) **2° 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 & β – Sheet.

→ These structures aries due to regular folding of backbone of polypeptide chain due to hydrogen bonding between $-\overset{O}{\overset{\|}{C}}-$ and $-NH-$ groups of peptide bond.



α - Helix —: It is one of the most common ways in which a polypeptide chain forms all possible hydrogen bonds by twisting into a right handed screw (helix). This hydrogen bond is in between $-NH-$ group of each amino acid to the $-\overset{O}{\overset{\|}{C}}-$ group of an adjacent turn of helix. [Delhi 2013 / CBSE 2018] → (1M)



β- pleated sheet —: In β- structure, all peptide chains are stretched out to maximum extent and then laid side by side (which are held together by intermolecular hydrogen bonding).

→ The structure resembles the pleated folds of drapery and therefore is known as β- pleated sheet.

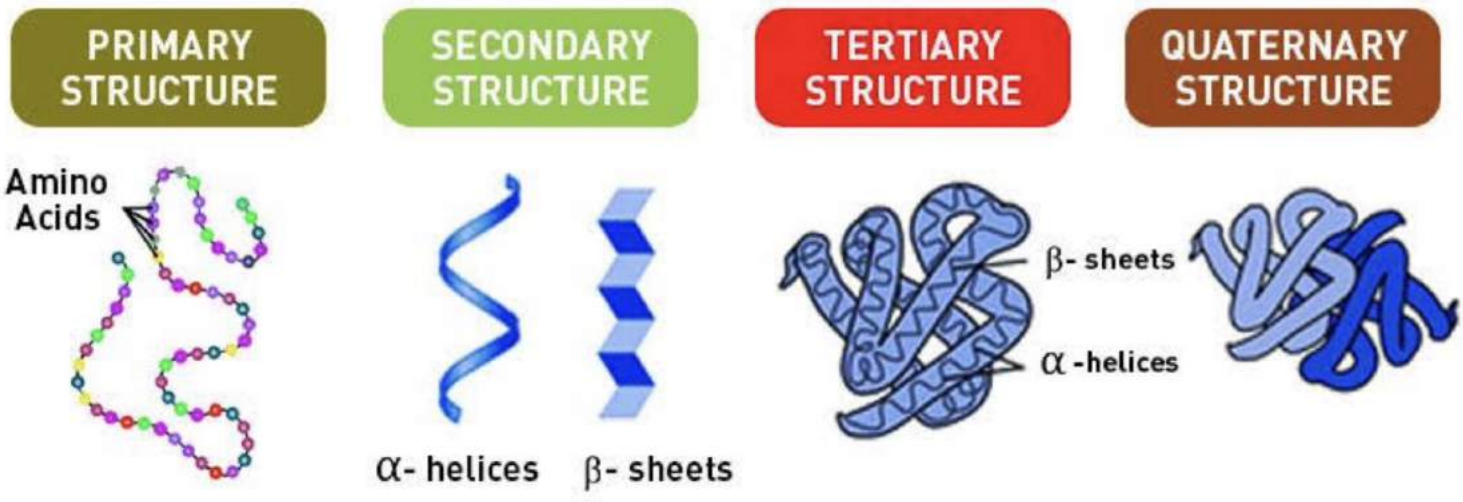
c.) **Tetiary structure of proteins** —: It represents further folding of secondary structure. It gives rise to two major molecular shapes → fibre and globular.

→ Stability of this structure depends on H-bonding, disulphide linkages, Vander Waals force of attraction and electrostatic forces of attraction.

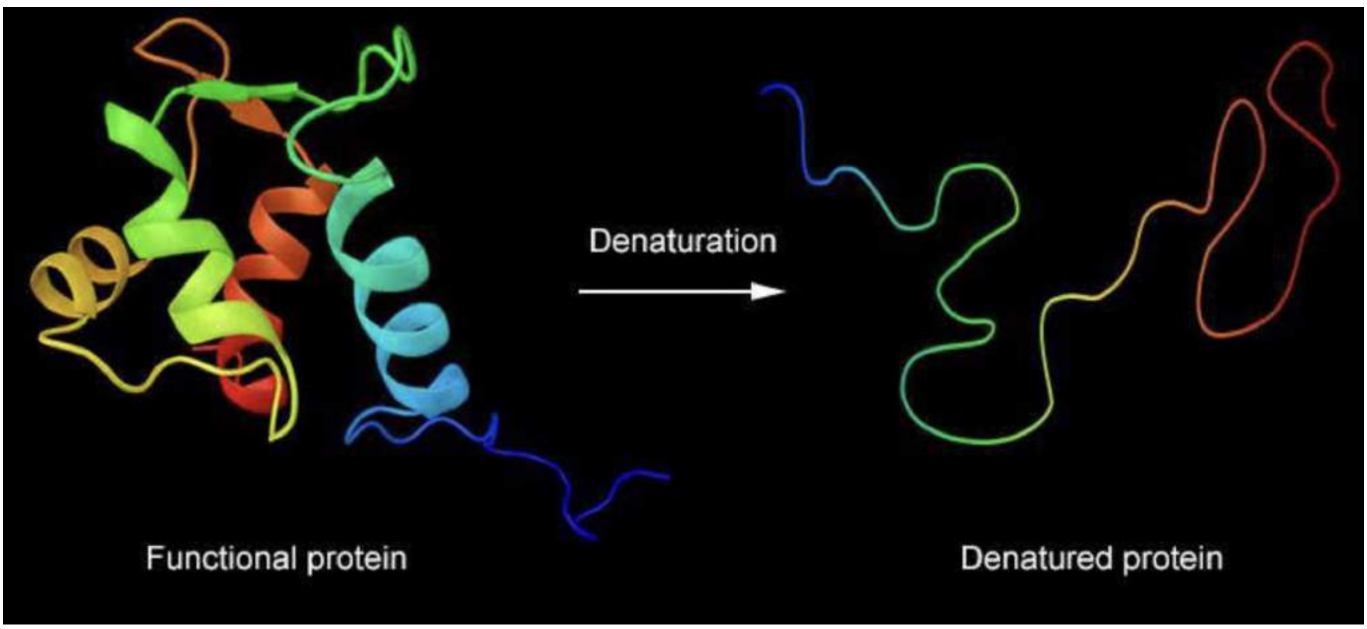
d.) **Quaternary structure of proteins** :— The Spatial arrangement of sub units of proteins [which are composed of two or more polypeptide chains] with respect to each other is known as quaternary structure.

Denaturation of Proteins —:

Native Protein → Protein found in a biological system with a unique three dimensional structure (3D) and biological activity is called native protein.



Desaturation of Protiens



→ When a native form of protein is subjected to a physical change (like change in temperature) or chemical change (like change in pH) hydrogen bonds are disturbed. Due to this unfolding of proteins or uncoiling of helix happens and protein loses its biological activity. This is called Denaturation of protein.

→ During denaturation 2°/3° structures are destroyed but 1° structure remains intact. [Delhi 2013/2014 CBSE 2010/2015] (1M)

Example → The coagulation of egg white on boiling → upon boiling the egg, denaturation followed by coagulation occurs. The water present in egg gets adsorbed/absorbed in coagulated proteins through Hydrogen bonding.

→ Curdling of milk [Delhi 2010C] → (1M)

Nucleic Acids

→ Nucleus of a living cell is responsible for the transmission of inherent characters.

→ The particles in nucleus of cell (responsible for heredity), are called chromosomes.

→ Chromosomes are made up of proteins and nucleic acids.

→ [Deoxyribonucleic acid] DNA ← Nucleic Acids → RNA [Ribonucleic Acid]

Chemical Composition of nucleic acids —: [Delhi 2012/2011 | CBSE 2011/2014] (1M)

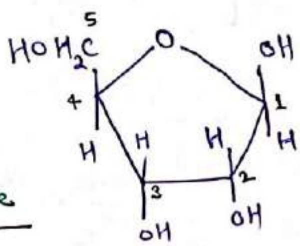
→ Nucleic Acid $\xrightarrow{\text{Hydrolysis}}$ Pentose Sugar + Phosphoric acid + base

↑ Nitrogen containing heterocyclic compounds.

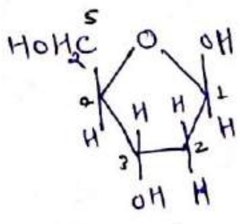
→ DNA ⇒ β-D-2-deoxyribose + Phosphoric acid + [A G C T]

→ RNA ⇒ β-D-ribose + Phosphoric acid + [A G C U]

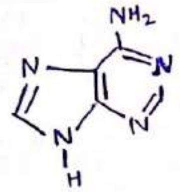
Pentose sugar →

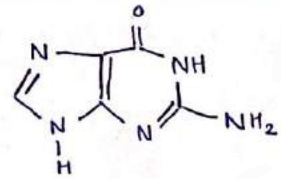


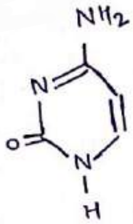
β-D-ribose

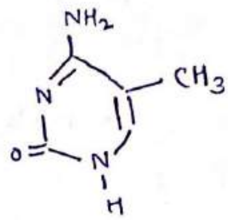


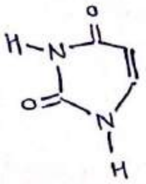
β-D-2-deoxy ribose

→ Adenine (A) 

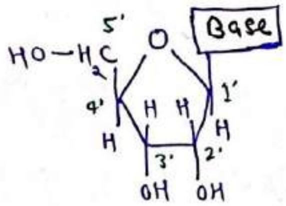
→ Guanine (G) 

→ cytosine (C) 

→ Thymine (T) 

→ Uracil (U) 

[Delhi 2010C / 2014]

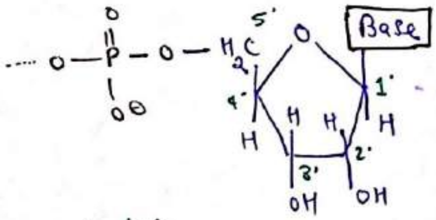


← Nucleoside

→ Nucleoside = Sugar + base

→ Nucleotide = phosphate + Nucleoside

= phosphate + sugar + base



Nucleotide

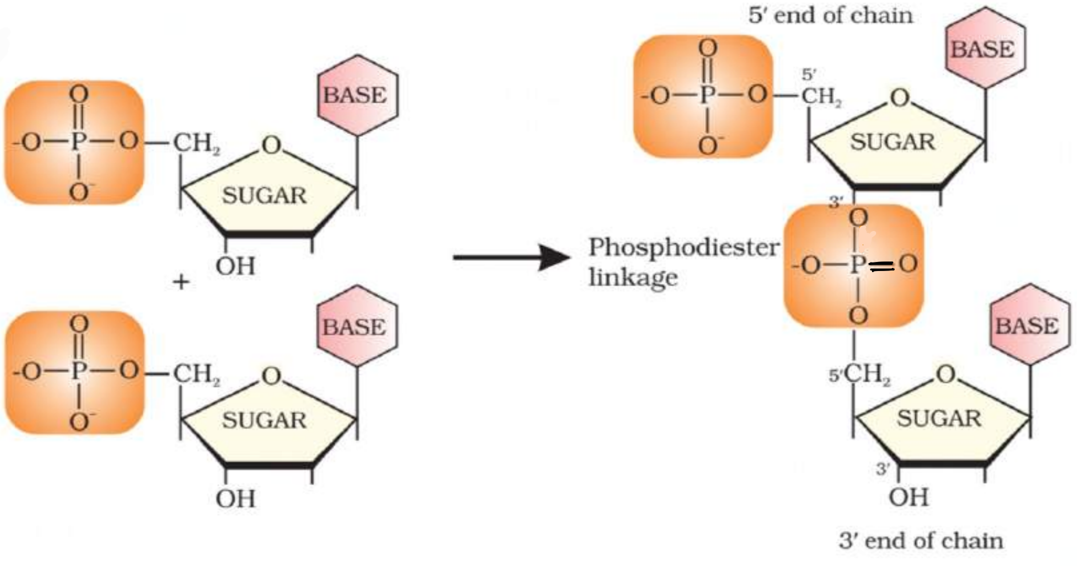
→ Nucleic Acid = Many nucleotides = Polynucleotides

= Long chain polymer of nucleotides.

$$\text{Nucleic Acid} \Rightarrow \cdots - \overset{\substack{\text{Base}\\|}}{\text{Sugar}} - \text{phosphate} - \overset{\substack{\text{Base}\\|}}{\text{sugar}} - \text{Phosphate} - \overset{\substack{\text{Base}\\|}}{\text{sugar}} \cdots\cdots$$

→ In a nucleotide, base is connected to 1' carbon of sugar and phosphate is connected to 5' carbon of sugar.

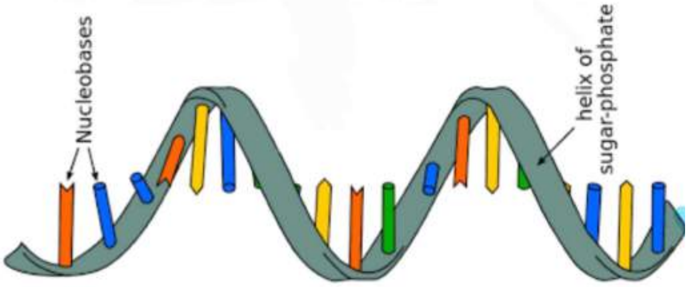
→ Nucleotides are joined together by phosphodiester linkage between 5' and 3' carbon atoms of the pentose sugar.

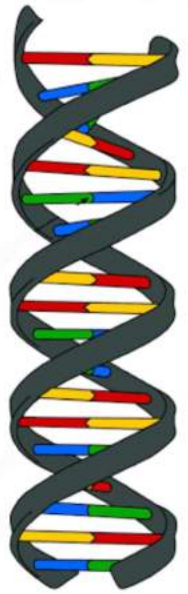


→ Double Strand helix structure for DNA -: The two strands are complementary to each other because the hydrogen bonds are formed between specific pairs of bases. Adenine forms hydrogen bonds with Thymine, whereas Cytosine forms hydrogen bonds with Guanine. [G≡C | A=T] [Delhi 2010]

G≡C ↓ 3 Hydrogen bonds

A=T → 2 Hydrogen bonds.





RNA -: Structure -: Single stranded helix.

→ RNA molecules are of 3 types. (i) messenger RNA [m-RNA]

[Delhi 2013] → (1M) (ii) Ribosomal RNA [r-RNA]

(iii) Transfer RNA [t-RNA]

Biological Functions of Nucleic Acids :- DNA is the chemical basis of heredity and may be regarded as the reserve of genetic information. Another important function of nucleic acids is the protein synthesis in the cell.