PART: I – INTRODUCTION

- Chemistry plays a very important role in day to day life.
- There are different types of branches comes under chemistry.
- **Biochemistry** is a branch of chemistry which deals with Knowledge that goes on chemically within a living system to create life.
- The term "Biochemistry" was coined in 1903 by German chemist named Carl Neuber while studying about living system.
- Biochemistry is often called Biomolecules.
- The four main classes of biomolecules are carbohydrates, proteins, lipids, and nucleic acids.

NOTE:

- ✓ Cell is a basic structural and functional unit of life.
- ✓ Cell contains biomolecules such as C.P.L.Have.V.I.N.E.

- **MEANING OF BIOMOLECULES** : (Bio = life & Molecules = Any chemical substance)

  A Biomolecule is Any molecule that is produced by living organism.

  i.e. (living organism – Plants, Human being, Other Animals)

- **DEFINITION OF BIOMOLECULES:**

  Biomolecules are ***lifeless molecules*** which combine in a specific manner to produce a life or control the biological processes.

- **EXAMPLES OF BIOMOLECULES :**

1. Carohydrates: Process of photosynthesis plants produce carbohydrates.
2. Proteins: Plants utilize the minerals absorbed by their roots to produce proteins.
3. Lipids: Lipids are the main ingredient of vegetable oils and milk fats.

4. Hormones: Hormones are chemical messenger secreted by endocrine glands.
5. Vitamins: Vitamins which are essential for normal growth and nutrition and are required in small quantities in the diet.
6. Insulin: Insulin is a hormone that plays a central role in controlling blood sugar levels in the body.
7. Nucleic Acid: Nucleic acids constitute the genetic material of organisms.(DNA & RNA)
8. Enzyme: Enzymes are bio-catalyst which performs biological reaction.

NOTE:
As Per Syllabus the Four Principal Biomolecules Namely, Carbohydrates, Proteins, Nucleic Acids and Enzyme.

PART – I – EXERCISE: IMPORTANT QUESTION – (EACH 1 MK)

1. Define Biochemistry.
2. Define Biomolecules. .
3. Biomolecules are also called as?
4. Write examples of biomolecules
5. What are the constituents of balanced diet?
6. What are the products of digestion of carbohydrates?
7. Which constituent of diet is useful for building muscles?
8. Which constituent of diet is a source of high energy?
9. What is the genetic material of organisms?

PART: II – CARBOHYDRATES

INTRODUCTION:

- It is a naturally occurring biomolecules.
- It is an organic compound containing Carbon, Hydrogen and Oxygen only.
- It is primarily produced by plants (example: cellulose, starch, wheat, rice, corn etc.) and secondarily produced by animals (example: milk , honey etc.).
- It is also known as Saccharides because the term saccharide is derived from Greek word "sakkharon" means sugar which is sweet in taste. (Except cellulose , starch)
- The general formula of carbohydrate is $C_x(H_2O)_y$ or $C_n(H_2O)_n$ and were considered as hydrates of carbon.
- The definition based on general formula and Hydrates of carbon do not satisfied all the conditions of carbohydrates.
- Example:

Case: I

Name of Compound	Formula	General Formula $C_n(H_2O)_n$
Glucose	$C_6H_{12}O_6$	$C_6(H_2O)_6$
Fructose	$C_6H_{12}O_6$	$C_6(H_2O)_6$
Sucrose	$C_{12}H_{22}O_{11}$	$C_{12}(H_2O)_{11}$
Raffinose	$C_{18}H_{32}O_{16}$	$C_{18}(H_2O)_{16}$
Stachyose	$C_{24}H_{42}O_{21}$	$C_{24}(H_2O)_{21}$

Above examples satisfied general formula and sweet in taste.

Case: II

Name of Compound	Formula	General Formula $C_n(H_2O)_n$
Formaldehyde	$C_1H_2O_1$	$C_1(H_2O)_1$
Acetic acid	$C_2H_4O_2$	$C_2(H_2O)_2$

Above examples satisfied general formula but not sweet in taste.

Case: III

Name of Compound	Formula	General Formula $C_n(H_2O)_n$
Rhamnose	$C_6H_{12}O_5$	x

Above example do not satisfied general formula but sweet in taste.

- **CONDITIONS FOR CARBOHYDRATES:**

  It must contain

1. Minimum 3 carbon atom (All are sp^3 hybridized except one is sp^2)
2. Minimum one carbon is optically active(Asymmetric carbon)
3. More than one –OH group. (Polyhydroxy)
4. Either Ketonic group (– CO –) or Aldehyde group (– CHO).

   NOTE: If Carbohydrate is in ring form than it must contain Hemiacetyl group/Hemiketal group.

- **DEFINITION OF CARBOHYDATES:**

  Carbohydates are optically active polyhydroxy aldehydes or polyhydroxy ketones or the compounds that on hydrolysis produce polyhydroxy aldehyde or polyhydroxy ketone.

- Example :

1. Glucose($C_6H_{12}O_6$) + H_2O → Glucose Solution

   (Glucose is a optically active polyhydroxy aldehyde which cannot be hydrolysed further because it already exist in simplest form)

2. Sucrose($C_{12}H_{22}O_{11}$) + H_2O → Glucose ($C_6H_{12}O_6$) + Fructose ($C_6H_{12}O_6$)
   polyhydroxy aldehyde polyhydroxy ketone

   (Sucrose is a complex carbohydrates which can be hydrolysed to form Glucose is a optically active polyhydroxy aldehyde and Fructose is optically active polyhydroxy ketone)

CLASSIFICATION OF CAROHYDRATES:

NOTE:

Carbohydrates can be broadly classified into Three Types

I. Classification based on Hydrolysis
II. Classification based on Solubility
III. Classification based on Reducing properties.

AS PER SYLLABUS WE NEED TO STUDY ONLY CLASSIFICATION BASED ON HYDROLYSIS

- Carbohydrates are broadly classified on the **Basis of hydrolysis** into three types.

1. Monosaccharides :

- Definition: A carbohydrates which cannot be hydrolyzed further into smaller units of polyhydroxy aldehydes or ketones are called monosaccharides.
- There are 20 monosaccharides are occur in nature.
- Monosaccharides contain C3 – C8.
- Most common carbohydrates have 5 – carbon called Pentose and 6 – carbon called Hexose.
- The formula of Monosaccharides is $C_nH_{2n}O_n$.
- Example: $C_5H_{10}O_5$ - Ribose, $C_6H_{12}O_6$ - Glucose, Fructose etc.

2. Oligosaccharides :

- Definition: A carbohydrates that on hydrolysis yield two to ten units of monosaccharides are called Oligosaccharides.
- They are further classified as disaccharides to decasaccharides.
- Example: Sucrose, Maltose, Lactose, Raffinose, Stachyose etc.
- **Disaccharides:**

The Disaccharides have formula $C_nH_{2n-2}O_{n-1}$.

Disaccharides contain 12 – carbon atoms and formula $C_{12}H_{22}O_{11}$.

Disaccharides on hydrolysis yield two units of monosaccharides have formula $C_6H_{12}O_6$.

Example:

1. $\underset{C_{12}H_{22}O_{11}}{\text{Sucrose}} \xrightarrow[H_2O]{\text{Hydrolysis}} \underset{C_6H_{12}O_6}{\text{Glucose}} + \underset{C_6H_{12}O_6}{\text{Fructose}}$

2. $\underset{C_{12}H_{22}O_{11}}{\text{Maltose}} \xrightarrow[H_2O]{\text{Hydrolysis}} \underset{C_6H_{12}O_6}{\text{Glucose}} + \underset{C_6H_{12}O_6}{\text{Glucose}}$

3. $\underset{C_{12}H_{22}O_{11}}{\text{Lactose}} \xrightarrow[H_2O]{\text{Hydrolysis}} \underset{C_6H_{12}O_6}{\text{Galactose}} + \underset{C_6H_{12}O_6}{\text{Glucose}}$

- **Trisaccharides:**

The Trisaccharides have formula $C_nH_{2n-4}O_{n-2}$.

Trisaccharides contain 18 – carbon atoms and formula $C_{18}H_{32}O_{16}$.

Trisaccharides on hydrolysis yield three units of monosaccharides have formula $C_6H_{12}O_6$.

Example:

1. $\underset{C_{18}H_{32}O_{16}}{\text{Raffinose}} \xrightarrow[2\,H_2O]{\text{Hydrolysis}} \underset{C_6H_{12}O_6}{\text{Glucose}} + \underset{C_6H_{12}O_6}{\text{Fructose}} + \underset{C_6H_{12}O_6}{\text{Galactose}}$

- **Tetrasaccharides:**

The Tetrasaccharides have formula $C_nH_{2n-6}O_{n-3}$.

Tetrasaccharides contain 24 – carbon atoms and formula $C_{24}H_{42}O_{21}$.

Tetrasaccharides on hydrolysis yield four units of monosaccharides have formula $C_6H_{12}O_6$.

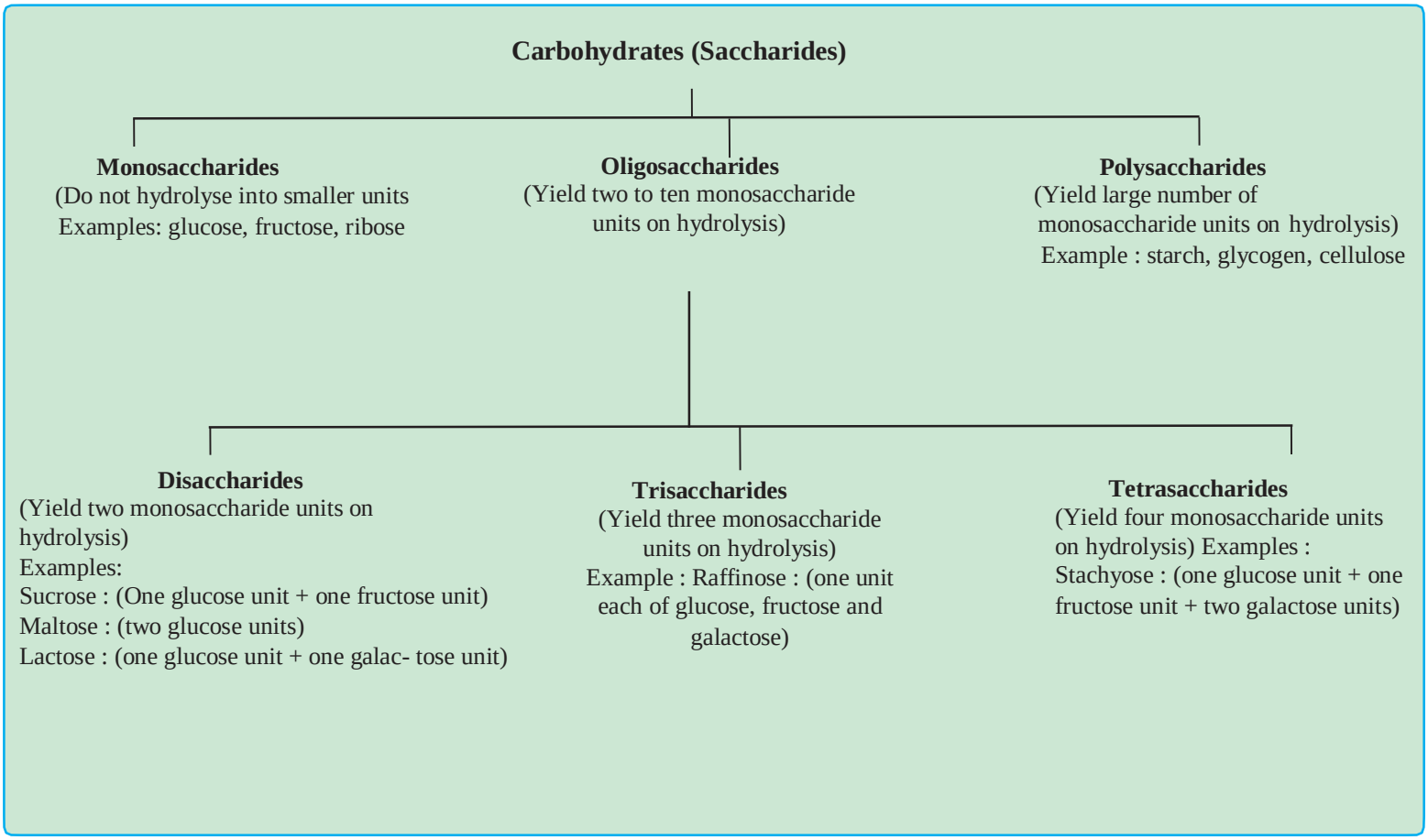
Example:

1. $\underset{C_{24}H_{42}O_{21}}{\text{Stachyose}} \xrightarrow[3\,H_2O]{\text{Hydrolysis}} \underset{C_6H_{12}O_6}{\text{Glucose}} + \underset{C_6H_{12}O_6}{\text{Fructose}} + \underset{C_6H_{12}O_6}{\text{Galactose}} + \underset{C_6H_{12}O_6}{\text{Galactose}}$

3. Polysaccharides :

- Definition: A carbohydrates that on hydrolysis yield very large (more than ten) number of monosaccharide units are called Polysaccharides.
- Most common polysaccharides are obtained from plants and animals.
- Example: Starch, Cellulose, Glycogen, Inulin, Marine gum, Pectin, Chitin Etc.

1. $\underset{(C_6H_{10}O_5)_n}{\text{Starch}} \xrightarrow[n\,H_2O]{\text{Hydrolysis}} \underset{C_6H_{12}O_6}{n\,\text{Glucose}}$



PART – II – EXERCISE – 1 : IMPORTANT QUESTION – (EACH QUESTION – 2 Mark)

1. Name the functional group present in carbohydrates.
2. Write the condition of Carbohydrates.
3. Define Carbohydrates. Write its example.
4. What is carbohydrates? How carbohydrates are classify based on hydrolysis?
5. Identify the carbohydrates into Monosaccharides, Disaccharides, Trisaccharides, Tetrasaccharides and Polysaccharides.
   a. Ribose
   b. Glucose
   c. Fructose
   d. Starch
   e. Cellulose
   f. Raffinose
   g. Stachyose
   h. Glycogen

NOMENCLATURE OF MONOSACCHARIDES:

- According to IUPAC system of nomenclature, general name for monosaccharide is **Glycose**.
- Monosaccharide with one aldehydic carbonyl group is called **Aldose.**
- Monosaccharides with one ketonic carbonyl group is called **Ketose**.
- Monosaccharides will be further classified on the basis of number of carbon atoms.

Molecular formula	Class of Aldose	Example
$C_3H_6O_3$	Aldotriose	Glyceraldehyde
$C_4H_8O_4$	Aldotetrose	Erythrose , Threose
$C_5H_{10}O_5$	Aldopentose	Ribose , Arbinose
$C_6H_{12}O_6$	Aldohexose	Glucose , Mannose

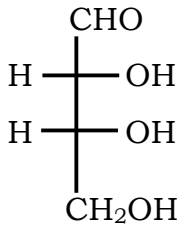
Molecular formula	Class of Ketose	Example
$C_3H_6O_3$	Ketotriose	Dihydroxyacetone
$C_4H_8O_4$	Ketotetrose	Erythrulose
$C_5H_{10}O_5$	Ketopentose	Ribulose
$C_6H_{12}O_6$	Ketohexose	Fructose

- **NOTE : RULES FOR WRITING FORMULA OF CARBOHYDRATES:**

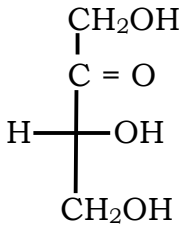
1. Carbohydrates can be represented by molecular formula, condensed formula, structural formula , Fischer projection formula and Haworth projection formula.
2. Fischer projection is the most common representation for carbohydrates.

RULE NO: 1: FISCHER PROJECTION FORMULA ; (+)

- A compound in which tetrahedral carbon atom is represented by two cross line are called Fischer projection formula.
- *Horizontal line* represents a bond which is coming outside of the plane of paper having one side –OH group and other side –H atom.
- *Vertical line* represents a bond which is coming inside of the plane of paper having most oxidized carbon at the top (Either Aldehydic or Ketonic group) and least oxidized carbon at the bottom. ($-CH_2-OH$ group).



Aldose structure



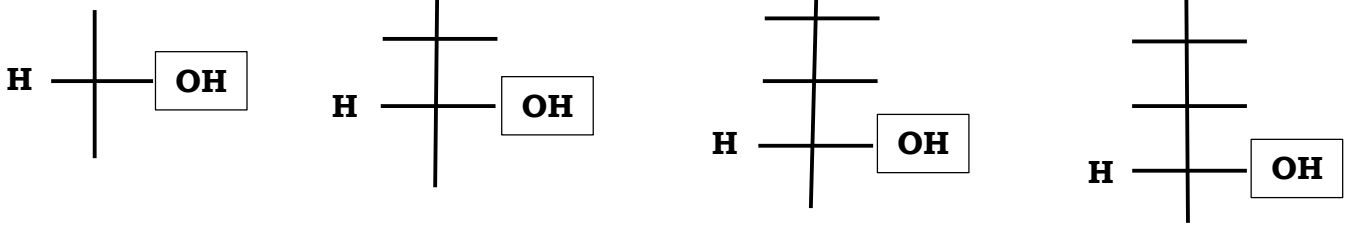
Ketose structure

RULE NO: 2 : D & L CONFIGURATION SYSTEM /FAMILY/SUGAR

- The system that is used to designate the configurations of chiral carbons of naturally occurring compound is called the D and L convention or system.
- D and L system can be represented by horizontal line. (Last horizontal line)

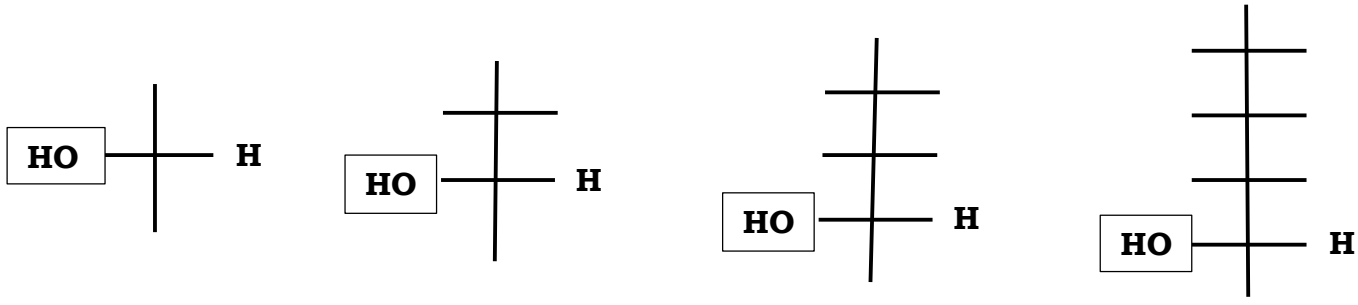
D – CONFIGURATION: (D-means Right side)

If OH group is placed on right side of last horizontal line (chiral carbon) than it is D – Sugar.



L – CONFIGURATION: (L-means Left side)

If OH group is placed on Left side of last horizontal line (chiral carbon) than it is L – Sugar



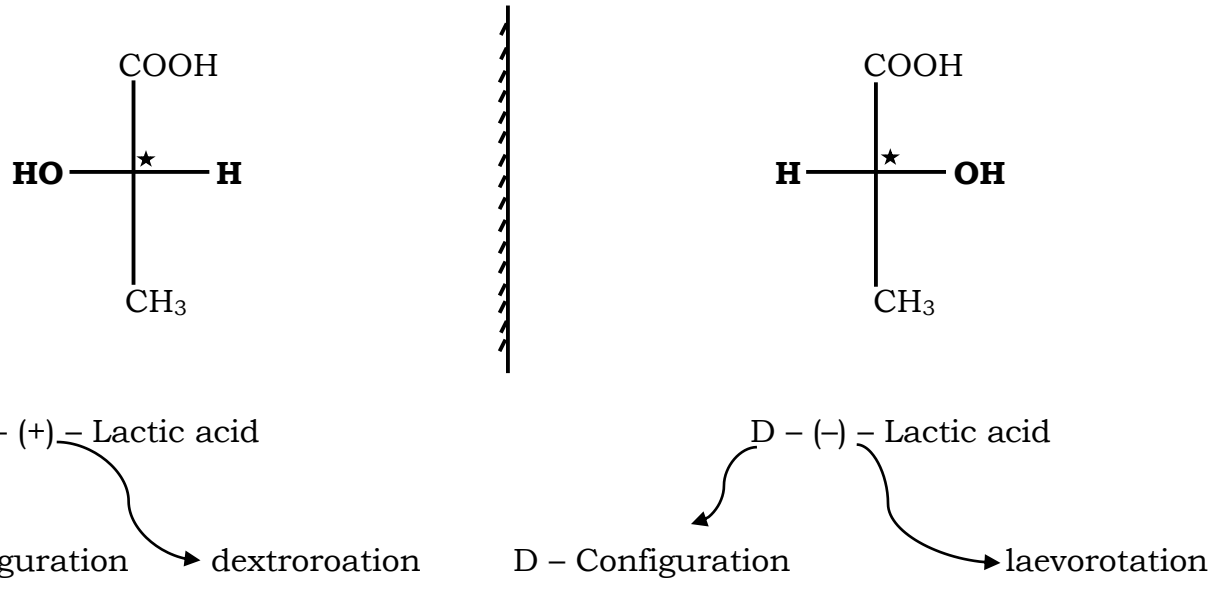
RULE NO: 3: (OPTICAL ISOMERISM)

- Optical isomers are two compounds which contain the same number and kinds of atoms, and bonds (i.e., the connectivity between atoms is the same), and different spatial arrangements of the atoms, but which have ***non-superimposable mirror images*** & phenomenon is known as optical isomerism.
- Each non-superimposable mirror image structure is called an ***enantiomer***.
- Enantiomer is one of two stereoisomers that are mirror images of each other that are non-superimposable, much as one's right (dextrotatory)(d)(+) and left (laevorotatory)(*l*)(-) hands are mirror images of each other that cannot appear identical simply by reorientation.
- Enantiomers can be alternately defined as optical isomers that are non-superimposable mirror images of each other due to presence of chiral carbon atoms.
- Optical isomer which can be determined using formula,

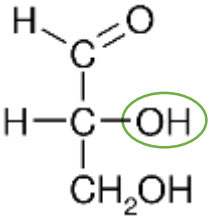
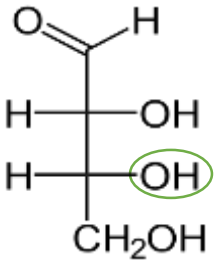
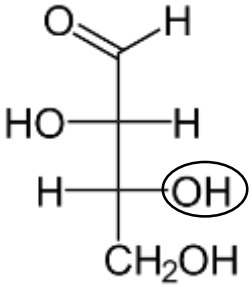
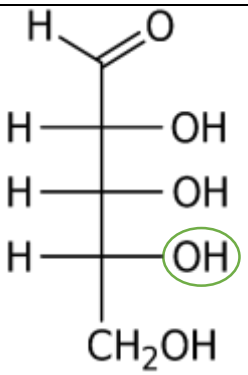
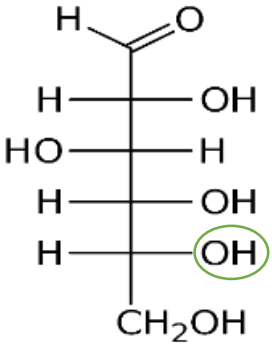
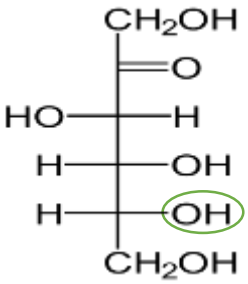
$$\textbf{Optical isomers} = 2^n$$

Where n = number of chiral carbon atom.

- Example : Optical isomers = $2^n = 2^1 = 2$ optical isomers (n = chiral carbon atom is 1)

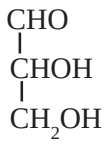
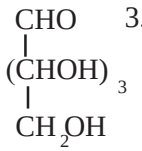
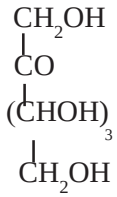


Dextro – rotation and Laevo rotation of compound can be determine by using Polari meter machine only Where D & L configuration can be determine by representing OH group placed on last horizontal line(Chiral carbon)

Structural formula	Name of Class	Famous name
	Aldotriose	Glyceraldehyde D – (+) – Glyceraldehyde
	Aldotetrose	Erythrose D – (–) – Erythrose
	Aldotetrose	Threose D – (–) – Threose
	Aldopentose	Ribose D – (–) – Ribose
	Aldohexose	Glucose D – (+) – Glucose
	Ketohexose	Fructose D – (–) – Fructose

PART – II – EXERCISE – 2: IMPORTANT QUESTION – (EACH QUESTION – 2 Mark)

1. Write the general name of Monosaccharides. (1 M)
2. Write the examples of Aldoses having different carbons in Monosaccharides.
3. Write the examples of Ketoses having different carbons in Monosaccharides.
4. Write the IUPAC name of following monosaccharides.

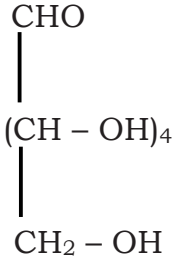
1. 
2. 
3. 

5. Write the Fischer projection formula of following monosaccharides.
   1. D – (+) – Glucose
   2. D – (–) – Fructose
   3. D – (–) – Ribose
   4. D – (+) – Glyceraldehyde

GLUCOSE :

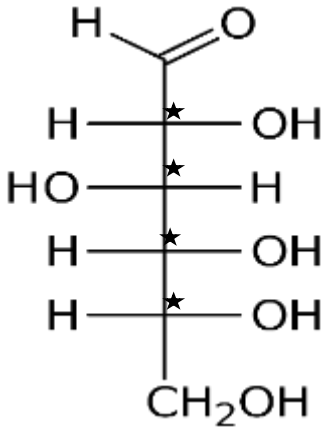
- **INTRODUCTION:**

1. Glucose occurs in nature in free as well as in combined state.
2. It is present in sweet fruits, honey and essential component of human blood.
3. It is most abundant monosaccharides present in nature.
4. It produces instant energy and available in Dextrose form.
5. Glucose is a optically active pentahydroxy aldehyde contain 4 chiral carbon atom.
6. Molecular formula : $C_6H_{12}O_6$
7. Structural formula :



NOTE: 1 – Primary Alcoholic group (– CH_2 – OH) and
4 – Secondary alcoholic group (>CH – OH)

8. Fischer projection formula: D – (+) – Glucose



NOTE: 4 – Chiral carbon atom, Optical isomers = $2^n = 2^4 = 16$

- **METHOD OF PREPARATION OF GLUCOSE**:

METHOD – I – LABORATORY METHOD – [FROM SUCROSE]

$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow[333\ K,\ 2\text{ - }3\ Hours]{\text{Dil. HCl or Dil. } H_2SO_4} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Fructose}}{C_6H_{12}O_6}$$

Explanation:

1. Sucrose is hydrolyzed by warming with dilute hydrochloric acid or sulfuric acid for about two hours to undergo hydrolysis and converts sucrose into mixture of glucose and fructose.
2. Glucose is separated from fructose by adding ethanol during cooling where glucose being almost insoluble in alcohol crystallizes out first. The solution is filtered to obtain crystals of glucose.

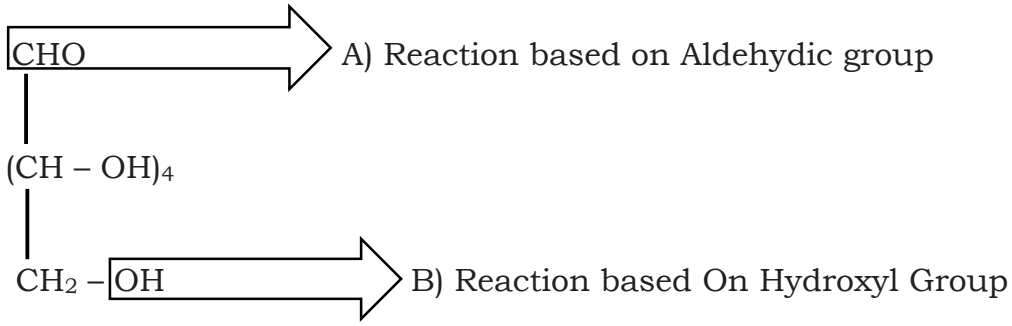
METHOD – II – COMMERCIAL METHOD – [FROM STARCH]

$$\underset{\text{Starch}}{(C_6H_{10}O_5)_n} + n\,H_2O \xrightarrow[393\ K,\ 2\text{ - }3\ atm,\ pressure]{\text{Dil. HCl or Dil. } H_2SO_4} \underset{\text{Glucose}}{n\,C_6H_{12}O_6}$$

Explanation:

1. Commercially glucose is obtained by hydrolysis of starch by boiling it with dilute sulfuric acid at 393K under 2 to 3 atm pressure.
2. The glucose formed during the process is acidic and can be neutralized with chalk powder which further mixed with charcoal powder to remove all the impurity from glucose.
3. Finally Glucose is heated and cooling produces pure crystal of glucose.

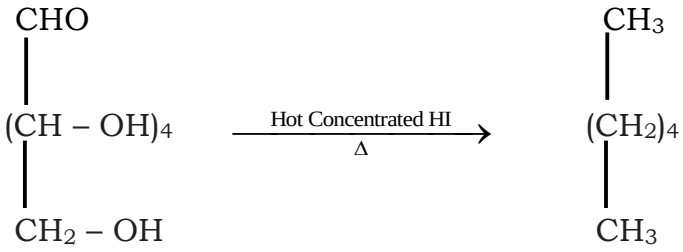
- **CHEMICAL PROPERTIES OF GLUCOSE:**



A) Reaction based on Aldehydic group:

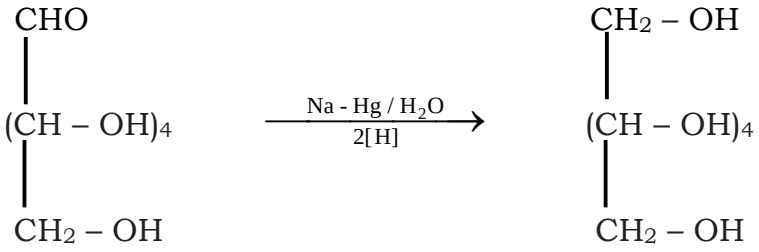
1. Reduction of Glucose: → **Strong Reducing Agent**

a) Complete reduction : (Using Hot Con. HI)



Glucose **n – Hexane**

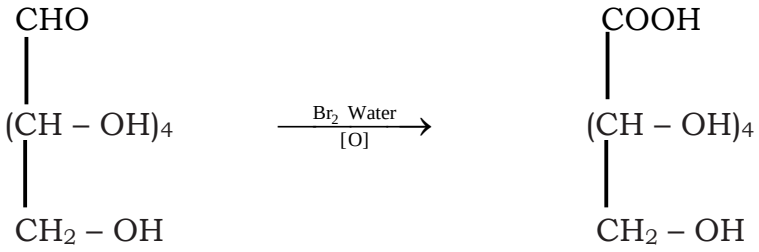
b) Partial reduction : (Using Na – Hg /H_2O) → **Mild Reducing Agent**



Glucose **Sorbitol**

2. Oxidation of Glucose: → **Mild Oxidizing Agent**

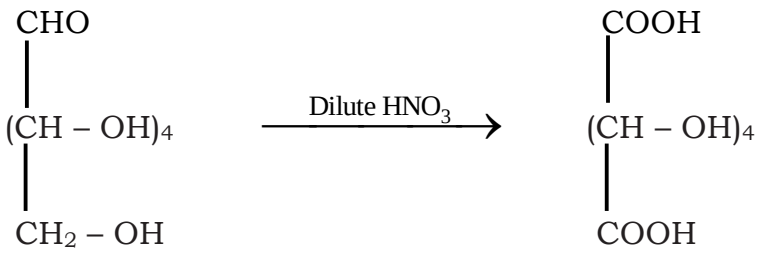
a) Partial oxidation : (Using Br_2 - Water)



Glucose **Gluconic Acid**

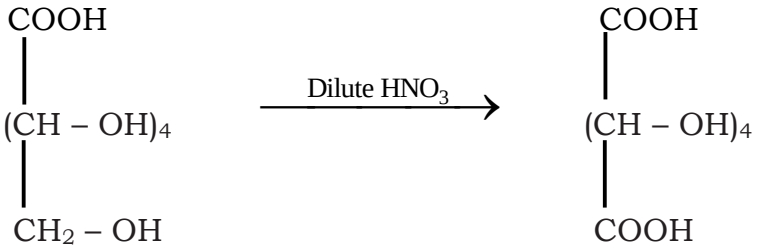
b) Complete Oxidation : (Using Dilute HNO_3) → **Strong oxidizing Agent**

i.



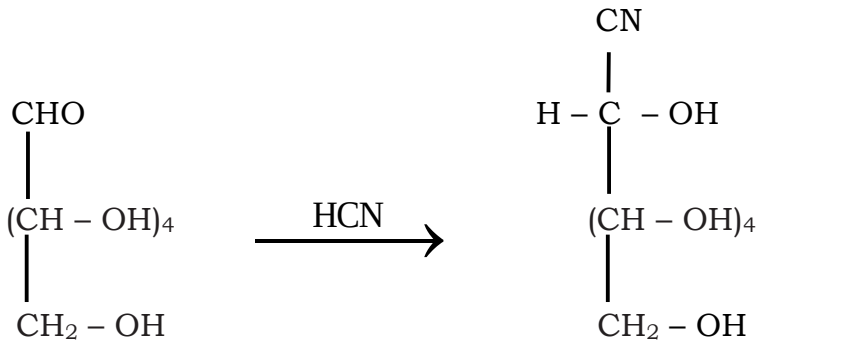
Glucose **Saccharic Acid**

ii.



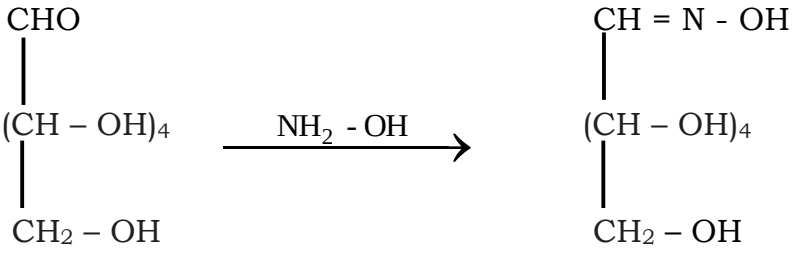
Gluconic Acid **Saccharic acid**

3. Reaction with Hydrogen Cyanide (HCN) :



Glucose **Glucosecyanohydrine**

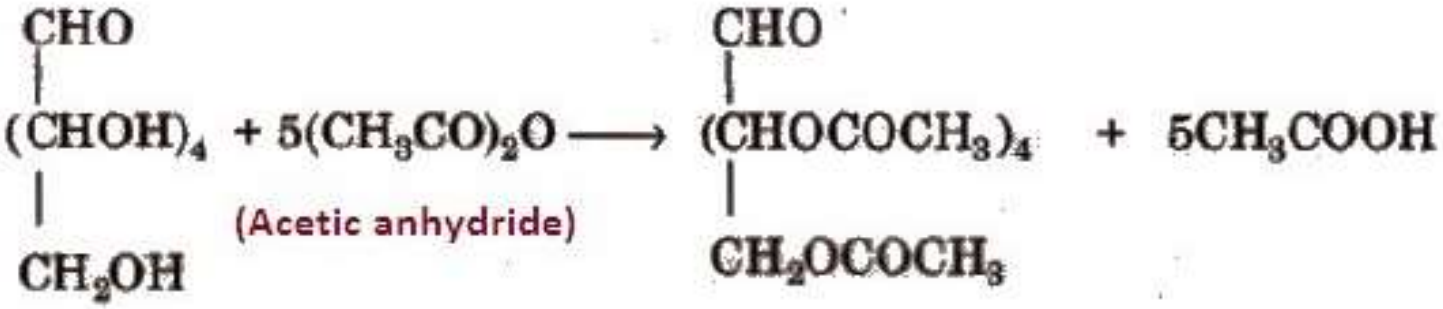
4. Reaction with Hydroxyl amine (NH_2 – OH):



Glucose **Glucoxime**

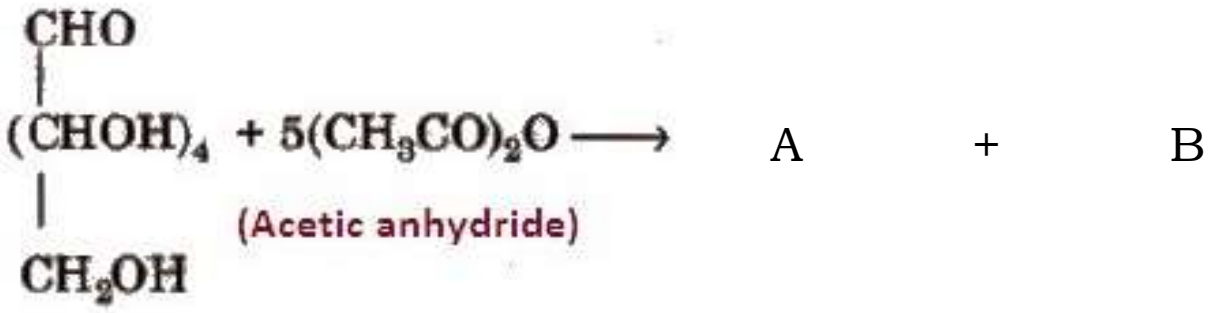
B) Reaction based on Alcoholic group:

5. Reaction with Acetic Anhydride



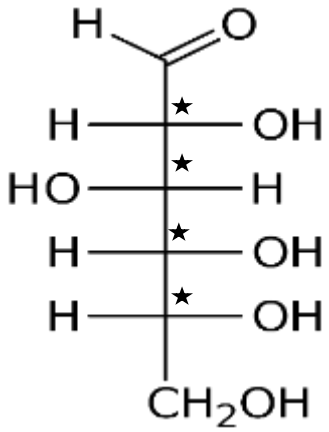
PART – II – EXERCISE – 3: IMPORTANT QUESTION – (EACH QUESTION – 2 Mark)

1. Write the Functional group present in D-(+)-Glucose. (1 M)
2. Write the Fischer projection formula of D-(+)-Glucose. (1 M)
3. How is Glucose prepared from Starch?
4. Write a note on commercial method of preparation of Glucose.
5. How are the following Conversion carried out?
   a) Glucose to n – Hexane
   b) Gluconic acid to Saccharic acid
6. What is the action of following reagents on Glucose?
   a) Br_2 water
   b) Dilute HNO_3
7. What happens when,
   a) Glucose treated with NH_2OH?
   b) Glucose treated with HCN?
8. Identify A and B of the following reaction and rewrite the reaction.



OPTICAL ISOMERISM IN GLUCOSE:

- ***Optical isomersism*** is a form of stereoisomerism in which two compounds contain the same number and kinds of atoms, and bonds (i.e., the connectivity between atoms is the same), and different spatial arrangements of the atoms, but which have non-superimposable mirror images.
- Each non-superimposable mirror image structure is called an enantiomer and phenomenon is known as **enantiomerism.**
- Compounds, molecules or ions that exist as optical isomers are called ***chiral*** because the compound containing optical active carbon (Asymmetric cabron).
- Optical Isomers can be calculated using " $\mathbf{2^n}$ " where n = no of chiral carbon.
- Example : D – (+) – Glucose



No of chiral carbon atom = n = 4

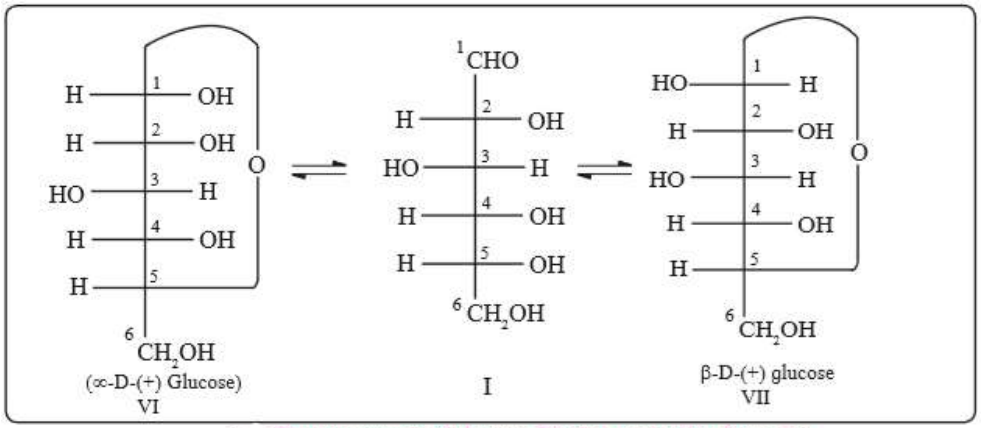
Optical isomers = $2^n = 2^4 = 16$ isomers

- Glucose is an optically active compound and has its specific rotation $[\propto]_D^{20}$ equal to $+52.7^0$, due to its dextrorotation glucose is also called dextrose.

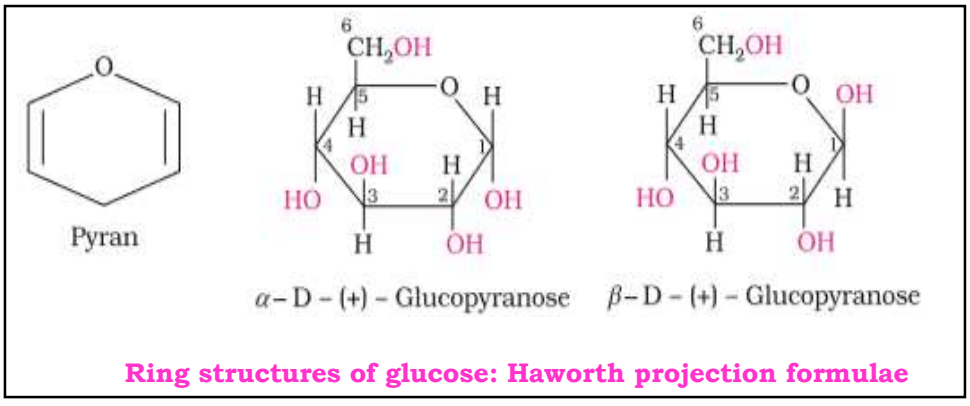
RING/CYCLIC STRUCTURE OF GLUCOSE:

- On the basis of chemical evidence stereo structure of D-(+)-glucose was represented by the Fischer projection formula.
- Glucose, however, was found to exhibit some more chemical properties which could not be explained on the basis of the Fischer projection formula.
- It was necessary to write another structure for glucose which will explain all the properties.
- Ring structure of glucose fulfils this requirement.
- Glucose is found to have two cyclic structures which are in equilibrium with each other through the open chain structure (Fischer projection formula) in aqueous solution.

- A ***Haworth projection*** is a common way of writing a structural formula to represent the cyclic structure of monosaccharides with a simple three-dimensional perspective.
- The ring structure of glucose is formed by reaction between the formyl (-CHO) group and the alcoholic (-OH) group at C-5. Thus, the ring structure is a hemiacetal structure.
- The two hemiacetal structures differ only in the configuration of C-1 , the additional chiral centre resulting from ring closure.
- The two ring structures are called **∝-anomers** and **β- anomers** of glucose and C-1 is called the anomeric carbon.
- The ***anomeric carbon*** is the carbon derived from the carbonyl carbon compound (the ketone or aldehyde functional group) of the open-chain form of the carbohydrate molecule.
- The ring of the cyclic structure of glucose contains five carbons and one oxygen. Thus, it is a six membered ring. It is called pyranose structure, in analogy with the six membered heterocyclic compound pyran. Hence glucose is also called glucopyranose.
- The groups which appear on right side in the Fischer projection formula appear on α-side in the Haworth formula, and viceversa.



Ring structures of glucose: Fischer projection formulae



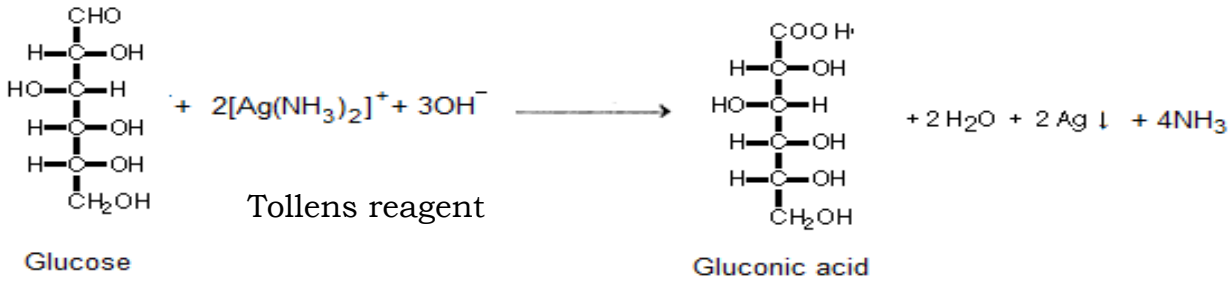
Ring structures of glucose: Haworth projection formulae

REDUCING NATURE OF GLUCOSE:

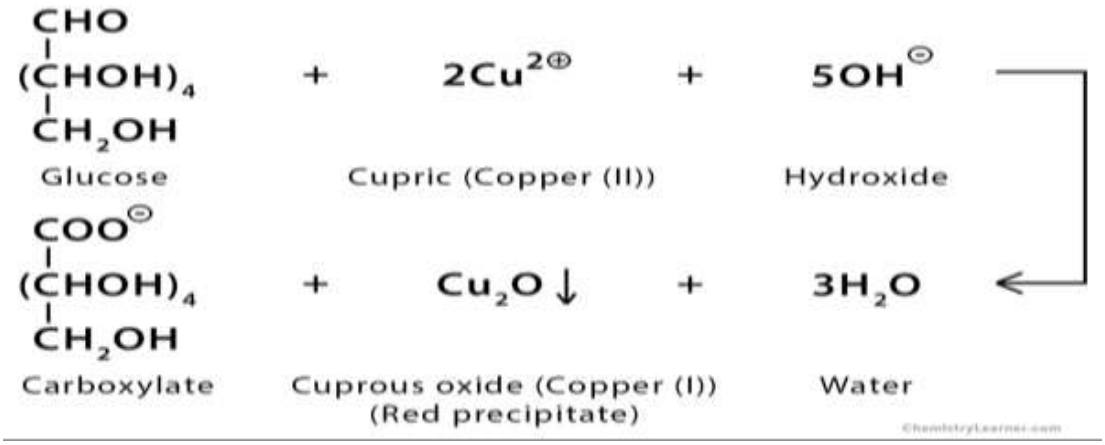
- Hemiacetal group of glucopyranose structure is a potential aldehyde group.
- It imparts reducing properties to glucose.
- Glucose gives positive Tollens test and positive Fehling test

NOTE:

a) Tollens Test/Silver mirror test:



b) Fehling test:



c) Benedict's test:

Glucose + Benedict's reagent ($CuSO_4$ +Na_2CO_3 + Sodium citrate)

↓

Brown/Orange precipitate

d) Barfoed's test:

Glucose + Barfoed's reagent ($CuSO_4$ + Acetic acid)

↓

A scanty brick red precipitate

e) Molisch's test:

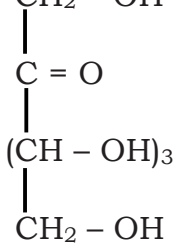
Glucose + Molisch's reagent (α – naphthol + con. H_2SO_4)

↓

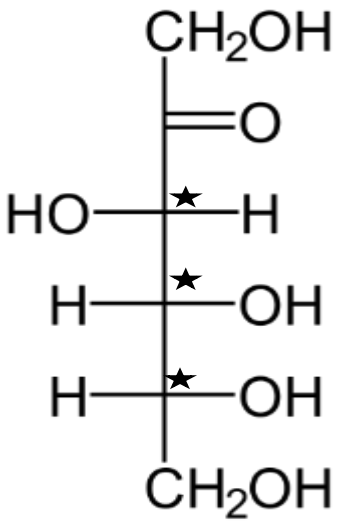
Reddish violet / Purple colour

REPRESENTATION OF FRUCTOSE STRUCTURE:

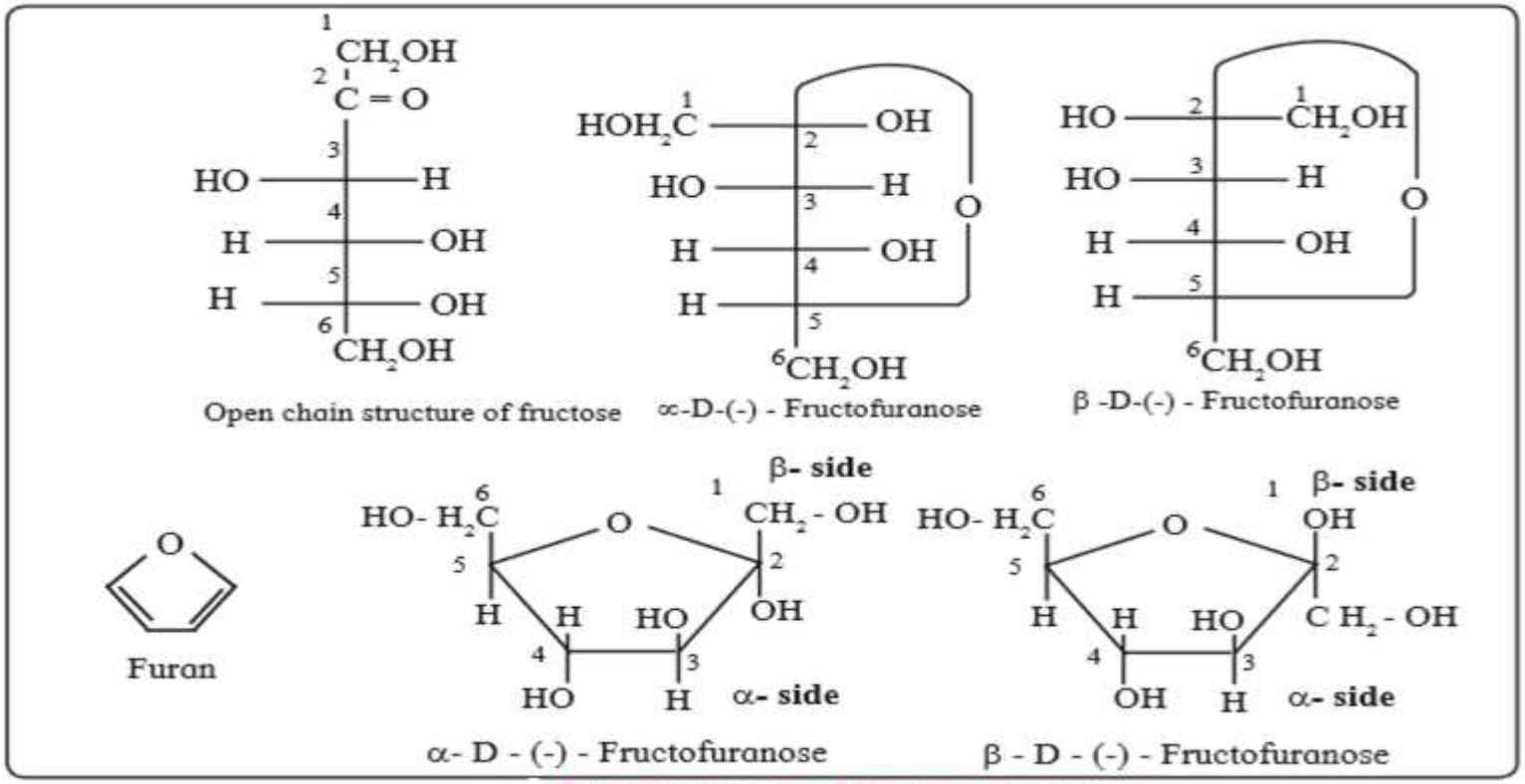
- Fructose is a optically active pentahydroxy ketone contain 3 chiral carbon atom.
- Molecular formula : $C_6H_{12}O_6$
- Structural formula :



- NOTE: 2 – Primary Alcoholic group (– CH_2 – OH) and 3 – Secondary alcoholic group (>CH – OH)
- Fischer projection formula: D – (–) – Fructose



- NOTE: 3 – Chiral carbon atom, Optical isomers = $2^3 = 2^3 = 8$
- Fructose is an optically active compound and has its specific rotation, $[\propto]_D^{20}$, equal to – 92.4^0, due to its laevorotation fructose is also called laevulose.
- In Free State it exists as mixture of fructopyranose (major) and fructofuranose.
- In combined state fructose is found in the form of fructofuranose ring structure.
- The name furanose is given by analogy with furan, a five membered heterocyclic compound.
- The open chain structure of fructose contain keto group and ring structures of ∝- and β-anomers of fructofuranose contain hemiketal as a functional group.



Representations of fructose structure

REDUCING NATURE OF FRUCTOSE:

- Hemiketal group of fructofuranose structure is a potential ketone group.
- It imparts reducing properties to Fructose.
- Tollen's test, Fehling's test, Benedict's test, Barfoed's test, Molisch's test can easily shows reducing nature of fructose.

DISACCHARIDES:

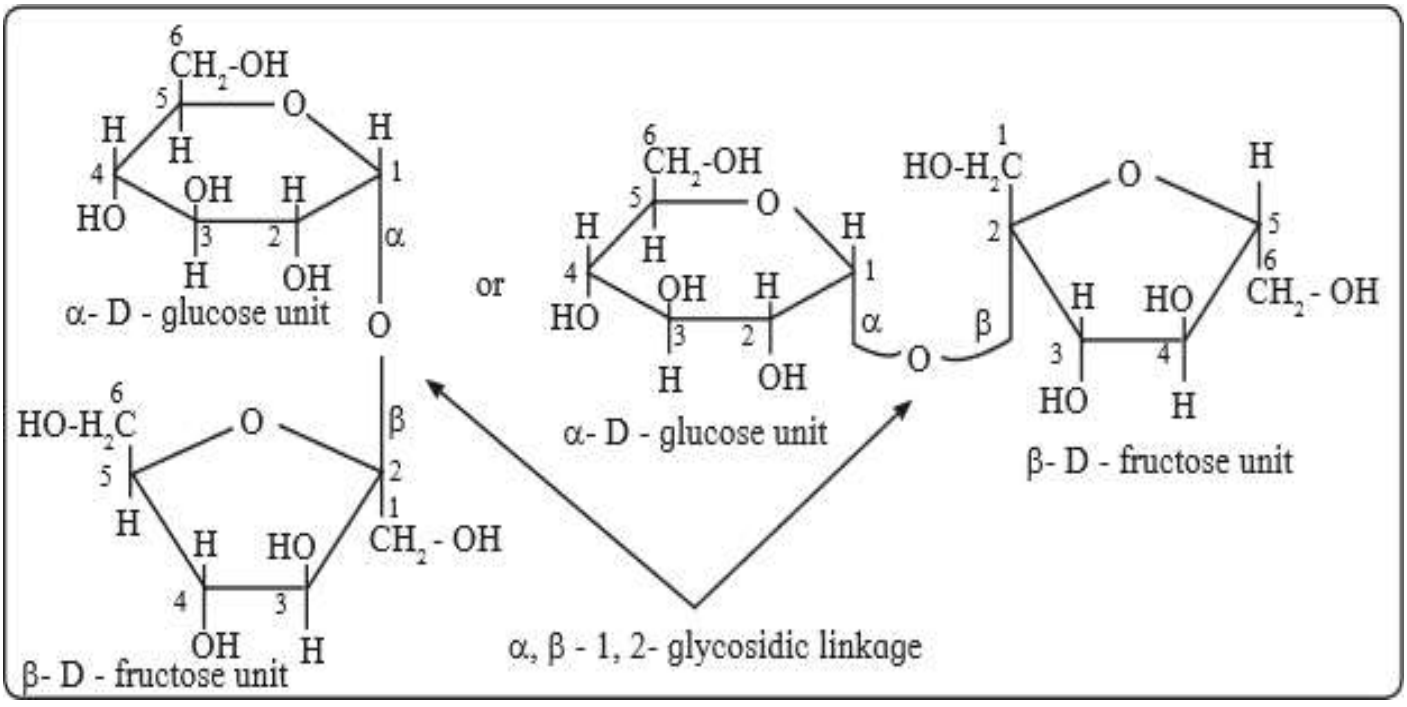
- Disaccharides give rise to two units of same or different monosaccharides on hydrolysis with dilute acids or specific enzymes.
- The two monosaccharide units are linked together by an ether oxide linkage (-O-), which is termed as glycosidic linkage in carbohydrate.
- Glycosidic linkage is formed by removal of a water molecule by reaction of two hydroxyl (-OH) groups from two monosaccharide units.
- At least one of the two monosaccharide units must use its anomeric hydroxyl group in formation of the glycosidic linkage.
- Three most common disaccharides are sucrose, maltose and lactose.

1. SUCROSE: [Enzyme used for hydrolysis is Invertase]

- Sucrose is a formation of C – 1 carbon of α – D – (+) – Glucopyranose and C – 2 carbon of β – D – (–) – Fructofuranose through gylcosidic linkage (ether linkage).
- It is obtained from Cane sugar.
- Sucrose ($C_{12}H_{22}O_{11}$) is dextrorotatory (+66.50). On hydrolysis with dilute acid or an enzyme called invertase sucrose gives equimolar mixture of D-(+) glucose and D-(-) fructose.

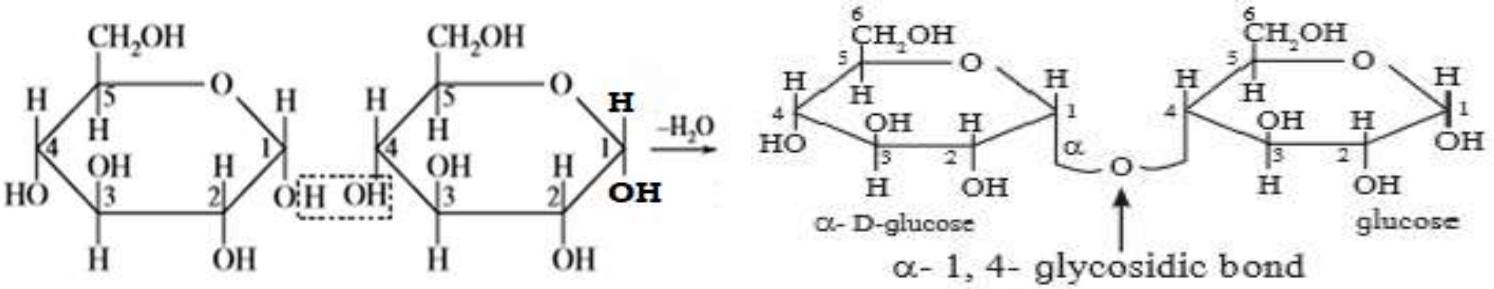
$$\underset{C_{12}H_{22}O_{11}}{\text{Sucrose}} \xrightarrow[H_2O]{\text{Hydrolysis}} \underset{\substack{C_6H_{12}O_6 \\ \text{D – (+) – Glucose}}}{\text{Glucose}} + \underset{\substack{C_6H_{12}O_6 \\ \text{D – (–) – Fructose}}}{\text{Fructose}}$$

- Since the laevoratotion of fructose (-92.40) is larger than the dextrorotation of glucose (+52.70), the hydrolysis product has net laevorotation. Hence hydrolysis of sucrose is also called inversion of sucrose and the product is called **invert sugar.**
- The potential aldehyde and ketone groups of both the monosaccharide units are involved in formation of the glycosidic bond, **sucrose is a non- reducing sugar**.
- Sucrose is Soluble in water and sweet in taste.
- Sucrose gives negative Tollen's test.
- Sucrose gives negative Fehling's test.



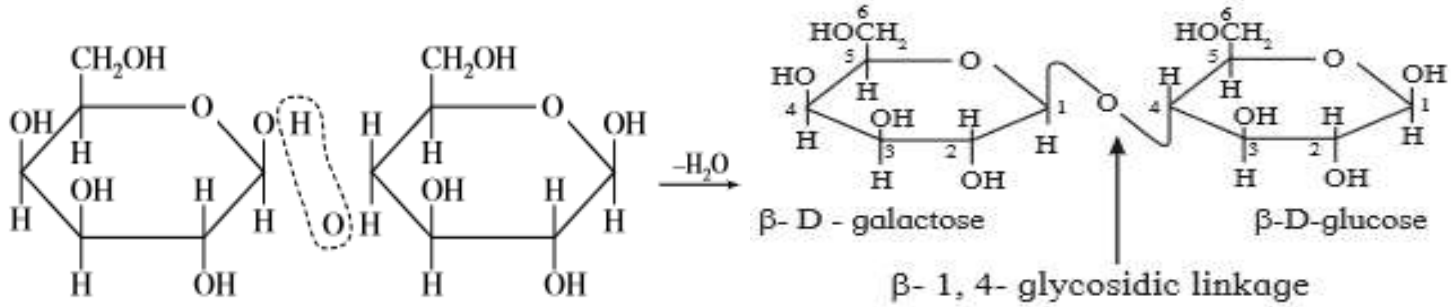
2. MALTOSE: [Enzyme used for hydrolysis is Maltase]

- Maltose ($C_{12}H_{22}O_{11}$) is the formation of C – 1 carbon of α – D – (+) – Glucopyranose and C – 4 carbon of α – D – (+) – Glucopyranose of another molecule through gylcosidic linkage (ether linkage).
- It is obtained from partial hydrolysis of starch.
- It is also known as malt sugar.
- The hemiacetal group at C-1 of the second ring is not involved in glycosidic linkage. Hence maltose is a **reducing sugar**.
- Maltose gives positive Tollen's test.
- Maltose gives positive Fehling's test.



3. LACTOSE: [Enzyme used for hydrolysis is Lactase]

- Lactose ($C_{12}H_{22}O_{11}$) is the formation of C – 1 carbon of β – D – (+) – Galactopyranose and C – 4 carbon of β – D – (+) – Glucopyranose of another molecule through gylcosidic linkage (ether linkage).
- It is obtained from Milk.
- It is also known as Milk sugar.
- The hemiacetal group at C-1 of the second ring is not involved in glycosidic linkage. Hence lactose is a **reducing sugar**.
- Lactose gives positive Tollen's test.
- Lactose gives positive Fehling's test.



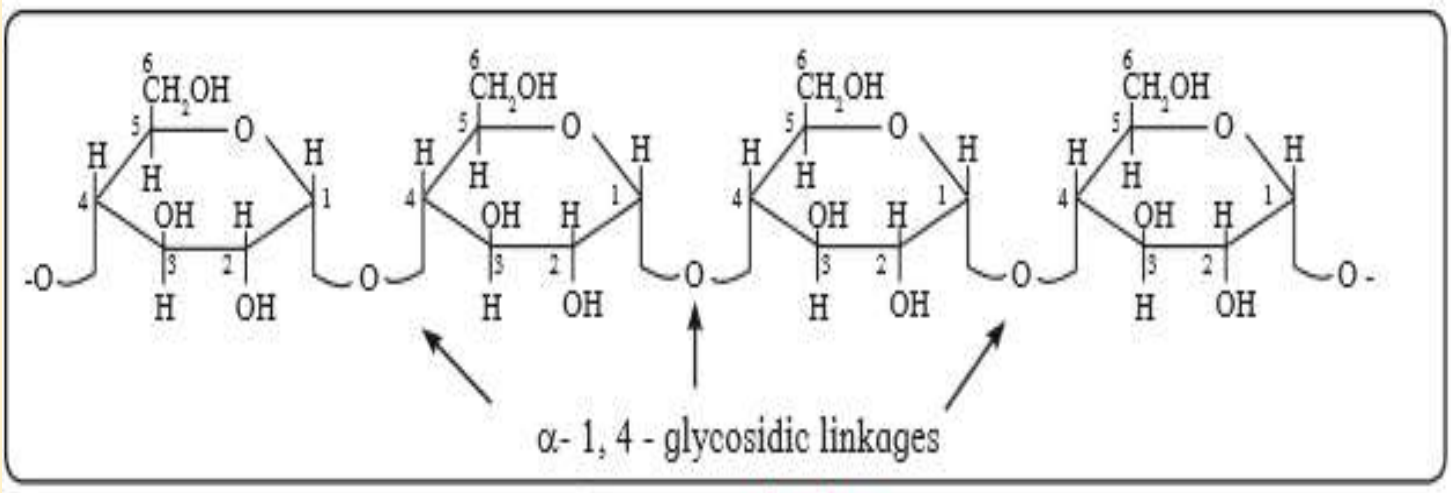
POLYSACCHARIDES:

- Polysaccharides are formed by linking large number of monosaccharide units by glycosidic linkages.
- These are linear polymers and also highly branched polymers.
- These are not called as sugar because are not sweet in taste Except Insulin which is sweet.
- Starch, cellulose and glycogen are the most common natural polysaccharides.

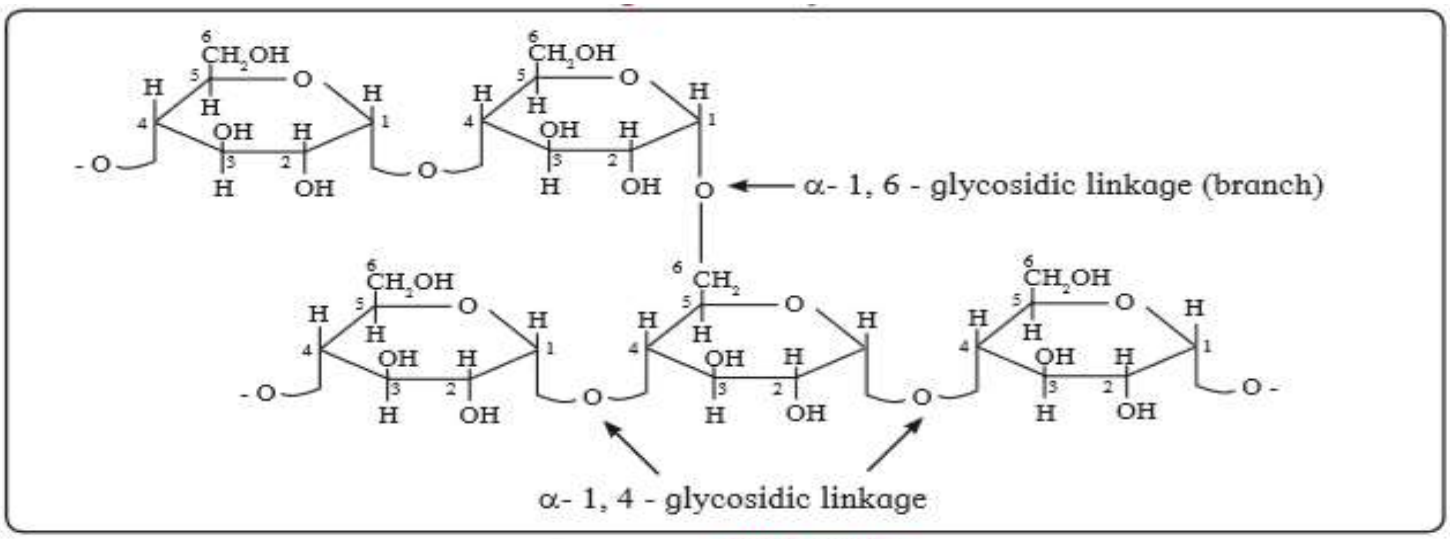
1. STARCH: [$(C_6H_{10}O_5)_n$ – Enzyme used for hydrolysis is Amylase]

- Starch is storage carbohydrate of plants and important nutrient for humans and other animals.
- Starch is a polymer of ∝-D-glucose.
- Starch has two components, namely, amylose (15-20%) and amylopectin (80-85%).

No	Amylose	Amylopectin
1	It contains 15-20% of starch.	It contains 80-85 % of starch.
2	It is soluble in water.	It is insoluble in water.
3	It is unbranched helical structure	It is a branched chain structure.
4	It contains 200-1000 ∝-glucose units linked by ∝-1,4- glycosidic linkages	The chains are formed by ∝-1,4- glycosidic linkages between ∝-glucose units, whereas branches (Branch of 24–30 glucose monomers) are formed by ∝-1,6- glycosidic linkages
5	It gives blue colour with I_2.	It gives blue-violet colour with I_2.



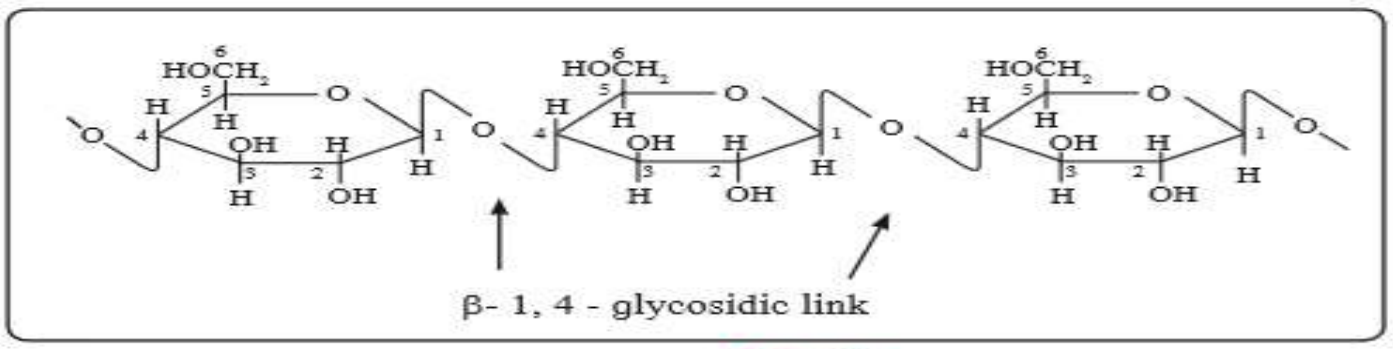
Amylose



Amylopectin

2. CELLULOSE: [$(C_6H_{10}O_5)_n$ – Enzyme used for hydrolysis is Cellulase]

- Cellulose is the main constituent of cell wall of plant and bacterial cells.
- It is also main constituent of wood and cotton.
- It is insoluble in water,
- Cellulose is a straight chain polysaccharide of β-glucose units linked by β-1, 4 – glycosidic bonds.
- Chemical hydrolysis of cellulose requires use of concentrated strong acids at high temperature and pressure.
- This implies that the β-1,4- glycosidic bond is very strong and difficult to hydrolyze.
- Humans do not have enzymes which can hydrolyze this linkage. Hence cellulose cannot be digested by human beings; it serves as the fibrous content of food useful for bowel movement.
- It does not give colour with I_2.



Cellulose

3. GLYCOGEN : [$(C_6H_{10}O_5)_n$]

- Glycogen constitutes storage carbohydrate of animals and is present in liver, muscles and brain.
- It is also found in yeast and fungi.
- Glycogen has its structure similar to that of amylopectin, but it is more highly branched.
- It gives red colour with I_2.

PART – II – EXERCISE – 4 : IMPORTANT QUESTION – (EACH QUESTION – 2/3 Mark)

1. Explain optical isomerism in Glucose.
2. Write Fischer projection formula of α – D – (+) – Glucopyranose and β – D – (-) – Glucopyranose.
3. Write Haworth projection formula of α – D – (+) – Glucopyranose and β – D – (-) – Glucopyranose.
4. Write Fischer projection formula of α – D – (-) – Fructofuranose and β – D – (-) – Fructofuranose.
5. Write Haworth projection formula of α – D –(-)– Fructofuranose and β – D –(-)– Fructofuranose.
6. Explain reducing nature of Glucose.
7. Write a short note on Sucrose.
8. Write a short note on Maltose.
9. Write a short note on Lactose.
10. Write a short note on Starch.
11. Write a short note on Cellulose.
12. Write distinguish between Amylose and Amylopectin.
13. Write the structure of following compounds.
    a) Sucrose
    b) Lactose
    c) Maltose

SOME IMPORTANT POINTS TO REMEMBER FOR MULTIPLE CHOICE QUESTIONS

1. Monosaccharide's and Oligosaccharides are water soluble , sweet in taste and reducing in nature (due to presence of aldehyde, ketone, hemiacetal and hemiketal group) except sucrose which is non – reducing in nature.
2. Polysaccharides do not have sweet test (except insulin) and are non – reducing in nature.(due to absence of aldehyde, ketone, hemiacetal and hemiketal group)

Name of test	Glucose	Fructose	Sucrose	Maltose	Lactose	Starch	Cellulose	Glycogen
Tollens Test	Positive	Positive	Negative	Positive	Positive	Negative	Negative	Negative
Fehling Test	Positive	Positive	Negative	Positive	Positive	Negative	Negative	Negative
Benedict's test	Positive	Positive	Negative	Positive	Positive	Negative	Negative	Negative
Barfoed's test:	Positive	Positive	Negative	Negative	Negative	Negative	Negative	Negative
Molisch's test:	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive
Iodine test	----------	----------	----------	----------	----------	Positive	Negative	Positive

PART: III – PROTEINS:

INTRODUCTION

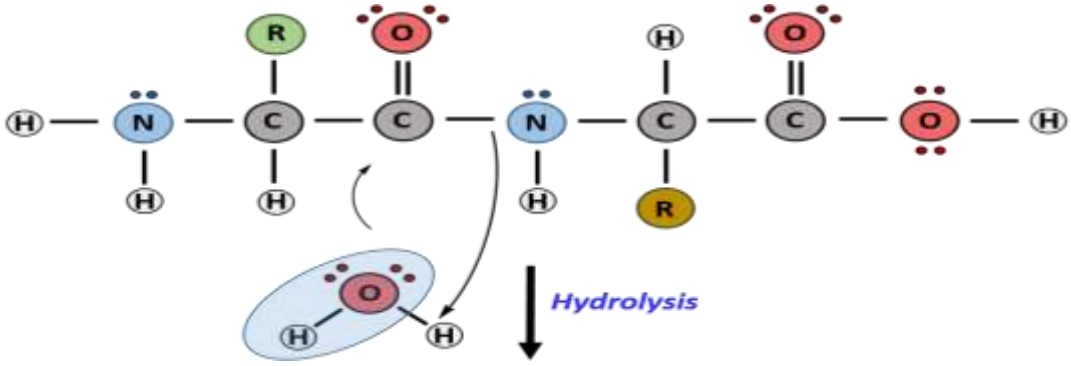
1. It is a naturally occurring biomolecules.
2. The term protein is derived from Greek word 'Proteios' means "Of prime importance".
3. The chief sources of proteins are cereals of grain, cheese, pluses, peanuts, egg, fish, meat & must for balanced diet.
4. It is found in living cells & are present in hair, skin, muscles, nerves, enzymes, antibodies, hormones etc.
5. Proteins contains C,H,O,N,S,P & other elements such as Co,Fe,Mg,Cu,Zn.

DEFINITION OF PROTEINS

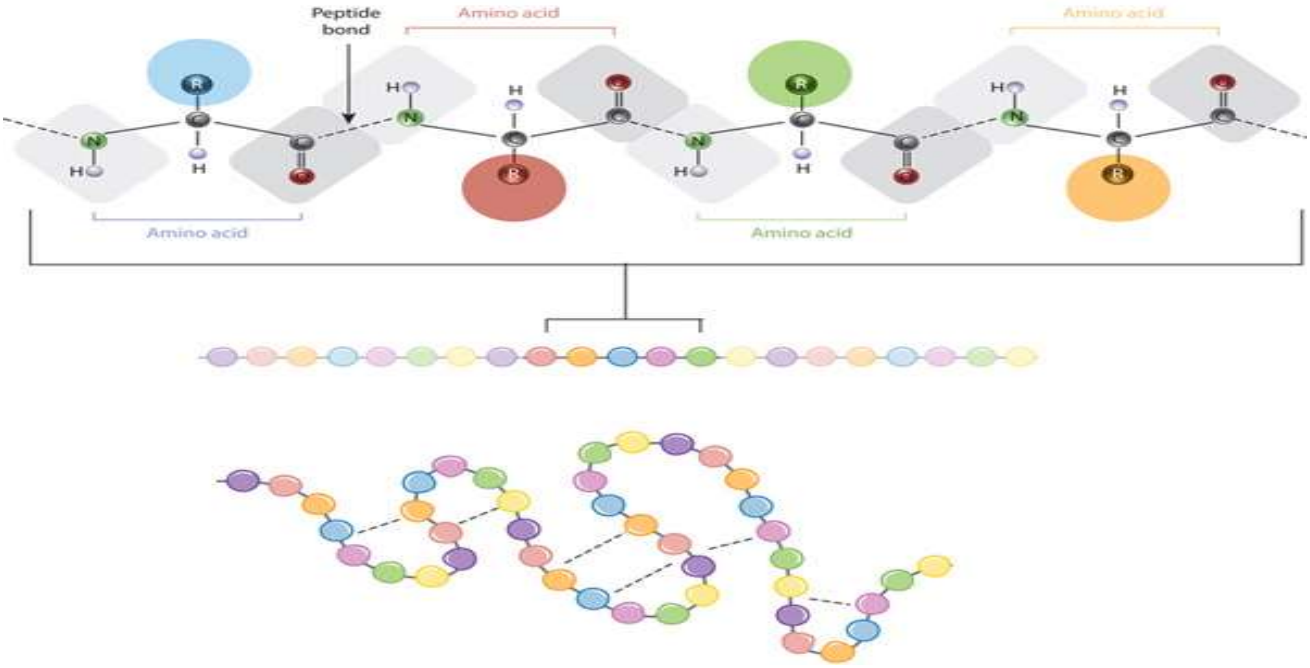
Proteins are higher molecular weight biopolymer containing nitrogenous compound and on hydrolysis yields ∝ – amino acid.

OR

Proteins are polyamides having high molecular weight polymers of the monomer units called ∝-amino acids.

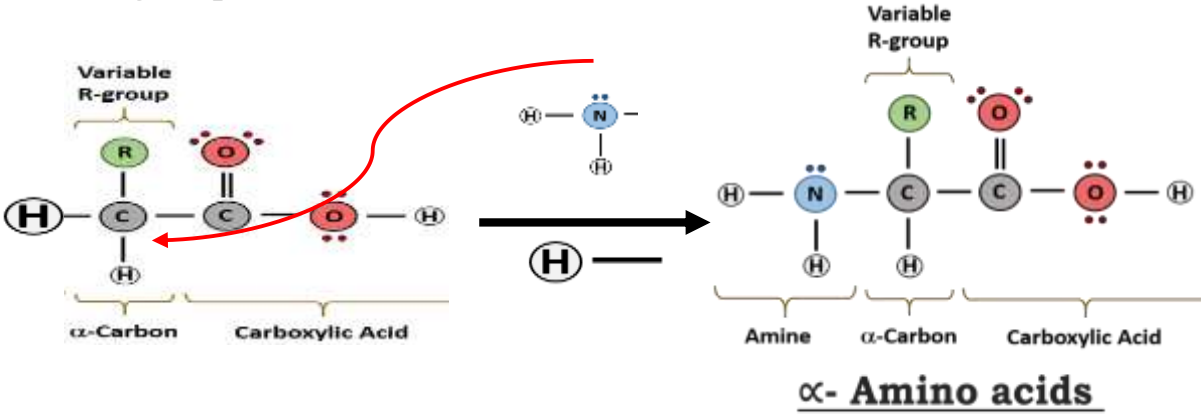


Structural Representation of Proteins

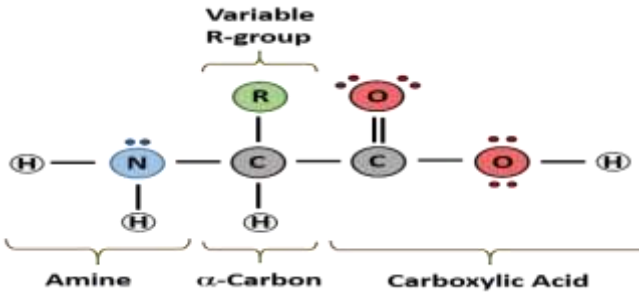


∝- AMINO ACIDS

∝ - amino acid are derivatives of carboxylic acids obtained by replacing ∝ - hydrogen atom by amino group.

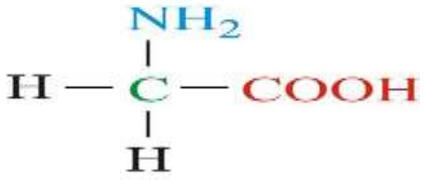


- General representation of ∝ - amino acids:



- Where 'R' in the structure of ∝ - amino acids represents side chain and may contain additional functional groups.

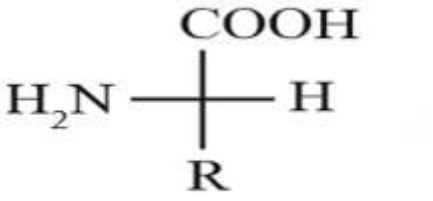
- ∝ - carbon in all ∝ - amino acids is chiral in nature. (Except glycine).



Note:

Proteins on hydrolysis give about 30 amino acids, out of 20 amino acids are most common.

- It is found that the ∝- carbon in ∝-amino acids obtained by hydrolysis of proteins has 'L' configuration.
- The L-∝ - amino acids are represented by the Fischer projection formula.



L-∝-amino acid

CLASSIFICATION OF ∝- AMINO ACIDS

A. On the basis of Side chain (Based on Nature)

1. **Acidic amino acid:**
   If 'R' contains a carboxyl (-COOH) group the amino acid is acidic amino acid.
   OR
   If amino group are less than carboxylic group than the amino acid is acidic in nature.

   Example: Glutamic acid, Aspartic acid (GA)

2. **Basic amino acid:**
   If 'R' contains an amino (1^0,2^0 or 3^0) group, the amino acid is Basic amino acid.
   OR
   If amino group are more than carboxylic group than the amino acid is Basic in nature.

   Example: Histidine, Arginine, Lysine (HAL)

3. **Neutral amino acid:**
   If 'R' do not contains any functional group, the amino acid is Neutral amino acid.

   OR

   If amino group and carboxylic group are equal in number than the amino acid is neutral in nature.

   Example: Glycine, Alanine, Valine (GAV)

B. On the basis of Synthesis:

1. **Essential amino acids:**

   The amino acids which do not synthesize in body and are supplied through diet are called Essential amino acids.

   Example: Lysine, Valine

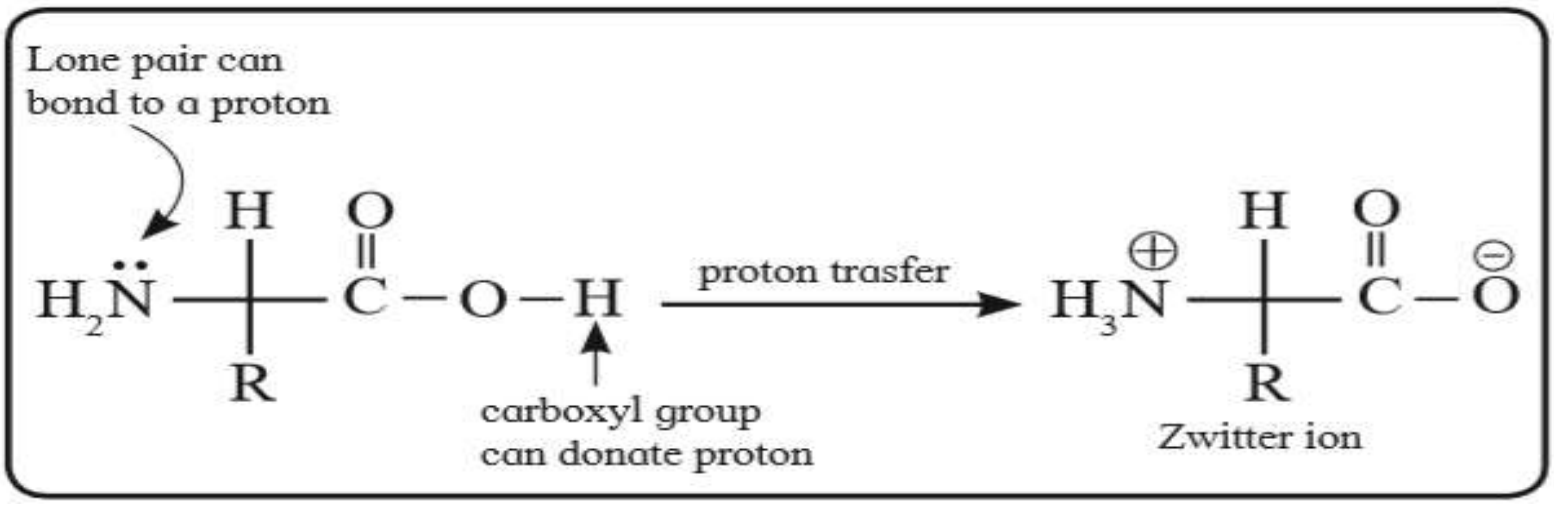
2. **Non – Essential amino acids:**

   The amino acids which are synthesize in body are called Non - essential amino acids.

   Example: Glutamic acid, Serine.

Explain Zwitter ion.

- ∝ - amino acids are crystalline, colorless, water soluble, non – volatile, high melting point solid.
- ∝ - amino acids in their aqueous solutions forms salt due to presence of both acidic carboxyl group (-COOH) as well as basic amino group ($-NH_2$) in same molecule.
- Such **Dipolar ion** called as Zwitter ion.



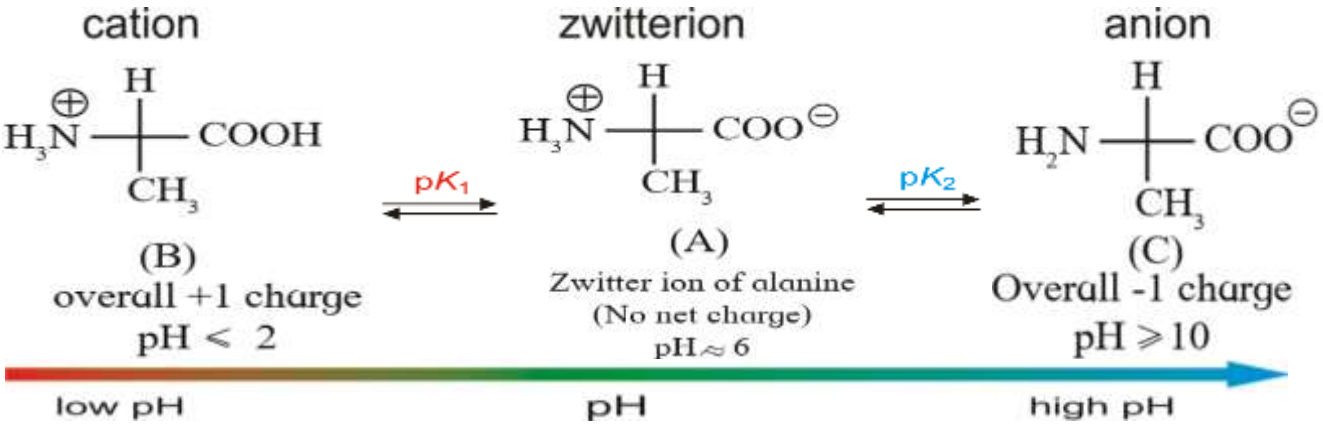
NOTE: - 1

∝ - amino acids have high melting points compared to the corresponding amines or carboxylic acids of comparable molecular mass because the peculiar structure called zwitter ion structure of ∝ - amino acids formed when it dissolved in water.

Formula	Molecular mass	Melting point
$CH_3 - \underset{\displaystyle NH_2}{\underset{|}{CH}} - COOH$	89	293.5°C
$C_5H_{11} - NH_2$	87	-55°C
$C_3H_7 - COOH$	88	-7.9°C

NOTE : - 2

∝ - Amino acid can exist in different forms depending upon the pH of the aqueous solution in which it is dissolved.



<u>Amino acids are the building blocks for proteins.</u>

Proteins $\longrightarrow$ α - Amino acids

Proteins $\longrightarrow$ Polypeptides $\longrightarrow$ α - Amino acids

- ✓ Proteins are polypeptides having *<u>more than 100 amino acid</u>* residues linked by peptide bonds.
- ✓ Polypeptides are formed when more than 10 amino acids linked by peptide bonds.
- ✓ ∝ - amino acids are the simplest form of monomer used to prepare Polypeptide chain and Proteins.

Definition of Peptide bond/Peptide linkage

The bond that connects ∝ - amino acids to each other is called peptide bond.

Explanation:

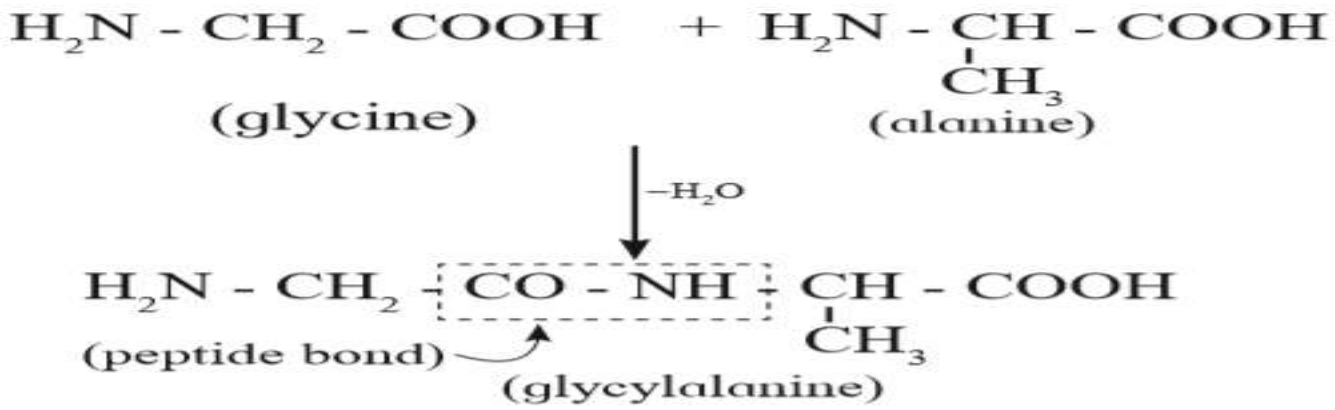
When Amino acids are joined together by peptide bonds, in which the amino group

(– NH_2) of one amino acid bonds to the carboxyl group (–COOH) group of another amino acid.

Note:

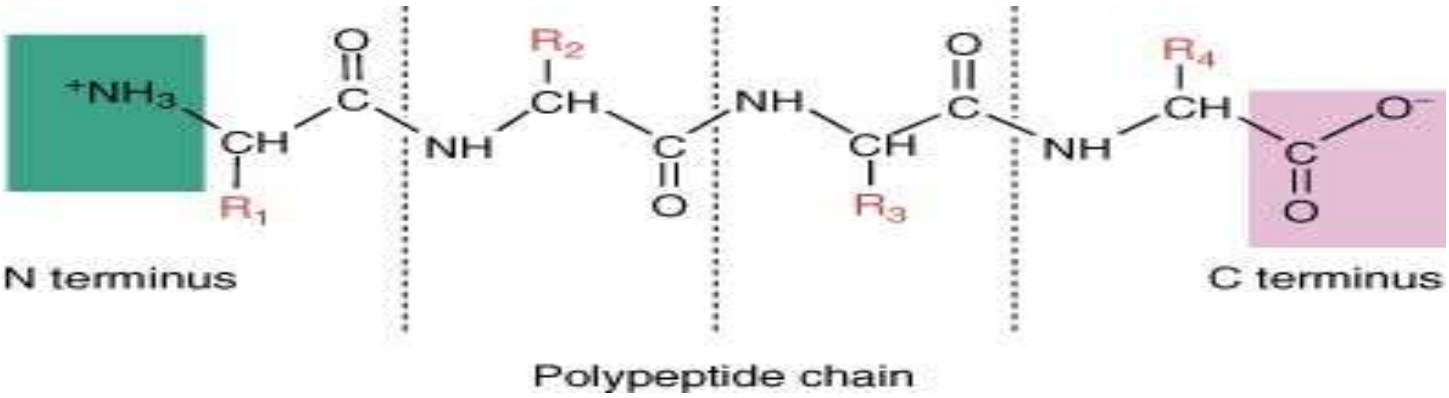
Peptide linkage is same as secondary amide. (–CONH –).

Example:



Explain Polypeptide

- The number of α – amino acids linked by peptide bonds is more than ten, the products are called polypeptides.
- The – CHR – units linked by peptide bond are referred to as 'amino acid residues'.
- The two ends of polypeptide chain of protein are not identical.
- The end having free carboxyl group is called **C – terminal** while the other end having free amino group is called **N –terminal.**



TYPES OF PROTEINS

Depending upon the molecular shape proteins are classified into two types.

a. **Fibrous proteins :**

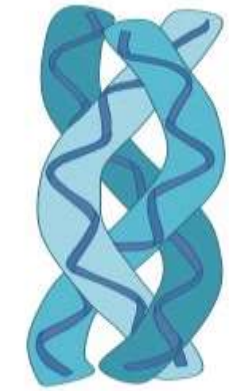
- The proteins in which polypeptide chains lie parallel to each other to form a thread like or rod like structure called Fibrous protein.
- The chains are held together by Hydrogen bonds & Disulfide bonds.
- The proteins are tough and insoluble in water, dil. acid, base, alcohol.
- Examples:

K	Keratin	Hair, Skin , Nails, Horn , Feathers
F	Fibroin	Silk
C	Collagen	Tendons
Meal	Myosin	Muscles

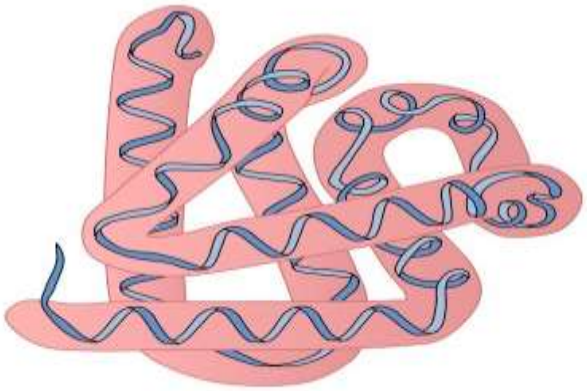
b. **Globular proteins :**

- The proteins in which polypeptide chains are folded to form spherical or coil like structure called Globular protein.
- The chains are held together by intramolecular Hydrogen bonding.
- The proteins are soft and soluble in water, dil. acid , base, alcohol.
- Examples:

H	Haemoglobin	From Blood
A	Albumin	From Egg
T	Thyroglobulin	From Thyroid gland
I	Insulin	From Pancreas



Fibrous Protein



Globular Protein

Note:

The shapes of protein molecules (Fibrous and globular) are the result of four level structure of proteins.

STRUCTURE OF PROTEINS

1. **Primary structure of protein:**

- Primary structure of proteins is the simple sequence of constituent ∝-amino acid residues linked by peptide bonds.
- Primary structure of proteins is represented by writing the three letter symbols of amino acid residues as per their sequence in the concerned protein.
- The symbols are separated by dashes.

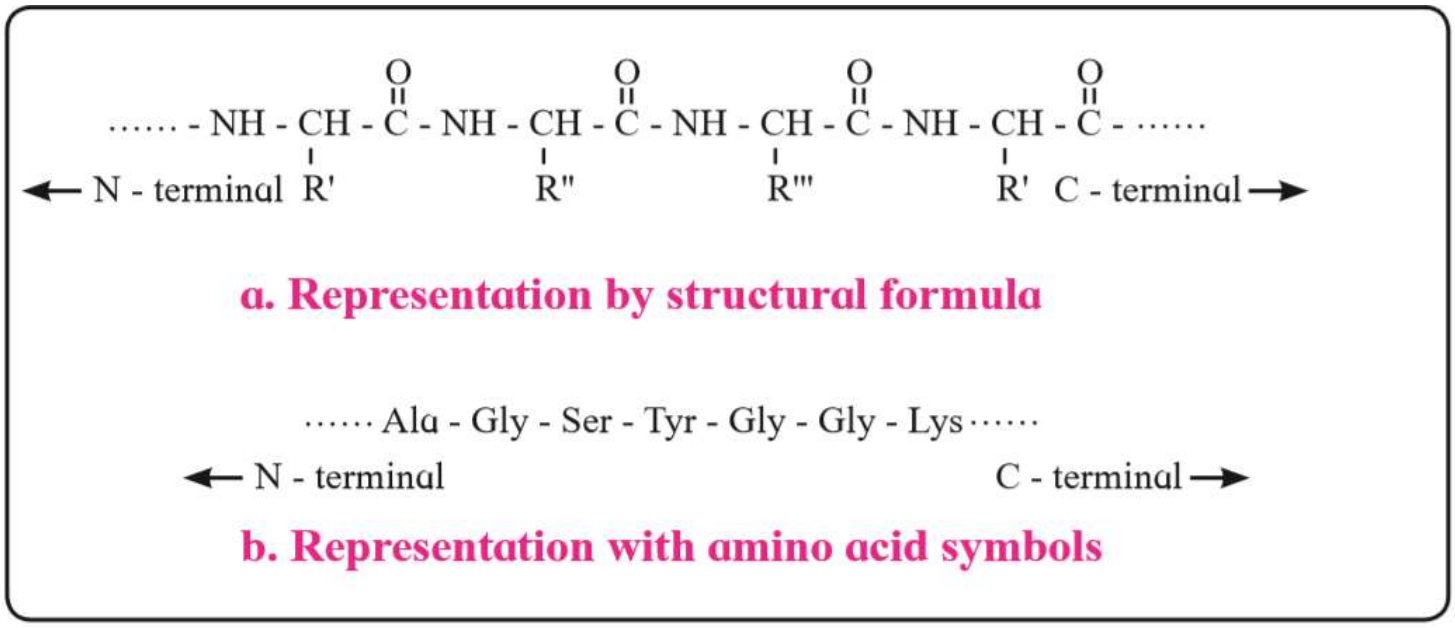
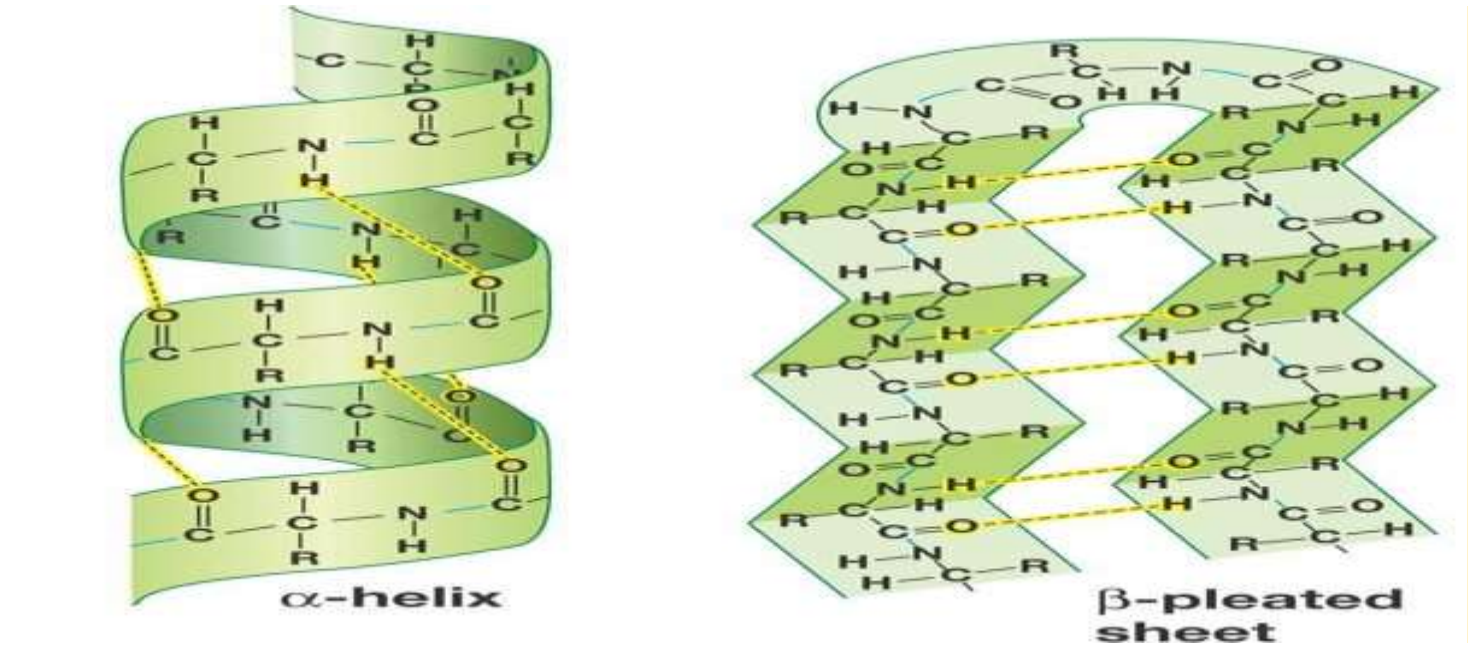


Fig. 14.18 : Representation of primary structure of protein

2. Secondary structure of protein:

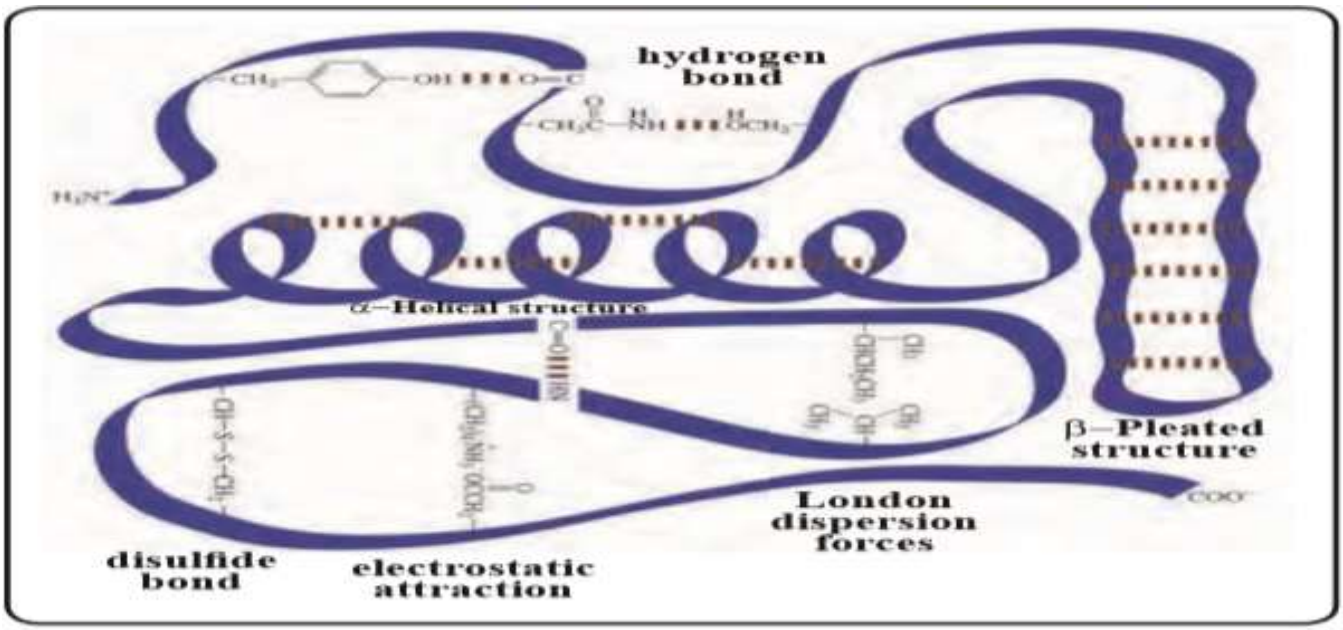
- The three-dimensional arrangement of localized regions of a protein chain is called the secondary structure of protein.
- Hydrogen bonding between N-H proton of one amide linkage and C=O oxygen of another gives rise to the secondary structure.
- The secondary structure of protein refers to the shape in which a long polypeptide chain can exist.
- Two types of secondary structures commonly found in proteins are ∝-helix and β-pleated sheet.

∝-helix	β-pleated sheet.
The ∝-helix forms when a polypeptide chain twists into a right handed or clockwise spiral.	The β – pleated sheet forms when a polypeptide chains lie parallel side by side.
The chain is held together by Intramolecular hydrogen bonding.	The chains are held together by Intermolecular hydrogen bonding.
A C=O group of one amino acid is hydrogen bonded to N-H group of the fourth amino acid along the chain.	Hydrogen bonding occurs between the N-H and C=O groups of nearby amino acid residues in the neighboring chains.



3. Tertiary structure of protein:

- The three-dimensional shape adopted by the entire polypeptide chain of a protein is called its tertiary structure.
- It is the result of folding of the chain in a particular manner that the structure is itself stabilized and also has attractive interaction with the aqueous environment of the cell.
- The globular and fibrous proteins represent two major molecular shapes resulting from the tertiary structure.
- The forces that stabilize a particular tertiary structure include hydrogen bonding, dipole dipole attraction (due to polar bonds in the side chains), electrostatic attraction (due to the ionic groups like $-COO^-$, $NH_3^{\oplus}$ in the side chain), London dispersion forces & disulfide bond.



4. Quaternary structure of protein:

- When two or more polypeptide chains with folded tertiary structures come together into one protein complex, the resulting shape is called quaternary structure of the protein.
- For example: Haemoglobin consists of four subunits called haeme held together by intermolecular forces in a compact three dimensional shape.
- Haemoglobin can do its function of oxygen transport only when all the four subunits are together.

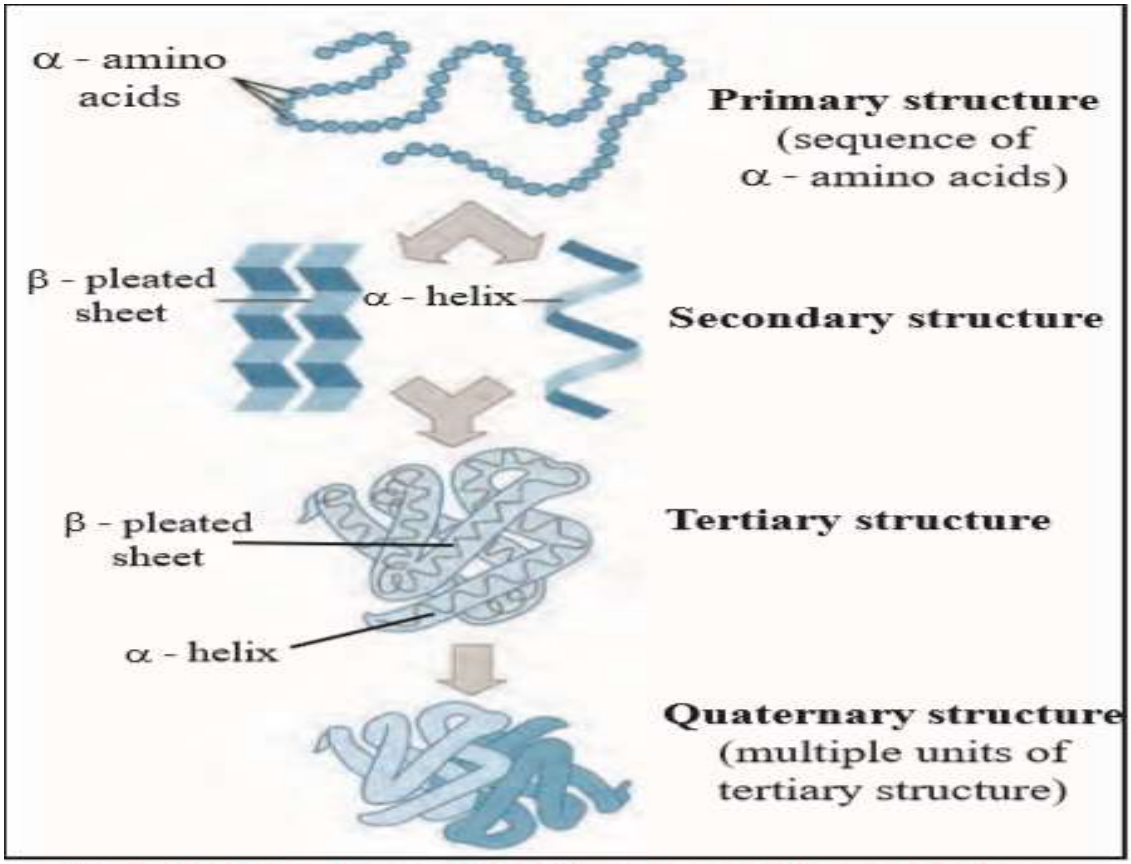


Fig. 14.22 : Four levels of protein structure

DENATURATION OF PROTEINS

DEFINITION:

Denaturation is the process by which the molecular shape of protein changes without breaking the amide/peptide bonds that form the primary structure.

OR

A process that changes the three dimensional structure of native protein is called denaturation of protein.

- Denaturation can be caused by change in pH, heating, cooling, addition of electrolyte, addition solvent like water, alcohol etc.
- Denaturation uncoils the protein, destroy the shape and thus loses their characteristic biological activity.
- For example:

1. Coagulation of Egg
2. Coagulation of Mil

CHEMICAL DISTINGUISH TEST FOR PROTEINS
[For MHT – CET / NEET / JEE]

1. BIURET REAGENT:

TEST:

Protein + 10 % NaOH + Drop of $CuSO_4$ → Reddish Violet

[Presence of –CONH – linkage]

2. MILLON'S REAGENT:

TEST:

Protein + $HgNO_3$ + $Hg(NO_3)_2$ + HNO_3 →

White ppt → (After heating) – Brick red

[Presence of –OH group (phenolic) - Tyrosine]

3. XANTHOPROTIC TEST:

TEST:

Protein + Con. HNO_3 → Yellow → (After heating)

Orange on addition of NH_4OH

[Presence of Benzene ring – Tryptophan , Skin protein]

4.NINHYDRIN SOLUTION:

TEST:

Protein + Dil Ninhydrin → Violet color

[Presence of –CONH – linkage]

PART – III – EXERCISE – IMPORTANT QUESTION (QUESTION – 2/3 Mark)

1. Define Proteins. Write examples of Proteins.
2. Explain the term α – amino acids.
3. How are α – amino acids classified on the basis of side chain?
4. What are essential amino acids? Write two examples.
5. Explain Zwitter ion.
6. What is peptide bond? How is it formed?
7. Write a short note on polypeptide.
8. Explain the following terms:
   a. Globular proteins
   b. Fibrous proteins
9. Write a note on primary structure of proteins.
10. Write a note on $2^0/3^0$ structure of proteins.
11. Explain denaturation of protein.

PART: IV – ENZYMES:

INTRODUCTION:

- It is a naturally occurring biomolecules.
- The term Enzyme is derived from Greek word "in leaven" or "in yeast", to describe this process.

DEFINITION OF ENZYMES;

Enzymes are naturally occurring bio-catalyst produced by living cells which catalyze many biological reaction in plants and animals.

OR

The proteins which perform the role of biological catalysts in the body are called enzymes.

EXPLANATION:

Every living cell contains at least 1000 different enzymes.
Most enzymes catalyze only one reaction or one group of similar reactions. Thus, enzyme catalysis is highly specific.

EXAMPLES:

1. **Insulin**, an enzyme secreted by pancreas, controls blood sugar level.
2. **Amylase**, an enzyme present in saliva, hydrolyzes starch into Glucose.

$$\text{Starch} \xrightarrow[\textit{Amylase}]{\text{Hydrolysis}} \text{n Glucose}$$

3. **Maltase**, an enzyme which hydrolyzes maltose into Glucose.

$$\text{Maltose} \xrightarrow[\textit{Maltase}]{\text{Hydrolysis}} \text{2 molecule of Glucose}$$

4. **Lactase**, an enzyme which hydrolyzes lactose into Galactose & Glucose.

$$\text{Lactose} \xrightarrow[\textit{Lactase}]{\text{Hydrolysis}} \text{Galactose \& Glucose}$$

5. **Zymase**, an enzyme that catalyzes the fermentation of sugar into ethanol and carbon dioxide.

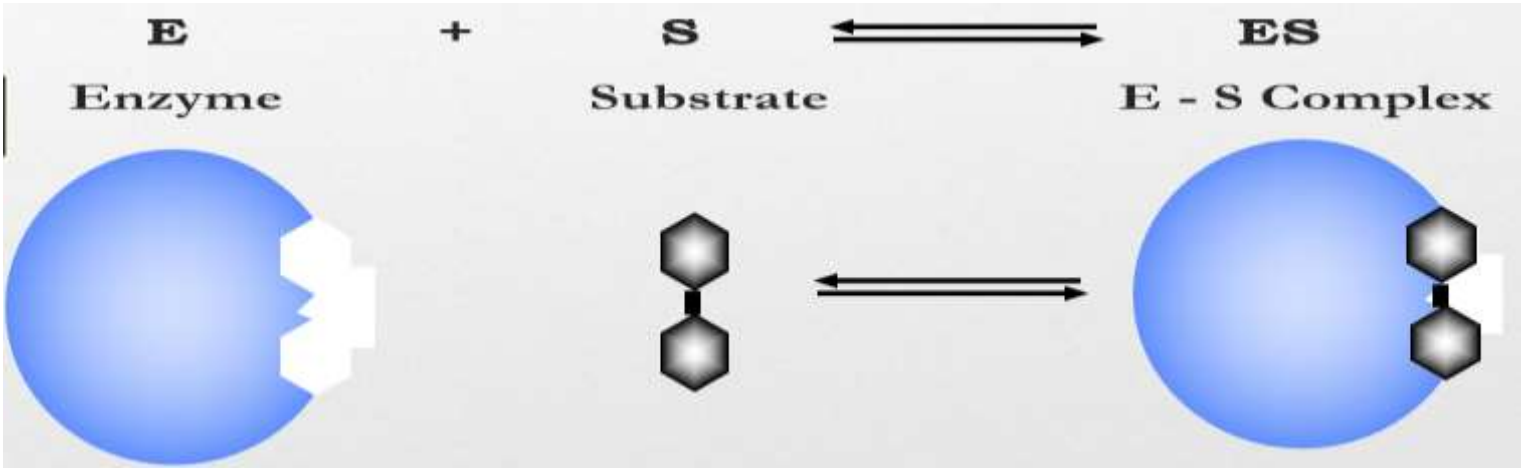
$$\text{Glucose} \xrightarrow{\textit{Zymase}} \text{Ethanol \& Carbon dioxide.}$$

MECHANISM OF ENZYME: (How Enzyme work as Bio – catalyst?)

- Action of an enzyme on a substrate is described as lock-and-key mechanism. Mechanism is divided in to 3 Steps.

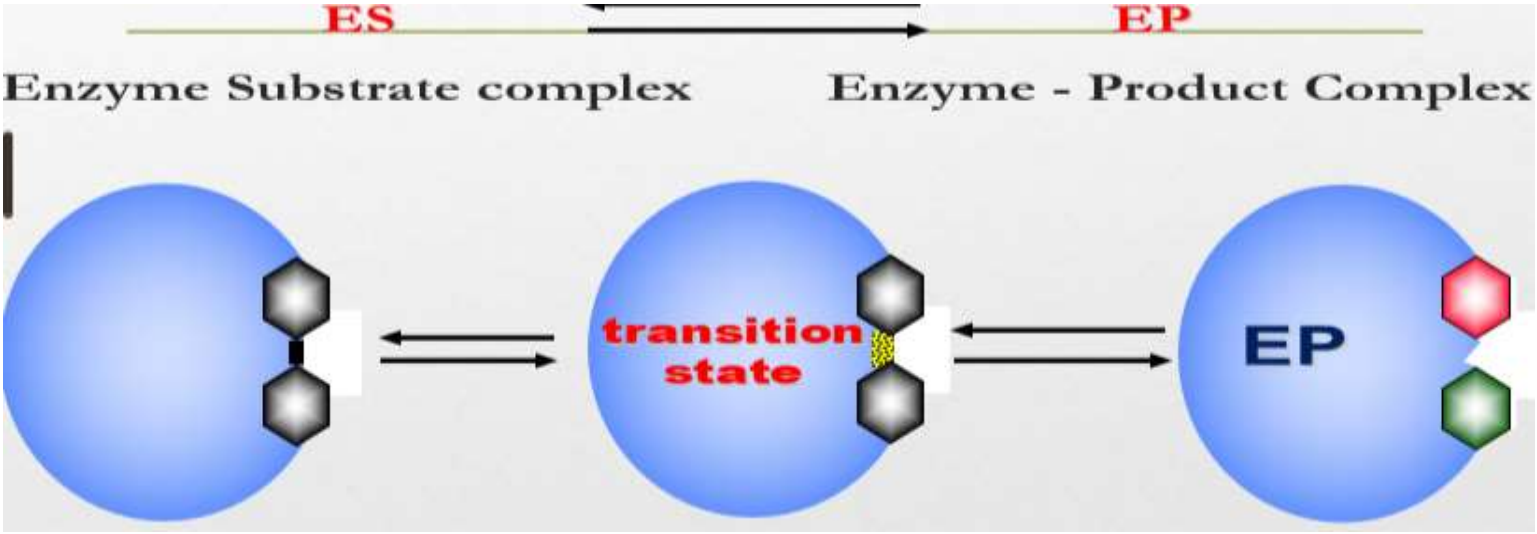
STEP – I – FORMATION OF ENZYME – SUBSTRATE COMPLEX

A substrate molecule can attach to this active site only if it has the right size and shape. Once in the active site, the substrate is held in the correct orientation to form enzyme – substrate complex.



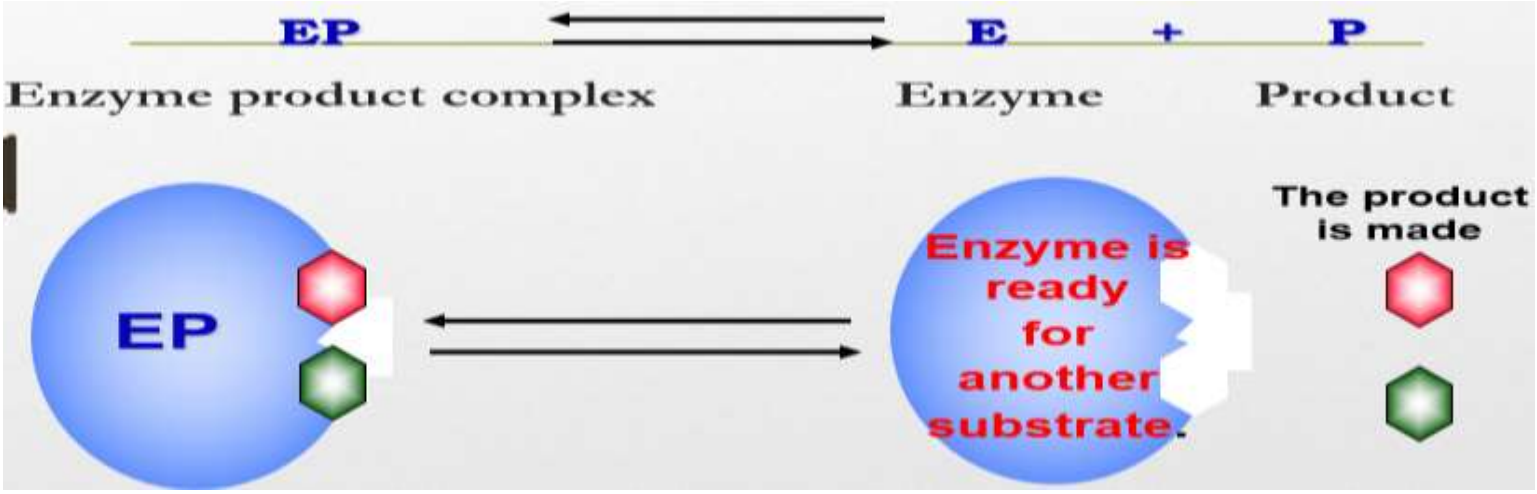
STEP – II – FORMATION OF ENZYME – PRODUCT COMPLEX

An enzyme – substrate complex slowly gets converted to Enzyme product complex because of breaking of old bond & making of new bonds.

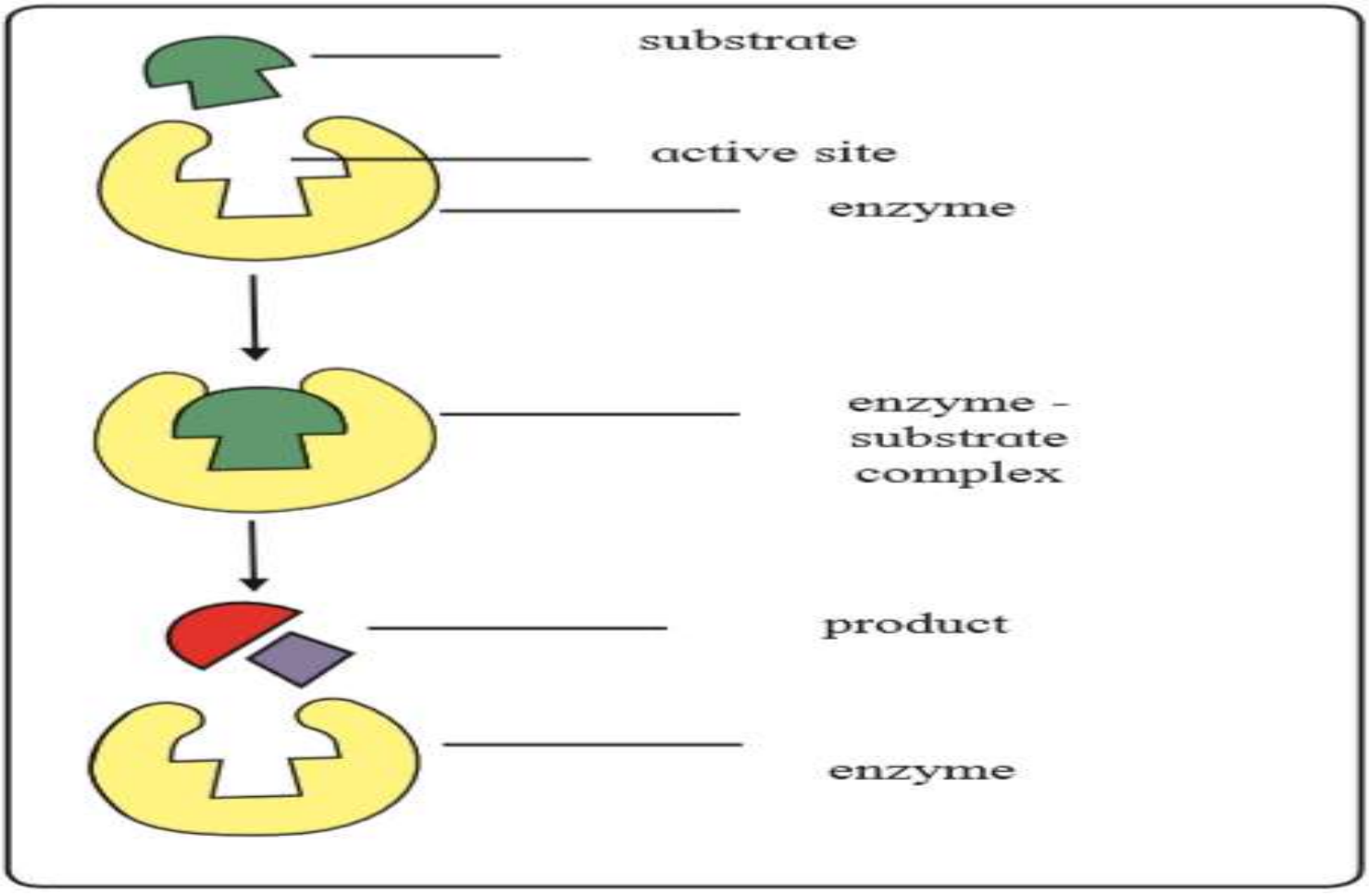


STEP – III – SEPARATION OF ENZYME & PRODUCTS:

Once the enzyme – product complex formed, products leave the active site and the enzyme is then ready to act as catalyst again.



BELOW REPRESENTATION IS FROM GOVERNMENT TEXTBOOK



INDUSTRIAL APPLICATION OF ENZYME

- Conversion of glucose to sweet-tasting fructose, using glucose isomerase.
- Manufacture of new antibiotics, using penicillin G acylase.
- Manufacture of laundry detergents, using proteases.
- Manufacture of esters used in cosmetics, using genetically engineered enzyme.
- Manufacture of cheese from Milk.

PART – IV – EXERCISE – IMPORTANT QUESTION (QUESTION – 2/3 Mark)

1. Define Enzyme. Write examples of Enzyme.
2. Explain the mechanism of Enzyme.
3. Write the application of Enzyme.