02 Biomolecules

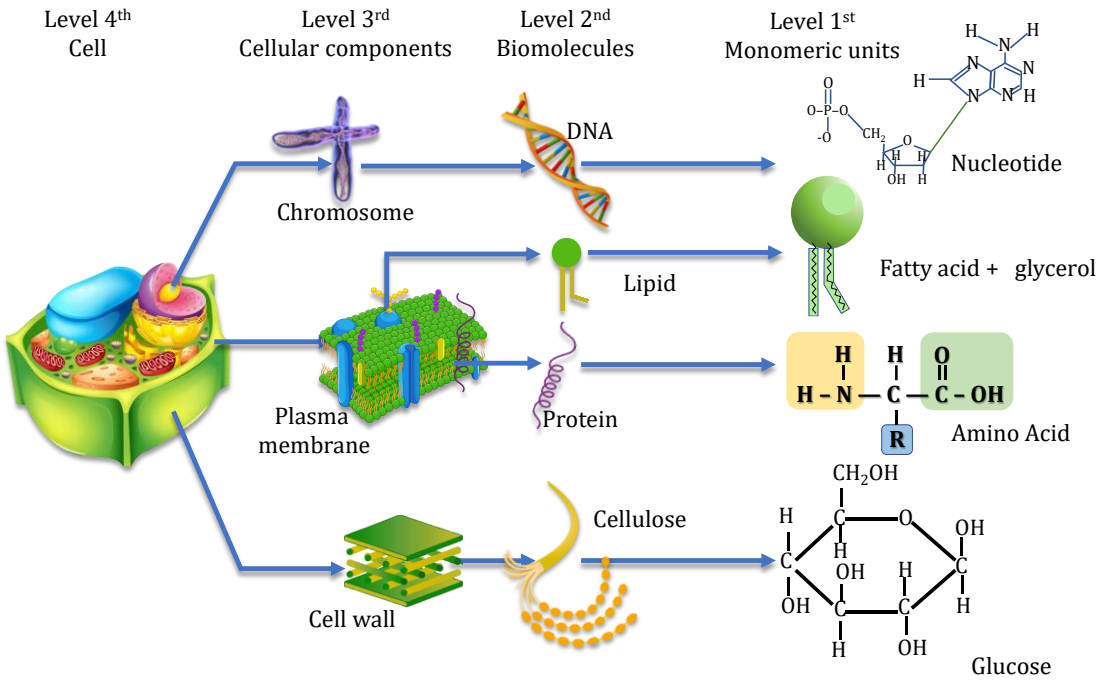


Fig. : Schematic representation from cellular level to molecular level

01. INTRODUCTION

All the organic compounds/molecules that can be obtained from a living cell/tissue/organism are known as biomolecules.

There is a wide diversity in living organisms in our **biosphere** (part of the earth's surface and atmosphere in which plants and animals can live).

Now a question that arises in our minds is: Are all living organisms made of the same chemicals, i.e., elements and compounds?

- All living organisms are made up of the same elements and compounds.
- If we perform an analysis of a plant tissue, animal tissue or a microbial paste, Carbon, Hydrogen, Oxygen and several other elements are obtained.
- The same analysis made on a non-living matter like a piece of Earth's crust, gives a list of similar chemicals.
- A close examination reveals that the relative abundance of **Carbon** and **Hydrogen** with respect to other elements is higher in living beings than in Earth's crust.

02. HOW TO ANALYSE CHEMICAL COMPOSITION ?

- Various biomolecules present in a living tissue (like a vegetable or a piece of liver) can be studied by their chemical analysis.

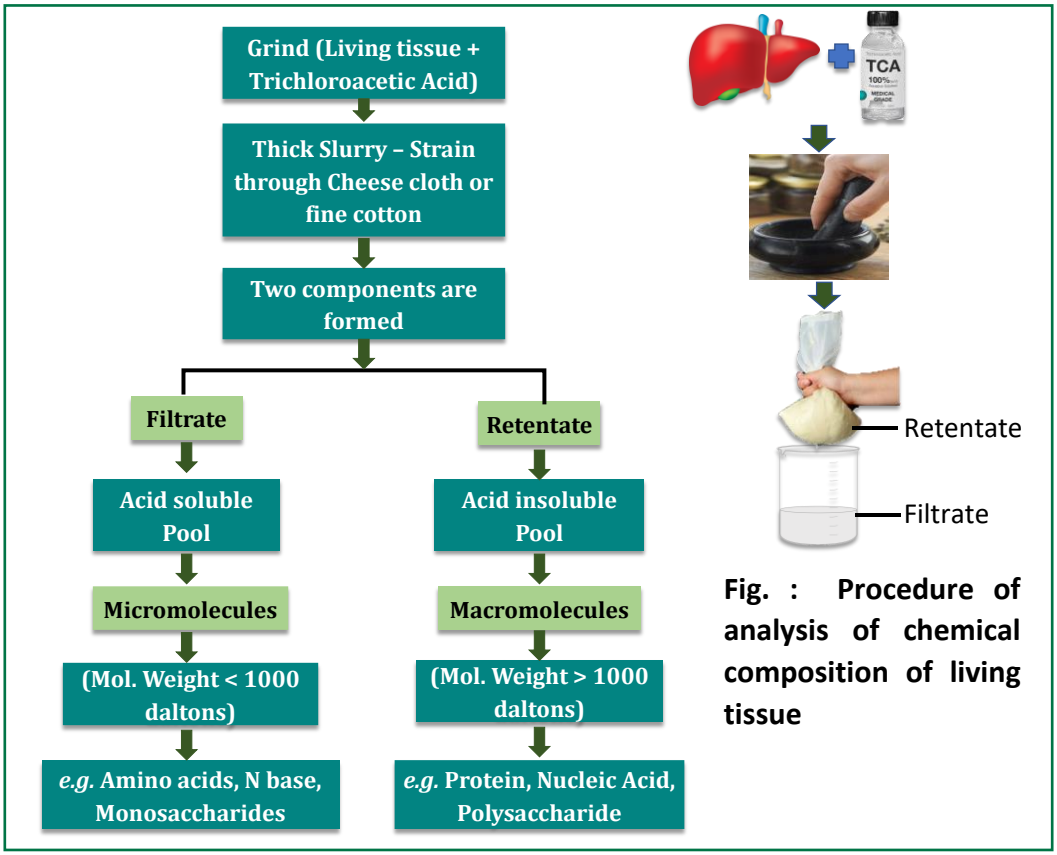


Fig. : Procedure of analysis of chemical composition of living tissue

- Take a living tissue and grind it in **Trichloroacetic acid (Cl_3CCOOH)** using a mortar and pestle. We obtain a thick slurry.
- When we strain this slurry through cheese cloth or cotton, it gives two fractions.
- One is called filtrate or acid soluble pool having thousands of organic compounds.
- Other fraction is called retentate or acid insoluble pool containing proteins, nucleic acid, polysaccharides etc.

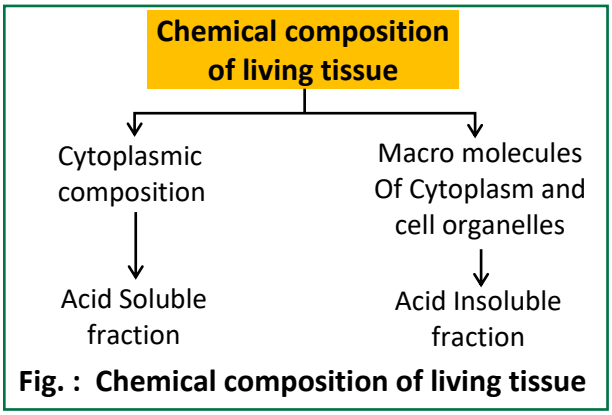


Fig. : Chemical composition of living tissue

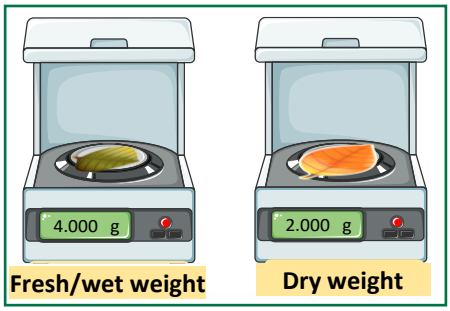
- **The acid soluble** pool contains chemicals with small molecular mass of 18–800 daltons approximately. They are called **macromolecules or biomacromolecules**. They include amino acids, sugars, nucleotides etc.
- The acid-insoluble fraction contains organic compounds that have molecular weights in the range of ten thousand daltons and above. They are known as **macromolecules or biomacromolecules**. They include polysaccharides, proteins, nucleic acids.

NCERT Question :

What are macromolecules? Give examples.

- The **acid-soluble** fraction represents roughly the cytoplasmic composition (without organelles), while the acid insoluble fraction represents the macromolecules of the cytoplasm and cell organelles. The two fractions together represent the entire chemical composition of living tissues or organisms.
- **Lipids are not strictly macromolecules**. Their molecular weight do not exceed 800 Da, but they come under the macromolecular fraction because when we grind a tissue, cell membrane and other membranes are broken into pieces and **form vesicles** which are not water soluble (lipids are also present in structures like cell membrane and other membranes).

ANALYSIS OF INORGANIC ELEMENTS AND COMPOUNDS :



- Inorganic elements and compounds are also present in the living organisms which can be known with the help of **'Ash' analysis technique**.
- A small amount of a living tissue (e.g. Leaf or liver) is weighed (this is called wet weight) and dried. All the water evaporates.
- When the tissue is fully burnt, the Carbon compounds are oxidised to gaseous form like CO_2, water vapour are removed and the remnant is called 'Ash'. This ash contains many inorganic elements like Calcium, Magnesium etc.

Fig. : Ash Analysis

- In the acid-soluble fraction - inorganic compounds like Sulphates, Phosphates etc are also present.
- Elemental analysis gives composition of living tissue in the form of O, C, H, N etc.
- Analysis of compounds gives an idea of the kind of organic and inorganic constituents as mentioned in the table.

A List of Representative Inorganic Constituents of Living Tissues

Component	Formula
Sodium	Na^+
Potassium	K^+
Calcium	Ca^{++}
Magnesium	Mg^{++}
Water	H_2O
Compounds	NaCl, $CaCO_3$, PO_4^{3-}, SO_4^{2-}

* **The concentration of cation inside the cell i.e. ICF is $K^+ > Na^+ > Ca^{++}$**
* **The most abundant cation in ECF is Na^+ ion.**

Table: A comparison of elements present in non-living and living matter

Element	% weight of	
	Earth's crust	Human body
Hydrogen (H)	0.14	9.5
Carbon (C)	0.03	18.5
Oxygen (O)	46.6	65.0
Nitrogen (N)	**Very little**	3.3
Sulphur (S)	0.03	0.3
Sodium (Na)	2.8	0.2
Calcium (Ca)	3.6	1.5
Magnesium (Mg)	2.1	0.1
Silicon (Si)	27.7	**Negligilble**

METABOLITES :

- Metabolites are the intermediate products of metabolism. (**Metabolism** is a term that is used to describe all **chemical reactions** involved in maintaining the living state of the cells and the organism)

03. PRIMARY AND SECONDARY METABOLITES

Primary metabolites	Secondary metabolites
These are essential for the growth or reproduction of an organism.	These are not essential for the growth or reproduction of an organism.
These are found in all organisms.	These are not found in all organisms. e.g. plant, fungal, and microbial cells.
Their physiological roles are known.	Their physiological roles are not known. However, these may have ecological or economic importance.
E.g. Amino acids, sugars, fatty acids, nucleotides etc.	**E.g.** (1) Alkaloids such as morphine, codeine (2) Drugs such as vinblastin (3) Antibiotics

TABLE: - Some Secondary Metabolites

Pigment	Carotenoids, Anthocyanins, etc.
Alkaloids	Morphine, Codeine, etc.
Terpenoides	Monoterpenes, Diterpenes etc.
Essential oils	Lemon grass oil, etc.
Toxins	Abrin, Ricin
Lectins	Concanavalin A
Drugs	Vinblastin, Curcumin, etc.
Polymeric substances	Rubber, Gums, Cellulose

The acid insoluble fraction, has only **four types** of organic compounds: -

1. Proteins 2. Nucleic acids 3. Polysaccharides 4. Lipids

- These classes of compounds with the exception of lipids, have molecular weights in the range of ten thousand daltons and above. For this very reason, biomolecules, i.e., chemical compounds found in living organisms are of two types. One, those which have molecular weights less than one thousand dalton and are usually referred to as micromolecules or simply biomolecules while those which are found in the acid insoluble fraction are called macromolecules or **biomacromolecules**.
- The molecules in the insoluble fraction with the exception of lipids are polymeric substances.
- Then why do lipids, whose molecular weights do not exceed 800 Da, come under acid insoluble fraction, i.e., macromolecular fraction?
- Lipids are indeed small molecular weight compounds and are present not only as such but also arranged into structures like cell membrane and other membranes. When we grind a tissue, we are disrupting the cell structure. Cell membrane and other membranes are broken into pieces, and form vesicles which are not water soluble. Therefore, these membrane fragments in the form of vesicles get separated along with the acid insoluble pool and hence in the macromolecular fraction.
- **Lipids are not strictly macromolecules.**
- The acid soluble pool represents roughly the cytoplasmic composition. The macromolecules from cytoplasm and organelles become the acid insoluble fraction. Together they represent the entire chemical composition of living tissues or organisms**. Water is the most abundant chemical in living organisms.**

Average composition of Cells

Component	% of the total cellular mass
Water	70-90
Proteins	10-15
Carbohydrates	3
Lipids	2
Nucleic acids	5-7
Ions	1

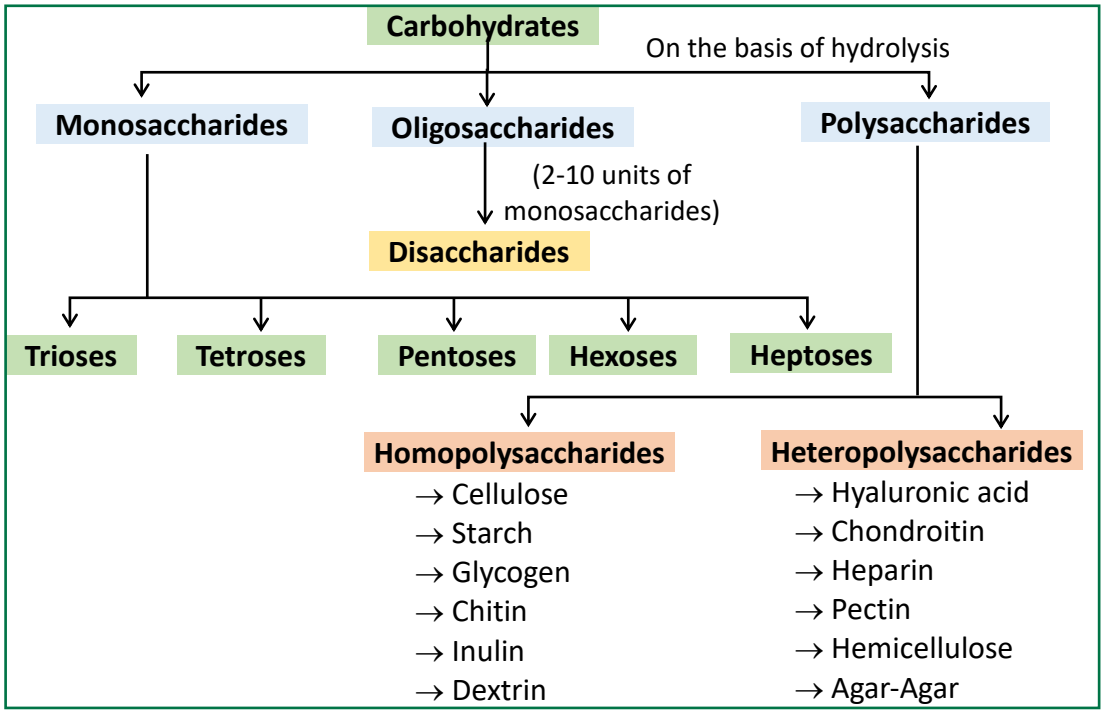
Note :-
In dry weight of an animal cell, protein forms 60 - 70% part.
In dry weight of a plant cell, carbohydrate forms 80% part because plant cell wall is made up of cellulose.

04. CARBOHYDRATES

- Main source of energy.
- First respiratory substrate – carbohydrate
- Compounds of Carbon, Hydrogen and Oxygen with ratio of H and O is 2:1, so they are also called as **Hydrates of Carbon**.
- Generalised formula of carbohydrates is $\mathbf{C_x(H_2O)_y}$, e.g. $C_6H_{12}O_6$ or $C_6(H_2O)_6$
- Chemically all carbohydrates are **polyhydroxy aldehydes or ketones**.
- Simple carbohydrates which are soluble in water and sweet in taste are called "**Sugars**"

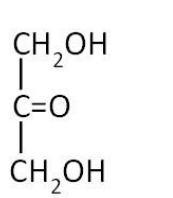
CLASSIFICATION OF CARBOHYDRATES :

On the basis of number of saccharide units obtained upon hydrolysis, Carbohydrates are classified as:

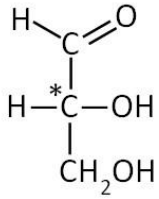


(A) MONOSACCHARIDES :

- They are simplest sugars which cannot be further hydrolysed.
- In their generalised formula x is mostly equal to y i.e. number of Carbon and Oxygen atoms are same.



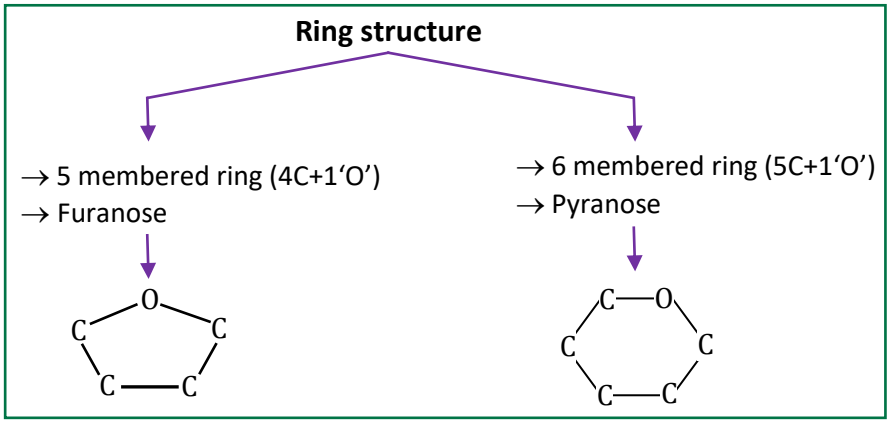
Dihydroxyacetone
(Chiral Carbon Absent)



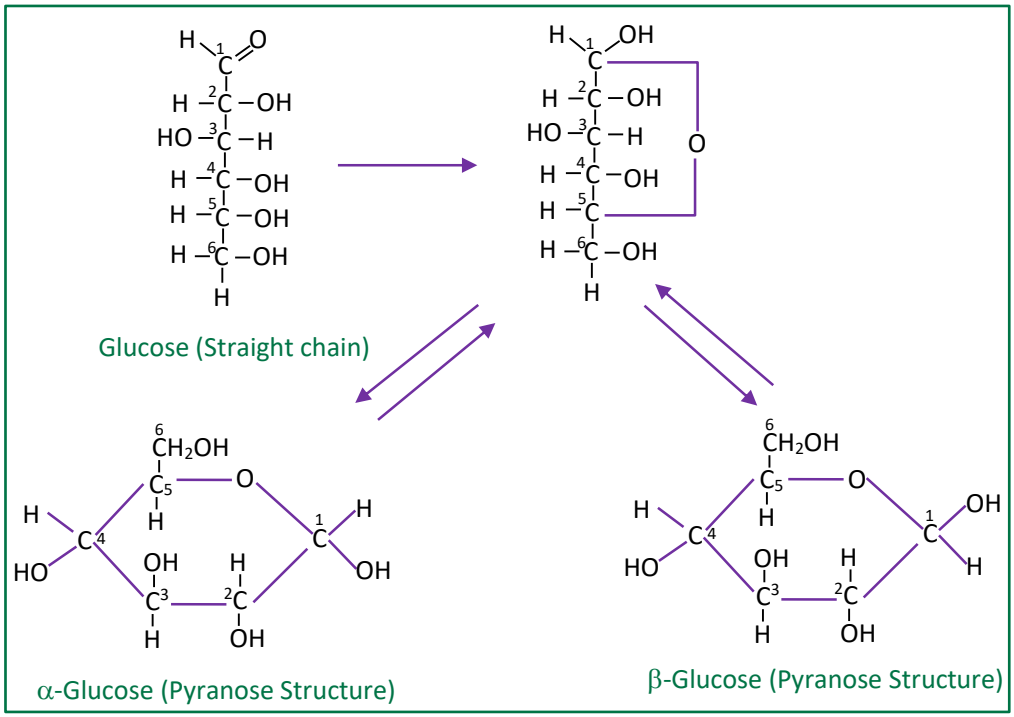
Glyceraldehyde
(Chiral Carbon Present)

- All monosaccharides occur in d and l form, except the **Dihydroxyacetone** because chiral carbon is absent in **Dihydroxyacetone.**

  Chiral Carbon :- A Carbon atom that is attached to four different types of atoms or groups of atoms.
- The structure of saccharides is either ring or straight chain.
- A six membered ring is known as pyranose and five membered ring is furanose**. Pyranose** and **furanose** name were given by "**Haworth**."

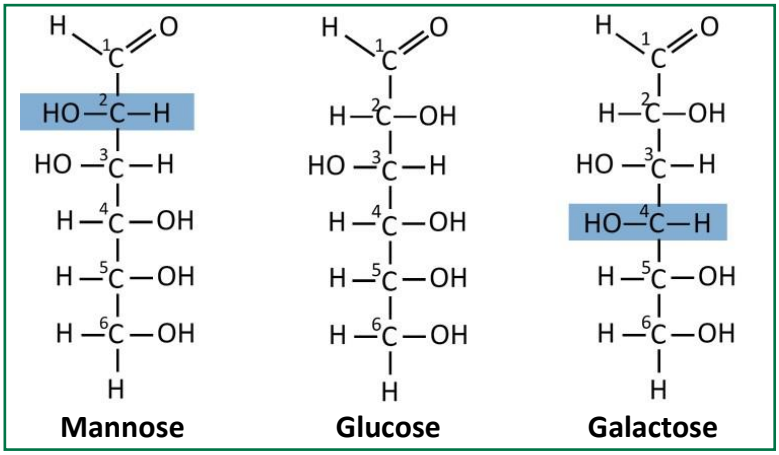


1. **Anomers** – In aqueous solution, Glucose mainly occurs in cyclic structure. In anomers, position of –H and –OH groups are changed at anomeric carbon (C1 in case of glucose). **Anomers exist only** in **cyclic forms**.



2. **Epimers :** Isomers formed as a result of interchange of the –OH and –H groups on just one carbon atom, for example C-2 or C-4 of glucose, are known as epimers. **Epimers exist in both linear and cyclic forms**.

Epimers of Glucose : Mannose (Difference on C_2 carbon) , Galactose (Difference on C_4 carbon)

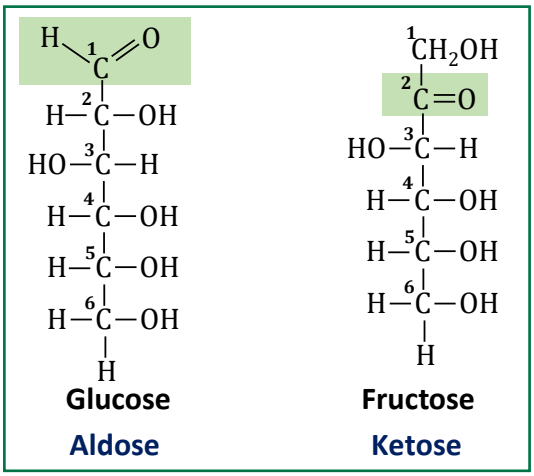


Classification of monosaccharides on the basis of number of Carbon atoms

Trioses (3C)	Tetroses (4C)	Pentoses (5C)	Hexoses (6C)	Heptoses (7C)
$C_3H_6O_3$	$C_4H_8O_4$	$C_5H_{10}O_5$	$C_6H_{12}O_6$	$C_7H_{14}O_7$
(Simplest monosaccharides) Dihydroxy – acetone, Glyceraldehyde	Erythrose Erythrulose	Xylose Xylulose Deoxyribose Deoxyribose Arabinose Ribose Ribulose	Glucose Fructose Galactose Mannose	Sedoheptulose

Note :

- Monosaccharides with free aldehyde group are termed as **Aldoses** (PGAL, Erythrose, Ribose, Arabinose, Deoxyribose, Glucose, Galactose, Mannose).
- While monosaccharides with free ketone group are called **Ketoses** (DHAP, Erythrulose, Ribulose, Xylulose, Fructose, Sedoheptulose).



Important Examples of Hexoses

Glucose :

- Most abundant organic compound on Earth.
- More abundant in grapes so also known as **grape sugar**.
- Most abundant sugar in blood so known as **blood sugar**.
- **Main respiratory substrate**.
- It rotates PPL (Plane Polarised Light) in right direction so it is dextrorotatory and also known as **dextrose**.

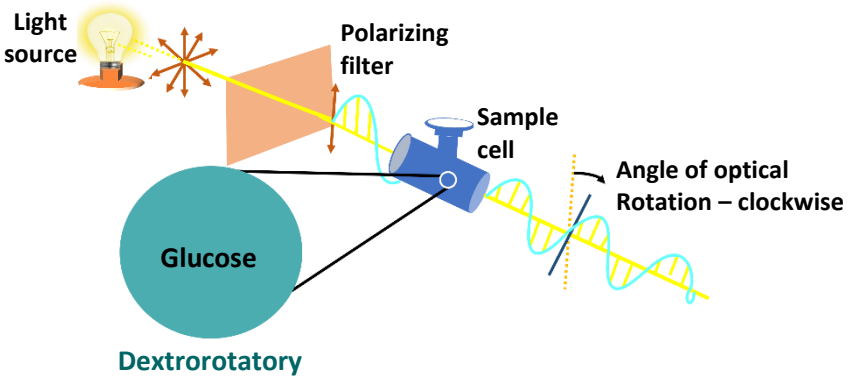


Fig. : Dextrorotatory nature of Glucose

Fructose :

- **Sweetest carbohydrate.**
- More abundant in honey and sweet fruits, so also known as **fruit sugar**.
- Rotates PPL (Plane Polarised Light) in left direction so it is laevorotatory and also known as **'Laevulose**

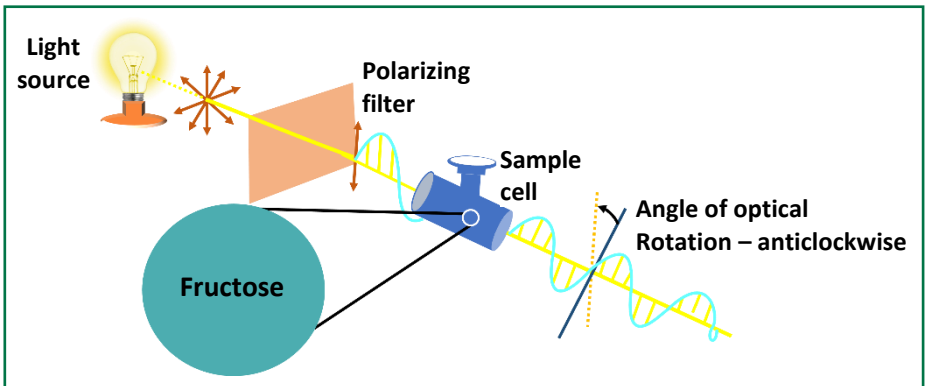


Fig. : Laevorotatory nature of Fructose

Galactose :

- Most abundant in brain and nervous tissue so called as **'brain sugar'**.
- It rarely occurs in free form. It mostly occurs as a component of some compounds.
  e.g. Hemicellulose, Lactose, Pectin, Glycolipid

Mannose :

- It also rarely occurs in free form.
- It is present as a component of some compounds.
  e.g. Hemicellulose – Wood

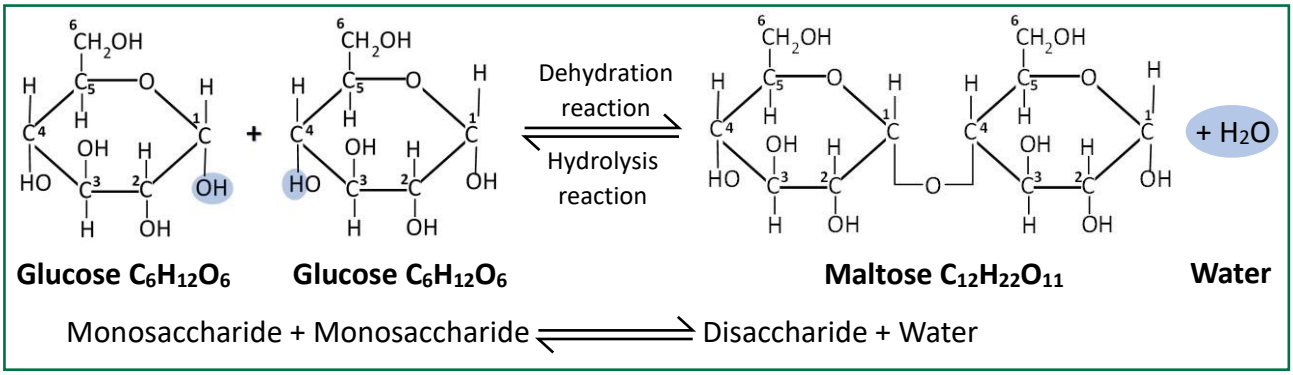
(B) OLIGOSACCHARIDES :

- Oligosaccharides are those carbohydrates which on hydrolysis yield 2 to 10 monosaccharide units (monomers).
- In oligosaccharides, monosaccharides are linked together by **glycosidic bonds.**
- Aldehyde or ketone group of one monosaccharide reacts with alcoholic group of another monosaccharide to form glycosidic bond.
- One molecule of H_2O eliminates during glycosidic bond formation **(dehydration synthesis).**
- Direction of glycosidic bond is mostly 1'-4".
- When another monosaccharide unit is fructose then the direction of linkage is 1'-2". (Non-reducing sugars). For ***e.g.*** Sucrose

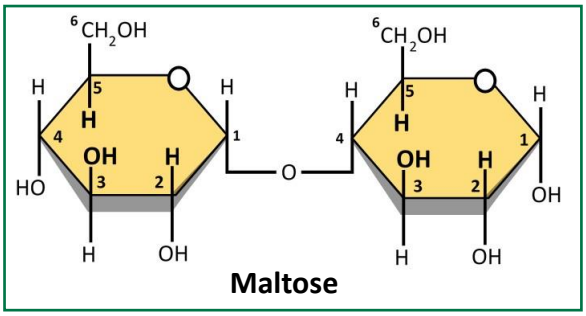
Types of oligosaccharide -

Disaccharides :

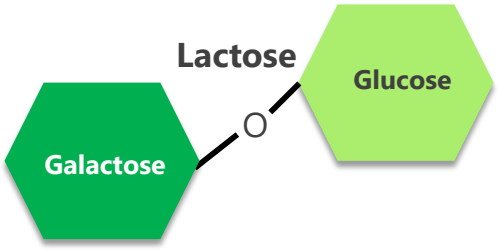
- Composed of two monosaccharide units. e.g. Maltose, Sucrose, Lactose, Trehalose.
- All disaccharides are water soluble and sweet in taste, so they are known as **sugar**.



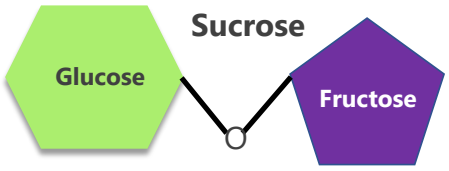
➢ **Maltose–** Maltose is commonly called **malt sugar**. It is an intermediate compound in starch digestion. Maltose is more abundant in germinating starchy seeds.



➢ **Lactose–** Lactose is **milk sugar** Lactose is least sweet sugar. Maximum % of lactose in human milk ≈ 7



➢ **Sucrose :** In plants, transport of sugars mainly occurs in the form of sucrose. Sucrose is also known as **Invert sugar**. Sucrose is called **Cane Sugar** or **Table Sugar** or **Commercial Sugar**.



➢ **Trehalose :** Trehalose is present in haemolymph of insects.

Summary Table for Disaccharides

S. No.	Disaccharide	Monosaccharide units	Type of glycosidic bond	Nature
1.	Maltose	α – D – Glucose + α – D – Glucose	α 1 $\rightarrow$ 4	Reducing
2.	Lactose	β – D – Glucose + β – D – Galactose	β 1 $\rightarrow$ 4	Reducing
3.	Sucrose	α – D – Glucose + β – D – Fructose	1 $\leftrightarrow$ 2	Non-reducing
4.	Trehalose	α – D – Glucose + α – D – Glucose	1 $\leftrightarrow$ 1	Non-reducing

Note : Concept of Reducing & Non-reducing sugars

$Cu^{2+} + e^{-} \xrightarrow{\text{Reduction of Cupric ion}} Cu^{+}$

Present in Benedict's and Fehling's solution **(Blue in colour)**

gets precipitated as Cuprous oxide **(Red in colour)**

- All monosaccharides are reducing in nature.
- Some disaccharides/oligosaccharides are reducing in nature while others are non-reducing in nature. **(Sucrose and Trehalose)**
- All polysaccharides are non-reducing in nature.

(C) POLYSACCHARIDES :

Polysaccharides/Glycans :

- Polysaccharides are composed of large number of monosaccharide units.
- Polysaccharides are insoluble in water and do not taste sweet.
- **All polysaccharides are non-reducing but in a polysaccharide chain, the right end is called the reducing end and the left end is called the non-reducing end.**
- According to function, they are classified as nutritive and structural.

Polysaccharides

Nutritive	**Structural**
Present as stored food	Used in structure formation
e.g. Starch & Glycogen	**e.g.** Cellulose & Chitin

On the basis of type of monomers, they are classified as -

Polysaccharides

Homopolysaccharides	**Heteropolysaccharides**
→ Cellulose	→ Hyaluronic acid
→ Starch	→ Chondroitin
→ Glycogen	→ Heparin
→ Chitin	→ Pectin
→ Inulin	→ Hemicellulose
→ Dextrin	

(I) Homopolysaccharides :- **Composed of same monomers**. Biologically important homopoly-saccharides are as follows:

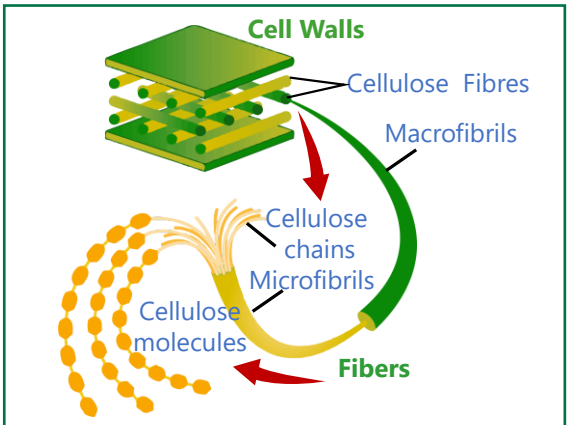


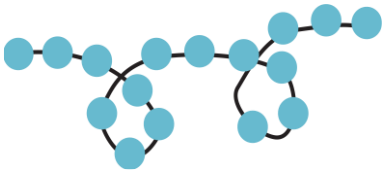
Fig. : Plant cell wall made up of cellulose

(a) Cellulose : Unbranched, linear polymer of **β-D-glucose units (6000 to 10,000)**. It has β 1'-4" linkage.

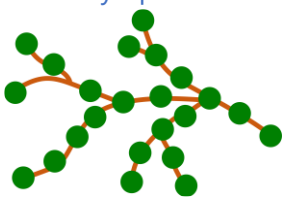
- Cellulose is main component of plant cell wall. In wood, cellulose is 50% and in cotton, it is 90%.
- Most **abundant organic compound** of the plant kingdom.
- It is also used to form **Rayon fibre (Artificial silk)**.
- Paper made from plant pulp is cellulose.

(b) Starch : It is main stored food in plants. Starch is polymer of **α-D-glucose units**. Starch gives blue colour with iodine solution. Starch consists of two types of chains

20% amylose

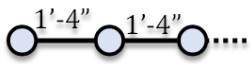
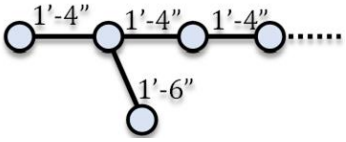


80% amylopectin



- Starch present in potato contains **20% amylose** and **80% amylopectin**.

Starch consists of two type of chains

Amylose **(Unbranched chain)**	**Amylopectin** **(Branched chain)**
α 1'-4" linkage  	α 1'-4" linkage & α 1'-6" linkage  At branching points α 1'-6" linkage Branching occurs at approximately every 24-30 α-D-Glucose units
Made up of less number of α-D Glucose units	Made up of more number of α-D Glucose units

(c) **Glycogen :–** Storage form of carbohydrate in animals, storage region of glycogen is **liver** and **muscles**. Storage of glycogen in liver > muscles. Glycogen is also called as **animal starch**.

- Glycogen is **highly branched** polymer of α -D-glucose. It is made up of approximately **6,00,000 α -D-Glucose units**.
- Glycogen has 1'-4" glycosidic linkage at long chain and 1'-6" glycosidic linkage at branching point. Branching occurs at approximately 8-12 glucose units.

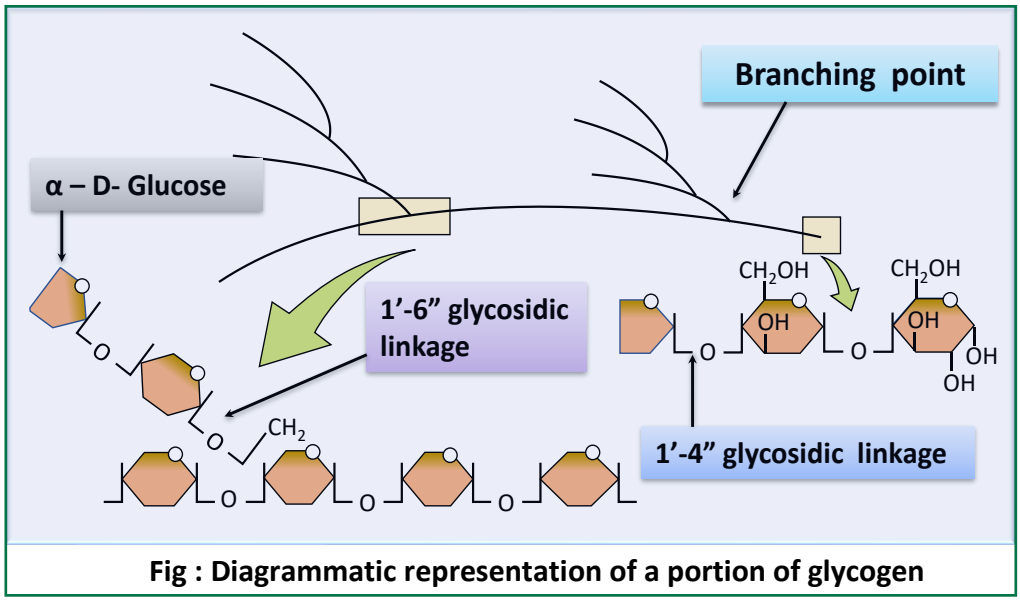


Fig : Diagrammatic representation of a portion of glycogen

(d) **Chitin :** Linear polymer of **N-acetyl-D-glucosamine**.

Chitin is an important component of exoskeleton of Arthropods and cell wall of fungi. It is also called as **Fungal cellulose**.

Exoskeleton of arthropods is made up of chitin

(e) **Inulin :** Linear polymer of 25-35 fructose units linked by β -1'-2" bonds. Inulin is found in roots of Dahlia and Artichoke. Inulin is a **water-soluble polysaccharide**.

It is smallest storage polysaccharide.

(f) **Dextrin** – Dextrin is an intermediate substance obtained by the digestion of glycogen and starch. By hydrolysis of **dextrin, maltose and glucose are formed**.

$$\text{Dextrin} \xrightarrow{\text{Hydrolysis}} \text{Maltose} \longrightarrow \text{Glucose}$$

Summary Table for Homopolysaccharides

S. No.	Name of homopolysaccharide	Monomer	Type of glycosidic bond
1.	Cellulose (Unbranched)	β – D – Glucose	β 1 → 4
2.	Chitin (Unbranched)	N – acetyl – D – Glucosamine	β 1 → 4
3.	Starch	α – D – Glucose	α 1 → 4 and α 1 → 6
4.	Glycogen (Highly branched)	α – D – Glucose	α 1 → 4 and α 1 → 6
5.	Inulin (Unbranched)	β – D – Fructose	β 1 → 2

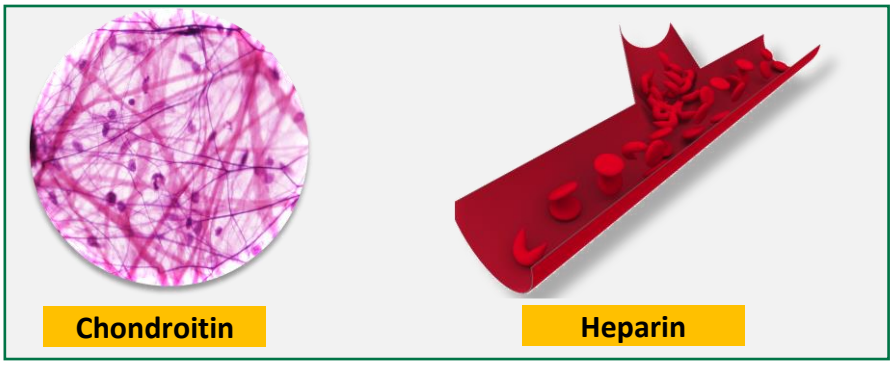
(II) **Heteropolysaccharides :– Composed of different monosaccharide units**.

(a) **Hyaluronic acid** – Found in extracellular matrix of connective tissue in the form of lubricating agent. It also occurs in animal cell coat as binding material **(Animal cement)**. Hyaluronic acid is made up of **D-glucuronic acid** and **N-acetyl – D-glucosamine** arranged in alternate order.

It accounts for the toughness and flexibility of cartilage and tendon.

(b) **Chondroitin** – Chondroitin occurs in connective tissue.

(c) **Heparin** – It is anticoagulant of blood.


Chondroitin **Heparin**

(d) **Pectin** – Pectin is found in cell wall where it binds cellulose fibrils in bundles. Salts of pectin i.e. **Ca** and **Mg-pectates** form **middle lamella in plants** **(Plant cement)**.

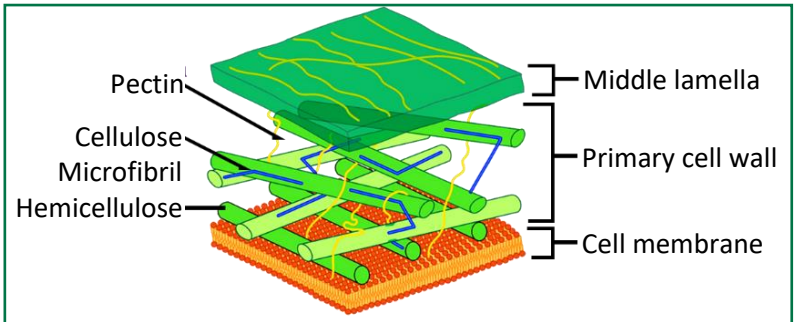


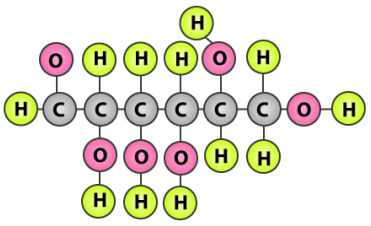
Fig. : Diagrammatic representation of plant cell wall

(e) **Hemicellulose** – **Present in cell wall**.

(f) **Agar** – Is a mucopolysaccharide obtained from **red algae**. It is made of galactose and 3, 6-anhydro L-glucopyranose. It is **used as culture medium** in laboratory.

Golden Key Points

- Chitin is an example of Homopolysaccharide.
- Starch forms helical secondary structures. In fact, starch can hold I_2 molecules in the helical portion. The starch-I_2 is blue in colour.
- Cellulose does not contain complex helices and hence cannot hold I_2.
- Paper is made up of pulp of wood which is mainly constituted by cellulose. Cellulose is a polymer of glucose molecules joined together. About 85 billion tonnes of cellulose is formed annually in the biosphere. Paper manufacture consumes 0.5 billion tonnes of wood. The increase in consumption of wood has led to a great loss in vegetation.
- Gums are heteropolysaccharides formed by different monosaccharide units associated with glycosidic bonds. On the other hand, Fevicol is different from gums, as it is made up of synthetic polymers.
- Agar-Agar
- Polysaccharides are easy to store in bulk because they are **chemically non-reactive and osmotically inactive**.
- Ball and stick model of Glucose.



NCERT Question :

Can you attempt building models of biomolecules using commercially available atomic models (Ball and Stick models).

NCERT Question :

What are gums made of? Is Fevicol different?

NCERT Question :

Find out how much cellulose is made by all the plants in the biosphere and compare it with how much of paper is manufactured by man and hence what is the consumption of plant material by man annually. What a loss of vegetation?

BEGINNER'S BOX-1 STARTING TO CARBOHYDRATE

1. Which is not true about monosaccharides ?
(1) reducing nature (2) soluble in water (3) sweet in taste (4) always ketose
BBM199

2. Glucose and galactose are two isomeric monosaccharides known as :
(1) Anomers (2) Epimers (3) Sugars (4) Amino sugars
BBM200

3. Choose the mis-match :
(1) Amylose $\rightarrow$ contains α-1, 4 glycosidic bond.
(2) $K^+ \rightarrow$ most abundant mineral element in ICF.
(3) $Na^+ \rightarrow$ most abundant mineral element in ECF.
(4) Cellulose $\rightarrow$ violet colour with iodine solution.
BBM201

4. Sum total of all the reactions that are taking place in a cell is known as :-
(1) catabolism (2) anabolism (3) metabolism (4) redox reaction
BBM202

5. Which of the following is minimum in human body ?
(1) Hydrogen (2) Carbon (3) Silicon (4) Nitrogen
BBM203

6. Which of the following is most abundant element present in human body?
(1) Carbon (2) Hydrogen (3) Oxygen (4) Nitrogen
BBM204

7. Which of the following is correct descending order of elements in human body?
(1) O > C > H > N (2) O > H > C > N (3) N > H > C > O (4) H > O > C > N
BBM205

8. Most abundant and least abundant element in earth crust are respectively :-
(1) O and Si (2) Si and O (3) S and N (4) O and N
BBM206

9. A secondary metabolite that acts as a toxin is -
(1) Carotenoids (2) Curcumin (3) Abrin (4) Monoterpenes
BBM207

10. A secondary metabolite that is alkaloid in nature is -
(1) Codeine (2) Anthocyanin (3) Gum (4) Abrin
BBM208

11. What are anthocyanins?
(1) Pigment (2) Alkaloid (3) Drug (4) Toxin
BBM209

12. Which one is reducing sugar?
(1) Glucose (2) Fructose (3) Erythrose (4) All
BBM210

13. Maltose is a :-
(1) Disaccharide (2) Reducing sugar (3) Malt sugar (4) All
BBM211

14. Which one is Laevulose?
(1) Glyceraldehyde (2) Dihydroxyacetone (3) Fructose (4) Glucose
BBM212

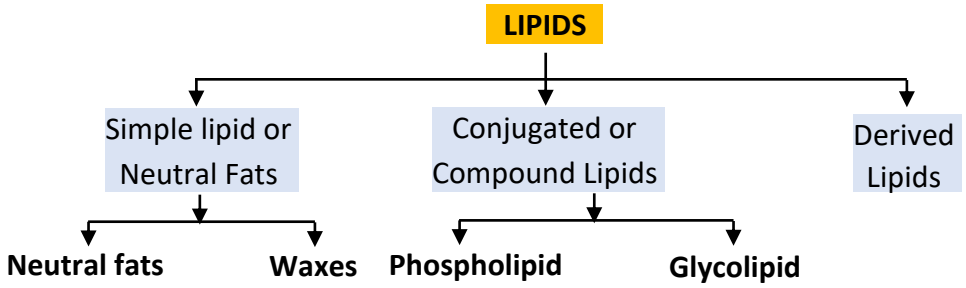
15. Which of the following is not strictly a biomacromolecule?
(1) Proteins (2) Lipids (3) Polysaccharides (4) Nucleic acid
BBM213

16. Which of the following is not a homopolysaccharide?
(1) Cellulose (2) Glycogen (3) Chitin (4) Hemicellulose
BBM214

05. LIPIDS

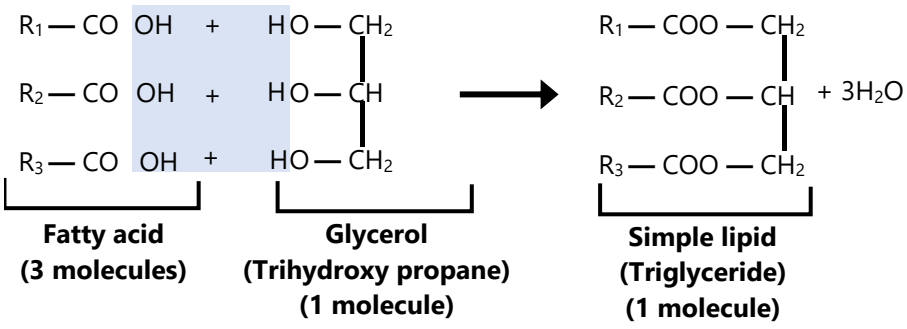
- Fats and its derivatives are combinedly known as lipids.
- Compounds of C, H, O but the ratio of Hydrogen and Oxygen is not 2:1. The amount of oxygen is considerably very less.
- Lipids are **insoluble in water** and soluble in organic solvents like Acetones, Chloroform, Benzene, Hot alcohol, ether etc.
- Lipids occur in protoplasm as minute globules.
- Lipids **do not form polymer**.
- Lipids provide more than **double energy** as compared to carbohydrates.
- In animals, fats are present in subcutaneous layer and work as **food reservoir** and **shock-absorber**.
- Lipid requires less space for storage as compared to carbohydrate because lipid molecule is hydrophobic and condense.
- Animals store maximum amount of food in the form of lipid.
- Lipids are micro molecules.

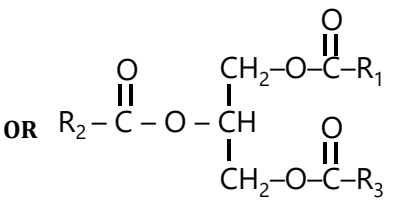
- Some lipids also have phosphorus like Lecithin.



(A) SIMPLE LIPID OR NEUTRAL FATS :–

- These are **esters of long chain fatty acids** and **alcohol**. In majority of simple lipids, the alcohol is a Trihydroxy alcohol i.e. **glycerol**.
- Three molecules of fatty acids are linked with one molecule of glycerol. The linkage is called **"ester bond"**. Such type of lipids are called as **Triglycerides**. Three molecules of water are released during formation of triglycerides (dehydration synthesis)
- Glycerol is also known as **Trihydroxy propane**.





Triglyceride (R_1, R_2 and R_3 are fatty acids)

NCERT Question :

Explain the composition of triglyceride.

Simple lipids contain two types of Fatty Acids

Saturated Fatty Acids	Unsaturated Fatty Acids
(a) Only single bonds are present between C-C atoms	(a) Double bonds are also present along with single bonds between C-C atoms.
(b) Also known as **non-essential fatty acids**, because they can be synthesized in animal body, so it is not essential to take them with food.	(b) Also known as **essential fatty acids** because they can't be synthesised in animal body, so it is essential to take them with food.

(c) Lipids with more amounts of saturated fatty acids are mostly present in **solid form** at normal temperature. **e.g. Butter, Ghee**	(c) Lipids with more amounts of unsaturated fatty acids are mostly present in **liquid form** at normal temperature. **e.g. Coconut oil, Mustard oil**.
(d) Metabolically they are very **less reactive**. So mostly don't participate in metabolism. So have tendency to store in animal body and cause obesity. Some amount of saturated fatty acids convert into cholesterol in liver. This cholesterol is deposited on inner wall of blood vessels, so cause high blood pressure & different types of cardio-vascular diseases.	(d) Metabolically they are **highly reactive**, so mostly participate in metabolic reactions. So don't have tendency to store in animal body. So no obesity, no cholesterol formation, no cardiovascular disease, no high B.P. & no harmful effect.
(e) Mostly **animal fat** contains high amount of saturated fatty acids. **Examples** — **No. of Carbon atoms** Palmitic acid = 16 $CH_3 – (CH_2)_{14}–COOH$ Stearic acid = 18 Arachidic acid = 20	(e) Mostly **plant fat** contains high amount of unsaturated fatty acids. **No. of Carbon atoms** — **No. of carbon-carbon double bonds** 18 Oleic acid = 1 → **MUFA** Monounsaturated fatty acid 18 Linoleic acid = 2 18 Linolenic acid = 3 20 Arachidonic acid = 4 → **PUFA** Polyunsaturated fatty acid

Waxes are monoesters with only one molecule of fatty acid attached to a monohydroxy alcohol. These are also simple lipids. E.g. Bee wax

(B) CONJUGATED OR COMPOUND LIPIDS :

(1) Phospholipids or phosphatide or phospholipins :–

2 Molecules of fatty acid + Glycerol + H_3PO_4 + Nitrogenous compound.

Phospholipids have both hydrophilic polar end (H_3PO_4 and nitrogenous compound) and hydrophobic non- polar end (fatty acids). Such molecules are called **amphipathic**. Due to this property, phospholipids form bimolecular layer in cell membrane. The lipid component of the membrane mainly consists of phosphoglycerides. **Phospholipids are most abundant type of lipids in protoplasm**.

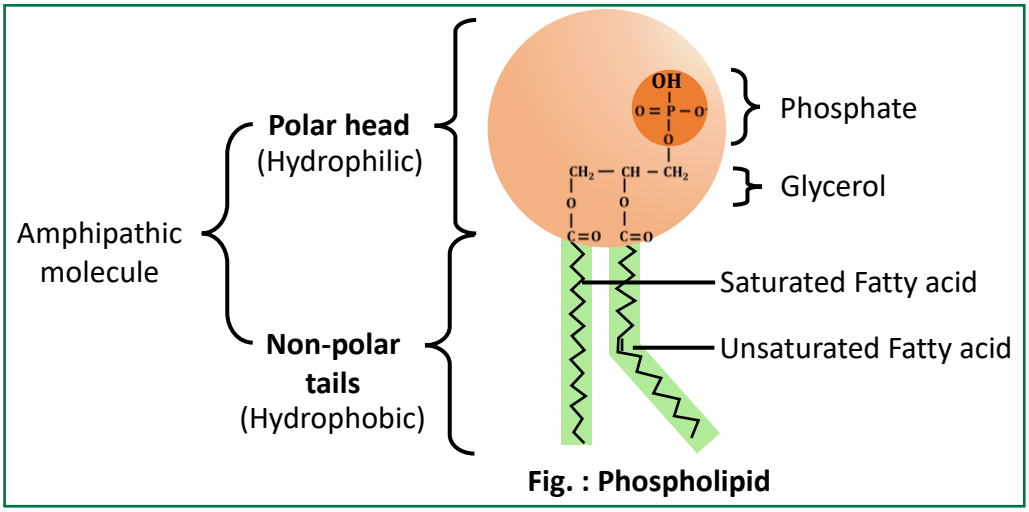


Fig. : Phospholipid

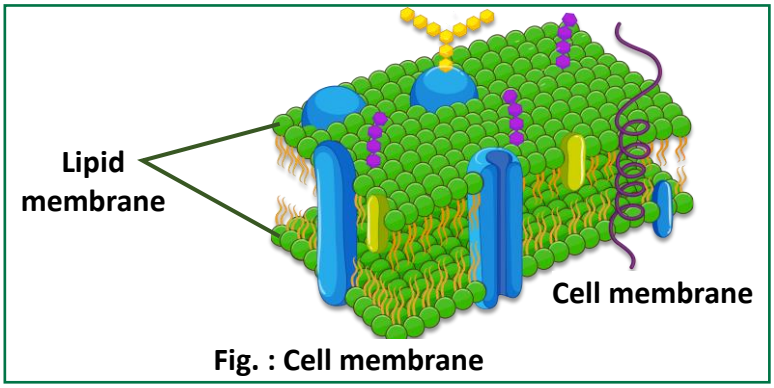
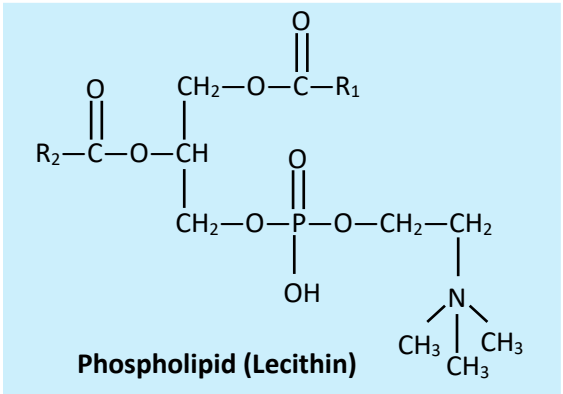


Fig. : Cell membrane

Some biologically important phospholipids are as following :

(a) Lecithin or Phosphatidyl choline : Nitrogenous compound in Lecithin is Choline. Lecithin occurs in cell membrane.



Phospholipid (Lecithin)

(b) Sphingolipids or sphingomyelins similar to lecithin but in place of glycerol it contains an **amino alcohol sphingosine**. Sphingolipids occur in myelin - sheath of nerves.

(2) Glycolipid :–

1 fatty acid + sphingosine + galactose

e.g. Cerebrosides which occurs in white matter of brain.

Gangliosides - These occur in nerve ganglia and spleen.

Glycolipids on the outer surface of plasma membrane are involved in cell to cell recognition (Blood group antigen).

(C) Derived Lipids :

Lipid derived from simple or conjugated lipid. Derived lipids are complex in structure. They are insoluble in water and soluble in organic solvents

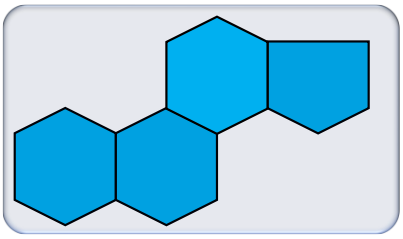


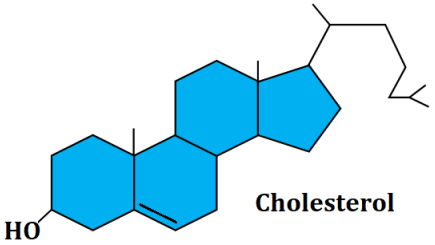
Fig. : Derived lipid

(1) Steroids : Steroids exhibit **tetracyclic structure** called "Cyclo pentano perhydrophenanthrene nucleus" On the basis of functional group.

Steroids are of two types –

(a) Sterols :-

- Alcoholic steroids **e.g. Cholesterol–Cholesterol** abundantly occurs in brain, nervous tissue, Adrenal gland and skin. Cholesterol is a parent steroid.



- Several other biologically important steroids are derived from cholesterol. (7-dehydrocholesterol) which occurs in skin is a provitamin. On exposure to ultraviolet radiation, it transforms in **Cholecalciferol i.e. vitamin D**

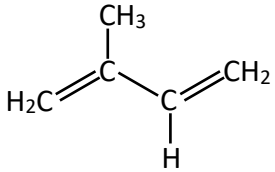
  Skin → sebaceous glands → secrete → waxy material → sebum → 7-dehydrocholesterol $\xrightarrow{\text{UV Rays}}$ cholecalciferol (Vit. D)

(b) Sterones :- Ketonic steroids, for **e. g.** sex hormones, Adreno corticoids.

e.g. sex hormones
- ♂ Male → Testosterone
- ♀ Female → Progesterone

(2) Chromolipid :-

- It is also called terpene. Most complex lipid in protoplasm.
- Chromolipids composed of repeated isoprene units. For e.g. β carotene (Precursor of vitamin A)



Terpene

06. PROTEINS

- Protein name is derived from a Greek word which means **" holding first place"**
- Essential elements in protein are C, H, O, N.
- Most of the proteins contain Sulphur. In some proteins Iodine, Iron and Phosphorus are present.
- After water, **proteins are most abundant compounds in protoplasm**.
- Proteins are polymers of amino acids.
- 20 types of amino acids are used in formation of proteins.
- Proteins are **heteropolymers** of amino acids.

Structure of amino acid :-

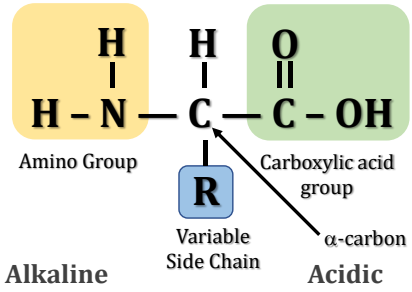
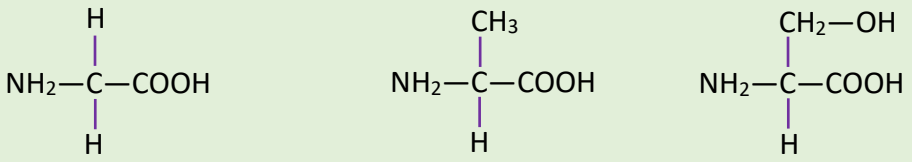


Fig. : General structure of on amino acid

Amino acids are **substituted methane**

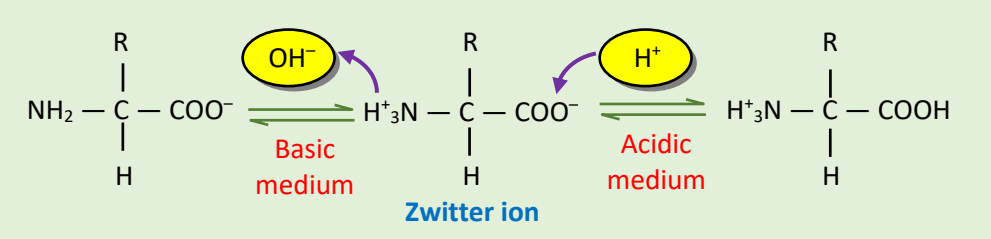


NCERT Question :

Draw the structure of the amino acid, alanine.

- Amino acids are organic compounds containing an amino group and an acidic group as substituents on the same carbon i.e., the α-carbon. Hence, they are called α-amino acids. They are **substituted methanes**. There are four substituent groups occupying the four valency positions.
- These are hydrogen, carboxyl group, amino group and a variable group designated as R group. Based on the nature of R group there are many amino acids. However, those which occur in proteins are only of twenty types.
- The R group in these proteinaceous amino acids could be a hydrogen (the amino acid is called glycine), a methyl group (alanine), hydroxy methyl (serine), etc.
- The chemical and physical properties of amino acids are essentially of the amino, carboxyl and the R functional groups.
- Each amino acid is **amphoteric compound** because it contains both **acidic -COOH** and an **alkaline group -NH_2**

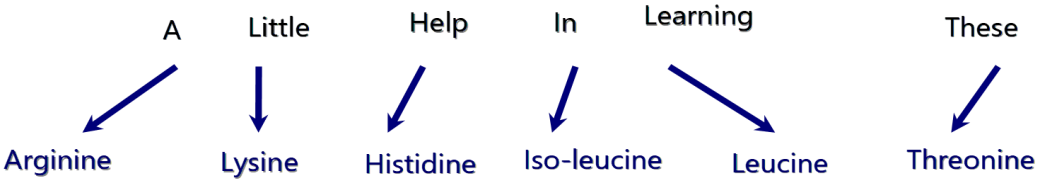
- Ionic structure of AA depends on pH of medium .



- **Isoelectric point is that point of pH at which amino acids have both positive and negative charge in equal amount. (i.e. exists as dipolar ion)**
- **Isoelectric point is specific value of pH at which amino acids move neither towards cathode nor towards anode.**
- Out of 20 amino acids, 10 amino acids are not synthesized in body of animals so they must be present in diet. These are called **Essential amino acids**. **e.g.** Threonine, Valine, Leucine, Isoleucine, Lysine, Methionine, Phenylalanine Tryptophan, Arginine, Histidine.
- Arginine and Histidine are **semi-essential amino acids**.
- 10 amino acids are synthesized in animal body so these are called **Non-essential amino acids** for example Glycine, Alanine, Serine, Cysteine, Aspartic acid, Glutamic acid, Asparagine, Glutamine, Tyrosine, Proline.

Essential and Non-Essential Amino Acids

Essential Amino Acids	Non-Essential Amino Acids
Threonine	Glycine
Valine	Alanine
Leucine	Serine
Isoleucine	Cysteine
Lysine	Aspartic acid
Methionine	Glutamic acid
Phenylalanine	Asparagine
Tryptophan	Glutamine
Arginine	Tyrosine
Histidine	Proline



- Amino acids join by peptide bond to form protein.
- **Peptide bond is also known as amide bond**.

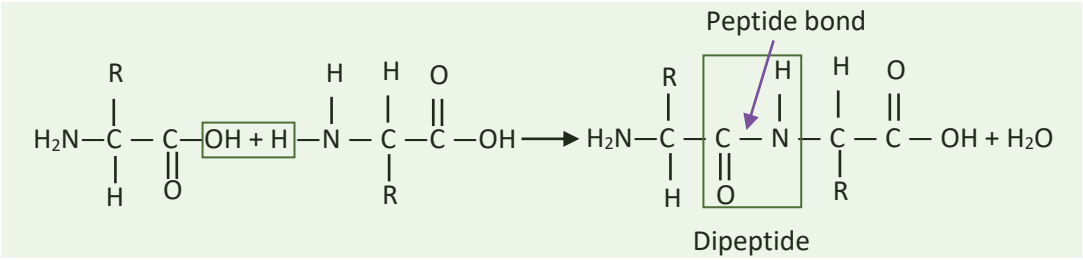


Fig. Peptide bond formation

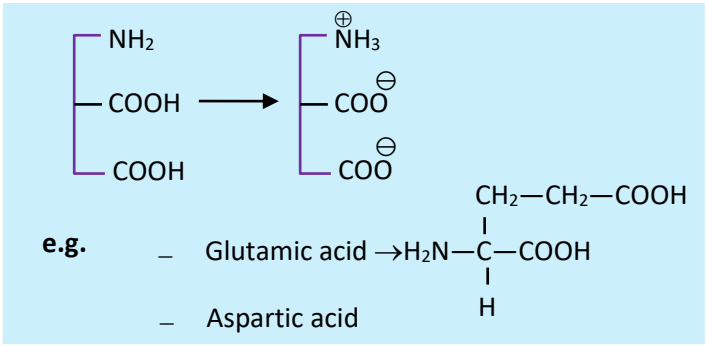
NOTE :

- Properties of proteins depend on sequence of amino acids and configuration of protein molecules.

  While variations in amino acids depend on side group.

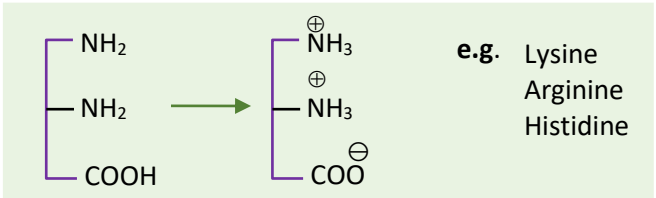
Classification of amino acids on the basis of number of carboxylic groups and Amino groups.

1. **Acidic amino acids** (Mono amino di carboxylic amino acids)
   - They have **one amino** and **two carboxylic** groups in their structure.



Acidic amino acid

2. **Alkaline amino acids (**Di amino mono carboxylic amino acids)
   - They have **two amino** and **one carboxylic** group.



Basic amino acid

3. **Neutral amino acids** (Mono amino mono carboxylic amino acids)
   - They have **one amino** and **one carboxylic group**. **e.g.** Rest 15 amino acids

Special Amino Acids :

1. **Tryptophan : Most complex amino acid** helps in formation of vitamin nicotinamide as well as plant hormone IAA.
2. **Tyrosine :** Helps in **synthesis of melanin pigment, Thyroxine hormone, Adrenaline (epinephrine) hormone, Noradrenaline (Norepinephrine) Hormone.**
3. In **proline amino acid, imino group (–NH) is present instead of amino (–NH_2)** group so this amino acid is also known as **imino acid**.
4. Cysteine, Cystine and methionine are **sulphur containing** amino acids.
5. Tyrosine, Tryptophan, Phenylalanine } Aromatic amino acid
6. Proline, Histidine } Heterocyclic amino acid because they have heterocyclic ring
7. Serine, Threonine } Alcoholic amino acid because they have –OH group in their structure

Functions of Protein :

- Proteins carry out many functions in living organisms, some transport nutrients across cell membrane, some fight infectious organisms, some are hormones, some are enzymes, etc.
- **Collagen is the most abundant protein in animal world.**
- **Ribulose bisphosphate Carboxylase-Oxygenase (RuBisCO) is the most abundant protein in the whole of the biosphere.**

Table some proteins and their functions

Protein	Functions
Collagen	Intercellular ground substance
Trypsin	Enzyme
Insulin	Hormone
Antibody	Fights infectious agents
Receptor	Sensory reception (smell, taste, hormone etc.)
GLUT-4	Enables glucose transport into cells under influence of insulin.

07. STRUCTURE OF PROTEIN MOLECULE

(A) PRIMARY CONFIGURATION OR STRUCTURE :

A straight chain of amino acids linked by **peptide bonds** forms primary structure of proteins.

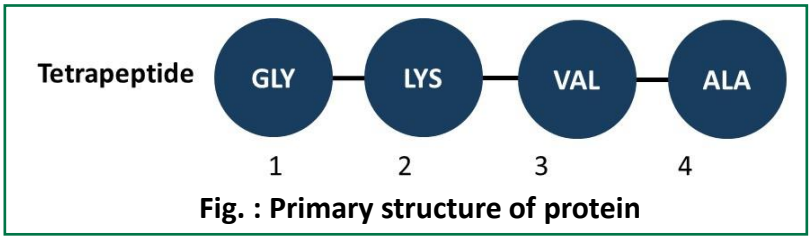


Fig. : Primary structure of protein

- This structure of proteins is **most unstable**.
- The sequence of amino acids i.e. **the positional information** in a protein - which is the first amino acid, which is second and so on is called primary structure.
- Newly formed proteins on ribosomes have primary structure.
- The first amino acid of chain is known as **N-terminal amino acid** and the last is known as **C-terminal amino acid**.

(B) SECONDARY CONFIGURATION :

- Protein molecules of sec. structure are spirally coiled.
- In addition to peptide bond, amino acids are linked by **hydrogen bonds** formed between oxygen of one amide group and hydrogen of another amide group.
- Proteins of secondary structure are **insoluble** in water and fibrous in appearance.

This structure is of two types –

(i) α–Helix:

Right handed rotation of spirally coiled chain with approximately 3 amino acids in each turn. This structure has **intramolecular hydrogen bonding** i. e. between two amino acids of same chain e.g. **Keratin, Myosin, Tropomyosin**.

Keratin is a fibrous, tough, resistant to digestion, scleroprotein. Hardness of keratin is due to abundance of **cysteine amino acid in its structure.**

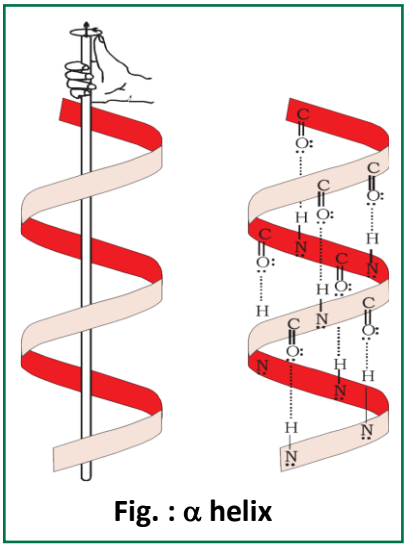


Fig. : α helix

(ii) β–pleated sheet structure:

Protein molecule has zig–zag structure.

The segments of a linear polypeptide chain form a β-pleated sheet with the help of hydrogen bonds.

β-pleated sheet may also be formed by segments of different polypeptide chains by intermolecular hydrogen bonds.

e.g. Fibroin (silk).

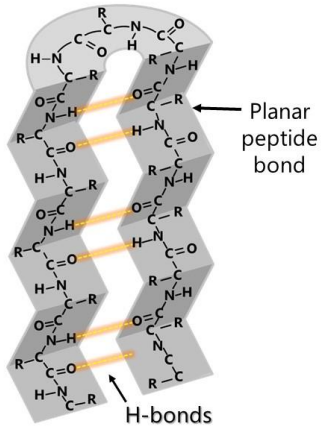


Fig. : β-pleated sheet

(C) TERTIARY STRUCTURE :

Tertiary structure gives us a 3-dimensional view of proteins. Proteins of tertiary structure are **highly folded to give a globular appearance**. They are **soluble** in **water** (colloid solution). This structure of protein has following bonds–

(a) Peptide bonds: Strongest bond in proteins.

(b) Hydrogen bonds

(c) Disulphide bond: These bonds form between - SH group of amino acid (Cysteine). These bonds are **second strongest bond** and stabilise tertiary structure of protein.

(d) Hydrophobic bond: Between amino acids which have hydrophobic side chains e.g. Aromatic amino acid

(e) Ionic bond: Formation of ionic bond occurs between two opposite ends of protein molecule due to electrostatic attraction.

Majority of proteins and enzymes in protoplasm exhibit tertiary structure, which is absolutely **necessary for biological activities of proteins**. e.g. Myoglobin protein found in muscle cell.

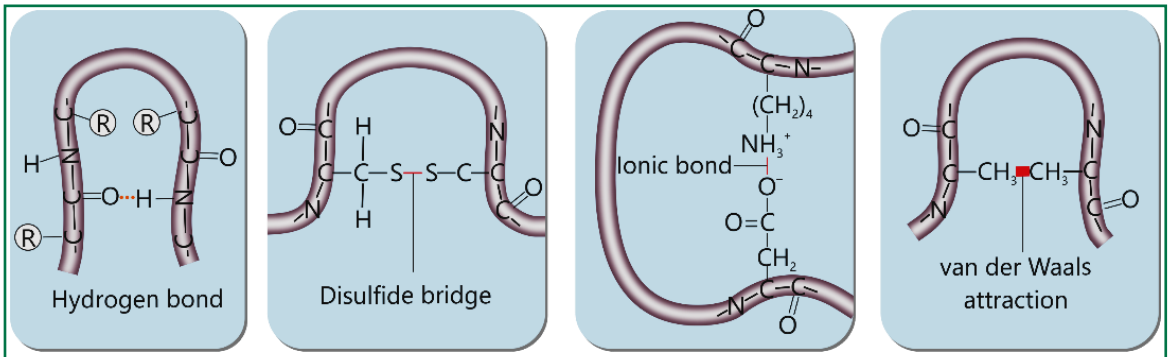


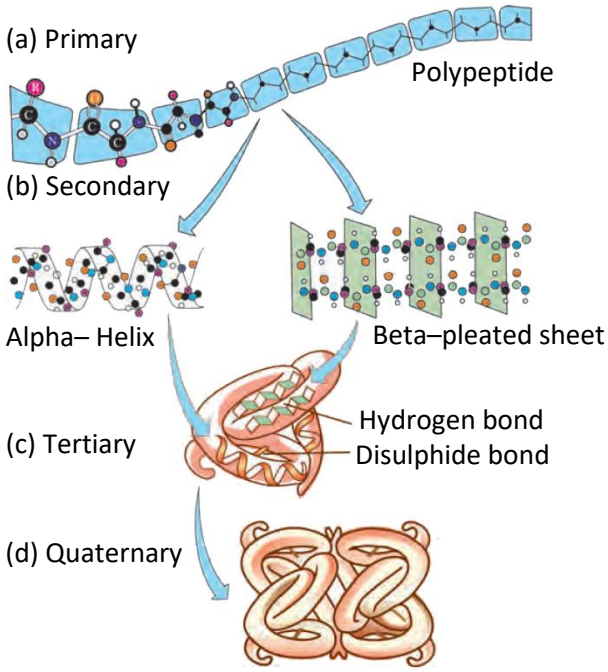
Fig. : Bonds present in tertiary structure of proteins

NCERT Question :

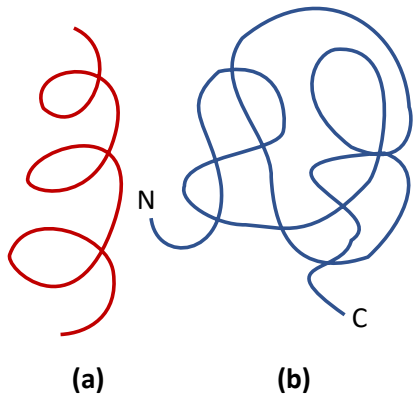
What is meant by tertiary structure of proteins?

(D) QUATERNARY STRUCTURE :

- Two or more polypeptide chains of tertiary structure unite by different types of bonds to form quaternary structure of protein.
- Different polypeptide chains may be similar **(Lactic dehydrogenase)** or dissimilar types **(Haemoglobin, Insulin)**.
- Quaternary structure is the **most stable structure** of protein.
- Adult human haemoglobin consists of 4 subunits. Two of these are identical to each other. Hence, two subunits of α type and two subunits of β type together constitute the human haemoglobin (Hb).



Various levels of Protein Structure



Cartoon showing :
(a) A secondary structure and
(b) A tertiary structure of proteins

Order of Stability :

Quaternary > **Tertiary** > **Secondary** > **Primary**

Some important proteins

(a) Collagen :-

- **Most abundant protein in animal body**
- 1/3 part of total proteins
- Present in connective tissue
- Threads of collagen are known as Tendon

(b) Rubisco :-

- Present in chloroplast.
- **Most abundant protein on the earth**

(c) Glycoprotein :-

- Prosthetic group is carbohydrate

  e.g. α, β, γ globulin of blood.
- Glycoproteins which are present on cell surface are helpful in cell recognition.

Denaturation of Protein :

- Changes in pH, salts, heavy metals, temperature, pressure, etc. also cause precipitation (denaturation) of proteins. Because of these changes, the secondary and tertiary configuration of proteins is destroyed and many times the tertiary structured globular proteins become converted to secondary configuration fibrous proteins. Such alternations in the physical state of proteins is called **denaturation**.
- If the change in the medium of protein is mild and for a short period, then denaturation of the protein is also temporary, however, if the change in medium is strong and prolonged then denaturation is permanent and the protein becomes coagulated.
- For example, the white or albumen of egg is a soluble globular protein but on heating it permanently coagulates into fibrous insoluble form. It is clear, that strong alternations result in the denaturation of proteins and they lose their biological properties and significance.
- This is the reason, that cells of organisms are unable to bear strong changes and they ultimately die.

★ Golden Key Points ★

- Proteins with therapeutic uses are insulin, oxytocin, ADH, thrombin, fibrinogen, renin, immunoglobulin, diastase, streptokinase, etc.
- Other applications of proteins are as :

  cosmetics- Protein such as casein is used in beauty creams, shampoos, etc.

  Sweeteners- Thaumatin and monellin are sweet proteins.

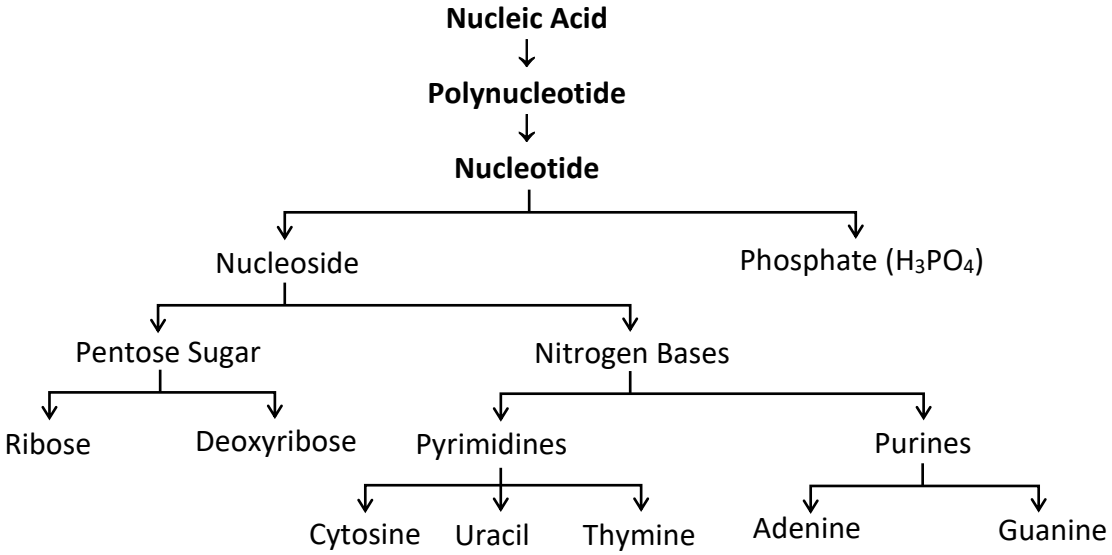
  Dietary supplements- Proteins can be used as dietary supplements.

NCERT Question :

Find out and make a list of proteins used as therapeutic agents. Find other applications of proteins (e.g., Cosmetics, etc.)

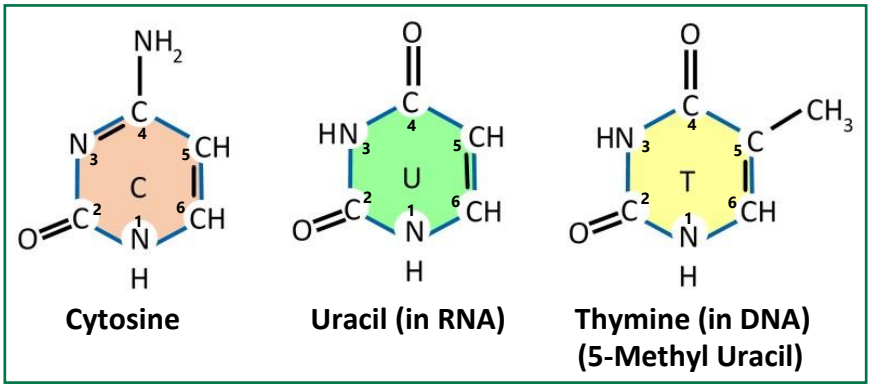
08. NUCLEIC ACID

- **F. Meischer** discovered nucleic acid in nucleus of pus cell and called it **"nuclein"**. The term nucleic acid was coined by "Altman."
- Nucleic acids are polymers of **nucleotides**.

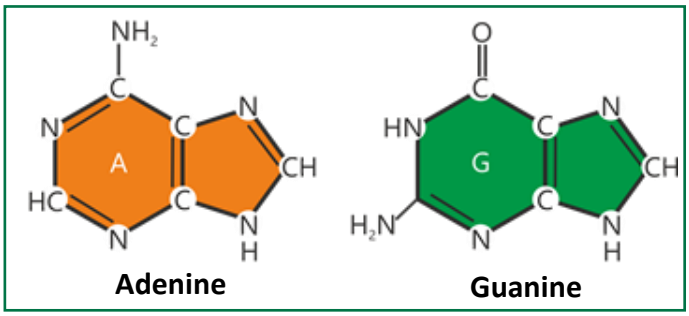


On the basis of structure nitrogen bases are broadly of two types :.

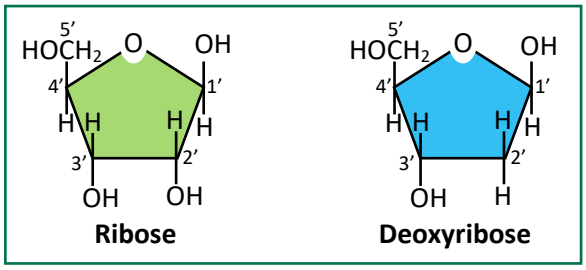
1. **Pyrimidines -** Consist of one pyrimidine ring. Skeleton of ring is composed of **two Nitrogen** and **four Carbon atoms**. ***e.g.*** Cytosine, Thymine and Uracil.



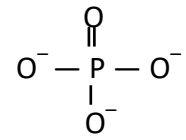
2. **Purines -** Consist of two rings i.e. **one pyrimidine ring (2N + 4C)** and **one imidazole ring (2N + 3C)** ***e.g.***



Pentose Sugar :



Phosphate :



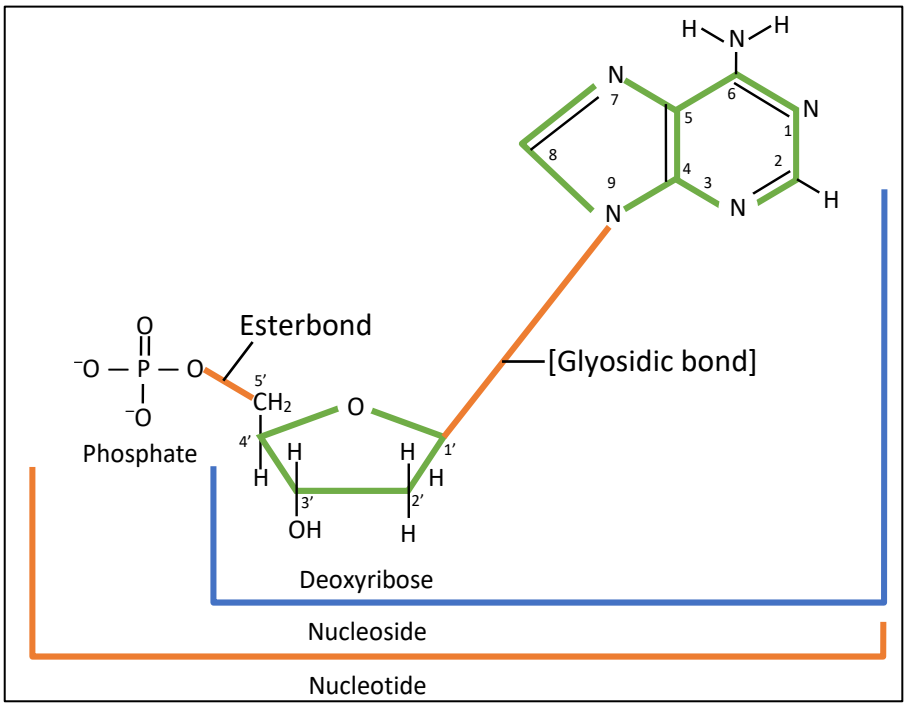
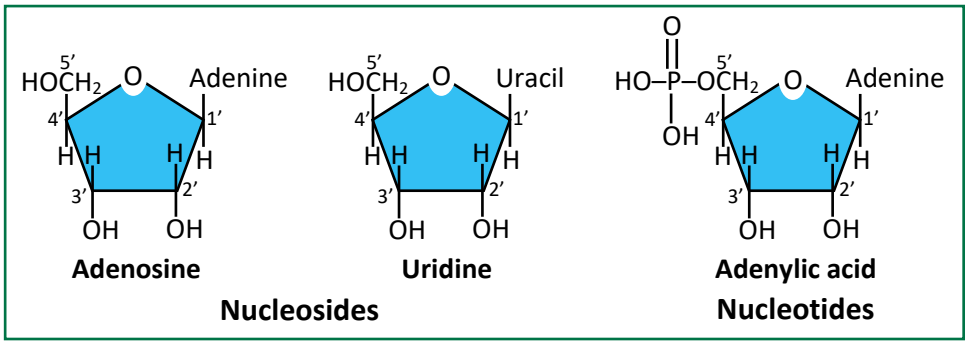


Fig. Linkage present in nucleotide & nucleoside

- Nitrogen base forms bond with first carbon of pentose sugar to form a **Nucleoside**.
- Nitrogen of first place (N_1) forms bond with sugar in case of pyrimidines while in purines nitrogen of ninth place (N_9) forms bond with sugar.
- Phosphate forms ester bond (covalent bond) with fifth Carbon of sugar to form a complete nucleotide.

Some Nucleosides and Nucleotides :



DNA :

- Discovered by - Meischer
- DNA term was given by - Zacharias
- In DNA pentose sugar is deoxyribose sugar and four types of nitrogen bases A, T, G, C.

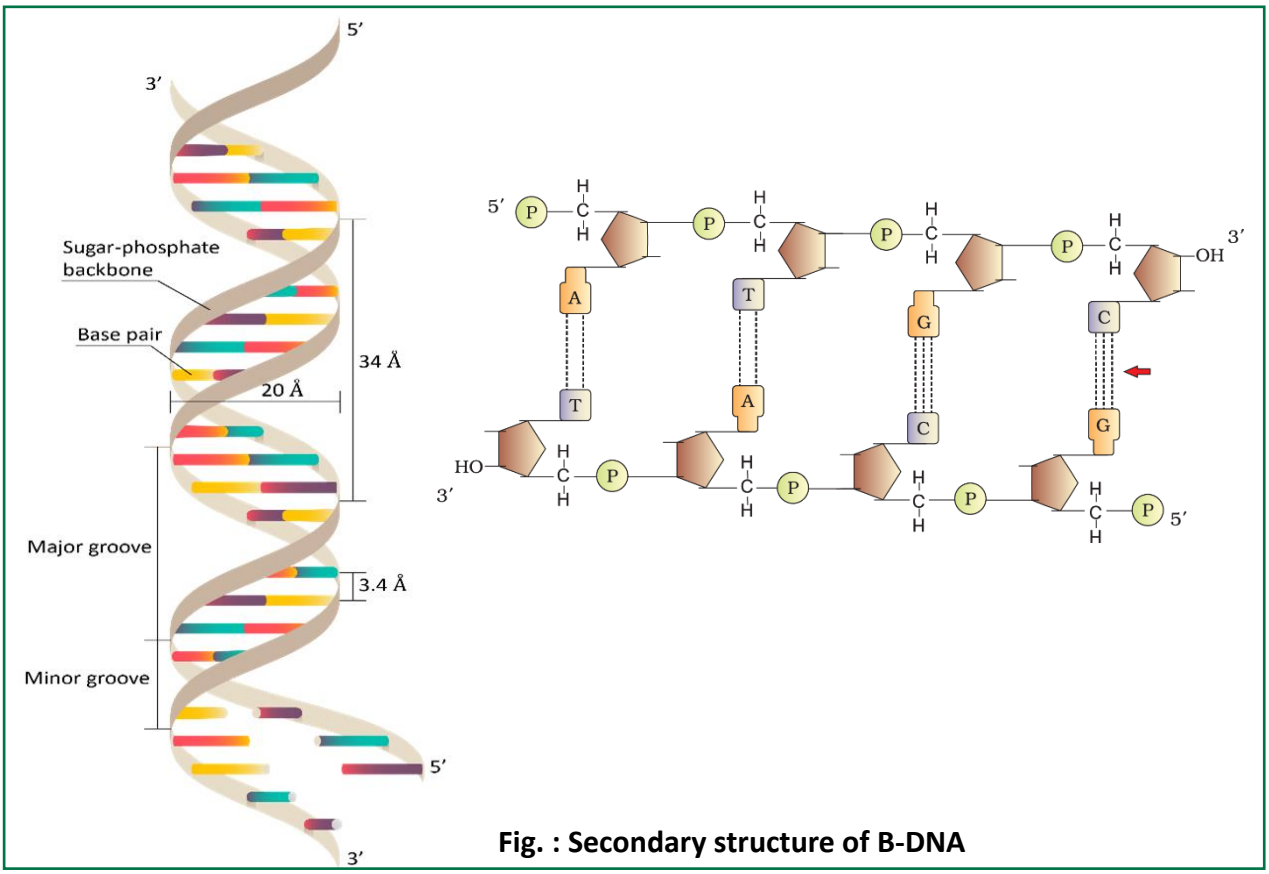


Fig. : Secondary structure of B-DNA

- Both the strands of DNA are parallel to each other according to Wilkins & Franklin.
- With the help of this study, Watson and Crick (1953) proposed a double helix model for DNA. For this model Watson, Crick and Wilkins were awarded by Nobel Prize in 1962.
- According to this model, DNA is composed of two polynucleotide chains.
- Both polynucleotide chains are **complementary** and **antiparallel** to each other.

- In the two strands of DNA direction of phosphodiester bonds is opposite. i.e. If direction of phosphodiester bonds in one strand is 3'-5' then it is 5'-3' in another strand.
- Both strands of DNA are held together by hydrogen bonds. These hydrogen bonds are present between nitrogen bases of both strands.
- **Adenine binds to Thymine by two hydrogen bonds and Cytosine binds to Guanine by three hydrogen bonds.**

  A = T

  G ≡ C

Configuration of DNA Molecule (B-DNA) :

- Two strands of DNA are helically coiled like a revolving ladder. Railings of this ladder (Back bones) are composed of phosphates and sugars while steps (bars) are composed of pairs of nitrogen bases.
- Distance between two successive steps is 3.4 Å. In one complete turn of DNA molecule there are such 10 steps (10 pairs of nitrogen bases). So, the length of one complete turn is 34 Å. This is called **pitch of the helix.**
- Diameter of DNA molecule i.e. distance between phosphates of two strands is 20 Å.
- At each step of ascent, strand turns 36°.
- Molecular weight of DNA is 10^6 to 10^9 dalton.
- Form of DNA is known as B-DNA

Ribo Nucleic Acid (RNA) :

Structure of RNA is fundamentally the same as DNA, but there are some differences. The differences are as follows:

(1) In place of De-oxyribose sugar in DNA, Ribose sugar is present in RNA.

(2) In place of nitrogen base Thymine in DNA, uracil is present in RNA.

(3) RNA is made up of only one polynucleotide chain i.e. RNA is single stranded.

Exception : RNA found in Reo - virus is double stranded, i.e. it has two polynucleotide chains

★ Golden Key Points ★

- In proteins, right handed helix are observed.
- Phospholipids are most abundant lipid in cell membrane.
- Aspartame/Aspartin is most commonly used artificial sweetener.
- Thymine is also known as **5-Methyl uracil**.

BEGINNER'S BOX-2 LIPID TO PROTEIN

1. The most abundant lipids in eukaryotic cell membrane are :-

(1) cholesterol (2) glycolipids (3) phospholipids (4) lipopolysaccharide

BBM215

2. Which of the following is alkaline amino acid :-

(1) glycine (2) valine (3) alanine (4) arginine

BBM216

3. Which biomolecule release maximum energy during oxidation :-

(1) lipid (2) protein (3) nucleic acid (4) carbohydrate

BBM217

4. An alpha helix represents :-

(1) primary structure of protein (2) aggregation of protein

(3) secondary structure of protein (4) tertiary structure of protein

BBM218

5. Which of the following bond is/are found in tertiary structure of protein :-

(1) peptide bond & hydrogen bond (2) disulphide & hydrophobic bond

(3) ionic bond (4) all the above

BBM219

6. Fatty acids are linked with glycerol by :-

(1) Ether bond (2) Ester bond (3) Diester bond (4) Disulphide bond

BBM220

7. Lecithin is a :-

(1) Type of wax (2) Phospholipid (3) Oil (4) Simple fatty acid

BBM221

8. Primary structure of protein is due to the presence of _____.

(1) Hydrogen bonds (2) Peptide bonds

(3) Disulphide linkages (4) Ionic bonds

BBM222

9. Two strands of DNA double helix are :-

(1) Parallel & complementary (2) Antiparallel & complementary

(3) Parallel & non-complementary (4) Antiparallel & non-complementary

BBM223

10. Watson & Crick proposed the structure of which DNA?

(1) A-DNA (2) B-DNA (3) Z-DNA (4) C-DNA

BBM224

09. ENZYMES

- **History -** Buchner discovered and isolated the enzyme **zymase** from yeast cells
- While Kuhne coined the term enzyme.
- **J.B. Sumner** purified and crystalized **urease** enzyme from Canavalia/Jack bean/Lobia plant.

NCERT Question :

Describe the important properties of enzymes.

(1) CHARACTERISTICS OF ENZYMES :

(1) Almost all enzymes are protein. Though, there are some nucleic acids that behave like enzymes. These are called **ribozymes**.

(2) Enzymes are colloidal substances, which are macromolecules of amino acids and are synthesised by ribosomes under genetic control.

(3) Enzyme can be depicted by a line diagram. An enzyme like any protein has –

(a) Primary structure: Amino acid sequence of the protein. It lacks active sites.

(b) Secondary structure: It is a helical structure which also lack active sites.

(c) Tertiary structure: In this structure backbone of the protein chain folds upon itself, the chain criss-crosses itself and hence many crevices or pockets are made such pockets represent **active sites**. The catalytic structure of most of the enzymes is tertiary and globular.

(d) Quaternary structure: Represented by isoenzymes and active sites are present.

(4) **Active site:** An active site of an enzyme is a crevice or pocket into which the substrate fits. Thus, enzymes through their active site catalyse reactions at a high rate.

(5) Enzymes are very specific to their substrate or reactions. They are required in very small amount to catalyse a reaction.

Catalytic power of an enzyme depends upon –

(a) Turn over number (b) K_m constant

(a) Turn over number: It is the number of substrate molecules converted into products per unit time by a molecule of enzyme. Thus, **catalytic power is directly proportional to turn over number. Carbonic anhydrase enzyme is considered as the fastest enzyme**.

ENZYME	TURNOVER NUMBER
CARBONIC ANHYDRASE	**360 lakhs/minute**
Catalase	50 lakhs/minute
Flavoprotein	50 /minute
Lysozyme	30 /minute

(b) K_m constant: This was coined by Michaelis and Menten. It is the concentration of substrate at which rate of reaction attains half of its maximum velocity.

$$K_m = \frac{1}{2}V_{max}$$

Catalytic power of an enzyme is inversely proportional to its K_m value.

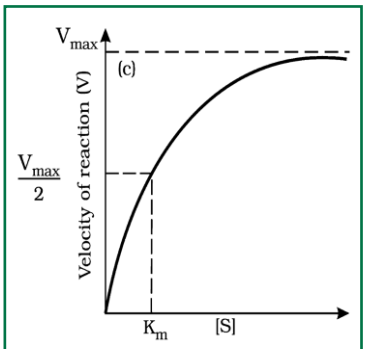


Fig. : K_m constant

(6) Enzyme increase the rate of reaction several times by **lowering down activation energy**.

(7) Catalytic power of an enzyme remains same even outside the living system.

(8) Enzymes when not in use, represent inactive form, called **zymogen** or **pro-enzyme**. Pepsinogen is an inactive form of pepsin, similarly trypsinogen is an inactive form of trypsin.

Enzyme (Biocatalyst)	Inorganic catalysts
Enzymes are thermo-sensitive and get damaged at high temperatures (say above 40° C)	They work efficiently at high temperatures and high pressures.

NOTE :

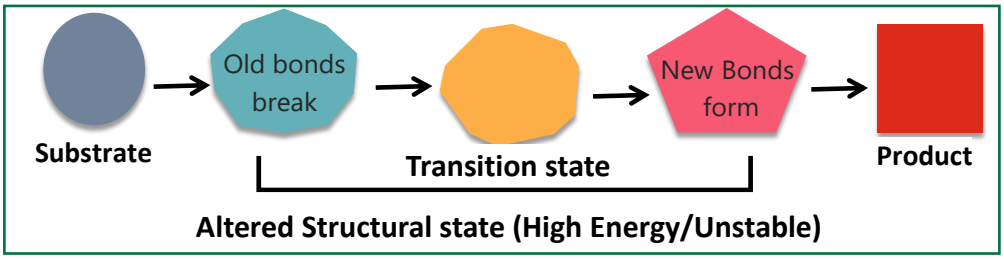
However, enzymes isolated from organisms who normally live under extremely high temperatures (***e.g***. hot vents and sulphur springs), are stable and retain their catalytic power even at high temperature. Thermal stability is thus an important quality of such enzymes isolated from thermophilic organisms.

e.g. Taq polymerase.

Uncatalyzed reaction versus catalysed reaction :

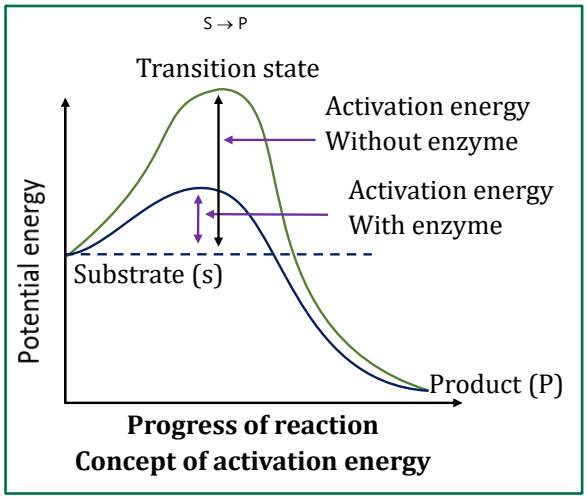
$$\underset{\text{Carbon dioxide}}{CO_2} + \underset{\text{Water}}{H_2O} \xrightleftharpoons{\text{Carbonic anhydrase}} \underset{\text{Carbonic acid}}{H_2CO_3}$$

In the absence of an enzyme this reaction is very slow, with about **200 molecules of H_2CO_3 being formed in an hour**. However, in the presence of enzyme **Carbonic anhydrase** inside cytoplasm the reaction speeds dramatically with about **600,000 molecules being formed every second.** The enzyme has accelerated the reaction rate by about **10 million times**.



(2) HOW DO ENZYMES BRING ABOUT SUCH-HIGH RATES OF CHEMICAL CONVERSIONS?

The chemical or metabolic conversion refers to a **reaction**. The chemical which is converted into a product is called a **substrate**. Hence enzymes, i.e. proteins with three dimensional structures including an active site converts a **substrate (S)** into a **product (P)**.



Concept of activation energy

The y-axis represents the potential energy content. The x-axis represents the progression of the structural transformation or states through the **'transition state'**. In above graph 'P' is at a lower level than 'S', thus this reaction is an **exothermic reaction**. (No need to supply energy in order to form the product.) However, whether it is an exothermic or spontaneous reaction or an endothermic or energy requiring reaction, the 'S' has to go through a much higher energy state or transition state.

"The difference in average energy content of Substrate 'S' from that of this transition state is called activation energy".

Enzymes eventually bring down this energy barrier making the transition of 'S' to 'P' more easy. All changes (ES complex, EP complex) occurred during transition state are **transient** and **unstable**.

(3) NATURE OF ENZYME ACTION :

Each enzyme(E) has a substrate (S) binding site in its molecular structure so that a highly **reactive enzyme substrate complex (ES) is produced**. This complex is short-lived and dissociates into its product(s) P and the **unchanged enzyme** with an intermediate formation of the **enzyme-product complex (EP)**. The formation of the ES complex is essential for catalysis.

$$Enzyme + Substrate \rightleftharpoons ESC \rightarrow EPC \rightarrow Enzyme + Product$$

The catalytic cycle of an enzyme action can be described in the following steps:

1. First, the **substrate binds to the active site** of the enzyme, fitting into the active site.

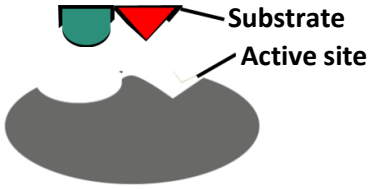


Fig : Substrate entering Active site of enzyme

2. The **binding of the substrate induces the enzyme to alter its shape, fitting more tightly** around the substrate.

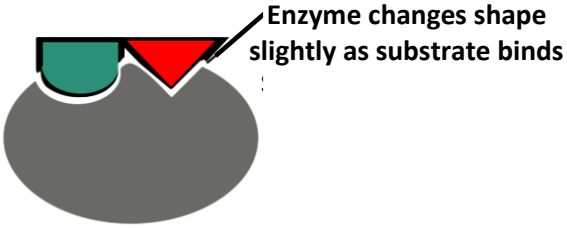


Fig : Enzyme Substrate complex

3. The **active site of the enzyme**, now in close proximity of the substrate **breaks or form the chemical bonds of the substrate and the new enzyme- product complex is formed**.

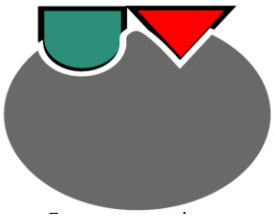


Fig : Enzyme Products complex

4. The **enzyme releases the products** of the reaction and the free **enzyme is ready to bind** to another molecule of the substrate and run through the catalytic cycle once again.

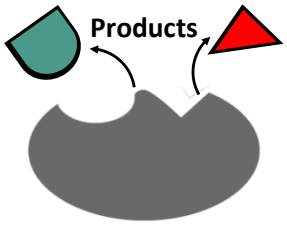


Fig : Products leaving Active site of enzyme

(4) CO-FACTORS :

Enzymes are composed of one or several polypeptide chains. However, there are a number of cases in which non-protein constituents called cofactors are bound to the enzyme to make the enzyme catalytically active. In these instances, the protein portion of the enzymes is called the **apoenzyme** and non-protein portion is called the **cofactor**.

Three kinds of cofactors may be identified: **Co-enzymes**, **Prosthetic groups** and **Metal ions**.

ENZYME

Simple enzyme
They are made up of protein only.
e.g. Pepsin, trypsin etc.

Conjugated enzyme (holoenzyme)

Apoenzyme
(Protein part)

Co-factor
(Non-protein part)

Co-enzyme

- They are **organic compounds** They are **loosely bound** to the apoenzyme.
- Their association with apoenzyme is only **transient** (usually occurring during the course of catalysis) Most of them are vitamin derivatives

Prosthetic group

- They are **organic or Inorganic compounds** They are **tightly bound** to the apoenzyme.
- In peroxidase and catalase, haem is the prosthetic group and it is a part of the active site of the enzyme.

Metal activators

- They are **loosely attached Inorganic co-factor.**
- They form coordination bonds with side chains **at the active site** and at the same time form one or more coordination bonds with the substrate.

Important examples of coenzymes and metal activators :

Examples of co-enzyme	Examples of metal activator
Co. I (NAD/DPN) : Derivative of **niacin**	**Fe^{++} :** Cytochrome c oxidase, catalase, peroxidase, aconitase
Co. II (NADP/TPN) : Derivative of **niacin**	**Cu^{++} :** Cytochrome c oxidase, tyrosinase
FAD : Derivative of **riboflavin**	**Zn^{++} :** Carbonic andydrase, alcohol dehydrogenase, carboxypeptidase.
FMN : Derivative of **riboflavin**	**Mg^{++} :** Hexokinase, glucokinase, pyruvate kinase, PEPcase, RuBisCO.
TPP : Derivative of **thiamine**	**K^{+} :** Pyruvate kinase
Co. Q : Derivative of **ubiquinone**	**Mn^{++} :** Arginase, ribonucleotide reductase, decarboxylase
Co. R : Derivative of **biotin**	**Mo :** Nitrogenase complex, nitrate reductase
Co. A : Derivative of **pantothenic acid**	**Se :** Glutathione peroxidase

(5) CLASSIFICATION AND NOMENCLATURE OF ENZYMES :

Thousands of enzymes have been discovered, isolated and studied. Most of these enzymes have been classified into different **groups based on the type of reactions they catalyse**. Enzymes are divided into **6 classes** each with **4-13 subclasses** and named accordingly by a four-digit number (E.C. number).

(i) Oxidoreductases/Dehydrogenases : Enzymes which catalyse oxidoreduction (oxidation-reduction) between two substrates i.e. **S** and **S'**.

e.g. Cytochrome c oxidase, Dehydrogenase etc.

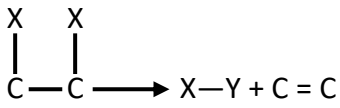
$$S \text{ reduced} + S' \text{ oxidised} \longrightarrow S \text{ oxidised} + S' \text{ reduced}$$

(ii) Transferases : Enzymes catalysing a transfer of a group, **G (other than hydrogen)** between a pair of substrate S and S'. e.g. Transaminase, Hexokinase etc.

$$S - G + S' \longrightarrow S + S' - G$$

(iii) Hydrolases : Enzymes catalysing hydrolysis of ester, ether, peptide, glycosidic, C–C, C–halide or P–N bonds with addition of water. **e.g.** Proteases, Lipases, Carbohydrases etc.

(iv) Lyases : Enzymes that catalyse removal of a group from substrate by mechanisms other than hydrolysis and leaving double bonds. **e.g.** Aldolase.



(v) Isomerases : Includes all enzymes catalysing inter-conversion of optical, geometric or positional isomers. ***e.g.*** Hexomerase, Mutase etc.

$$\text{Glucose-6-phosphate} \overset{\text{Isomerase}}{\rightleftharpoons} \text{Fructose-6-phosphate}$$

(vi) Ligases/synthase : Enzymes catalysing the linking together of two compounds. Such enzymes catalyse joining of C–O, C–S, C–N, P–O etc. bonds.

e.g. Citrate synthase, DNA ligase etc.

(6) FACTORS AFFECTING ENZYME ACTIVITY :

The activity of an enzyme can be affected by a change in the conditions which can alter the tertiary structure of the protein. These include :

(1) Temperature (2) pH

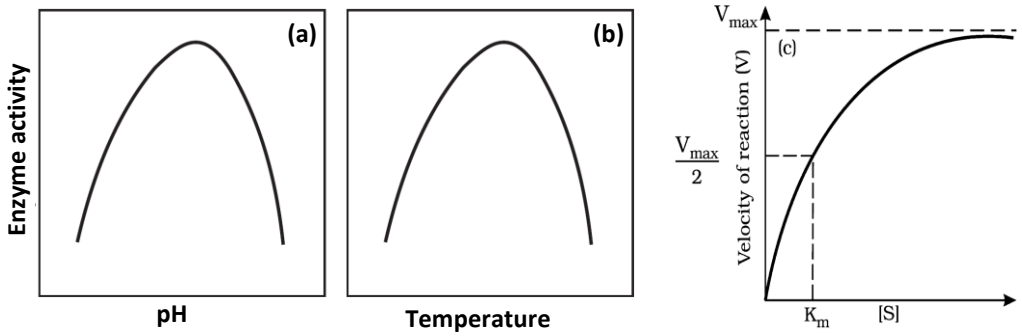
(3) Change in substrate concentration (4) Inhibitor

(1) Temperature : Enzymes generally function in a **narrow range** of temperature.

Each enzyme shows its highest activity at a particular temperature called the **optimum temperature**. Activity declines both below and above the optimum value. **Low temperature preserves the enzyme in a temporarily inactive state** whereas high temperature destroys enzymatic activity because **proteins are denatured by heat**.

A general rule of thumb is that rate doubles or decreases by half for every 10°C change in either direction. Thus, value of Q_{10} for enzymatic activities is 2.

(2) pH : Enzymes generally function in a **very narrow range** of pH. Each enzyme shows its highest activity at a particular pH called the **optimum pH**. Activity declines both below and above the optimum value.



Effect of change in :

(a) pH (b) Temperature and (c) Concentration of substrate on enzyme activity

(3) Change In Substrate Concentration : With the increase in substrate concentration, the velocity of the enzymatic reaction **rises at first**. The reaction ultimately reaches a maximum velocity ($V_{max.}$).

This velocity is not exceeded by any further rise in concentration of the substrate.

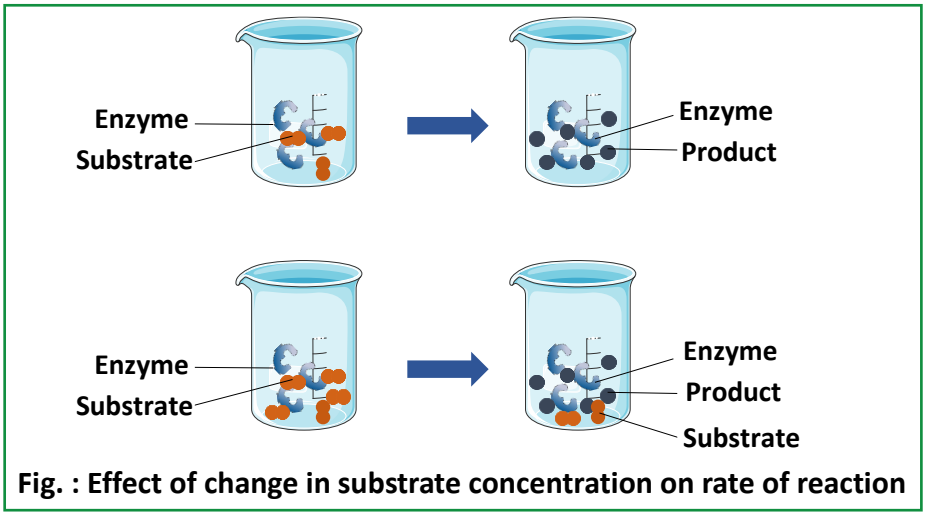


Fig. : Effect of change in substrate concentration on rate of reaction

Reason : The enzyme molecules are fewer than the substrate molecules and after saturation of these enzyme molecules, there are no free enzyme molecules available to bind with the additional substrate molecules.

(4) Inhibitors /Enzyme Inhibition : The activity of an enzyme is also sensitive to the presence of **specific chemicals that bind to the enzyme**. When the binding of the chemical shuts off (inhibits) enzyme activity, the process is called **inhibition** and the chemical is called an inhibitor.

It is of two types :

(A) COMPETITIVE INHIBITION :

- When the inhibitor closely resembles the substrate (**substrate analogues**) in its molecular structure and binds with active site of enzyme leads to inhibition of enzyme activity.

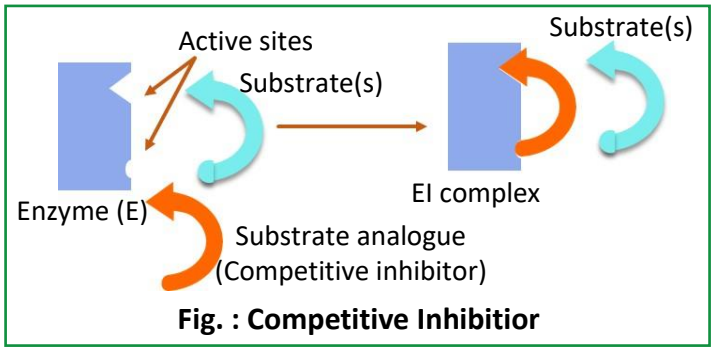


Fig. : Competitive Inhibitior

- It is competitive as well as reversible because inhibitor binds with active site (competitive) and can be detached by increasing concentration of substrate. (reversible)

e.g. **(a)** Inhibition of **Succinate dehydrogenase** by malonate. Malonate and succinate are **structural analogues**.

(b) Inhibition of folic acid synthesis by sulpha drugs.

p-amino benzoic acid (PABA) is a **precursor of folic acid.** Sulpha drugs are structural analogues of p-amino benzoic acid, thus inhibits synthesis of folic acid. This competitive inhibition is often used in the control of bacterial pathogens.

Reason : Bacteria requires folic acid for growth and multiplication.

In the presence of competitive inhibitor **K_m increases while $V_{max.}$ remains unchanged**.

(B) NON COMPETITIVE INHIBITION :

It is again of two types :

(i) Non competitive irreversible :

- When the inhibitor binds irreversibly with the **site other than active site**.

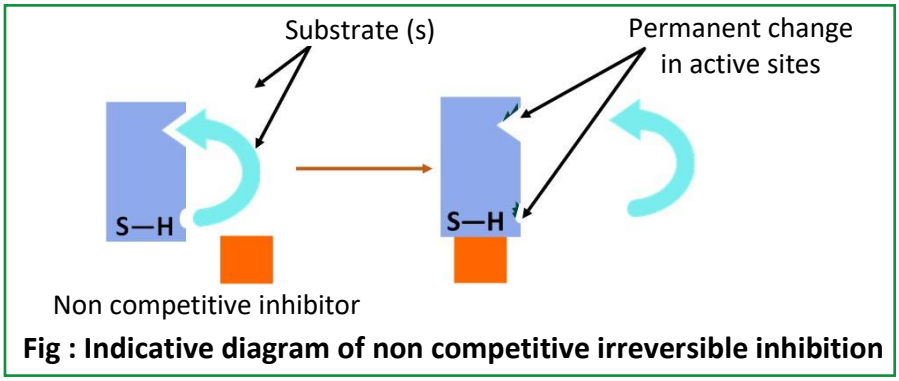


Fig : Indicative diagram of non competitive irreversible inhibition

e.g. Cyanide binds with Cu center of cytochrome c oxidase during cyanide poisoning in animals.

(ii) Non competitive reversible : (Mostly)

- Some enzymes have **allosteric site** to control active site. This control is called **modulation.**
- Most of non-competitive inhibitors bind reversibly with **allosteric site** and negatively change the configuration of active site. Such inhibition is called **non-competitive reversible inhibition or negative allosteric modulation.**

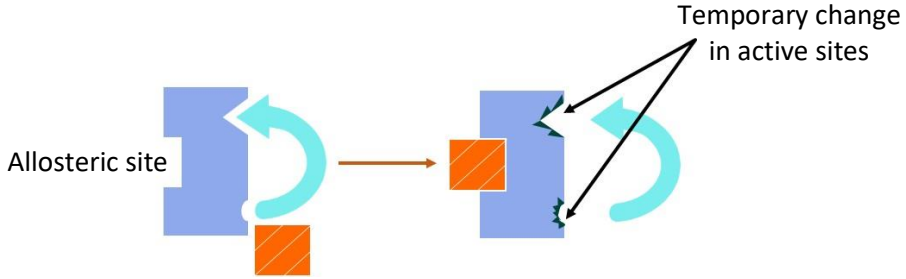


Fig. : Indicative diagram of non competitive reversible inhibition

e.g. **Phosphofructokinase/PFK (pacemaker enzyme)** of glycolysis is inhibited reversibly by excess of ATP **(negative modulation)**.

The action of AMP on PFK enzyme is positive allosteric modulation.

- Some allosteric enzymes are inhibited by the product of that biochemical reaction which is catalysed by them, such inhibition called **feedback inhibition** or **retro inhibition** or **product inhibition.**

e.g. $\text{Glucose} + \text{ATP} \xrightarrow[Mg^{++}]{\text{Hexokinase}} \text{Glucose-6-phosphate} + \text{ADP}$

In above reaction the enzyme Hexokinase is inhibited reversibly by excess of product (Glucose-6-phosphate)

★ Golden Key Points ★

- Almost all enzymes are protein. Though, there are **some nucleic acids** that behave like enzymes. These are called **ribozymes.**
- The **protein portion of the enzymes is called the apoenzyme and non protein portion is called the cofactor**.
- **Co-enzyme** are organic compounds. They are loosely bound to the apoenzyme.
- **Prosthetic group** are organic or inorganic compounds. They are tightly bound to the apoenzyme.
- **Metal ion** are loosely attached inorganic co-factor.
- **A general rule of thumb is that rate doubles or decreases by half for every 10°C change in either direction.**
- Competitive inhibition is often used in the control of bacterial pathogens.

BEGINNER'S BOX-3 ENZYME : INTRODUCTION TO THE LIVING STATE

1. Non protein organic compound, which shows transient association with apoenzyme usually during the course of catalysis, is known as :-

(1) Coenzyme (2) Prosthetic group (3) Metal ion (4) Pathogen

BBM225

2. The full name of NAD is :-

(1) Nicotinamide adenosine dinucleotide

(2) Nicotinamide adenine dinucleotide

(3) Nicotinamide adenine diamide

(4) Nicotinamide adenosine diamide

BBM226

3. The action of AMP on phosphofructokinase enzyme is :-

(1) Negative allosteric modulation

(2) Competitive inhibition

(3) Non competitive irreversible inhibition

(4) Positive allosteric modulation

BBM227

4. With continuously increasing substrate concentration, enzymatic activity :-

(1) Continuously increases

(2) Continuously decreases

(3) First increases then decreases

(4) First increases then become constant

BBM228

5. Which of the following is true for transition state ?

(1) Altered structural state (2) High Energy state

(3) Unstable state (4) All of the above

BBM229

6. Vitamin serves the function of :-

(1) An enzyme (2) A coenzyme (3) A holoenzyme (4) A hormone

BBM230

7. Substrate concentration at which an enzyme attains half of its maximum velocity is?

(1) Half-life of enzyme

(2) Km-constant of enzyme

(3) Concentration ratio

(4) Turn over number (TON) of enzyme E

BBM231

8. Which of the following statements is incorrect with respect to inorganic catalysts?

(1) They do not occur in living cells

(2) They are not specific for any reaction

(3) They get damaged at high temperature

(4) They work efficiently at high pressure

BBM232

9. Enzymes catalyse biochemical reactions by -

(1) Lowering the activation energy

(2) Increasing the activation energy

(3) Establishing stable bonds with substrate

(4) Increasing temperature

BBM233

10. Value of Q_{10} for enzymatic activities is -

(1) 2 (2) 1 (3) 3 (4) 0

BBM234

BEGINNER'S BOX ANSWERS KEY

BEGINNER'S BOX-1	**Que.**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Ans.	**4**	**2**	**4**	**3**	**3**	**3**	**1**	**4**	**3**	**1**
	Que.	**11**	**12**	**13**	**14**	**15**	**16**				
	Ans.	**1**	**4**	**4**	**3**	**2**	**4**				

BEGINNER'S BOX-2	**Que.**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Ans.	**3**	**4**	**1**	**3**	**4**	**2**	**2**	**2**	**2**	**2**

BEGINNER'S BOX-3	**Que.**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Ans.	**1**	**2**	**4**	**4**	**4**	**2**	**2**	**3**	**1**	**1**

Biomolecule → All the carbon compound that present in living tissue.

Biomolecule

Micromolecule	Macromolecule
(Mol. Weight < 1000 daltons)	(Mol.Weight > 1000 daltons)
↓	↓
Present in acid soluble pool	Present in acid insoluble pool
↓ e.g.	↓ e.g.
Amino acid, Nucleotide bases, Monosaccharide, Lipid	Protein, nucleic acid, Polysaccharide

- But exceptionally lipid is micromolecule but present in acid insoluble fraction.

Polysaccharides

- Although polysaccharide is non-reducing but in a polysaccharide chain left end is reducing and right end is non-reducing.
- Starch form helical structure so starch can hold I_2 molecules in the helical portion so starch-I_2 is blue in colour. While cellulose have linear structure so it cannot hold I_2 and don't give Iodine test.
- Paper made from plant pulp is cellulose.
- Difference between gums and fevicol → Gums are natural mucopolysaccharide while fevicol is synthetic rubber based adhesive.

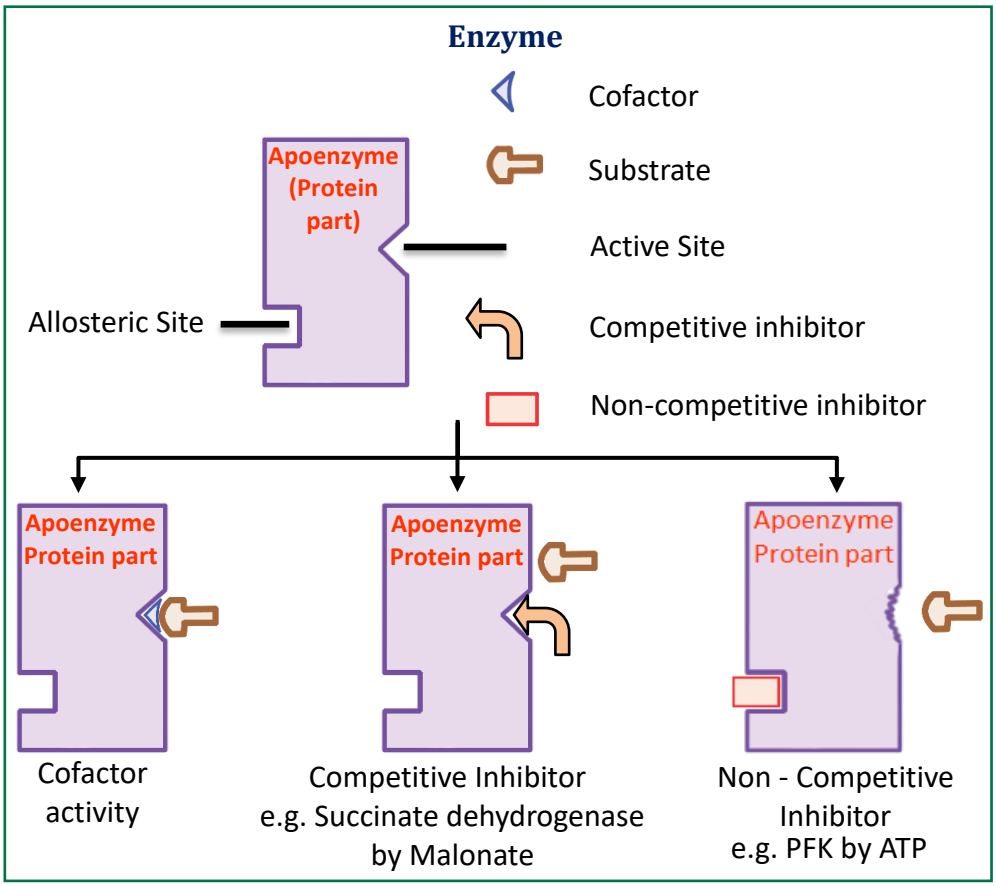
LIPID

- Fatty acids are of two types →
  (i) Saturated→ e.g. Palmitic acid (16 carbon compound), Stearic acid (18 Carbon compound)
  (ii) Unsaturated → e.g. Oleic acid, Linoleic acid, Linolenic acid, Arachidonic acid (20 carbon compound)
- Glycerol is trihydroxy propane.
- Lipids are called fats and oils on the basis of melting point. Oils have lower melting point and fats have higher melting point.
- Some lipids also have phosphorus like Lecithin.

PROTEIN

- Proteins are heteropolymer of amino acids.
- Amino acids contain an amino group and carboxylic group on the same carbon i.e. the α-carbon so they are called α-amino acids.
- Amino acid are substituted methane.

- Amino acids are of two types :–
  (i) Essential amino acids (ii) Non-essential amino acids
- Protein show mainly four types of configuration:–
  (A) Primary configuration (B) Secondary configuration
  (C) Tertiary configuration (D) Quaternary configuration



Classification of Enzymes

1. Oxidoreductases/dehydrogenases: Catalyse the transfer H / e⁻ between two substrates
2. Transferases: Catalyse the transfer of group other than hydrogen between two substrates
3. Hydrolases : Breakdown of ester, ether, peptide, glycosidic, C-C, C-halide or P-N bonds with the help of water.
4. Lyases: Enzymes that catalyse removal of groups from substrates without help of water.
5. Isomerases: Includes all enzymes catalysing inter-conversion of optical, geometric or positional isomers.
6. Ligases: Enzymes catalysing the linking together of 2 compounds.

Qualitative Test for Proteins, Fats And Amino Acids

Test	Name of item	Procedure	Result	Conclusion
Biuret's test	Fruit juice	Juice + biuret's reagent	Change of colour from light blue to purple	Presence of protein
	Saliva	Saliva + biuret's reagent	Change of colour from light blue to purple	Presence of protein
	Sweat	Sweat + biuret's reagent	Colour does not change	Absence of protein
	Urine	Drops of urine + biuret's reagent	Change of colour from light blue to purple	Presence of protein
Grease test	Fruit juice	Few drops of juice on brown paper	A translucent spot is not observed	Absence of oils and fats
	Saliva	Few drops of saliva on the brown paper	A translucent spot is not observed	Absence of oils and fats
Solubility test	Sweat	Water added with sweat	Oil presence	Fats or oils can be present
	Urine	Water added to a few drops of urine	Slight oily presence	Fats may or may not be present
Ninhydrin test	Fruit juice	Juice+ninhydrin reagent (boil for few minutes)	Change of colour from no colour to purple, pink or blue	Presence of amino acids
	Saliva	saliva+ninhydrin reagent (boil for a few minutes)	Change of colour from no colour to purple, pink or blue	Presence of amino acids
	Sweat	sweat+ninhydrin reagent (boil for a few minutes)	No colour change	Absence of amino acids
	Urine	urine+ninhydrin reagent (boil for a few minutes)	Depending upon the type of amino acid, the colourless solution changes to purple, pink or blue colour	Presence of amino acids

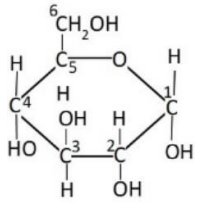
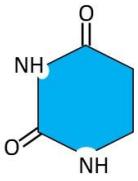
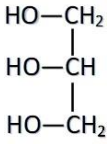
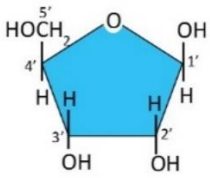
NCERT Question :

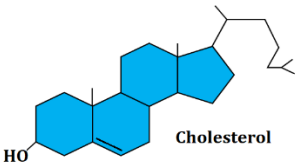
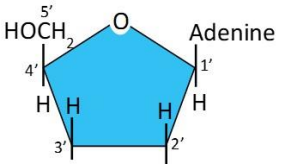
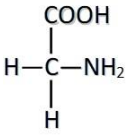
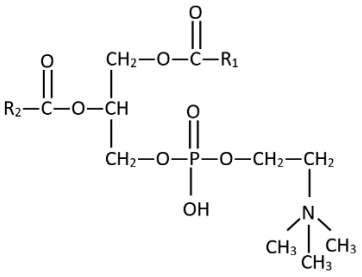
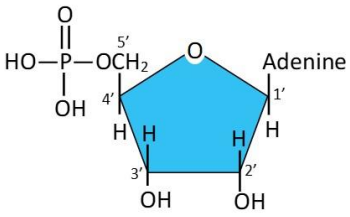
Find out a qualitative test for proteins, fats and oils, amino acids and test any fruit juice, saliva, sweat and urine for them.

NCERT Question :

Find and write down structures of 10 interesting small molecular weight biomolecules. Find if there is any industry which manufactures the compounds by isolation. Find out who are the buyers.

Ans.

Name of the biomolecule	Structure
Glucose ($C_6H_{12}O_6$)	 Glucose
Uracil	 Uracil
Glycerol	 Glycerol
Ribose	 Ribose

Name of the biomolecule	Structure
Cholesterol	 Cholesterol
Adenosine	 Adenosine
Glycine	 Glycine
Phospholipid	 Phospholipid
Adenylic acid	 Adenylic acid

Compound	Manufacturer	Buyer
Starch	Premier starch products private limited	Research institutes and laundries
Liquid Glucose	Imperial liquid glucose	Used in making flavoured drinks and in research
Enzymes like amylase, protease, and cellulase	Planet Biotech India	Used in research

NCERT SUMMARY

Although there is a bewildering diversity of living organisms, their chemical composition and metabolic reactions appear to be remarkably similar. The elemental composition of living tissues and non-living matter appear also to be similar when analysed qualitatively. However, a closer examination reveals that the relative abundance of carbon, hydrogen and oxygen is higher in living systems when compared to inanimate matter. The most abundant chemical in living organisms is water. There are thousands of small molecular weight (<1000 Da) biomolecules. Amino acids, monosaccharide and disaccharide sugars, fatty acids, glycerol, nucleotides, nucleosides and nitrogen bases are some of the organic compounds seen in living organisms. There are 20 types of amino acids and 5 types of nucleotides. Fats and oils are glycerides in which fatty acids are esterified to glycerol. Phospholipids contain, in addition, a phosphorylated nitrogenous compound.

Only three types of macromolecules, i.e., proteins, nucleic acids and polysaccharides are found in living systems. Lipids, because of their association with membranes separate in the macromolecular fraction. Biomacromolecules are polymers. They are made of building blocks which are different. Proteins are heteropolymers made of amino acids. Nucleic acids (RNA and DNA) are composed of nucleotides. Biomacromolecules have a hierarchy of structures –primary, secondary, tertiary and quaternary. Nucleic acids serve as genetic material. Polysaccharides are components of cell wall in plants, fungi and also of the exoskeleton of arthropods. They also are storage forms of energy (e.g., starch and glycogen). Proteins serve a variety of cellular functions. Many of them are enzymes, some are antibodies, some are receptors, some are hormones and some others are structural proteins. Collagen is the most abundant protein in animal world and Ribulose bisphosphate Carboxylase-Oxygenase (RuBisCO) is the most abundant protein in the whole of the biosphere.

Enzymes are proteins which catalyse biochemical reactions in the cells. Ribozymes are nucleic acids with catalytic power. Proteinaceous enzymes exhibit substrate specificity, require optimum temperature and pH for maximal activity. They are denatured at high temperatures. Enzymes lower activation energy of reactions and enhance greatly the rate of the reactions. Nucleic acids carry hereditary information and are passed on from parental generation to progeny.