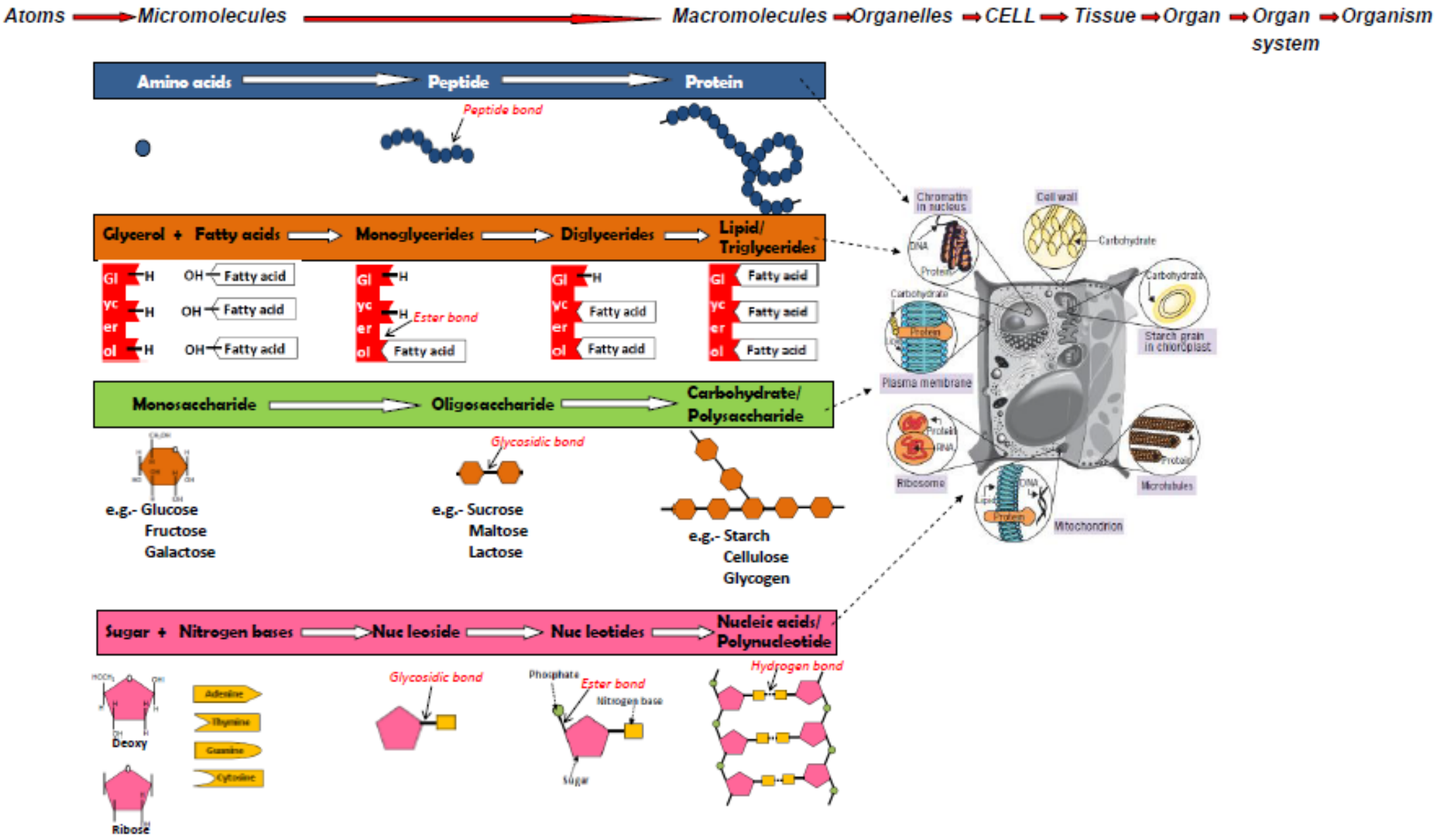
ZLGY-MM: XI

9. BIOMOLECULES

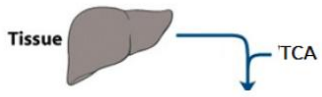
The compounds present in living systems are called ***Biomolecules***. They include organic and inorganic compounds.

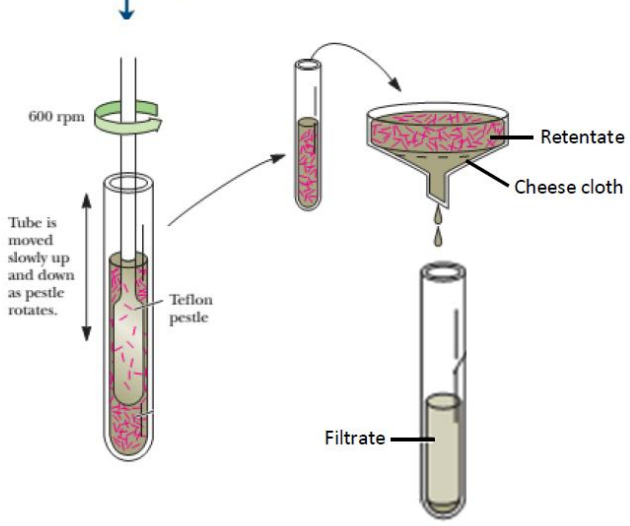


ANALYSIS OF ORGANIC COMPOUNDS

(Step-1) Take a living tissue (a vegetable / piece of liver etc).

(Step-2) Grind it in **trichloroacetic acid (Cl_3CCOOH)** using a mortar and a pestle to get a thick slurry.





(Step-3) Filter the slurry through a cheesecloth or cotton; it will get separated to 2 fractions-

I. **Filtrate** (acid-soluble pool)
Compounds such as amino acids, nucleotides, simple sugars, nitrogen bases etc. are seen in this pool, having molecular weights ranging from 18 -800 daltons (Da) which are referred to as **micromolecules**.

II. **Retentate** (acid-insoluble fraction)

- The **acid insoluble fraction**, has 4 types of organic compounds i.e., proteins, nucleic acids, polysaccharides and lipids. These classes of compounds with the exception of lipids have molecular weights 10,000 Da and above are called **macromolecules**.

> Molecular weight of **lipids** is less than **800 Da**. But it comes under **acid insoluble fraction** because lipids, when a tissue is grinded form vesicles which are water insoluble, i.e. lipids are not strictly macromolecules.

ANALYSIS OF INORGANIC COMPOUNDS

(Step-1) Take a living tissue and dry it.

(Step-2) It is burnt fully (to oxidize all the carbon compounds to CO_2 and water vapour).

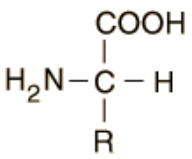
(Step-3) The remaining ash contains **inorganic elements (Ca^{2+}, Mg^{2+} etc)** and **inorganic compounds (SO_4^{2-}, PO_4^{3-} etc).**

BIOMICROMOLECULES

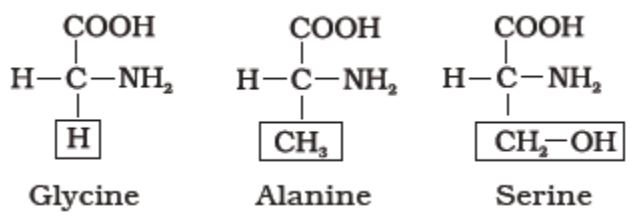
➔ Biomolecules having molecular weight **less than 1000 Da** are called **micromolecules.**

1. Amino acids

- **Amino acid** are organic compound containing an amino group ($-NH_2$), an acid group (-COOH), H & a variable group (R) attached to a C- atom (C_α).
- There are 20 amino acids used as building blocks for protein synthesis.



E.g. -



Classification -

A. Based on **requirement** by animals, amino acids are 2 types:

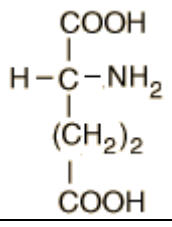
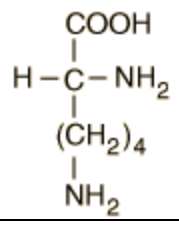
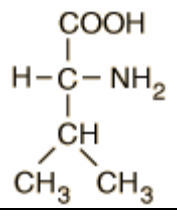
o **Essential amino acids** (should get through diet)

Lysine, leucine, isoleucine, methionine, phenylalanine, tryptophan, histidine, threonine, arginine and valine include in this type.

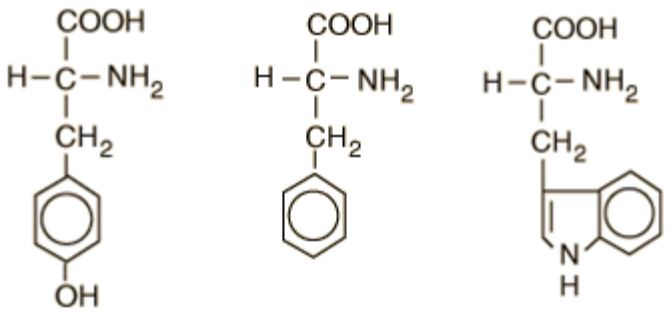
o **Non-essential amino acids** (body can synthesize)

Alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, proline, serine, and tyrosine.

B. Based on the no. of amino & carboxyl group

Type	Definition	Example
Acidic	1 amino group and 2 carboxyl group OR have a acidic group (-COOH) in R	**Glutamic acid** 
Basic	2 amino group and 1 carboxyl group OR have a basic group ($-NH_2$) in R	**Lysine** 
Neutral	1 amino group and 1 carboxyl group OR have neither acidic nor basic group in R	Valine 

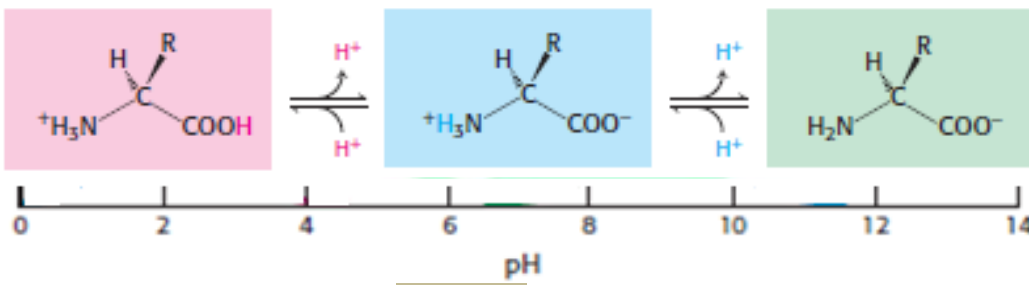
❖ **Aromatic** - Amino acids with cyclic structure in the variable group



Ex: Tyrosine Phenyl alanine Tryptophan

➢ The structure of amino acids changes in solutions of diff. pH, because they have ionizable $–NH_2$ & –COOH groups.

Amino acid, *at a particular pH*, possessing both NH_3^+ (cationic) & COO^- (anionic) is termed as ***zwitter ionic*** (***zwitter***^{German}= both).



2. Lipids

➢ **Lipids** are esters of fatty acids with various alcohols.

Classification -

A. Based on melting point, lipids are 2 types: **fats** and **oils.**

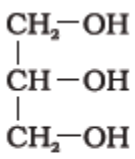
❖ **Oils** have low melting point. So they remain in *liquid* form at room temperature.

❖ **Fats** have high melting point. So they remain in *solid* form at room temperature

B. Based on composition, lipids are ***3 types-***

I. The **simple lipids** are formed of ***alcohol*** like glycerol and ***fatty acids***

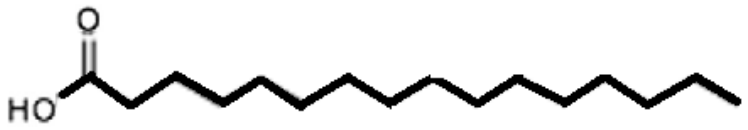
♥ Glycerol is *trihydroxy propane*.



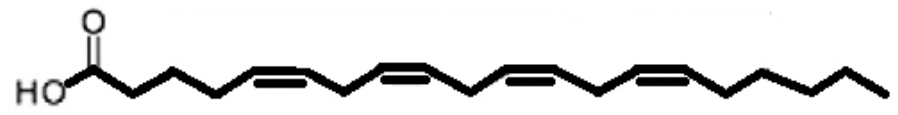
♥ Fatty acid are organic acids with hydrocarbon chain ending in a carboxyl group (–COOH).

Fatty acids are 2 types:

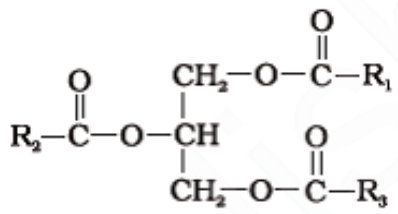
o **Saturated fatty acids:** No double bonds between C- atoms
Eg: Palmitic acid-16 C.



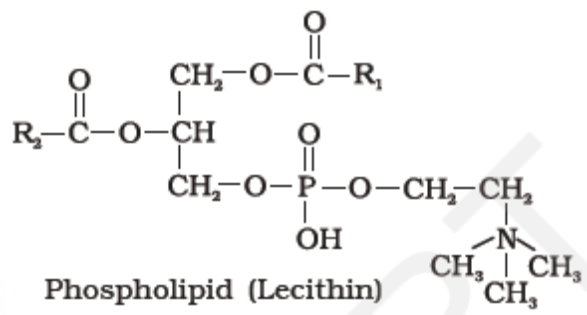
o **Unsaturated Fatty acids:** Have **o**ne or more C=C bonds
Eg: Arachidonic acid- 20 C, double bonds b/w C5-6, 8-9, 11-12 & 14-15.



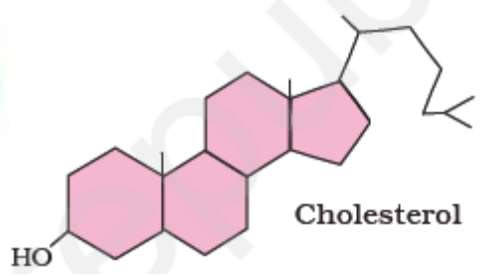
It includes **monoglycerides**= glycerol + 1 fatty acid
diglycerides = glycerol + 2 fatty acids
triglycerides = glycerol + 3 fatty acids



II. Phospholipids are esters of fatty acid and alcohol with phosphorus compounds
E.g. ***Lecithin*** (found in cell membrane)

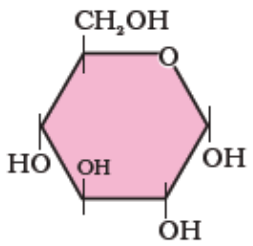

Phospholipid (Lecithin)

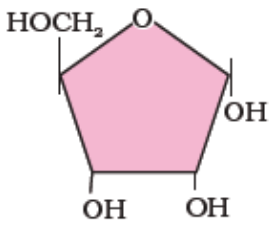
III. Sterols are compounds of fused hydrocarbon ring and a long hydrocarbon side chain. e.g.: Cholesterol.


Cholesterol

3. Sugars/ Saccharide

➢ Sugars are sweet and water soluble carbohydrates.
E.g.:


$C_6H_{12}O_6$ (Glucose)


$C_5H_{10}O_5$ (Ribose)

4. Nucleotides

A nucleotide has 3 components:

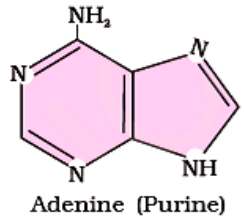
1. **A nitrogenous base,** 2 types -
   - **Purines:** It includes **Adenine** and **Guanine.**
   - **Pyrimidines:** It includes **Cytosine, Thymine** & **Uracil.**
2. **A pentose sugar (ribose** in **RNA & deoxyribose** in **DNA)**
3. **A phosphate group**

▪ A nitrogenous base is linked to the pentose sugar through an **N-glycosidic linkage** to form **nucleoside.**

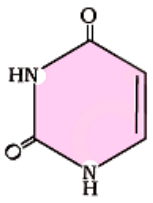
▪ When a phosphate group is linked to nucleoside through **ester linkage**, a corresponding **nucleotide** is formed.

➢ **Nitrogen base + Sugar = *Nucleoside* + phosphate = *Nucleotide***

Adenine + sugar = ***Adenosine*** + phosphate = ***Adenylic acid***
Guanine + sugar = ***Guanosine*** + phosphate = ***Guanylic acid***
Cytosine + sugar = ***Cytidine*** + phosphate = ***Cytidylic acid***
Thymine + sugar = ***Thymidine*** + phosphate = ***Thymidylic acid***
Uracil + sugar = ***Uridine*** + phosphate = ***Uridylic acid***

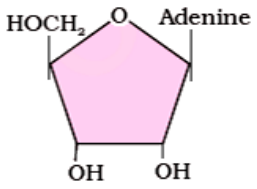


Adenine (Purine)

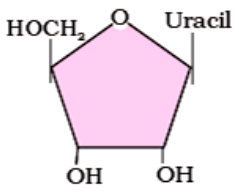


Uracil (Pyrimidine)

Nitrogen bases

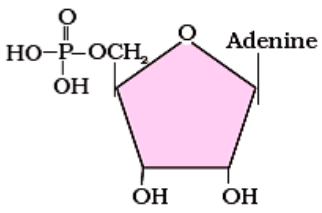


Adenosine



Uridine

Nucleosides



Adenylic acid

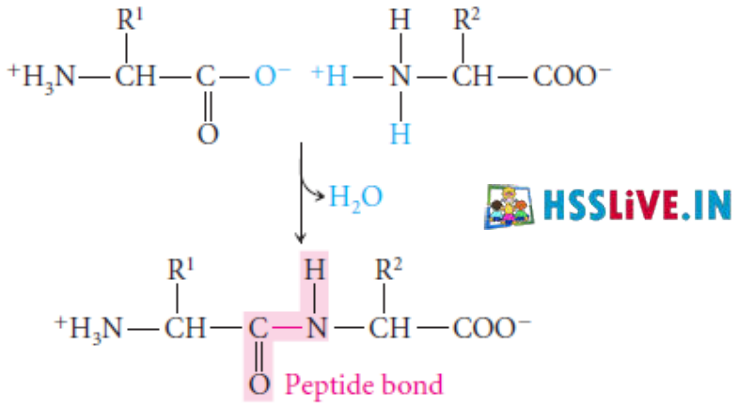
Nucleotide

BIOMACROMOLECULES

✓ Biomolecules having molecular weight **greater than 1000 Dalton (Da)** is called **macromolecules.**

1. Proteins /Polypeptides

- They are *heteropolymers of amino acids* linked by peptide bonds.
- ***Peptide bond*** is formed when –COOH group of one amino acid reacts with $–NH_2$ group of next amino acid by releasing a molecule of water (dehydration).



HSSLiVE.IN

Functions of protein:

- **Transport** nutrients across cell membranes (e.g. GLUT-4 enables glucose transport into cell).
- Acts as intercellular **ground substance** (e.g. collagen).
- Acts as **antibodies** to fight infectious organisms.
- Acts as **receptors** (e.g. receptors of smell, taste, hormones).
- Some are **hormones** (e.g. Insulin), **enzymes** (e.g. trypsin), etc.
  - Most abundant protein in animal world: **Collagen**
  - Most abundant protein in the biosphere: **RuBisCO**

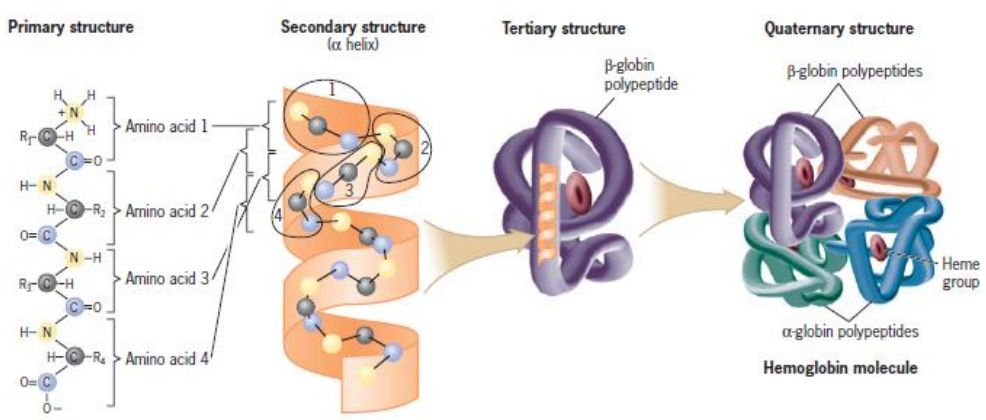
Structure of protein

4 levels of protein structure can be recognised:

1. **Primary structure:** Here, the amino acids are arranged in a **linear sequence**.
   The first amino acid (on left) is also called as N-terminal amino acid because its $–NH_2$ is free. The last amino acid (on right) is called the C-terminal amino acid because its –COOH is free.

HSSLiVE.IN

2. **Secondary structure:** A protein thread is folded in the form of a helix.
3. **Tertiary structure:** Long protein chain is folded extensively upon itself. .
4. **Quaternary structure:** Protein that are an assembly of **more than one polypeptide** or **subunits**.
   E.g. Hb has 4 subunits (2 α and 2 β subunits)



2. Carbohydrates /Polysaccharides

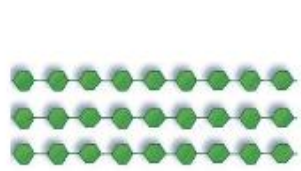
✓ These are polymers of sugars (monosaccharides) linked by *glycosidic bond*.

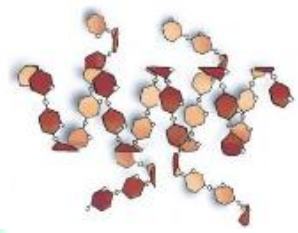
✓ **Glycosidic bond** is formed when individual monosaccharides are linked between 2 carbon atoms by dehydration.

E.g:

- ❖ **Starch** (polymer of glucose)
  - Store energy in plant tissues
  - Forms helical structure and hence it can hold I_2 molecules in the helical portion giving blue colour.
- ❖ **Cellulose** (polymer of glucose)
  - Component of plant cell wall and cotton fibre
  - It has no complex helices and so cannot hold I_2.
- ❖ **Glycogen** (polymer of glucose)
  - Reserve food in animals.


Starch


Cellulose


Glycogen

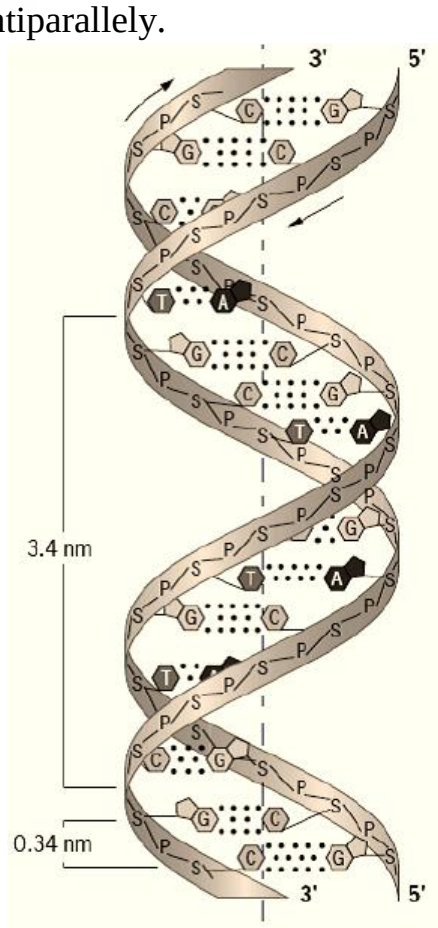
- ❖ Inulin (polymer of fructose)
- ❖ Chitin (polymer of N-acetyl glucosamine)
  - Found in cell wall of fungi & exoskeleton of arthropods)

3. Nucleic Acids /Polynucleotide

- Nucleic acids are **heteropolymer** of nucleotides.
- A nucleic acid containing deoxyribose is called deoxyribonucleic acid (DNA) while that which contains ribose is called ribonucleic acid (RNA).

2^0 structure of DNA (Watson - Crick Model)

- DNA exists as a **double helix**. The 2 **polynucleotide strands** are arranged antiparallely.



- One full turn of helical strand have **10 steps (10 base pairs).** Length of one full turn = **34 Å (i.e. 3.4 Å for each step).** At each step the strand turns **36^0 (360^0 for a full turn).**
- The backbone of DNA is formed by the ***sugar-phosphate-sugar chain***. ***Nitrogen base pairs*** form the steps of DNA.
- A pairs with T **(A=T)** by 2 hydrogen bonds.
  G pairs with C **(G≡C)** by 3 hydrogen bonds.
- A phosphate molecule links the **3'-carbon** atom of one sugar of one nucleotide to the **5'-carbon** of the sugar of the succeeding nucleotide.
  There is an ***ester bond*** between PO_4^{3-} and –OH group of sugar**.**
  As there is one such ester bond on either side, it is called ***phosphodiester bond.***

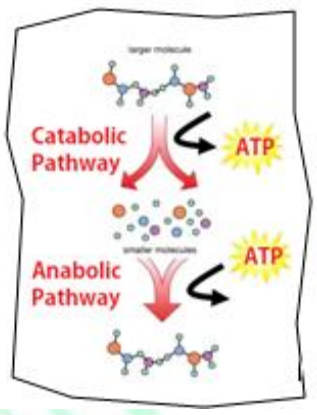
METABOLISM

- All the biochemical reactions taking place inside a living system together constitute **metabolism.**
- **Metabolites** are the organic compounds taking part in metabolism. They are 2 types:-
  - **Primary metabolites:** the compounds which involve directly in the normal growth, development and reproduction of an organism.
    E.g. amino acids, sugars etc.
  - **Secondary metabolites** are biomolecules which are not directly involved in basic metabolism. E.g.
    - **Pigments:** Carotenoids, Anthocyanins etc.
    - **Alkaloids:** Morphine, Codeine etc.
    - **Terpenoides:** Monoterpenes, Diterpenes etc.
    - **Essential oils:** Lemon grass oil etc.
    - **Toxins:** Abrin, Ricin etc.
    - **Lectins:** Concanavalin A.
    - **Drugs:** Vinblastin, curcumin etc.
    - **Polymeric substances:** rubber, gums, cellulose etc.

- In metabolism, there is a series of linked reactions called **metabolic pathways. Metabolic pathways are 2 types:**

Anabolic (biosynthetic) pathways:	Catabolic pathways:
✓ Pathway in which simpler molecules form complex structures (**synthesis**). ✓ It consumes energy. E.g. - Acetic acid becomes cholesterol	✓ Pathway in which complex organic molecules are broken down into simple units (**degradation**). ✓ It releases energy. E.g. - Amino acids polymerise to form protein. - Glucose →Ethanol (in yeast, due to fermentation)

The energy released through **catabolism** is stored in **adenosine triphosphate (ATP).** When needed, this ATP is utilized for **anabolism**. Hence ATP is known as "***energy currency"*** in the living system**.**



ENZYMES

- Enzymes are ***biological catalysts*** which influence biochemical reactions. There is no uncatalysed metabolic conversion in living systems.

Nature of Enzymes

- Almost all enzymes are **proteins**. But sometimes RNA act as enzymes called ***Ribozymes***.
- The tertiary structure of an enzyme has some pockets called **'active site'** into which the substrate fits.

ENZYMES

- **Simple Enzyme** — Made up of only proteins
- **Holoenzyme** — Made-up of protein + Non-protein part
  - **Protein part** (*Apoenzyme*)
  - **Non-protein part** (*Co-factor*)
    - **Prosthetic group:** *Organic. Permenantly bound to apoenzyme.* E.g. **Haem** in *peroxidase* and *catalase*.
    - **Co-enzymes:** Organic. *Bound to apoenzyme only during the time of catalysis.* E.g. **Niacin** in *NAD* and *NADP*
    - **Metal ions:** Form co-ordination bonds with active site and the substrate. E.g. **Zn** in ***Carboxypeptidase.***

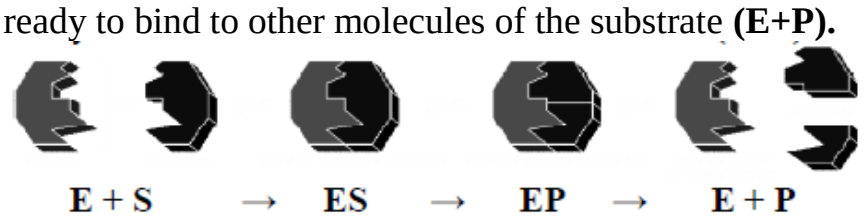
Enzyme action (Catalytic Cycle)

(Step-1) The substrate binds to the **active site** of enzyme **(E+S).**

(Step-2) Binding induces the enzyme to **alter its shape**, so that it fits more tightly around the substrate **(ES).**

(Step-3) The active site breaks chemical bonds of the substrate. As a result, new **enzyme-product complex** is formed **(EP).**

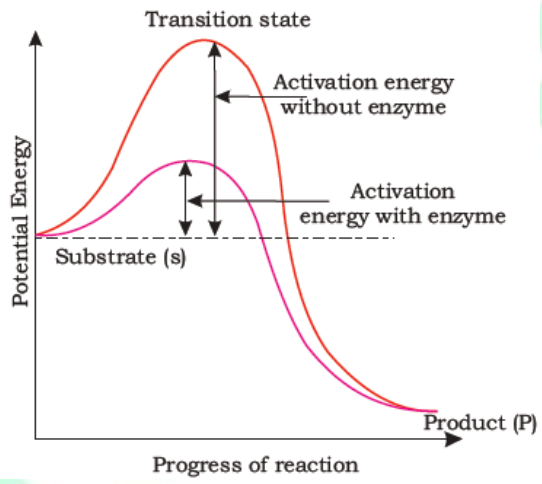
(Step-4) The **enzyme releases the products** and the free enzyme is ready to bind to other molecules of the substrate **(E+P).**



Mechanism of Acceleration (Concept of Activation Energy)

- In a reaction, the substrate has to go through a much higher energy state. It is called **transition state energy.**
- **Activation energy** is the difference between average energy of substrate and transition state (ES) energy.

➔ In a biochemical reaction, ***enzymes lower the activation energy***. As a result, speed of the reaction increases.



Factors affecting enzyme activity

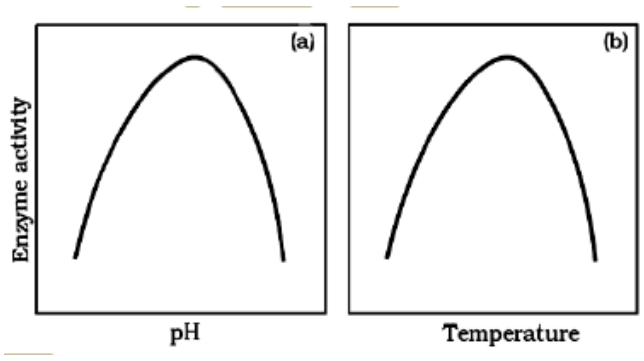
a) Temperature

♥ ***Optimum temperature***: Temperature at which particular enzymes show highest activity.
Activity declines below and above optimum value.

- **At low temperature:** Enzyme temporarily inactive.
- **At high temperature:** Enzymes destroy because proteins are denatured by heat.

b) pH

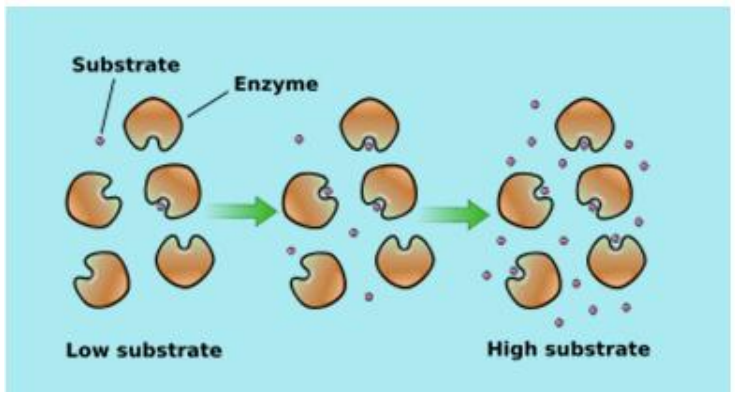
♥ ***Optimum pH***: pH at which particular enzymes show highest activity.

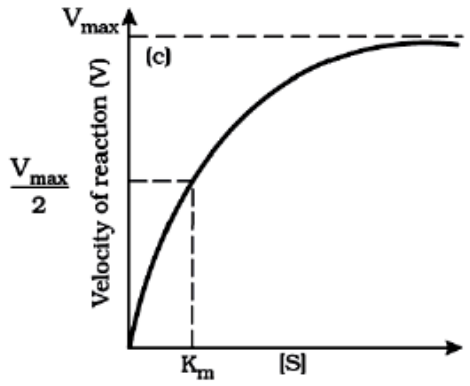


c) Concentration of substrate

♥ With the increase in substrate concentration, the velocity of enzyme action rises at first and reaches a *maximum velocity* (V_{max}).

♥ This is not exceeded by further rise in concentration because enzyme molecules are fully saturated. i.e., *no active site is left free to bind with additional substrate molecules*.





Classification of Enzymes

Class	Type of reaction catalysed	Exemplified Reaction
1. Oxidoreductases/ dehydrogenases	Reaction involving the exchange of H_2 atom or ion between two substrates	$S_{red} + S'_{ox} \rightarrow S_{ox} + S'_{red}$
2. Transferases	Transfer of a group (other than H) between a pair of substrate S and S'	$S - G + S' \rightarrow S + S' - G$
3. Hydrolases	Hydrolysis of ester, ether, peptide, glycosidic, C-C, C-halide or P-N bonds.	$S + H_2O \rightarrow X + Y$
4. Lyases	Removal of groups from substrates by mechanisms other than hydrolysis leaving double bond.	
5. Isomerases	The rearrangement of molecular structure to form isomer.	$X \rightarrow Y$
6. Ligases	The linking together of 2 compounds of C-O, C-S, C-N, P-O etc. bonds.	$X + Y \rightarrow X - Y$