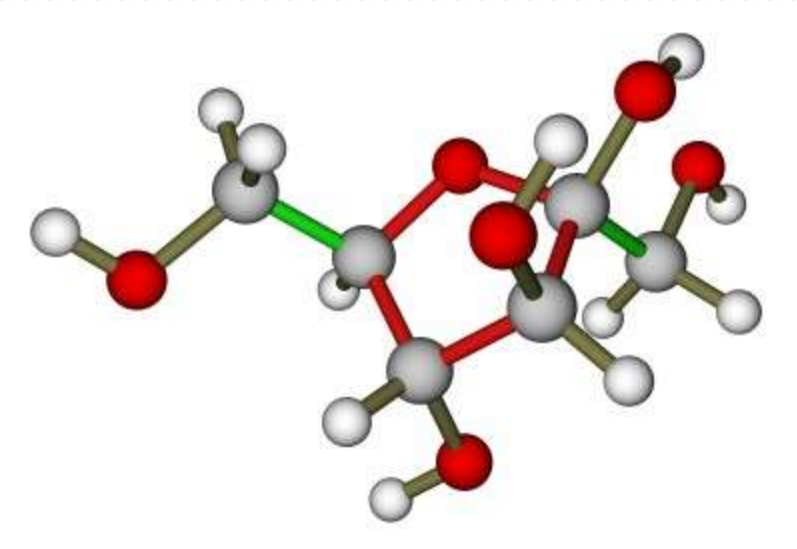
CHAPTER 9 : BIOMOLECULES



K C MEENA

PGT BIOLOGY

How to analyse chemical composition

- Living cells are composed of both organic and inorganic components.

How to analyse chemical composition:

For organic compounds:

- Living tissue + trichloro acetic acid (Cl_3CCOOH) and grind it to form slurry.
- Filter the slurry to obtain 2 fractions like Filtrate/ acid soluble and Retentate/ acid insoluble

For inorganic compounds:

- Sample of tissue should be burnt to obtain ash and different kinds of inorganic compounds were identified.

Types of biomolecules

- **Micro molecules and Macro molecules**
- Micro molecules are known as monomers
- Macromolecules are known as polymers

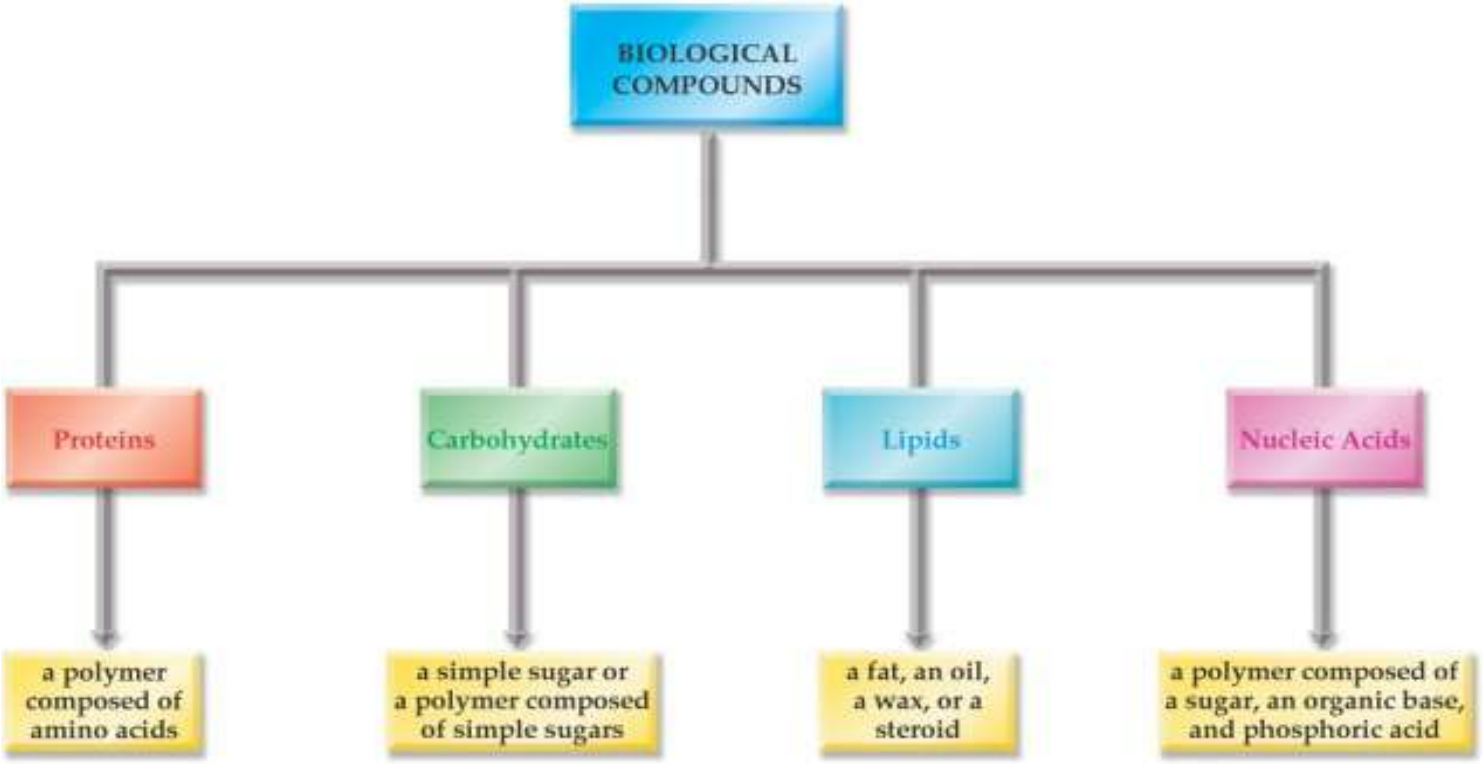
Primary and Secondary metabolites:

- **These are biomolecules in living cells metabolites.**
- ***Primary metabolites* are those which have identifiable functions and play specific roles in normal** physiological processes. Eg. Amino acids, nitrogenous bases, proteins and nucleic acid.

- ***Secondary metabolites are product of certain metabolic pathways from primary metabolites.***
- Pigments – anthocyanin, carotenoids
- Drugs – vinblastin, curcumin
- Alkaloids - morphine, codeine
- Essential oils – lemon grass oil
- Polymeric compounds - rubber gum, cellulose, resins

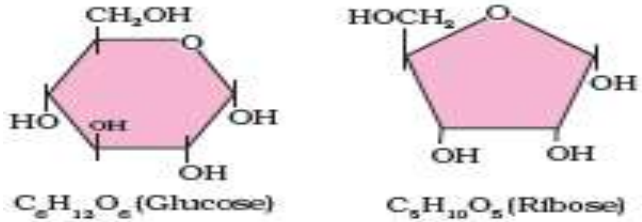
Biomacromolecules

- It is molecules with weight greater than 1000 dalton found in acid insoluble fraction.
- Eg- polysaccharides, nucleic acid, proteins and lipids.

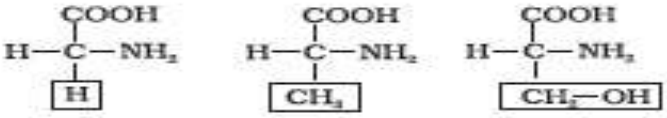


Average Composition of Cells

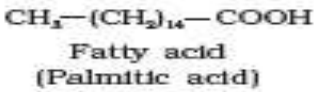
COMPONENT	% OF THE TOTAL CELLULAR MASS
Water	70-90
Proteins	10-15
Carbohydrates	3
Lipids	2
Nucleic acids	5-7
Ions	1

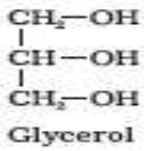


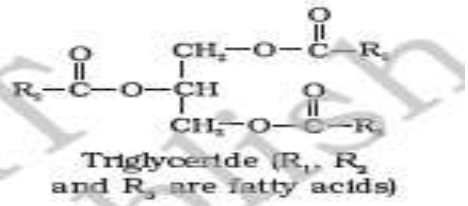
Sugars (Carbohydrates)

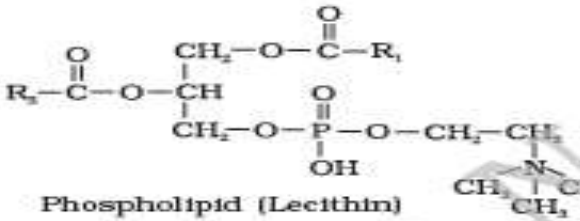


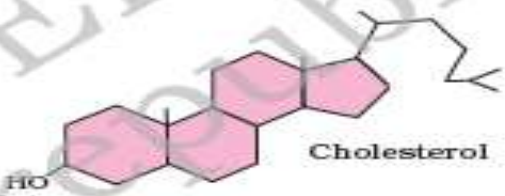
Amino acids



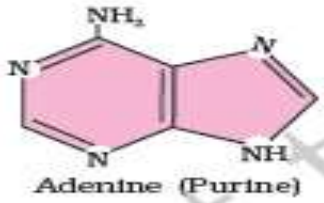


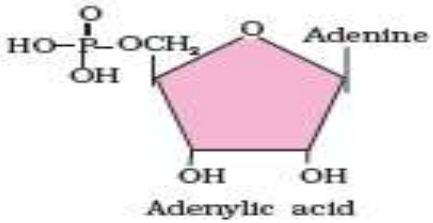




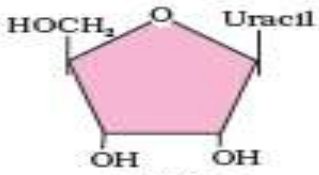


Fats and oils (lipids)





Nitrogen bases



Nucleosides

Nucleotide

Polysaccharides :

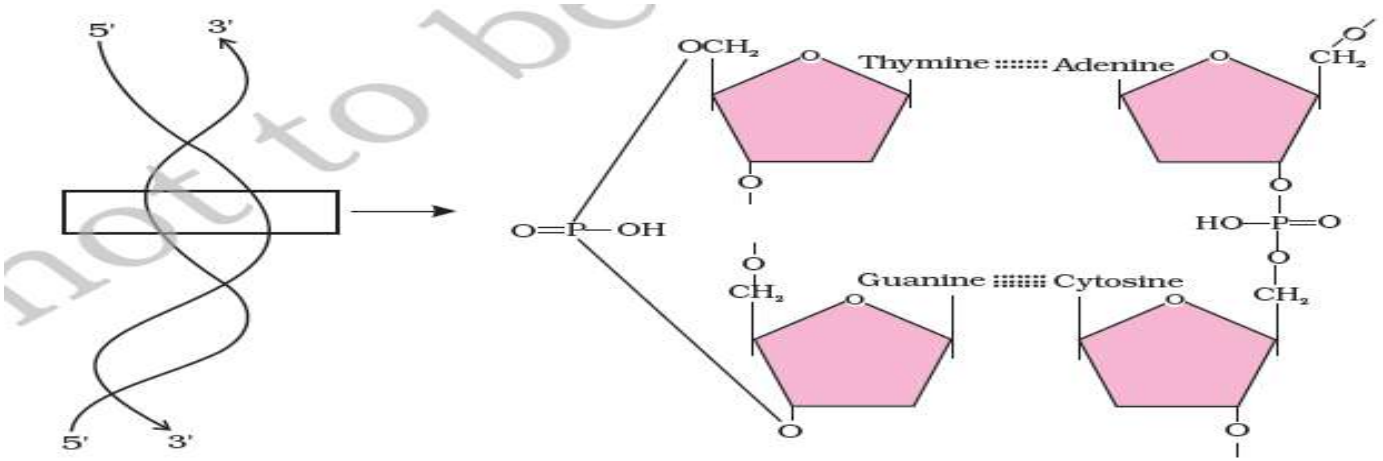
- Long chain of polymers of monosaccharides – 2 types of Mono-polysaccharides (cellulose, starch – made of only Glucose monomers).
- Heteropolymer – chitin
- Inulin -is a polymer of fructose
- Glycogen – polymer of glucose in animal tissues
- Monosaccharides are joined by Glycosidic acid bond, right end is reducing and left end is non reducing.
- Starch forms helical secondary structures. Starch can hold Iodine molecules in helical portion and form blue colour. But Cellulose does not contain complex helices and cannot hold iodine.

Complex polysaccharide: .Plant cell wall (cellulose), Paper (plant pulp), Cotton, Fibre (cellulose)

- Exoskeleton of animals, building blocks, amino-sugars and chemically modified Sugars like, Eg. –
- Giucosamine (N – acetyl galactosamine).

Nucleic acids:

- DNA – Polynucleotide chain, double stranded (deoxy ribose sugar) – nitrogenous bases are A, G,C and T
- RNA – single stranded Polymer of ribo-nucleotides (ribose sugar) – A, G, C and U
- Nucleotides – nitrogenous base + pentose sugar + phosphate group
- Nucleoside – nitrogenous base + pentose sugar
- Nitrogenous bases
- Adenine (A)
- Guanine(G)
- Cytosine(C)
- Thymine (T)
- Phospho-diester bonds – covalent bond formed between nucleotides.



Proteins:

Polymer of amino acids (peptide bonds)

The chemical and physical properties of amino acids are essentially of the amino, carboxyl and the R functional groups.

Based on number of amino and carboxyl groups, there are acidic (e.g., glutamic acid), basic (lysine) and neutral (valine) amino acids.

Similarly, there are aromatic amino acids (tyrosine, phenylalanine, tryptophan).

A particular property of amino acids is the ionizable nature of $-NH_2$ and –COOH groups. Hence in solutions of different pHs, the structure of amino acids changes

Structure

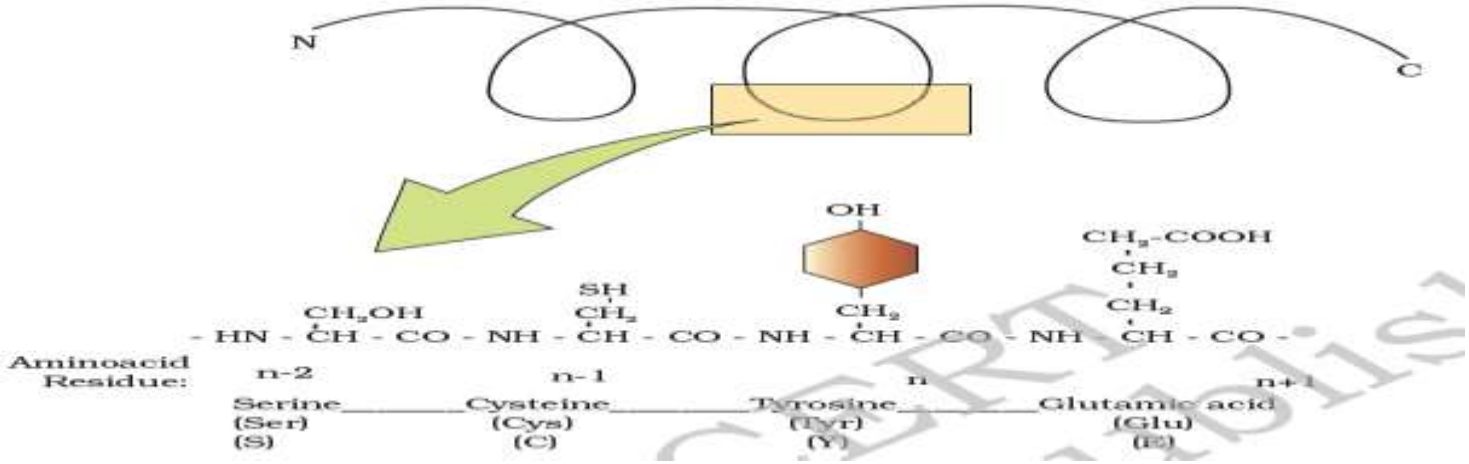
Primary structure – linear chain of aminoacids linked by peptide bonds – non functional.

Secondary structure – alpha-helix or beta-pleated structure with peptide and hydrogen bonds.

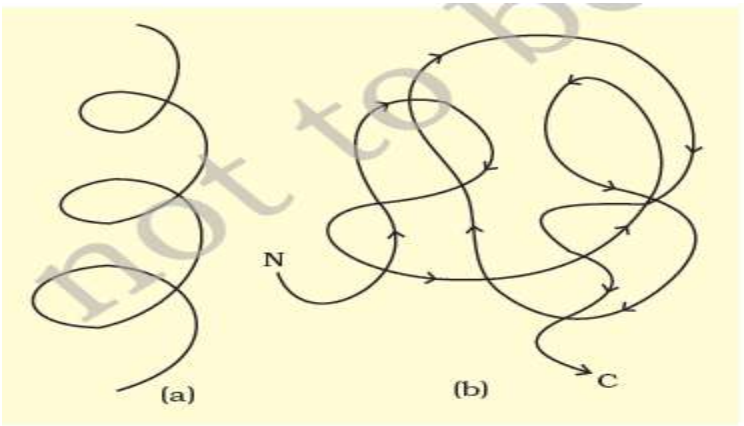
Tertiary structure – long chain of coiled structure with peptide, hydrogen, disulphide and ionic bonds – functional structurte of protein.

Quaternary structure – group of more than two tertiary structured proteins (eg.-haemoglobin

- – made of two alpha and two beta chains).



Primary structure of a portion of a hypothetical protein. N and C refer to the two termini of every protein. Single letter codes and three letter abbreviations for amino acids are also indicated



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

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

Nature of bonds linking monomers in a polymer

- Amino acids are linked by Peptide bonds
- Monosaccharides are linked by Glycosidic bond
- Nucleotides are linked by Phosphodiester bond between 3-C of one nucleotide with
- 5-C of another - Each helix of DNA contains 10 base pairs with the length of 3.4 nm (34 Ao).

Concept of Metabolism

- Biomolecules have turn over (because constantly changing from one form to another) Chemical reactions are called metabolism.

Examples:

- Amino acids can be formed by the removal of amino group in a nucleotide base.
- Hydrolysis of disaccharides – 2 monosacharides
- Linked chemical reactions are called Metabolic pathways, it is a catalysed reaction by enzymes.

Metabolic pathways in living system:

- Anabolic pathways - making / constructing big molecules from micromolecules (eg – photosynthesis)
- Catabolic pathways – breaking down of big molecules in to smaller ones (eg – respiration)
- For both ATP is required (energy currency)

Lipids

- Lipids are generally water insoluble.
- They could be simple fatty acids. A fatty acid has a carboxyl group attached to an R group.
- The R group could be a methyl ($-CH_3$), or ethyl ($-C_2H_5$) or higher number of $-CH_2$ groups (1 carbon to 19 carbons). For example, palmitic acid has 16 carbons including carboxyl carbon. Arachidonic acid has 20 carbon atoms including the carboxyl carbon.
- Fatty acids could be saturated (without double bond) or unsaturated (with one or more C=C double bonds).
- Another simple lipid is glycerol which is trihydroxy propane. Many lipids have both glycerol and fatty acids. Here the fatty acids are found esterified with glycerol.
- They can be then monoglycerides, diglycerides and triglycerides. These are also called fats and oils based on melting point. Oils have lower melting point (e.g., gingely oil) and hence remain as oil in winters.

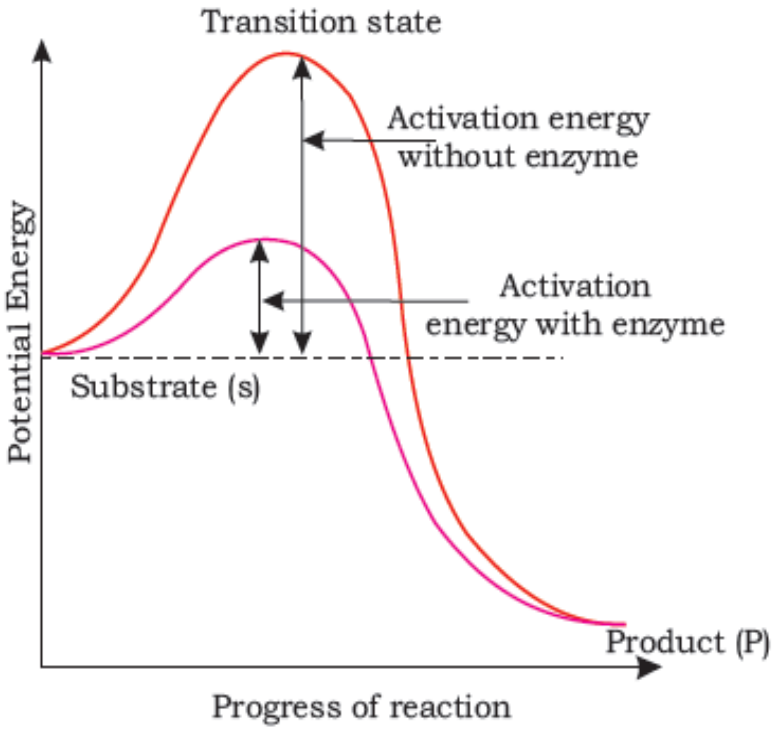
The living state

- Blood glucose – should be 4.5 -5.0mM
- Hormones – in nanograms/mL
- System at equilibrium cannot perform work
- As living organisms work constantly, it is non equilibrium.
- Hence the living state is non equilibrium steady state to be able to perform work.

Enzyme

helps in chemical reactions

- Inorganic reaction :- $Ba(OH)_2 + H_2SO_4 \rightarrow BaSO_4 + 2\ H_2O$ – No enzyme used.
- Organic reaction - Enzyme used Carbonic anhydrase – fastest enzyme - without enzyme 200 molecules / hr - with enzyme 600,000 molecules / sec.
- Activation energy is the energy needed to do work.



Concept of activation energy

Nature of enzyme action

- Enzyme + Substrate --> ES complex --> Enzyme + Product

- The catalytic cycle of an enzyme action can be described in the following steps:
- First, the substrate binds to the active site of the enzyme, fitting into the active site.
- The binding of the substrate induces the enzyme to alter its shape, fitting more tightly around the substrate.
- The active site of the enzyme, now in close proximity of the substrate breaks the chemical bonds of the substrate and the new enzyme-product complex is formed.
- 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.

Enzymes Vs Catalysts

Enzymes

- It is produced by living cells and made of protein.
- It can work well at optimum temperature
- of 40o C.
- It reduces the activation energy.

Catalysts:

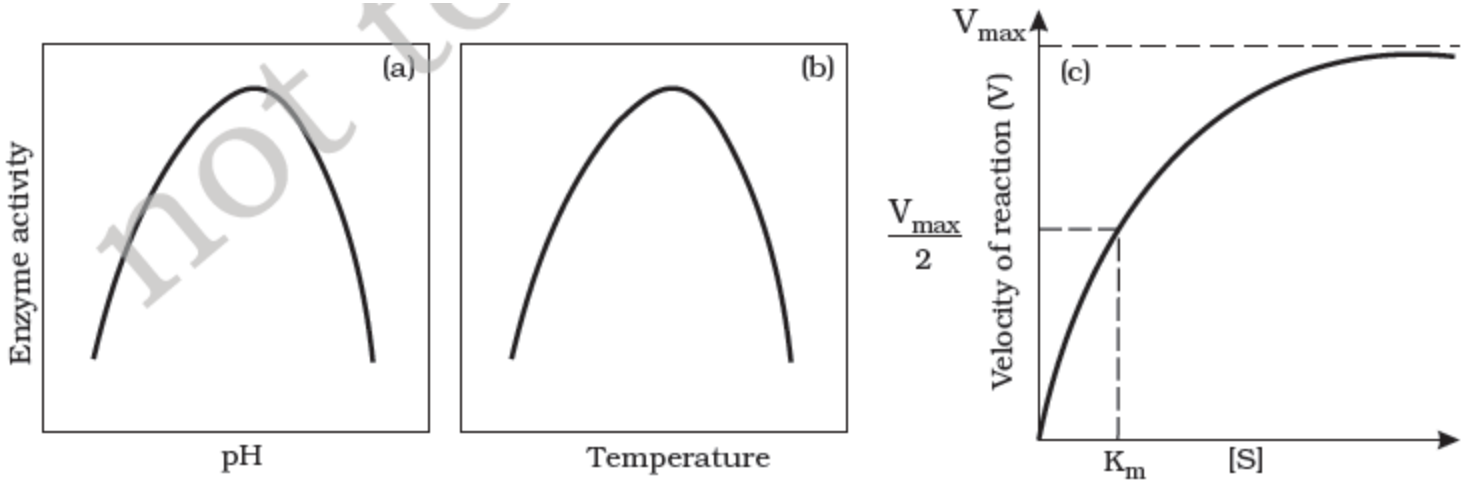
- It is chemical substances and help in chemical reactions.
- It can work even at 80 – 90o C.
- It requires different level of energy.

Properties of Enzymes:

- All enzymes are proteins, but all proteins are not enzymes.
- Enzymes are specific with their substrates as their active sites are different for different substrates.
- Enzymes are of 2 types 1. Builders. 2. Breakers
- Enzyme does not get used up during the reaction, as it does not change its shape – hence less enzymes are required.
- ***Denaturation:***
- The enzyme changes its shape and the substrate cannot bind with the enzyme - affect tertiary structure of the protein.

Factors affecting enzyme activity

- Effect of temperature: temperature at which the enzyme gives its maximum rate of reaction is known as optimum temperature (40o C).
- Effect of pH - different enzymes work at different pH, for example, enzyme pepsin works at pH 2, and enzyme amylase at pH 7, it is called optimum.
- Substrate concentration



Effect of change in : (a) pH (b) Temperature and (c) Concentration of substrate on enzyme activity

Enzyme inhibition

- ***– enzyme action can be inhibited by other chemical molecules called inhibitors.***
- ***Competitive inhibition: Inhibitor chemical molecule resembles the structure of substrate and bind with*** the active site of enzyme instead of substrate, hence there is no production of products.
- Eg. Inhibition of Succinic dehydrogenase by Malonate (inhibitor), which resembles the substrate Succinate in structure.
- All enzymes are proteins but all proteins are not enzymes. Eg. Heamoglobin is a protein but not an enzyme.
- Enzymes at low temperature become inactive, enzymes at high temperature denatures.

Classification and nomenclature of enzymes

Based on type of reaction they classified into 6 classes.

- **Oxidoreductases/dehydrogenases:** Enzymes which catalyse oxidoreduction between two substrates S and S' e.g.,
- **Transferases:** Enzymes catalysing a transfer of a group, G (other than hydrogen) between a pair of substrate S and S' e.g.,
- **Hydrolases:** Enzymes catalysing hydrolysis of ester, ether, peptide, glycosidic, C-C, C-halide or P-N bonds.
- **Lyases:** Enzymes that catalyse removal of groups from substrates by mechanisms other than hydrolysis leaving double bonds.
- **Isomerases:** Includes all enzymes catalysing inter-conversion of optical, geometric or positional isomers.
- **Ligases:** Enzymes catalysing the linking together of 2 compounds, e.g., enzymes which catalyse joining of C-O, C-S, C-N, P-O etc. bonds.

Co-factors

- It is a non – protein part, makes enzyme more active – protein part is called *Apoenzyme*.

There are 3 kinds of factors:

- Prosthetic group - tightly bound with apoenzyme. Eg. Peroxidase, Catalases.
- Co-enzyme – bound transient form. Eg. NAD, NADP (Nicotinamide Adenine
- Dinucleotide Phosphate)
- Metal ions - Form coordination bonds. Eg. Fe, Zn.