# BIOMOLECULE

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# Syllabus

## Biomolecule

**Carbohydrates, Proteins, Lipids, DNA, RNA, Ribonucleic Acid (RNA), Inorganic Constituents of Protoplasm**

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# BIOMOLECULE

## LEVEL - I

**1.** One molecule of triglyceride is produced using
(A) One fatty acid and one glycerol
(B) One fatty acid and three glycerols
(C) Three fatty acids and three glycerols
(D) Three fatty acids and one glycerol

**2.** Which of the following statements is wrong for sucrose ?
(A) It is a disaccharide
(B) It is a non-reducing sugar
(C) It accumulates in the cytoplasm
(D) It is comprised of maltose and fructose

**3.** The protein component of a holoenzyme is know as
(A) Coenzyme (B) Cofactor (C) Prosthetic group (D) Apoenzyme

**4.** Km is
(A) Product (B) Enzyme (C) Constant (D) Unit

**5.** Which of the following amino acids contains sulphur atom in its side chain ?
(A) Methionine (B) Alanine (C) Tryptophan (D) Phenylalanine

**6.** Which of the following sugars cannot be hydrolyzed further to yield simple sugars ?
(A) Ribose (B) Maltose (C) Sucrose (D) Lactose

**7.** Consider the following statements :
A. All enzymes reauire an additional chemical component called cofactor or coenzyme for their catalytic function.
B. The cofactor for pyruvate kinase is $K^+$
Which of the statements given above is/are correct ?
(A) A (B) B (C) Both A & B (D) Neither A nor B

**8.** The Michaelis constant is a measure of which one of the following ?
(A) Concentration of enzyme (B) Catalytic efficiency of the enzyme
(C) Thermo-stability of enzyme (D) Affinity of the enzyme for its substrate

**9.** The initial source of energy to all the varied forms of life is
(A) A glucose molecule (B) An ATP molecule
(C) The solar energy (D) A protein molecule.

**10.** The bioenergetic reactions are peculiar in the fact that they keep on managing the body at
(A) A megathermic level (B) An isothermic level
(C) A microthermic level (D) A hekistothermic level.

**11.** In a living system, the chemical energy is principally stored in the form of
(A) Nucleotide diphosphates (B) Nucleoside triphosphates
(C) Nucleotide triphosphates (D) Nucleoside diphosphates.

**12.** Choose the correct statement(s)
(A) Living steady state has a self regulatory mechanism called homeostasis
(B) Energy flow and energy transformation of living system follow law of thermodynamics
(C) Metabolism is release and gain of energy
(D) All

**13.** Which one is incorrect ?
(A) Organisms live at the expense of free energy
(B) ATP powers the cellular work by complying exergonic reaction to endergonic reactions
(C) All living organisms exist in a steady state characterized by concentrations of biomolecules. Biomolecules are in a metabolic flux
(D) None

**14.** Choose the false statement -
(A) The living state is a non-equilibrium steady state to be able to perform work
(B) The constant flow of material or energy in and out of cell prevent from reaching equilibrium
(C) Living state and metabolism are synonymous
(D) None

**15.** What is the most correct about enzymes ?
(A) All enzymes are basically proteins (B) All proteins are basically proteins
(C) Some proteins are enzymes (D) Some enzymes are proteins

**16.** The energy required for life processes must be extracted from an organisms -
(A) Nucleus (B) Biosynthesis (C) Enzyme (D) Environment

**17.** Which of the following are unique features about the enzyme ?
(A) They are not consumed by the enzyme-mediated reaction
(B) They are not altered by the enzyme-mediated reaction
(C) They lower the activation energy
(D) All

**18.** Which statement about the enzymes is true ?
(A) They act to speed up a biochemical reaction
(B) They are made up of protein or RNA in some cases
(C) They are sensitive to temperature and pH
(D) All

**19.** The most common monomer of carbohydrates is a molecule of -
(A) Glucose (B) Fructose (C) Ribose (D) Deoxyribose

**20.** In a spontaneous reaction, the free energy of a system -
(A) Decreases (B) Increases (C) Becomes equal to zero (D) Remains unchanged



## Answer Key (Level - I)

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1.** | D | **2.** | D | **3.** | D | **4.** | C | **5.** | A | **6.** | A |
| **7.** | B | **8.** | D | **9.** | C | **10.** | B | **11.** | B | **12.** | D |
| **13.** | D | **14.** | D | **15.** | A | **16.** | D | **17.** | D | **18.** | D |
| **19.** | A | **20.** | A | | | | | | | | |

## LEVEL - II

**1.** Which of the following statements is correct ?

(A) Enzymes accelerate reactions by stabilizing transition state

(B) A chemical reaction of substrate to form product goes through a transition state that a higher energy than either substrate or a product(s)

(C) The rate of formation of E–S complex is the same as the rate of breakdown of this complex either to products or back to reactant

(D) All

**2.** Select the false statements for an enzyme promoting a chemical reaction by -

I. Lowering the energy of activation

II. Causing the release of heat, which acts as a primer

III. Increasing molecular motion

IV. Changing the free energy difference between substrate and product

(A) I and IV (B) II and III (C) II, III, IV (D) III and IV

**3.** Which one is correct ?

(A) $E + S \longrightarrow ES \longrightarrow E + P \longrightarrow EP$ (B) $E + S \longrightarrow ES \longrightarrow E - P \longrightarrow E + P$

(C) $E + S \rightleftharpoons ES \rightleftharpoons E - P \rightleftharpoons E + P$ (D) $E + S \rightleftharpoons ES \longrightarrow E - P \longrightarrow E + P$

**4.** Which of the following is an important attribute of life ?

(A) Energy transformation (B) Self-duplication

(C) Process of evolution (D) All of the above

**5.** The life as such is an expression of a series of process passing through a purely

(A) Conservation of energy (B) Endergonic phase

(C) Thermodynamic phase (D) Destruction energy

**6.** A living organism in terms of its energy requirements from the environment, operates as

(A) An open system (B) A close system

(C) An inefficient system (D) An incognizable system

**7.** Which of the following forms of energy is of no use to the living organisms -

(A) Radiant energy (B) chemical energy

(C) Free energy (D) Heat energy

**8.** _______ is a globular protein of ~6 kDa consisting of 51 amino acids, arranged in 2 polypeptide chains held together by disulphide bridge.

(A) Insulin (B) Keratin (C) Glucagon (D) Fibrinogen

**9.** Which of the following fatty acids is liquid at room temperature ?

(A) Palmitic acid (B) Stearic acid (C) Oleic acid (D) Arachidic acid

**10.** What kind of molecule is represented by the structure below ?

$$CH_3CH_2CH_2CH_2CH{=}CHCH_2CH_2CH_2CH_2CH_2CH_2CH_2COOH$$

(A) a sugar (B) an unsaturated fatty acid

(C) a saturated fatty acid (D) a disaccharide

**11.** Given below are two statements A and B. Choose the correct answer related to the statements.

**Statement A -** Amino acids are amphoteric in their function.

**Statement B -** All amino acids are necessary for our body.

(A) Statement A is wrong, statement B is correct (B) Both the statement A and B are wrong

(C) Statement A is correct, statement B is wrong (D) Both the statement A and B are correct

**12.** Even though starch and cellulose are made up of the same repeating units of glucose, they are very different in their properties. The main difference between starch and cellulose is that

(A) cellulose has all its glucose repeats oriented in same direction

(B) starch has alternate glucose repeats oriented at $180^0$ to each other

(C) starch has all its glucose repeats oriented perpendicular to each other

(D) cellulose has alternate glucose repeats oriented at $180^0$ to each other

**13.** Which one of the following biomolecules is correctly characterised ?

(A) Lecithin - a phosphorylated glyceride found in cell membrane

(B) Palmitic acid - an unsaturated fatty acid with 18 carbon atoms

(C) Adenylic acid - adenosine with a glucose phosphate molecule

(D) Alanine amino acid - Contains an amino group and an acidic group anywhere in the molecule

**14.** Which one is the most abundant protein in the animal world

(A) Trypsin (B) Hemoglobin (C) Collagen (D) Insulin

**15.** Macro molecule chitin is :

(A) Phosphorus containing polysaccharide (B) Sulphur containing polysaccharide

(C) Simple polysaccharide (D) Nitrogen containing polysaccharide

**16.** The essential chemical components of many coenzymes are :

(A) Nucleic acids (B) Carbohydrates (C) Vitamins (D) Proteins

**17.** Transition state structure of the substrate formed during an enzymatic reaction is :

(A) transient but stable (B) permanent but unstable

(C) transient and unstable (D) permanent and stable

**18.** Select the option which is not correct with respect to enzyme action :

(A) Substrate binds with enzyme at its active site.

(B) Addition of lot of succinate does not reverse the inhibition of succinic dehydrogenase by malonate.

(C) A non-competitive inhibitor binds the enzyme at a site distinct from the which binds the substrate.

(D) Malonate is a competitive inhibitor of succinic dehydrogenase.

**19.** Which one of the following is a non-reducing carbohydrate ?

(A) Maltose (B) Sucrose (table sugar)

(C) Lactose (D) Ribose 5 - phosphate

**20.** Which of the following statements about enzymes is wrong ?

(A) Enzymes require optimum pH and temperature for maximum activity

(B) Enzymes are denatured at high temperatures

(C) Enzymes are mostly proteins but some are lipids also

(D) Enzymes are highly specific

## Answer Key (Level - II)

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1.** | D | **2.** | C | **3.** | D | **4.** | D | **5.** | B | **6.** | A |
| **7.** | D | **8.** | A | **9.** | C | **10.** | B | **11.** | D | **12.** | D |
| **13.** | A | **14.** | C | **15.** | D | **16.** | C | **17.** | C | **18.** | B |
| **19.** | B | **20.** | C | | | | | | | | |

## LEVEL - III

**1.** Which of the following statement is correct ?
(A) Enzymes generally function in a narrow range of temperature and pH
(B) Enzymes show maximum activity at optimum temperature and optimum pH
(C) Enzymes remain in temporary inactive state at low temperature but higher temperature destroy enzymatic activity due to denaturation of proteins.
(D) All

**2.** Choose the correct statement(s) -
(A) Km (Michaelis - Menten) constant is the substrate concentration at which the enzymatic reaction attains half of its maximum velocity (1/2 Vmax)
(B) At lower Km, higher the substrate affinity for enzyme
(C) Vmax is reached when all the active sites of an enzyme a re saturated with substrate
(D) All

**3.** In competitive inhibition -
(A) Inhibitor resembles the substrate in molecular system
(B) Competition between substrates and inhibitors to occupy active sites
(C) Binding of the inhibitors to activities sites declines the enzyme action
(A) All

**4.** Sulpha drugs/sulphanilamides kill bacteria by inhibiting synthesis of folic acid from para-aminobenzoic acid. This type of control of bacterial pathogens is -
(A) Noncompetitive inhibition (B) Allosteric inhibition
(C) Competitive inhibition (D) Negative feed back

**5.** Inhibition of succinate dehydrogenase by malonate is the example of -
(A) Noncompetitive inhibition (B) Competitive inhibition
(C) Allosteric inhibition (D) Negative feed back

**6.** Enzymes are divided into
(A) 6 classes, each with 4 - 13 subclasses and named according by a four-digit number
(B) 7 classes, each with 4 - 13 subclasses and named according by a four-digit number
(C) 6 classes, each with 4 - 13 subclasses and named according by a three-digit number
(D) 6 classes, each with 4 - 20 subclasses and named according by a four-digit number

**7.** According to IUB system, isomerases belong to which class ?
(A) I (B) III (C) V (D) IV

**8.** Apoenzyme and coenzyme collectively produce -
(A) Holoenzyme (B) Enzyme product complex
(C) Cofactor (D) Prosthetic group

**9.** The suffix '–' added to substrate for naming the enzyme is -
(A) –ase (B) –in (C) –sine (D) –ose

**10.** The enzyme concerned with transfer of electrons is -
(A) Oxidoreductases (B) Cytochrome oxidase
(C) Dehydrogenase (D) All of the above

**11.** Amylase is an example of -
(A) Oxidoreductase (B) Transferase
(C) Hydrolase (D) Ligase

**12.** Which of the following enzymes does not belong to the class V of enzyme classification ?

(A) Isomerases (B) Mutases

(C) Epimerases (D) Dehydrogenases

**13.** When apoenzyme is separated from its metal component its activity is -

(A) Decreased (B) Increased

(C) Lost (D) Not effected

**14.** Cofactors are -

(A) Nonprotein organic molecules (B) Certain vitamins

(C) Metallic ions (D) All of the above

**15.** Which of the following combinations are correct ?

(A) Metal ions loosely attached with apoenzyme - Activators

(B) Non protein organic part attached to apoenzyme firmly - Prostatic group

(C) Non protein organic part attached loosely to apoenzyme - Coenzyme

(D) All of the above

**16.** Which one is not cofactor ?

(A) Coenzyme (B) Apoenzyme

(C) Prosthetic group (D) Metal ions

**17.** Which one is correct ?

(A) Cofactor plays crucial role in catalytic activity of the enzymes

(B) Zn is activator of carboxypeptidase

(C) Catalase and peroxidase have been as prosthetic group

(D) All

**18.** Suppose all the reactions in a unicellular organism have come to equilibrium. This

(A) Signals the birth of the organism (B) Happens when the organism is at rest.

(C) is true at all the times (D) leads to death

**19.** Which one of the following is made up of only one type of macromolecules ?

(A) virus (B) plasmid (C) ribosome (D) nucleosome

**20.** Ball and stick models emphasize th ________ of a molecule but fail to suggest its ________.

(A) Overall shape ; bonding (B) Bonding ; overall size

(C) Overall size ; bonding (D) Geometry ; overall shape



## Answer Key (Level - II)

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1.** | D | **2.** | D | **3.** | A | **4.** | C | **5.** | B | **6.** | A |
| **7.** | C | **8.** | A | **9.** | A | **10.** | D | **11.** | C | **12.** | D |
| **13.** | C | **14.** | D | **15.** | D | **16.** | B | **17.** | D | **18.** | D |
| **19.** | B | **20.** | D | | | | | | | | |

# Carbohydrates

## Macromolecules of Protoplasm

**Carbohydrates**

1. Compound of C, H and O are presented by the general formula $(CH_2O)_n$,
2. Most abundant in plant (part of cell wall), and animal cell (source of energy, e.g. glucose).
3. Polyhydroxy aldoses or ketoses.
4. *Monosaccharides* are simple sugars and have upto ten carbon atoms.
5. *Disaccharides* are found when two monosaccharides condense. *Oligosaccharides* have 3–10 monosaccharide units in a chain, while *polysaccharides* have more than 10 monosaccharides.
6. Monosaccharides are named according to the number of carbon atoms and contain free or potentially free aldehyde or ketone group along with hydroxyl group. Pentoses are linked with nucleic acids – ribose with RNA and deoxyribose with DNA.
7. Monosaccharides are widely distributed in animal and plant cells.
8. Most common disaccharides are maltose, surcose and lactose which on hydrolysis yield two monosaccharide molecules.
9. Oligosaccharide have 3–10 monosaccharide units linked by glycosidic bond.
10. Polysaccharides perform two vital functions.

    (a) Structural component of plant cell wall.

    (b) Storage product of energy in both plants (cellulose/starch) and animals (glycogen).

    Polysaccharides may be *homopolysaccharide* if all the monomer units are same i.e. glucose, e.g. glycogen and cellulose. If the monomer are different, they are called heteropolysaccharides. Further the molecule may manifest branched, cyclic or linear configuration. Polysaccharides are formed by linkage of many monosaccharides by glycosidic bond.
11. Polysaccharides may bond with protein (glycoprotein or proteoglycons) and these are also called mucopolysaccharide. Bacterial cell wall contains peptidoglycan ; antibodies, and receptor. Cellulare deposits of chondriotin. Many glycoproteins act as hormones, antibodies, and receptors.
12. Many carbohydrates from the structural components of the body, e.g., chitin, cellulose, protein hyaluronic acid. Others are used in production of energy, e.g., glucose, glycogen. Some form conjugates with lipids, proteins, purines and pyrimidine.

# Proteins

1. Proteins are the polymers of aminoacids (20 types) and are synthesized on ribosomes attached to mRNA as per genetic code. The bond between aminoacids are called peptide bond.

2. Proteins take part in a variety of cellular functions. They may participate in (a) structure (b) growth (c) cell division (d) development (e) differentiation (f) defence of body (g) and metabolic activities. Thus, proteins can act as structural unit of membranes, cells, tissues ; as enzyme they participate in any of the synthetic and degradation activity ; as immunological substances ; as receptors ; in generation of cell signals, and as hormones.

3. Protein structure is of four types (a) primary (b) secondary (c) tertiary and (d) quarternary.

(a) *Primary structure* is a linear chain of amino acids that occur in a specific sequence and number.

Some may have cross linkages in the form of disulfide (—S—S—) bonds.

(b) *The secondary structure* of protein has a specialised 3-D configuration. Tight coiling of polypeptide chain occurs due to formation of H-bond between carbonyl and imido group of individual amino acid. This folding gives it a form called $\alpha$-helix in which there are 3 single bonds called omega, phi and chi.

(c) *Tertiary structure* Further folding of polypeptides occurs. This structure is stabilised by various secondary bonds between specific R groups. There are three types of linkages.

(i) —S—S holding two polypeptide together

(ii) H-bonding and

(iii) Electrostatic bonds between +ve and –ve groups.

4. *Globular and Fibrous Proteins*

*Globular* : (a) They are soluble in body fluids.

(b) Act as enzymes, antibodies or hormones.

*Fibrous* : (a) Occur in muscles, skin, teeth

(b) May be contractile or elastic.

(c) Some are dissolved in plasma e.g. fibrinogen.

5. *Functions of Proteins*

(a) *Enzymes*, e.g. hydrolases, transferases, oxido reductases, etc.

(b) *Vectors* of $O_2$/$CO_2$ (haemoglobin), CO, etc

(c) *Stored products*, e.g. as ferritin — iron storage in spleen, caesin — amino acid storage in milk.

(d) *Structural components*, e.g. Plasma membrane, cell matrix, collagen fibres, in connective tissues.

(e) *Contraction*, e.g. as actin (globular and fibrous), myosin in muscles. (heavy and light)

(f) *Protection*, e.g. as antibodies (5 types IgG; IGE; IGD; IgM; IgA Immunoglobulin) to attack and destroy antigen ; as fibrinogen to facilitate clotting of blood.

(g) *Hormone*, e.g. Insulin in glucose metabolism; glucagon in glycogenolysis.

(h) *Toxin*, e.g. snake venom as hydrolytic enzyme.

(i) Regulates and influences ion distribution and exchange. Regulate cell Physiology.

(j) As receptors or in identification of molecules entering or exiting from cells and binding with them.

6. Proteins are involved in neurotransmission and can be analysed by a variety of methods.

7. *Proteins are of 3 types* :

(a) *Simple* : Made up of amino acid only. Soluble in different solvents and have variable thermal coagulability. This determines their molecular from and size, e.g. protamines, histones, kertin, collagen, elastin.

(b) *Conjugated* : Simple protein links to non-protein. Protein component is called *apoprotein* while the non-protein part is called the *prosthetic* group.

The whole molecule is called *holoprotein*. They are classified on the basis of their prosthetic groups into.

(i) Chromoprotein and flavoprotein (ii) Metalloprotein

(iii) Lipoprotein (iv) Glycoprotein

(c) *Derived protein* : Similar to natural protein, not soluble in water, fibrous.

# Lipids

1. They are compounds of C, H, O.
2. They are biopolymers of fatty acids.
3. Lipids are of 3 types
   (a) Glycerides
   (b) Phospholipids and
   (c) Steroids
4. Simple lipids are called glycerides — Fatty acid ester with glycerol as alcoholic component. Their general formula is :

$CH_2O–CO–R^1$ ← Fatty acid molecule (may or may not be similar)
|
$CH–O–CO–R^2$
|
$CH_2O–CO–R^3$

**Bases of lipids of animal tissues/cells.**

| Name of lipids | Chemical nature and functions |
|---|---|
| *Phospholipids* (Esters of fatty acids) | Contains nitrogenous and non-nitrogenous groups in addition to phosphate. Constituent of membrane, facilitates absorption of sterols and non-polar lipids, amphipathic molecule. Many types are known. |
| *Lecithin* | Contains glycerol, two fatty acids, phosphate group and nitrogenous base choline. Found in brain, liver, cardiac muscles and blood. |
| Caphalin | It contains ethanolamine instead of choline as a $N_2$-base (in brain). |
| *Lipoamino acid* | Contains serine, threonine or hydroxyprotein. Found in RBC and brain. |
| I. *Plasmalogens* | They are of many types, found in RBC, cardiac muscles and brain. |
| *Sphingiomyelin* | Found in blood, liver and brain |
| II. Sphingolipids | Contain sphingosin alcohol which is linked to fatty acid by amide bond. Many types are known. |
| (a) *Gangliosides* | Found in liver, RBC, neural tissues. |
| (b) *Sulphatides* | Found in liver, kidney and salivary glands. |
| (c) *Cerebrosides* | Found in nervous system. |
| (d) *Glycolipids* | Amphipathic molecules. |
| III. *Steroids* | Acts as hormones, e.g. corticoids, androgens, estrogens, progesterone. Found in liver secretion (Bile acids). |
| IV. *Cholesterol* | Found in blood, kidney, liver. |
| V. *Prostaglandins* | Found in tissue fluids, prostate, thymus, blood plasma, etc. |



Triglycerides are either solid or liquid.
Fatty acids are of two types :
(a) Saturated fatty acids e.g. palmitic acid and stearic acid
(b) Unsaturated fatty acid. They have double bond, e.g. oleic acid.

5. Phospholipids
   (a) Occur in the biological membranes and maintain their structure.
   (b) They are essentially triglycerides in which phosphoric acid and nitrogen compounds like choline or serine, etc. replace one of the fatty acids. They are called derivatives of phosphtidic acid.
   (c) They are found in both plants and animals. Cephalin is a phospholipid which is specific to neural

tissues of brain. Others are lecithin, spingomyelin, plasmolin and cardiolipin.

(d) They are formed by esterification of phosphatidic acid with a nitrogenous compound.

(e) Phospholipids of biological membranes facilitate ion-exchange, intercellular transport and cellular excretion. They are also implicated in electrogenesis in excitable cells, e.g. muscles and neurons.

6. Non-phosphorylated lipids form structural unit of cellular organelles. This includes glycolipids, sulpholipids and proteolipids. Glycolipids occur in nervous tissue of animals, sulpholipids in liver, kidney, testes and salivary gland.

7. Lipids are of critical importance in initiating and stimulating many physico-chemical processes.

8. Gangliosides are found in the gray matter of the nervous system in high amounts. Disorders due to breakdown of gangliosides is the cause of serious pathologies, e.g. Tay-Sachs disease which is inherited as an autosomal recessive trait.

# DNA

(a) Single stranded (viruses), circular (mitochondria, bacteria) or double stranded and helical (all eukaryote cells right or left handed).

(b) Consists of two purines, i.e. adenine (A) and guanine (G) and two pyrimidine i.e. thymine (T) and cytosine (C).

(c) A always pairs with T and G with C by hydrogen bonds, i.e. A = T and C = G.

(d) When a base pair is composed of Base + deoxyribose sugar it is called *nucleoside*, i.e. A + S., T + S., G + S., C + S. However, when it si composed of Base + deoxyribose + phosphate group it is called *nucleotide*.

(e) Nucleic acids are linear and unbranched molecules. Their monomers are linked together through phosphodiester bonds. The 3-D structure of DNA is represented by a double helix in which each turn has a dimeter of 34 Å and contains 10 base pairs at a distance of 3.4 Å. The 2 strands of helix are complementary but anti-parallel.

(f) DNa contains the blue print of the species. It is conclusively proved to be the genetic material.

(g) It forms 64 types of triplet codes of these, 61 are used in translation process. The other three serve as initiation and termination codons.

(h) DNA replicates by various modes (semi-conservative, conservative and dispersive) during cell division.

(i) Mutational changes occur in DNA. Sometimes change in a single base pair may occur (point mutation) or large number of bases or segments of DNA molecule are affected by mutagens (UV rays, chemicals). Spontaneous changes do occur in DNA which is the cause of variation. Variation selected through natural selection become the underlying basis for evolution.

(j) It is present in nucleus, mitochondria and plastids. The last two form the extra-nuclear sites of DNA.

# RNA

(a) Single stranded

(b) Genetic material of some viruses (RNA Viruses, e.g. HIV).

(c) Contains A, U, C and G and the sugar is called ribose. Thus, T of DNA is replaced by U (uracil).

(d) RNA is formed from DNA by transcription.

(e) It is found in nucleus, mitochondria, plastids and ribosomes.

(f) RNA is of the following types :

(i) mRNA synthesized on DNA template, carries genetic code in the form of triplets (64 types).

The decoding and translation of these leads to the formation of a protein molecule. mRNA has a short life and is unstable.

(ii) tRNA (20 types) each specific for a particular type of amino acid (20 types), highly stable, have a definite shape, clover-leaf like from. tRNA serves as an adaptor. It transports specific amino acids. tRNA is also called soluble RNA. [sRNA].

(iii) *Ribosomal* RNA (rRNA) It forms $\rightarrow$ rRNA which is a stable molecule and is associated with ribosomes (factory for protein synthesis). It animal cells, prokaryotes and plant cells rRNA can be identified on the basis of their differential sedimentation rate expressed by the Unit S (Svedberg Unit). rRNA is complexed with 50 different protein molecules in robosomes.

(iv) *Viral* RNA Single stranded, genetic material of some viruses e.g. $HIV_{1.3}$. However information from RNA $\rightarrow$ RNA does not occur. Instead RNA acts as the template for DNA synthesis by reverse transcriptase.

## Porphyrins (Derivatives of Porphyrins)

Large, flat, heterocyclic ring structure contain iron or magnesium found in plant and animal cells and subserve a variety of functions e.g. $O_2/CO_2$ transport (haemoglobin, myoglobin). Pholosynthesis (chlorophyll), enzymes (cytochromes, peroxides, catalase).

Heterocyclic ring structure is made up of 4 pyrrole rings linked by *Methin* bridge. They have side chains on ring and occur in different isomeric form.

## Polynucleotide Chain

In one nucleotide, one molecule of phosphoric acid is connected with $C_5$ of one molecule of deoxyribose sugar by a ester bond. The nearest nucleotide is bonded with the other by a phosphodiester bond. This bond exists between phosphatic of one nucleotide and sugar of another. This results in the formation of a deoxyribose – phosphate chain called polynucleotide chain. The phosphate molecule is bounded with the $C_3$ of the next nucleotide and the nitrogen base with the $C_1$ of deoxyribose. One end of polynucletoide has $C_3$ deoxyribose residue which does not bond with the other nucleotide whose other end does not join with $C_5$ sugar residue. These ends are callec $3^1$ and $5^1$ and the chain is coiled.

According to Watson and Crick, the following rules are followed in the bonding of nitrogenous bases of DNA.

1. Purine always bonds with pyrmidine, i.e. A with T and C with G.
2. The nearest chains are joined by H-bond. There are two H-bonds between A and T(A = T) and three between C and G (C $\equiv$ G).
3. In a given DNA molecule, the amount of purine and pyrimidine is equal.
4. The two chains of DNA are complementary, i.e., if the sequence of nitrogenous bases is A, T, G and C then in the other one it would be T, A, C and G.
5. One end of polynucleotide chain is called $3^1$ and the other $5^1$.
6. One molecule of DNA contains about 2000 nitrogenous bases.
7. The width of DNA molecules is 20 Å.
8. Each turn of DNA measures 34 Å and has 10 bases at a distance of 3.4 Å from each other.

Thus, DNA is polymer and has a high molecular weight $10^6$ and $10^9$ or even more. Molecular weight for purified DNA is in the range of 1000,000 to $120 \times 10^6$.

DNA occurs in many forms :

(a) Double stranded in all eukaryotes

(b) Single stranded in Bacteria, and Viruses

(c) Circular in E.Coli

**DNA or RNA**

Fredrick Miescher (1886) extracted a substance from pus cells by treating them with NaCl and called it Nuclein. Seglar confirmed the presence of Nuclein in eukaryotic cells of reptiles, birds and also in yeast. Altman and Albrechi are credited with coining the term nucleic acid and Levine and Jones studied their chemical nature to show that they are made of nitrogenous base, sugar and phosphoric acid. Nucleic acid were shown to act as genetic material by Franklin and Stahl. While Chargaff stated that the nitrogenous bases are present in equal ratio (Chargaff's rule), Wilkins provided the crystallographic data. The double helical model of DNA was given by Watson and Cricks who shared the Nobel Prize with Wilkins.

## Chemical nature of DNA

DNA is made up of variety of organic and inorganic compounds, e.g. nitrogen bases, sugar and phosphoric acid.

(a) Nitrogen bases These are four types of bases which are either purines or pyrimidines. The purine bases are adenine (A) and Guanine (G), while the pyrimidine bases are thymine (T) and Cytosine (C). The relative ratio of purines and pyrimidines in a DNA molecule is equal, i.e., A = T and G = C. However, the ratio of A + T/G + C differs in organisms, although it is similar in the same organims.

(b) Sugar The sugar in DNA is a 5-carbon sugar (pentose) called deoxyribose. It does not contain $O_2$ at $C_2$ position.

(c) Phosphoric acid These are linearly linked with deoxyribose in a DNA molecule at $C_3$ and $C_5$ position. Because of this, each DNA strand has two ends, i.e., a 5′ and 3′ end. The bond between sugars of two different nucleotide is called the phosphodiester bond.

## Molecular Organisation of Deoxyribo Nucleic Acid

One deoxyribose sugar molecule bonds with a nitrogenous base (A, or T, or C or G) to form n Nucleoside. The nucleoside joins with phosphoric acid to form a nucleotides. The nucleotides of DNA are called deoxynucleotides. They are of 4 types.

(a) deoxyadenylic acid : Adenine + deoxyribose + phosphoric acid.

(b) deoxyguanylic acid : Guanine + deoxyribose + phosphoric acid.

(c) deoxycytidilic acid : Cytosine + deoxyribose + phosphoric acid

(d) deoxythymidilic acid : Thymidine + deoxyribose + phosphoric acid.

**Types of DNA Replication**

1. Semiconservative  2. Conservative  3. Dispersive

1. *Semiconservative* : The salient features of this process are :

(a) unwinding of the double helix (but no rupture of separated strands).

(b) guided synthesis of complementary strands of each of the two separated polynucletodie strands.

(c) entire polynucleotide strands of parental DNA are passed on to the progeny in intact form.

(d) Progeny DNA receives either one half or none of its nucleotides from the parental DNA.

2. Conservative :

(a) Both the primary and secondary structure of DNA (parental) is conserved.

(b) Replication of DNA does not involve ruputure of individual DNA strands or unwinding of the helical duplex.

(c) A sequence of hydrogen bonded base pairs serves as genetic determinant on which specific nucleotides preferentially bind and determine their sequential position in the daughter polynucleotide.

(d) No redistribution of parental DNA among the progeny is permitted.

(e) The original DNA is transferred as an intact unit or not at all.

3. Dispersive : No experimental evidence is available to support this. It postulates

(a) general break up of the parental DNA and

(b) its more or less uniform distribution among the progeny.

## Biological significance of DNA

It all eukaryotes and majority of prokaryotes (except RNA viruses), DNA is the repository of all genetic information. It serves as information molecule and generates the codes for synthesis of proteins that subserve diverse functions. This is does by forming mRNA which carries the genetic code in the form of triples (64 types), tRNA (20 types) which carry anticodon and rRNA. DNA is a stable macromolecule but can undergo changes (mutation) that may involve substitution of a single nitrogenous base pair (point mutation) or several bases. Such mutations bring about changes in physico-chemical properties and functions of DNA coded proteins. If selected (natural selection) it leads to formation of new phenotypic characters. This is the basis of variation and cause of evolutionary changes.

DNA replicates during cell growth and cell division and thus is responsible for passing a copy to daughter cells. Mitotic cell division results in daughter cells that are exactly similar in structure, chromosome number (2n) and functions. However, during meiosis as a result of synapsis of homologous chromosomes, crossing over and reduction division, the daughter cells are not only genetically different from parental cells but also contain haploid (n) number of chromosomes. This genetic recombination often expresses itself by forming new types of phenotypic character at structure at structural and functional levels.

# Ribonucleic Acid (RNA)

RNA occurs in nucleus and cytoplasm freely or are found in association with ribosomes. Cell organelles such as plastids, mitochondria adn eukaryotic chromosomes also contain RNA. In Tobacco mosaic virus (TMV) and wound tumour it acts as genetic material. It may be single stranded, e.g. many prokaryotic and eukaryotic cells, or double stranded, e.g. wound tumour and Reovirus. RNA was first implicated in protein synthesis by Casperson (1950) and Brachet ((1956).

**Evidence for the "One Gene-One enzyme" hypothesis [Beadle and Tatum].**

RNA is a polymer of nucleotides. Like DNA it is also made up of purines adn pyrimidines. The purine bases are adenine and guanine (similar to DNA), but the pyrimidine bases are uracil (instead of thymine as found in DNA) and cytosine. The pentose sugar in RNA is called ribose. In RNA the nucleotides are : Adenine (A) + ribose + phosphoric acid and cytosine (C) + ribose + phosphoric acid. The nucleosides are accordingly A + ribose ; U + ribose ; C + ribose and G + ribose. The bond between nitrogenous base and sugar (N – C) is called glycosidic bond. In purine and sugar bonding, it is between $C_1$ and $N_9$, and in pyrimidine and guanine between $C_1$ and $N_3$. Purine and pyrimidine bases are present on the backbone which is formed of linearly arranged ribose sugar and phosphate.

The secondary structure of RNA is coiled like hairpin and this coiling is stabilised by A = U and C ≡ bond.

RNA occurs in many forms. Four major types of RNA have been identified in organisms :

1. Messenger RNA (mRNA) :Found in nucleus and is synthesized by DNA. mRNA acts as information molecule and carries genetic information for the synthesis of proteins in cytoplasm. It is synthesised as complementary strand during transcription form DNA. It contains the same sequence of nitrogenous bases except that instead of thymine (T), uracil (U) is present. It is translocated to cytoplasm after transcription and is stored in different forms of ribosomes. It acts as templete for protein synthesis (translation process), has a short life span and is dispersed after translation. mRNA is rapidly synthesized in metabolically active cells. The nucleotides of mRNA are same in all organisms but their sequence is different. mRNA is synthesized on one or the other strands of DNA. The transcription process starts from $5^1 – 3^1$ end. RNA polymerase catalyses mRNA synthesis.

   The life span of mRNA is bacteria is about two minutes but in eukaryotes it is a few hours.

2. *Transfer* RNA (tRNA) : It constitutes 10% of cells, has lower molecular weight ; synthesized in nucleus and later transferred to cytoplasm. It is involved in translation of genetic code. mRNA code is read by tRNA as it contains anticodon (triplet). tRNA (20 types) binds with the specific amino acid (one out of 20 types known) with the help of the enzyme aminoacyl synthetase (20 types).

   tRNA is synthesised under the direction of genetic code provided by nuclear genes DNA. In bacteria 40–80 cistrons are involved with transcription of tRNA but in Drosophila this number is 56.

   tRNA plays a pivotal role in insertion of activated and appropriate amino acid (as per code) on ribosomes leading to formation of polypeptide chain of aminoacids.

3. *Ribosomal* RNA (rRNA) : It is found in ribosomes in the form of ribonucleoprotein. Nearly 80% of cell weight consists of rRNA. rRNA is of two types in prokaryotes i.e., 28S and 16S. In eukaryotes it is of three types 28S, 18S and 5S.

   rRAN is synthesized n nucleus and is coded by DNA. The part of chromosomes which is concerned with rRNA formation is called *Nucleolar Organiser*. 28S and 18S rRNA is transcribed by nuclear DNA and has a larger molecular weight.

   In higher organisms, nearly 200–2000 rRNA cistrons take part in rRNA synthesis.

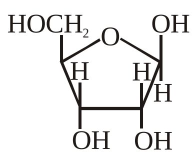
4. *Viral RNA* : It TMV and Influenza viruses, RNA is single stranded. It is the genetic material of retroviruses, e.g. HIV.

**Difference between DAN and RNA**

| DNA | RNA |
|---|---|
| 1. Genetic material of all eukaryotes and prokaryotes. | 1. Genetic matterial of retro viruses. |
| 2. Double-stranded and helical (nuclear) | 2. Single stranded having several forms. |

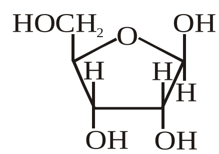
| | |
|---|---|
| (except viruses, in which it is single stranded, or mitochondria and plastids, in which it is circular. | Double stranded in few. |
| 3. Nitrogenous bases are A, T, G and C. | 3. NItrogenous bases are A, U, G and C. |
| 4. The pentose sugar is called deoxyribose | 4. The pentose sugar is called ribose. |
| 5. Codes for various forms of RNA | 5. Does not code for DNA. |
| | 6. Take  part in protein synthesis. |
| | 7. Several types of RNA known, e.g., mRNA, tRNA (20 types), rRNA and viral DNA. |

DNA

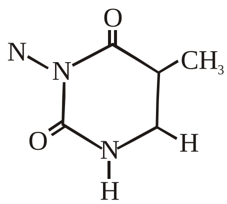


Deoxribose

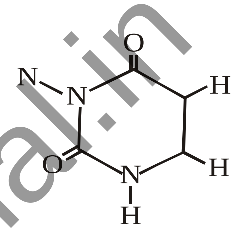
RNA



Ribose



Thymine



Uracil



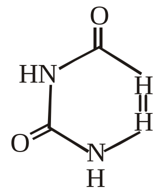
**Difference between DNA and RNA**

## Comparsion of different types of RNA

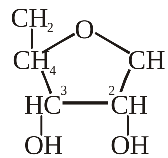
| Character | Ribosomal RNA (rRNA) | Messenger RNA (mRNA) | transfer RNA (tRNA) |
|---|---|---|---|
| 1. Percentage of total RNA of cell. | 80% | 3% - 5% | 10% - 20% |
| 2. Sedimentation coefficient | 28S, 18S, 5.8S and 5S | 8S | 3.8S, 5S |
| 3. Number of Nucleotides | 5S, 120 Nucleotides 16S-18S - 1600–2500 Nucleotides 23S-28S = 3200–5500 Nucleotides | E.coli : 8S 9000 to 500,000 | 5S=73–93 Nucleotides Nucleotides 25000–30,000 |
| 4. Molecular weight | 23S=$1.1 \times 10^6$ 30S=$0.55 \times 10^6$ | | |
| 5. Unusual bases | Small amount of methylated bases. | Small amount 1/30-40 bases | High contents [E.coli 1/100–150bases] |
| 6. Site of synthesis DNA Template | Derived from Nucleolar DNA | Synthesized in Nucleus on DNA template. | Synthesized in nucleus on DNA template. |
| 7. Function | Unpaired bases may bind | Conveys genetic information from | Adaptor for attaching aminoacids |

| | | | |
|---|---|---|---|
| to ribosomes | mRNA and tRNA | DNA of chromosomes to facilitate specific protein synthesis. | to mRNA template |

**Structure of uracil**




**Structure of ribose sugar**



# Inorganic Constituents of Protoplasm

## Water

1. Major and essential constituents of protoplasm (60-95%). Life without water does not exist.
2. Water is necessary for biochemical reaction.
3. It is required for maintenance of body temperature, formation fluids, as solvents for catabolites and anabolites.
4. Water is excreted from the body in the form of urine, as part of faeces, sweat and with expiratory air. For humans, sources of water are (a) Food and fluids, (b) Metabolic water (300–400 ml) produced by oxidation of carbohydrates, proteins and fats.
5. Water is an hydride of oxygen ($H_2O$). It has high melting and boiling point, heat of vaporisation and surface tension. It is a dipolar compound. Water acts as a excellent solvent.
6. Water facilitates maintenance of pH ($H^+$ ions concentration) of body fluids, e.g. blood (pH 7.40), intestinal juice (pH 8.0-9.0), gastric juice (pH 1.0-2.0).

## Minerals

### Calcium and Phosphorus

1. The concentration of $Ca^{2+}$ and P is regulated by parathormone and calcitonin. Vitamin D, Estrogen and testosterone also play this role.
2. In adult male and female the amount of $Ca^{2+}$ required is 500 mg. In pregnant women, 11 of $Ca^{2+}$ is needed.
3. $Ca^{+2}$ is the structural component of skeleton and teeth. It is required in blood coagulation ; for enzyme activity ; for synaptic transmission in neuron ; contraction of muscles ; permeability of gap junctions, and plasma membrane ; excitation of neural tissue, contraction of cardiac muscles, functions of hormones and in lactogenesis.
4. P is also an important constituent of skeleton and teeth. If facilitates (a) energy transfer (b) Acid-alkali balance (c) phosphorylation and phosphorylysis (d) enzyme action, and as constituent of phosphoprotein, nucleid acids, phospholipids and lipoprotein.



### Magnesium

1. About 350 mg of magnesium is needed in adults per day and 450 mg in pregnant women.
2. It is an important constituent of skeleton and teeth.
3. It helps in neuro muscular excitation.
4. It facilitates enzyme action.

### Sulphur

It is an important constituent of enzymes, e.g. some electron enzymes, and of several proteins and also of coenzyme A. About 80-90 gm of S is present in human body.

### Sodium

About 1.3–5.0 g per day is required in adult human. It is important for excitability of neurons, muscle cells, fluid balance, acid-base balance, cardiac muscles function, for ionic charge in membrane and also in enzyme activation, e.g. Na-activated ATPase. Regulated by aldosterone.

### Potassium

Daily requirement in adult male is 1.8–5.5 gm. Important in enzyme action (K-activated ATPase) or also with Na (Na-activated ATPase), acid-base balance, excitability of membranes, ionic charge of membrane and cardiac muscle function. Regulated by aldosterone. Human body has 110-130 gm of K.

### Chloride

About 1.5–5 g is needed by adult male per day. Important in maintenance of fluid balance, acid-base balance and cardiac function. Human body has 70.80 gm of $Cl^-$.

## Trace Elements

1. *Iron* (Fe) Adult male require 25 mg; female require 30 mg and pregnant women require 40 mg per day. It is circulate in the form of transferrin. Fe is linked for the synthesis of haemoglobin. It thus facilitates $O_2/CO_2$ transport.
2. *Copper* (Cu) Adult humans need 2.5 mg/day. Important in enzyme activity, e.g. in maturation of elastin fibres as a constituent of the respiratory pigment haemocyanin (found in spiders and molluscs).
3. *Zinc* (Zn) Adult humans require 15 mg and pregnant women 25 mg per day. Deficiency of Zn inhibits growth, attenuation of carbonic anhydrase in RBC, inhibition of development of genitalia and hairs in humans, dermatitis, neural disorders, eye defects. It is required also in enzyme action and in metabolism of vitamin A.
4. Manganese (Mg) Adult humans require 2.5 mg per day. It is a constituent of many enzymes and also acts as a cofactor. Many mitochondrial enzymes contains $Mn^{2+}$. Important for fertility in many organisms (e.g. cow) facilitates synthesis of porphyrins and protoglycan in many tissues.
5. *Molybdenum* (Mb) Adult human require 0.5 mg par day. Constituent of non-heme flavoprotein.
6. *Cobalt* (Co) Acts as co-factor for many enzymes. Constituent of vitamin $B_{12}$ Facilitates erythropoiesis and maturation of RBC.
7. *Selenium* (Se) Adult human require 0.2 mg per day. Constituent of (a) enzyme glutathione peroxidase, (b) microsomal protein. Seleno-proteins are related to oxidase system of membranes.
8. *Iodine* (I) Adult male require 140 mg, female 100 mg and pregnant female 125 mg par day. Inorganic iodide is accumulated in thyroid gland follicles. It facilitates iodination of tyrosins to form $T_1$, $T_2$, $T_3$, $T_4$ derivatives of which $T_3$ (Thyroxine) is most active. It is transported by globulin with which they conjugate (unstable) to form thyroglobulin.
9. *Fluorine* (F) Adult humans require 2–3 mg par day. Facilitates development of skeleton adn teeth. Higher concentration are toxic and are detrimental to skeleton, teeth muscles, kidney, brain, gonads, etc.
10. *Chromium* (G) Adult humans require 0.05–0.15 mg par day. Acts as a increased glucose tolerance factor.

## Vitamins

Vitamins are organic substance which are capable of subserving functions.

### Characteristics

1. Required in micro quantities and are linked with one or the other phases metabolic cycles of a cell.
2. May join with the non-proteinaceous part of an enzyme and act as co-enzyme, e.g. niacin acts as a co-enzyme in NAD biosynthesis.
3. Influences enzyme functions.
4. Plants can make their own vitamins but animals can synthesis only some vitamins. The latter phenomena is due to mutation and destruction of genes that are responsible for vitamin synthesis.
5. Vitamin deficiency causes many metabolic, cellular, tissue, organ disorders in animals and man.
6. Vitamins are either water soluble or fat soluble.
7. Vitamins are needed in diet on a 24 hours basis.

Table 1.10–1.11 describes the water and fat soluble vitamins, their common name, chemical nature, source, site of absorption and storage, functions, daily requirements and deficiency syndrome (symptoms and name of disease).

### Enzymes

Biochemical pathways and cycles are linked with anabolic and catabolic processes in cells. These are sequentially catalysed by *Enzymes*, a term coined by Kuhne ((1878). The nature of enzymes was defined by Brezelius (1827). Bucher extracted the enzymes from yeast which catalyse alcoholic fermentation. Schwann is credited with isolation of pepsin from gastric juices and later also identified another proteolytic enzyme – trypsin. Urease was first extracted and crystallised by Summer (1926).

Enzymes (3000 kinds known and 250 obtained in crystalline from) are soluble, colloidal, carbon compounds. All enzymes are proteins (polymers of aminoacids). They take part in many metabolic are deeply influenced by a variety of physical and chemical factors.

According to recommendations of the *International Union of Biochemists* (IUB) enzymes are classified into six categories.

1. *Oxido-reductases* Catalyses oxidation and reduction reaction in a cell. About 221 enzymes are placed in this category.
2. *Transferases* Facilitates transfer of one chemical group of a biochemical into another.
3. *Hydrolases* They break the structural and chemical bond of biochemical in a cell by introducing water (—OH). This process is also called *hydrolysis*. The substrates for these enzymes are glycosides, peptides, esters.
4. *Lyases* They are similar to hydrolases in all respects except that they catalyse removal of one group from the substrate. But, the double bond of the substrate remains intact. These enzymes act on C–S, C–O, C–N, and C–C groups.
5. *Isomerase* This catalyses internal reorganisation of molecules in a substrate.
6. *Ligase* Catalyse bonding of compounds of molecules in a substrate.

Enzymes are also classified on the basis of the kind of biochemical reaction they catalyse in a cell.

**Role of vitamins in biochemical reactions**

| | Type of biochemical reaction in the cell | Name of vitamin required | Name of required co-enzyme |
|---|---|---|---|
| 1. | Fixation of $CO_2$ | Biotin | Biotin |
| 2. | Oxidation-Reduction | Nicotinamide | (a) Diphosphopyridine nucleotide<br>(b) Triphosphopyridine nucleotide |
| 3. | Oxidation-Reduction | Ripoflavin | (c) Flavin mononucleotide (FMN)<br>(d) Triphosphopyridine nucleotide |
| 4. | Translocation of Acetyl group | Pantothenic acid | Co-enzyme A |
| 5. | Reaction with $C_1$ compounds | Folic acid | Tetrahydrofolic acid |
| 6. | Isomerisation C-series | Cyanocobalmin | Cobalamide coenzyme |
| 7. | (a) Decarboxylation<br>(b) Transamination | Pyridoxine | Pyridoxyl phosphate |
| 8. | Decarboxylation of ketoacids | Thiamine | Thiamine pyrophophate |



**Role of enzymes in biochemical reactions**

| | Category of enzyme | Biochemical reaction catalysed | Example |
|---|---|---|---|
| I. | Oxidoreductase | Biochemical oxidation and reduction | — |
| (a) | Dehydrogenases | | Removal of H and its translocation e.g. SDH. |
| (b) | Oxygenase | | Insertion of $C_2$ in place of double bond in a substrate. |
| (c) | Peroxidase | | Use of Hydrogen peroxide in oxidation. |
| (d) | Oxidative deaminase | | Insertion of —OH group. |

| | | | |
|---|---|---|---|
| II. | *Transferase* | Transfer of chemical group from one molecule to another | |
| (a) | Transminase | | Transfer of —$NH_2$ group. |
| (b) | Kinase | | Transfer of phosphate group from ATP to substrate |
| (c) | Phosphorylase | | Transfer of phosphate group without utilising ATP. |
| (d) | Acyl transferase | | Transfer of acetyl/acyl group to suitable receptor. |
| (e) | Glycosyl transferase | | Transfer of glycosyl group. |
| III. | *Hydrolase* | Cleaving of molecules by action of water (= Hydrolysis) | |
| (a) | Peptidase | | Hydrolyse peptide bonds. |
| (b) | Phosphatase | | Removal of chemical group from carbon compounds by hydrolysis. |
| (c) | Phosphodiesterase | | Hydrolysis of phosphate ester |
| (d) | Glycosidase | | Hydrolysis of glycosidic bond. |
| (e) | Esterases | | Hydrolysis of carboxylic ester. |
| (f) | Deaminase | | Hydrolysis of amines. |
| (g) | Deamidase | | Hydrolysis of amidase. |
| IV. | *Lyases* | Cleaving or conjugation of functional groups molecules (internally) to form isomers. | |
| (a) | Carboxylase | | Addition of —COOH |
| (b) | Decarboxylase | | Removal of —COO |
| (c) | Aldolase | | Cleaving of Ketose mono-, and diphosphate |
| V. | *Isomerase* | Redistribution and rearrangement of to form isomers. | e.g. Mutase, Racemase, Epimerase, cis-trans-isomerase |
| VI. | *Ligase* | Conjugation of molecules by using energy donated by ATP and other phosphates.. | Formation of C—C, C—N C—O and C—S bonds. |



## Co-enzymes and their functions

| Co-enzymes | Functions |
|---|---|
| Nicotinamide adenine dinucleotide ($NAD^+$) | Transfer of hydrogen atoms (electron). |
| Nicotinamide adenine dinucleotide phosphate ($NAD^+$) | Transfer of hydrogen atoms. |
| Thiamine pyrophosphate ($B_1$) | Decarboxylation and aldehyde group transfer. |
| Flavin monoculeotide (FMN) | Transfer of hydrogen atoms. |
| Flavin adenine dinucleotide (FAD) | Transfer of hydrogen atoms. |

| | |
|---|---|
| Lipoic acid | Transfer of acyl groups. |
| Biotin | Transfer of $CO_2$. |
| Pyridoxal phosphate ($B_6$) | Participates in transmination, decarboxylation and recamization reactions of amino acids. |
| Tetrahydrofolate | Transfer of methyl, methylene, formyl and formamino groups |
| Cyanocobalamine (vitamin $B_{12}$) | Transfer of alkyl groups in alkylation reactions. |
| Co-enzyme Q | Transfer of hydrogen atoms. |
| Co-enzyme A | Transfer of acyl groups. |

**Some co-enzymes containing a vitamin as their component**

| Type of vitamin | Co-enzyme or the active form |
|---|---|
| Thaimine | Thaimine pyroposphate (TPP) |
| Riboflavin | Flavin mononucleotide (FMN) |
| | Flavin adenine dinucleotide (FAD) |
| Nicotinic acid | Nicotinamide adenine dinucleotide (NAD) |
| | Nicotinamide adenine dinucleotide |
| Panthothenic acid | Co-enzyme A(CoA) |
| Pyridoxine | Pyridoxal phosphate |
| Biotin | Biocytin |
| Folic acid | Tetrahydrofolic acid |
| Vitamin $B_{12}$ | Co-enzyme $B^{12}$ |

**Molecular mechanism which contribute to the catalytic efficiency of enzyme**

| | Mechanisms | Remarks |
|---|---|---|
| 1. | Proximity effects | Temporary binding of reactants close to each other on an enzyme increases the chance of a reaction. |
| 2. | Orientation effects | Reactants are held by the enzymes in such a way that the bonds are exposed to attack and a transition state is readily achieved. |
| 3. | Strain effects | Enzyme may induce strain or distortion in the susceptible bond of the substrate molecule, making the bond easier to break. |
| 4. | Acid-base catalysis | Acidic and basic amino acids in the enzyme facilitate transfer of electrons to and from the reactants. |
| 5. | Covalent catalysis | Enzyme may combine with the substrate to form an unstable covalent intermediate that readily undergoes reactions to form the products. |
| 6. | Microenvironmental effects | Hydrolytic amino acids create a water-free zone in which non-polar reactants may react more easily. |

## Mechanism of enzyme action

Two theories have been advanced 1. Lock and key theory and 2. Induced fit theory of Koshland (1960).

A specific part of enzyme has a catalytic site which exerts binding force on hydrophilic or hydrophobic bonds. This causes formation of enzyme-substrate complex. Such reaction involve formation of covalent or electrostatic bond. Enzymes contain different sites for substrate binding and catalysis.

Enzymes have found different applications in biomedicine and industry. Thus pencillinase (of bacterial origin) is used in treatment of allergy, lysozyme (present in tear) is used as antibiotic for treatments of eye infection, trypsin is used in cleaning wounds, genetically engineered products are used in treatment of diabetes mellitus (Humulin from E-coli), and anti-cancer drugs. Proteases are used as components of detergents (alcoholase), meat tenderiser (Papain), cold pasteurisation (catalase), imparting flavour to chees (lipase), whitening of bread (lipoxygenlase) etc.

(a) Nucleus (for synthesis of histones, RNA and NAD)

(b) Mitochondrial enzymes of Krebs cycle, area cycle, electron transport chain, oxidative phosphorylation and oxidation.

(c) Lysosomes : site of hydrolytic action.

(d) Cytoplasmic enzymes of glycolysis, glycogenolysis, glycogenesis and Fatty Acid synthesis.

## Nature of enzymes

1. All enzymes are proteins.
2. Molecular weight ranges from 10,000 d + 50,000 d.
3. They can catalyse one type of reaction, e.g. Acid phosphatase can only catalyse hydrolysis but not oxidation or any other reaction.
4. Structurally enzymes can be simple protein e.g. Pepsin and trypsin or conjugated proteins. The conjugant is always a non-protein and is called co-factor. Such an enzyme is called holoenzyme, i.e. enzyme + co-factor. The enzyme part (apoenzyme) is colloidal and heat stable.
5. Co-factor are of two types
   (a) *Co-enzymes* Carbon compounds temporarily bonded to apoenzyme at the time of their catalytic reaction. They act as co-factors in many biochemical reactions catalysed by enzymes, e.g. B-complex group of vitamins.
   (b) *Prosthetic group* Carbon compound permanently bonded to enzymes. If removed, the enzyme becomes inert, e.g. peroxidase, catalase.
6. Many metalloenzymes contain ions $CO^{2+}$, $Fe^{2+}$, $Cu^{2+}$, $Mn^{2+}$ and $Zn^{2+}$ are examples of this.
7. Enzymes are needed in microquantities and can be reused. They catalyse the biochemical reaction but do not take part in it. At the end of the reaction they remain unchanged.
8. Depending on availability of energy, they can act in forward and backward direction.
9. Being protein, enzyme can be denatured to a variety of physical and chemical factors and thus become inert.
10. Enzymes are substrate and reaction specific.
11. They reduce the activation energy.
12. Enzyme-substrate reactions are specific.
13. Enzyme activity is significantly altered by temperature, pH, substrate concentration, concentration of enzyme vis-a vis substrate, product, ions, redox potential, storage of end-product which induces not only structural changes in enzymes (allosteric effects) but also suppress their catalytic activity. Antibiotics, toxins, antimetabolites, cause reversible and/or irreversible alterations and serve as enzyme inhibitors.
14. Enzymes occur in multiple form and these forms are called isoenzymes whose number, structure, chemical properties and function varies. These isoenzymes of an enzyme can be separated by electrophoresis. For example, in muscles of heart, five types of LDH isoenzymes have been delineated designated as LDH, –LDH5 while in spermatogenically active testes of aves and mammals, a sixth LDH isoenzyme called $LDH_x$ is consistently seen.