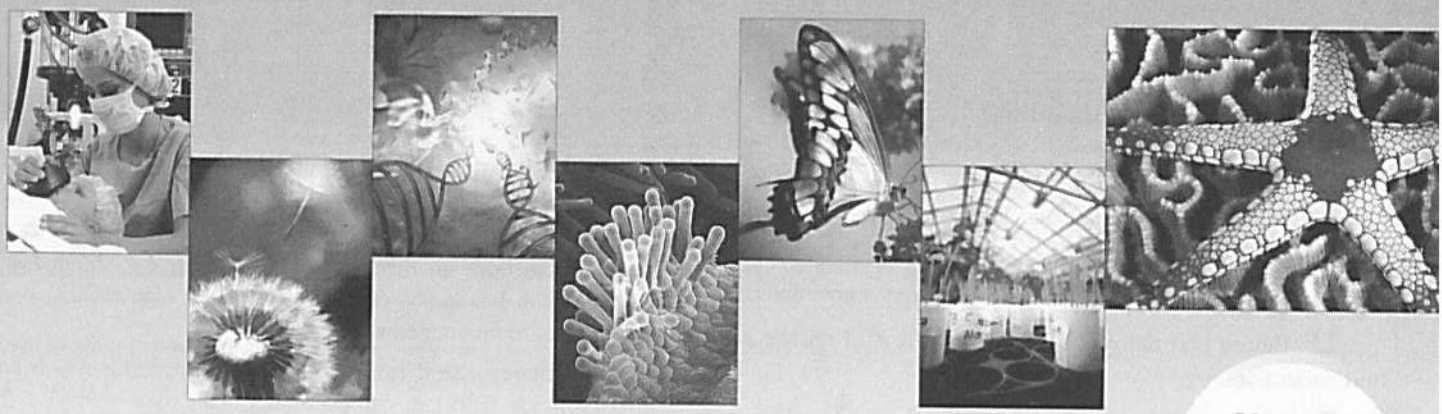

Chapter

3.2

Biomolecules

Micromolecules

These are molecules of low molecular weight and have higher solubility. These include minerals, water, amino acid, sugars and nucleotides. All molecules or chemicals functional in life activity are called *biomolecules*.

(1) **Elements :** On the basis of presence and requirement in plants and animals, they are grouped into major (*Ca, P, Na, Mg, S, K, N*) and minor (*Fe, Cu, Co, Mn, Mo, Zn, I*) bioelements.

On the basis of function, they may be of following types :

(i) **Framework elements :** Carbon, oxygen and hydrogen.

(ii) **Protoplasmic elements :** Protein, nucleic acid, lipids, chlorophyll, enzymes, etc.

(iii) **Balancing elements :** *Ca, Mg* and *K*.

(2) **Biological compounds**

(i) **Inorganic compounds :** Water 80%, inorganic salts 1-3%.

(ii) **Organic compounds :** Carbohydrates (1.0%), Lipids (3.5%), Proteins (12.0%) Nucleotides (2.0%), Other compounds (0.5).

(3) **Cellular pool :** Aggregated and interlinked various kinds of biomolecules in a living system. So cell is called cellular pool. It includes over 5000 chemicals. Inorganic chemicals are present mostly in aqueous phase while organic in both, aqueous and non-aqueous. Cellular pool comprises of both crystelloid and colloidal particles. Hence called as crystal colloids.

(4) **Water :** Liquid of life, major constituent of cell (about 60-90%) and exists in intracellular, intercellular and in vacuoles. In cells it occurs in free state or bound state (*KOH, CaOH* etc.).

Properties of water : It is colourless, transparent, tasteless and odourless, neutral (*pH*-7) liquid. It is universal solvent, as it can dissolve both polar and non-polar solutes. High boiling point due to hydrogen bonding. Shows high degree of cohesion and adhesion. It can undergo three states of matter *i.e.*, solid⇆ liquid⇆ gas. It is dense and heaviest at 4*C* and solid below it.

(5) **Carbohydrates :** *e.g.*, sugars, glycogen (animal starch), plant starch and cellulose.

Source of carbohydrate : Mainly photosynthesis. It exists only in 1% but constitutes 80% of the dry weight of plants.

Composition : It consists of carbon, hydrogen and oxygen in the ratio $C_nH_{2n}O_n$. It is also called saccharide and sugars are their basic components. Classification of carbohydrates are :

(i) **Monosaccharides :** These are single sugar units which can not be hydrolysed furthur into smaller carbohydrates. General formula is $C_nH_{2n}O_n$, *e.g.*, Trioses-3C, (Glyceraldehyde, dihydroxyacetone etc.), tetroses-4*C*, pentoses-5*C*, hexoses-6*C* etc.

Important Hexoses

Glucose : $C_6H_{12}O_6$. Grape sugar is dextrose. Grape is sour due to presence of tartaric acid. Fructose is called fruit sugar (sweetest among natural sugars) and glucose is called " sugar of body" (blood sugar). Normal level of blood glucose is 80-120mg/100ml. If it exceeds then condition is called "glucosuria".

Fructose : Occurs naturally in fruit juices and honey. Hydrolysis of cane sugar in body also yields fructose. The sweetest carbohydrate is fructose, which is also called fruit sugar because of its common occurrence in fruits (except grapes). It is also called levulose (because of its laevorotatory nature, *i.e.*, rotates the plane of polarized light towards left). It has a sweetening index of 170 (whereas the sweetening index of glucose is 70).

Galactose : It is called as brain sugar. It's an important constituent of glycolipids and glycoproteins.

Properties of monosaccharide

- ❑ Monosaccharides are colourless, sweet tasting, solids and show oxidation, esterification and fermentation.
- ❑ Due to asymmetric carbon, they exist in different isomeric forms. They can rotate polarized light hence they are dextrorotatory and laevorotatory.
- ❑ D-glucose after reduction gives rise to a mixture of polyhydroxy alcohol, sorbitol or mannitol.

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Functions of monosaccharides

- Glucose is the ultimate source of ATP in the cell respiration.
- Polymerisation of these molecules forms macromolecules.
- Ribose and deoxyribose are constituent of nucleic acids and nucleotides.
- Sugars have free aldehyde or ketone group which can reduce Cu^{++} to Cu^{+} and are called reducing sugars. Benedicts or Fehling's test are used to confirm the presence of reducing sugars.

(ii) **Oligosaccharides :** Formed due to condensation of 2-10 monosaccharide units, the Oxygen bridge is known as "glycoside linkage" and water molecule is eliminated. The bond may be α and β.

(a) **Disaccharides :** Composed of two molecules of same or different monosaccharide units. Also called "double sugars". Molecular formula is $C_{12}H_{22}O_{11}$.

Maltose : Also called "malt sugar" stored in germinating seeds of barley, oat, etc. It is formed by enzymatic (enzyme amylase) action on starch. It is a double sugar (disaccharide) made up of two molecules on each of α-*D* glucose and *β*-*D* glucose joined by α 1 → 4 glycosidic bond. It is a reducing sugar.

Sucrose : "Cane sugar" or " table-sugar". Obtained from sugarcane and beet root and on hydrolysis splits into glucose and fructose. It is a non reducing sugar.

Lactose : Milk sugar or 5% in mammalian milk. On hydrolysis yields glucose and galactose. *Streptococcus lacti* converts lactose into lactic acid and causes souring of milk.

(b) **Trisaccharides :** Composed of three molecules of sugars. Molecular formula is $C_{18}H_{32}O_{16}$.

Raffinose : Found in sugar beet, cotton and in some fungi. It is made up of glucose, fructose and galactose.

Gentianose : Found in rhizomes of gentian species, made up of glucose and fructose.

(c) **Tetrasaccharides :** Composed of four molecules of same or different sugars. Stachyose is found in *Stachys tubefera*. It is made up of two unit of galactose, one unit of glucose and one unit of fructose.

(d) **Polysaccharides :** General formula is $(C_6H_{10}O_5)_n$ formed by condensation of several molecules (300-1000) of monosaccharides, (Described under " Macromolecules").

(6) **Lipids :** Term lipid was coined by Bloor (1943). These are esters of fatty acids and alcohol. They are hydrophobic insoluble in water but soluble in benzene, ether and chloroform. Lipids are classified into three groups :

(i) **Simple lipids :** These are the esters of fatty acids and glycerol. Again they are typed as :

(a) **Fats and Oils :** (Natural lipids or true fats). These are triglycerides of fatty acid and glycerol. Fats which are liquid at room temperature are called oils.

(b) **Fatty acids :** Obtained by hydrolysis of fats. Formic acid is simplest fatty acid (*HCOOH*). These are of 2 types :

- **Saturated fatty acids :** The fatty acids which do not have double bond in between carbon atoms. *e.g.*, butyric acid, palmitic acid, hexanoic acid, etc. They have high melting points and solid at room temperature.
- **Unsaturated fatty acids :** The fatty acids which have double bonds (D.B.) in carbon atoms. *e.g.*, oleic acid (1 D.B.), linolic acid (2 D.B.), linolenic acid (3 D.B.), arachidmic acid (4 D.B.) one D.B. containing fatty acid is called MUFA, and with more than one D.B. fatty acid is called PUFA. They have lower melting points mostly found in plant fats and liquid at room temperature.

Linoleic acid, linolenic acid, arachidonic acid are essential fatty acid (Evans and Burr 1928). Deficiency of essential fatty acid causes follicular hyper keratosis disease.

(c) **Waxes :** These are simple lipids composed of one molecule of long chain fatty acid and long chain monohydric alcohol. Waxes have high melting point, insoluble in water. They reduce rate of transpiration by making plant tissue water proof. Wax present in blood called cholestrol.

Bees wax is a common example of wax. It is a combination of palmitic acid and mericyl alcohol ($C_{30}H_{61}OH$). Candil contains paraffin wax and stearic acid.

(ii) **Compound lipids :** They contain some additional element. Group with fatty acid and alcohol they may be of following types :

(a) **Phospholipids :** It is amphipathic molecule. These contain phosphoric acid. It helps in transport, metabolism, blood clotting and permeability of cell membrane. *e.g.*, Lecithin, cephalin (Soyabean oil).

(b) **Glycolipids :** These contain nitrogen and carbohydrate beside fatty acids. Generally found in white matter of nervous system. *e.g.*, sesocine frenocin.

(c) **Chromolipids :** It includes pigmented lipids *e.g.*, carotene.

(d) **Aminolipids / Sulpholipids :** It contains sulphur and amino acids with fatty acid and glycerol. Cutin and suberin are also compound lipids.

(iii) **Derived lipids :** These are obtained by hydrolysis of simple and compound lipids. Derived lipids include following components :

(a) **Sterols :** Lipids without straight chains are called sterols. They are composed of fused hydrocarbon rings and a long hydrocarbon side chain. Best known sterol is cholesterol.

(b) **Digitalin :** It is prepared from leaves of Foxglove (*Digitalis lantana*) is a heart stimulant.

(c) **Ergosterol :** Present in food, found in ergot and yeast.

(d) **Coprosterol :** It is found in faeces. It is formed as a result of the reduction by bacteria in intestine from the double bond of cholesterol between C_5 and C_6.

(e) **Terpenes :** It is essential oil and present mostly in oils of camphor, eucalyptus, lemon and mint. Phytol is a terpenoid alcohol present in Vitamin A, K, E and in pigments like chlorophyll carotenoid.

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Functions of lipids

- Oxidation of lipids yields comparatively more energy in the cell than protein and carbohydrates.
- The oil seeds such as groundnut, mustard, coconut store fats to provide nourishment to embryo during germination.
- They function as structural constituent *i.e.*, all the membrane system of the cell are made up of lipoproteins.
- Amphipathic lipids are emulsifier.
- It works as heat insulator and Used in synthesis of hormones.
- Fats provide solubility to vitamins *A, D, E,* and *K*.

(7) **Amino acids :** Amino acids are basic units of protein and made up of *C, H, O, N* and sometimes S. Amino acids are organic acids with a carboxyl group (*–COOH*) and one amino group ($-NH_2$) on the α -carbon atom. Carboxyl group attributes acidic properties and amino group gives basic ones. In solution, they serve as buffers and help to maintain *pH*. General formula is $R-CHNH_2.COOH$. They are 20 in number specified in genetic code and universal in viruses, prokaryotes and eukaryotes. Which take part in protein synthesis.

Amino acids are amphoteric or bipolar ions or Zwitter ions. Amino acids link with each other by peptide bond and long chains are called polypeptide chains. Total known amino acid are more than 200 out of these only 20 amino acid takes part in protein synthesis called protein amino acid.

Classification

(i) **Based on R-group of amino acids**

Simple amino acids : These have no functional group in the side chain. *e.g.*, glycine, alanine , leucine, valine etc. Glycine is a simplest amino acid.

Hydroxy amino acids : They have alcohol group in side chain. *e.g.*, threonine, serine, etc.

Sulphur containing amino acids : They have sulphur atom in side chain. *e.g.*, methionine, cysteine.

Basic amino acids : They have basic group ($-NH_2$) in side chain. *e.g.*, lysine, arginine.

Acidic amino acids : They have carboxyl group in side chain. *e.g.*, aspartic acid, glutamic acid.

Acid amide amino acids : These are the derivatives of acidic amino acids. In this group, one of the carboxyl group has been converted to amide ($-CO.NH_2$). *e.g.*, asparagine, glutamine.

Heterocyclic amino acids : These are the amino acids in which the side chain includes a ring involving atleast one atom other than carbon. *e.g.*, tryptophan, histidine.

Aromatic amino acids : They have aromatic group (benzene ring) in the side chain. *e.g.*, phenylalanine, tyrosine, etc.

(ii) **On the basis of requirements :** On the basis of the synthesis amino acids in body and their requirement, they are categorized as :

Essential amino acids : These are not synthesized in body hence to be provided in diet *e.g.*, valine, leucine, isoleucine, theronine ,lysine, tryptophan, phenylalanine, methionine etc.

Semi-essential amino acids : Synthesized partially in the body but not at the rate to meet the requirement of individual. *e.g.*, arginine and histidine.

Non-essential amino acids : These amino acids are derived from carbon skeleton of lipids and carbohydrate metabolism. In humans there are 12 non- essential amino acids *e.g.*, alanine, aspartic acid, cysteine, glutamic acid etc. Proline and hydroxyproline have, *NH* (imino group) instead of NH_2 hence are called imino acids.

(8) **Nucleotides** : Structurally a nucleotide can be regarded as a phosphoester of a nucleoside. A combination of nitrogenous base and a sugar is called nucleoside and combination of a base, a sugar and phosphate group is known as nucleotide.

N_2 base + Pentose sugar → 'Nucleoside'

Nucleoside + Phosphoric acid → 'Nucleotide' + H_2O .

Table : 3.2-1

Types of nitrogen base	Nucleoside	Nucleotide
Adenine	Adenosine	Adenylic acid
Guanine	Guanosine	Guanylic acid
Cytosine	Cytidine	Cytidilic acid
Thymine	Thymidine	Thymidylic acid
Uracil	Uridine	Uridylic acid

There are two types of pentose sugars, ribose found in RNA and deoxyribose found in DNA. There are two types of bases which occur in the nucleic acids.

(i) **Purines :** Purines are 9 membered double ringed nitrogenous bases which possess nitrogen at 1' ,3' ,7' and 9' positions. They are adenine (A) and guanine (G).

(ii) **Pyrimidines :** They are smaller molecule than purines. These are 6 membered single ringed nitrogenous bases that contain nitrogen at 1' and 3' positions like cytosine (C), thymine (T) and uracil (U). In DNA adenine pairs with thymine by two H_2 bond and cytosine pairs with guanine by three H_2 bond.

A nucleotide may have one, two or three phosphates, as one in AMP, two in ADP. The II and III phosphate bond is called high energy bond and it release about 8 *K cal*. ATP was discovered by *Karl Lohmann* (1929). Formation of ATP is endergonic reaction.

Functions of nucleotides

- **Formation of nucleic acids :** Different nucleotides polymerize together to form DNA and RNA.
- **Formation of energy carrier :** They help in formation of *ATP,AMP, ADP, GDP, GTP, TDP,TTP, UDP*, etc. which on breaking release energy.
- **Formation of Coenzymes :** Coenzymes like *NAD, NADP, FMN, FAD, CoA*, etc are formed.

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Macromolecules

Macromolecules are polymerisation product of micromolecules, have high molecular weight and low solubility. They include mainly polysaccharide, protein and nucleic acids.

(1) **Polysaccharide :** They are branched or unbranched polymers of monosaccharides jointed by glycosidic bond. Their general formula is $(C_6H_{10}O_5)_n$. Polysaccharides are amorphous, tasteless and insoluble or only slightly soluble in water and can be easily hydrolysed to monosaccharide units.

Types of polysaccharides

(i) **On the basis of structure**

Homopolysaccharides : These are made by polymerisation of single kind of monosaccharides. *e.g.*, starch, cellulose, glycogen, etc.

Heteropolysaccharide : These are made by condensation of two or more kinds of monosaccharides. *e.g.*, chitin, pectin, etc.

(ii) **On the basis of functions**

Food storage polysaccharides : They serve as reserve food. *e.g.*, starch and glycogen.

Structural polysaccharides : These take part in structural framework of cell wall *e.g.*, chitin and cellulose.

Description of some polysaccharides

Glycogen : It is a branched polymer of glucose and contain 30,000 glucose units. It is also called animal starch. It is also found as storage product in blue green algae, slime moulds, fungi and bacteria. It is a non-reducing sugar and gives red colour with iodine. In glycogen, glucose molecule are linked by 1 – 4 glycosidic linkage in straight part and 1 – 6 linkage in the branching part glycogen has branch points about every 8-10 glucose units.

Starch ($C_6H_{10}O_5$) : Starch is formed in photosynthesis and function as energy storing substance. It is found abundantly in rice, wheat, legumes, potato (oval and ecentric shaped), banana, etc. Starch is of two types. Straight chain polysaccharides known as amylose and branched chain as amylopectin. Both composed of D – glucose units jointed by $\alpha-1-4$ linkage and $\alpha-1-6$ linkage. It is insoluble in water and gives blue colour when treated with iodine.

Inulin : Also called "dahlia starch"(found in roots). It has unbranched chain of 30 – 35 fructose units linked by $\beta-2-1$ glycosidic linkage between 1 and 2 of carbon atom of D– fructose unit.

Cellulose : An important constituent of cell wall (20 – 40%), made up of unbranched chain of 6000 β-*D* glucose units linked by 1 – 4 glycosidic linkage. It is fibrous, rigid and insoluble in water. It doesn't give any colour when treated with iodine. It is a most abundant polysaccharide.

Chitin : It is a polyglycol consisting of N-acetyl–D–glucosamine units connected with $\beta-1,4$ glycosidic linkage. Mostly it is found in hard exoskeleton of insects and crustaceans and some times in fungal cell wall. Second most abundant carbohydrate. It is a most abundant heteropolysaccharide.

Agar-Agar : It is a galactan, consisting of both D and L galactose and it is used to prepare bacterial cultures. It is also used as luxative and obtained from cell wall of red algae *e.g.*, Gracilaria, Gelidium etc.

Pectin : It is a cell wall material in collenchyma tissue may also be found in fruit pulps, rind of citrus fruits etc. It is water soluble and can undergo sol ⇌ gel transformation. It contain arabinose, galactose and galacturonic acid.

Neutral sugars : It is found associated with cellulose in cell wall. The common sugars in hemicellulose are D-xylose, L–arabinose, D-galactose, D-mannose and D-glucusonic acid. *e.g.*, hemicellulose.

Gum : It secreted by higher plants after injury or pathogenic attacks. It is viscous and seals the wound. It involves sugars like L-arabinose, D-galactose, D-glucusonic acid. *e.g.*, gum arabic.

(2) **Mucopolysaccharides :** These are gelatinous substance, containing amino sugars, uronic acid, etc. All slimy substances of plant are mucopolysaccharide. *e.g.*, hyaluronic acid, vitreous humour, chondridine sulphate, heparin, husk of isabgol and mucilage also.

Glycoproteins : They include some plasmaprotein and blood group substances. They doesn't contain uronic acid.

Murein : It is a peptidoglycan, linked to short chains of peptides. It is constituent of cell wall of bacteria and blue green algae.

Functions

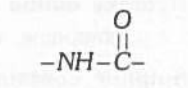
(i) Cellulose pectin and chitin are constituents in cell wall of higher plants but peptidoglycan in the cell wall of prokaryotes.

(ii) They are reserve food material and form protective covering.

(iii) Fibres obtained are used in making cloth and rope.

(iv) Nitrocellulose and trinitrate cellulose (gun-cotton) used as explosive.

(3) **Protein :** The word protein was coined by Berzelius in 1838 and was used by G. J. Mulder first time 1840. 15% of protoplasm is made up of protein. Average proteins contain 16% nitrogen, 50–55% carbon, oxygen 20–24%, hydrogen 7% and sulphur 0.3 – 0.5%. Iron, phosphorous, copper, calcium, and iodine are also present in small quantity.



Peptidelinkage

Structure of proteins : It is due to different rearrangement of amino acids. When carboxyl group (–*COOH*) of one amino acid binds with amino group ($-NH_2$) of another amino acid the bond is called peptide bond.

(i) **Primary structure :** The primary structure is the covalent connections of a protein. It refers to linear sequence, number and nature of amino acids bonded together with peptide bonds only. *e.g.*, ribonuclease, insulin, myoglobin and lysozyme.

(ii) **Secondary structure :** The folding of a linear polypeptide chain into specific coiled structure (α – helix) is called secondary structure. This α helix structure was discovered by Linus Pauling and Robert Corey (1952) using x-ray diffraction technique in silk fibres. *e.g.*, fur, keratin of hair claws, and feathers.

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(iii) **Tertiary structure :** The arrangement and interconnection of proteins into specific loops and bends is called tertiary structure of proteins. It is found in *e.g.*, globular proteins.

(iv) **Quarternary structure :** It is shown by protein containing more than one peptide chain. The protein consists of identical units. It is known as homologous quarternary structure *e.g.*, lactic dehydrogenase. If the units are dissimilar, it is called as heterogeneous quarternary structure *e.g.*, haemoglobin.

Classification of proteins : Proteins are classified on the basis of their shape, constitution and function.

On the basis of shape

Fibrous protein/Scleroprotein : Insoluble in water. Animal protein resistant to proteolytic enzyme is spirally coiled thread like structure form fibres. *e.g.*, *collagen* (in connective tissue), actin and myosin, keratin in hairs, claws, feathers, etc.

Globular proteins : Soluble in water. Polypeptides coiled about themselves to form oval or spherical molecules *e.g.*, albumin insulin hormones like ACTH, oxytosin, etc.

On the basis of constituents

Simple proteins : The proteins which are made up of amino acids only. *e.g.*, albumins, globulins, prolamines, glutelins, histones, etc.

Conjugated proteins : These are complex proteins combined with characterstic non–amino acid substance called as prosthetic group. These are of following types :

(i) **Nucleoproteins :** Combination of protein and nucleic acids, found in chromosomes and ribosomes. *e.g.*, deoxyribonucleoproteins, ribonucleoproteins, etc.

(ii) **Mucoproteins :** These are combined with large amount (more than 4%) of carbohydrates *e.g.*, mucin.

(iii) **Glycoproteins :** In this, carbohydrate content is less (about 2 – 3%) *e.g.*, immunoglobulins or antibiotics.

(iv) **Chromoproteins :** These are compounds of protein and coloured pigments. *e.g.*, haemoglobin, cytochrome, etc.

(v) **Lipoproteins :** These are water soluble proteins and contain lipids. *e.g.*, cholesterol and serum lipoproteins.

(vi) **Metalloprotein :** These are metal binding proteins, AB_1–globin known as transferring is capable of combining with iron, zinc and copper *e.g.*, chlorophyll.

(vii) **Phosphoprotein :** They are composed of protein and phosphate *e.g.*, casein (milk) and vitellin (egg).

Derived proteins : When proteins are hydrolysed by acids, alkalies or enzymes, the degredation products obtained from them are called derived proteins.

On the basis of nature of molecules

Acidic proteins : They exist as anion and include acidic amino acids. *e.g.*, blood groups.

Basic proteins : They exist as cations and rich in basic amino acids *e.g.*, lysine, arginine etc.

Function of Proteins

(i) Proteins occur as food reserves as glutelin, globulin casein in milk.

(ii) Proteins are coagulated in solutions, alkaline to the isoelectric *pH* by positive ions such as $Zn^{2+}, Cd^{2+}, Hg^{2+}$ etc. Casein – *pH* 4.6, cyt. *C* – 9.8, resum globulin 5.4, pepsin 2.7, lysozyme 11.0 etc.

(iii) Proteins are the most diverse molecule on the earth.

(iv) They are biological buffers.

(v) Monelin is the sweetest substance obtained from African berry (2000 time sweeter than sucrose).

(vi) Most abundant protein on earth is RUBP.

(vii) Myosin is structural as well as enzymatic protein (ATPase).

Nucleic acids

Nucleic acids are the polymers of nucleotide made up of carbon, hydrogen, oxygen, nitrogen and phosphorus and which controls the basic functions of the cell. These were first reported by Friedrich Miescher (1871) from the nucleus of pus cell. *Altmann* called it first time as nucleic acid. Nuclein was renamed nucleic acid by Altman in (1889). They are found in nucleus. They help in transfer of genetic information.

Types of nucleic acids : On the basis of nucleotides *i.e.*, sugars, phosphates and nitrogenous bases, nucleic acids are of two types which are further subdivided. These are DNA (Deoxyribonucleic acid) and RNA (Ribonucleic acid).

(1) **DNA (Deoxyribonucleic acids) :** Term DNA was given by **Zacharis**.

(i) **Types of DNA :** It may be linear or circular in eukaryotes and prokaryotes respectively.

Palindromic DNA : The DNA helix bears nucleotide in a serial arrangement but opposite in two strands.

–*T* – *T* – *A* – *A* – *C* – *G* – *T* – *T* – *A* – *A*.....

–*A* – *A* – *T* – *T* – *G* – *C* – *A* – *A* – *T* – *T*.....

Repetitive DNA : This type of arrangement is found near centromere of chromosome and is inert in RNA synthesis. The sequence of nitrogenous bases is repeated several times.

Satellite DNA : It may have base pairs upto 1 – 60 *bp* and are repetitive in nature. Microsatellite has 1 – 6 *bp* and minisatellite has 11 – 60 *bp*. They are used in DNA matching or finger printing (Jefferey). In eukaryotes, DNA is deutrorotatory and sugars have pyranose configuration.

(ii) **Chargaff's rule :** Quantitatively the ratio of adenine (A) to thymine (T) and guanine (G) to cytosine (C) is equal. *i.e.*, "Purines are always equal to pyrimidine".

(iii) **C value :** It is the total amount of DNA in a genome or haploid set of chromosomes.

(iv) **Sense and Antisense strand :** Out of two DNA strand one which carries genetic information in its cistrons is called sense strand while the other strand does not carry genetic information, therefore, doesn't produce mRNA. The non-functional DNA strand is called antisense strand.

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(v) **Heteroduplex DNA :** Hybrid DNA formed as a result of recombination is called heteroduplex DNA. It contains mismatched base pair of heterologous base sequence.

X-Ray crystallography study of DNA : It was done by Wilkins. It shows that the two polynucleotide chains of DNA show helical configuration.

Single stranded DNA (ssDNA) : It is single helixed circular and isolated from bacteriophage $\phi \times 174$ by *Sinsheimer* (1959). It does not follow chargaff's rule. The replicative form (RF) has plus – minus DNA helix. *e.g.*, parvovirus.

Double helical model of DNA: It is also known as Watson and Crick model.

(2) **RNA or Ribonucleic acid :** RNA is second type of nucleic acid which is found in nucleus as well as in cytoplasm *i.e.*, mitochondria, plastids, ribosomes etc. They carry the genetic information in some viruses. They are widely distributed in the cell. Genomic RNA was discovered by **Franklin and Conrat** (1957).

History of cellular enzymes

Enzymes (Gk. *en* = in; *zyme* = yeast) are proteinaceous substances which are capable of catalysing chemical reactions of biological origins without themselves undergoing any change. Enzymes are **biocatalysts**. Enzymes exist inside the cell in colloidal form. An enzyme may be defined as "a protein that enhances the rate of biochemical reactions but does not affect the nature of final product". Like the catalyst the enzymes regulate the speed and specificity of a reaction, but unlike the catalyst they are produced by living cells only. All components of cell including cell wall and cell membrane have enzymes.

Maximum enzymes (70%) in the cell are found in mitochondrion. Enzymes are also called '**biological middle man**'. The study of the composition and function of the enzyme is known as **enzymology**.

The term enzyme (meaning in yeast) was used by Willy Kuhne (1878) while working on fermentation. At that time living cells of yeast were thought to be essential for fermentation of sugar. Edward Buchner (1897), a German chemist proved that extract zymase, obtained from yeast cells, has the power of fermenting sugar (alcoholic fermentation). Zymase is complex of enzymes (Buchner isolated enzyme for the first time).

Later J.B. Sumner (1926) prepared a pure crystalline form of urease enzyme from Jack Bean (*Canavalia ensiformis*) and suggested that enzymes are proteins. Northrop and Kunitz prepared crystals of pepsin, trypsin and chymotrypsin. Arber and Nathans got noble prize in 1978 for the discovery of restriction endonucleases which break both strands of DNA at specific sites and produce sticky ends. These enzymes are used as microscissors in genetic engineering.

Nature of enzymes

Mostly enzymes are proteinaceous in nature. With some exception all enzymes are proteins but all proteins are not enzymes. Enzymatic protein consist of 20 amino acids. The polypeptide chain or chains of an enzyme show tertiary structure. Their tertiary structure is very specific and important for their biological activity. Loss of tertiary structure renders the enzymic activity.

Some enzymes like pepsin, amylase, urease, etc., are exclusively made up of protein *i.e.*, simple proteins. But most of the other enzymes have a protein and a non-protein component, both of which are essential for enzyme activity. The protein component of such enzymes is known as **apoenzyme** whereas the non-protein component is called **cofactor** or **prosthetic group.** The apoenzyme and prosthetic group together form a complete enzyme called **holoenzyme.**

Activity of enzyme is due to co-factor, which can be separated by dialysis. co-factor is small, heat stable and may be organic or inorganic in nature.

Three types of cofactors may be identified. Prosthetic group, coenzyme and metal ions.

Prosthetic group : Prosthetic groups are organic compounds distinguished from other cofactors in that they are permanently bound to the apoenzyme, *e.g.*, in peroxisomal enzymes peroxidase and catalase which catalyzes breakdown of hydrogen peroxide to water and oxygen.

Coenzymes : Fritz Lipmann discovered coenzymes. Coenzymes are also organic compounds but their association with the apoenzyme is transient, usually occurring only during the course of catalysis.

In general coenzymes not only assist enzymes in the cleavage of the substrate but also serve as temporary acceptor for one of the product of the reaction. The essential chemical component of many coenzymes are vitamins, *e.g.*, coenzyme nicotinamide adenine dinucleotide (NAD), nicotinamide adenine dinucleotide phosphate (NADP) contains the vitamin niacin, coenzyme A contains pantothenic acid, flavin mononucleotide (FMN), flavin adenine dinucleotide (FAD) contains riboflavin (Vitamin B_2), and thiamine pyrophosphate (TPP) contains thiamine (Vitamin B_1).

Metal ions : A number of enzymes require metal ions for their activity. The metal ions form coordination bonds with specific side chains at the active site and at the same time form one or more coordination bonds with the substrate. The latter assist in the polarization of substrate bonds to be cleaved by the enzyme. The common metal ions are Zn^{++}, Cu^{++}, Mg^{++}.

Inorganic part of enzyme acts as prosthetic group in few enzymes they are called activators. These activators are generally metals. Hence these enzymes are called Metalloenzyme such as :

Table : 3.2-2 Enzymes activators

Activators	Enzymes
Iron (*Fe*)	Acotinase, Catalase and Cytochrome oxidase
Zinc (*Zn*)	Alcohol dehydrogenase, Carbonic anhydrase
Copper (*Cu*)	Tyrosinase, Cytochrome oxidase
Magnesium (*Mg*)	Hexokinase, Phosphotransferase
Manganese (*Mn*)	Peptidase, Decarboxylase
Molybdenum (*Mo*)	Nitrate reductase
Nickel (*Ni*)	Urease
Boron	Enolase

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Nomenclature and Classification

Dauclax, (1883) introduced the nomenclature of enzyme. Usually enzyme names end in suffix-**ase** to the name of substrate *e.g.*, Lactase acts on lactose, maltase act on maltose, amylase on amylose, sucrase on sucrose, protease on proteins, lipase on lipids and cellulase on cellulose. Sometimes arbitrary names are also popular *e.g.*, Pepsin, Trypsin and Ptylin etc. Few names have been assigned on the basis of the source from which they are extracted *e.g.*, Papain from papaya, bromelain from pineapple (family Bromeliaceae). Enzymes can also be named by adding suffix–ase to the nature of chemical reaction also *e.g.*, Oxidase, dehydrogenase, catalase, DNA polymerase.

Modern names are given after chemical action. They are more systematic, informative but slightly longer. *e.g.*, ATP : D-glucose phosphotransferase.

Common simpler names used at the place of systematic names called **trivial names**.

According to older classification : The older classification of enzymes is based on the basis of reactions which they catalyse. Many earlier authors have classified enzymes into two groups :

(1) **Hydrolysing enzyme :** The hydrolysing enzymes of hydrolases catalyse reactions in which complex organic compounds are broken into simpler compounds with the addition of water. Hydrolytic reactions are reversible. Depending upon the substrate hydrolysing enzymes are :

Carbohydrases : Most of the polysaccharides, disaccharides or small oligosaccharides are hydrolysed to simpler compounds, *e.g.*, hexoses or pentoses under the influence of these enzymes.

Lactase on lactose to form glucose to galactose, sucrase/invertase on sucrose to form glucose and fructose, amylase or diastase on starch to form maltose, maltase on maltose to form glucose, cellulase on cellulose to produce glucose.

Easterases : These enzymes catalyse the hydrolysis of substances containing easter linkage, *e.g.*, fat, pectin, etc. into an alcoholic and an acidic compound.

$$\text{Fat} \xrightarrow{\text{Lipase}} \text{Glycerol} + \text{Fatty acid}$$

$$\text{Phosphoric acid easters} \xrightarrow{\text{Phosphatase}} \text{Phosphoric acid} + \text{Other compounds}$$

Proteolytic enzymes : The hydrolysis of proteins into peptones, polypeptides and amino acids is catalysed by these enzymes

$$\text{Protein} \xrightarrow{\text{Pepsin}} \text{Peptones}$$

$$\text{Polypeptides} \xrightarrow{\text{Peptidases}} \text{Amino acids}$$

Amidases : They hydrolyse amides into ammonia and acids.

$$\text{Urea} \xrightarrow{\text{Urease}} \text{Ammonia} + \text{Carbon dioxide}$$

$$\text{Asparagine} \xrightarrow{\text{Asparaginase}} \text{Ammonia} + \text{Aspartic acid}$$

(2) **Desmolysing enzymes :** Most of the desmolysing enzymes are the enzymes of respiration *e.g.*, oxidases, dehydrogenases, (concerned with transfer of electrons), transaminases carboxylases etc.

According to IUB system to classification : In 1961 the Commission on enzymes set up by the 'International Union of Biochemistry' (IUB) framed certain rules of their nomenclature and classification.

According to IUB system of classification the major points are :

- Reactions (and enzymes catalyzing them) are divided into 6 major classes each with 4-13 subclasses.
- The enzyme name has two parts-first name is of substrate. The second ending in *ase* indicates type of reaction.
- The enzyme has a systematic code No. (Enzyme code/Enzyme Commission). The first digit denotes the class, the second sub-class, the third sub-sub-class and the fourth one is for the particular enzyme name. Thus, E.C. 2.7.1.1 denotes class 2 (Transferases)-subclass 7 (transfer of phosphate) sub-sub-class 1 (an alcohol functions as phosphate acceptor). The 4th digit indicates hexokinase. Major classes of enzymes are as follows :

(i) **Oxidoreductases :** These enzymes catalyse **oxidation reduction** reactions, usually involving the transfer of hydrogen atoms or ions from one molecule to another. There are three main types of these enzymes :

Oxidases : Where the hydrogen is transferred from a molecule to oxygen, *e.g.*, cytochrome oxidase. They play very important role in E.T.S. in photosynthesis as well as respiration,

Dehydrogenases : Where the hydrogen is transferred to a coenzyme such as NAD^+, *e.g.*, Succinic dehydrogenase. They help in oxidation of organic molecules during aerobic respiration.

Reductase : It is cause of addition of hydrogen or an electron and remove oxygen. *e.g.*, Nitrate reductase requires NAD (coenzyme I) as coenzyme for the reaction.

(ii) **Transferases :** These enzyme catalyse the transfer of a specific group (*e.g.*, amino, methyl, acyl, phosphate) from one kind of molecule to another *e.g.*, transphosphorylases, transaminases, transpeptidases, transmethylases, kinases, etc.

(iii) **Hydrolases :** These enzyme catalyse the hydrolysis of organic foods *i.e.*, the breakdown of large molecules by addition of water. Most of the hydrolysing (digestive) enzymes are located in lysosomes. *e.g.*, all digestive enzymes such as lipases (digest the stored food material of castor seeds) amylases, esterases, phosphatases, carbohydrases, proteases.

(iv) **Lyases** (Desmolases) **:** These enzymes catalyse the breakage of specific covalent bonds and removal of groups without hydrolysis *e.g.*, fumerases, carboxylases, aminases, histidine decarboxylase that splits *C–C*-bond of histidine, forming CO_2 and histamine.

(v) **Isomerases :** These enzymes catalyse the rearrangement molecular structure to form isomers. *e.g.*, phosphohexose isomerase (phosphoglucomutase) act on glucose 6-phosphate to form fructose 6-phosphate (both C_6 compounds); epimerase, racemase.

(vi) **Ligases or Synthetases :** These enzymes form bonds and join two molecules together, using energy supplied from the breakdown of ATP, *e.g.*, DNA ligase is used to repair breaks in DNA molecules. Amino-Acyl synthetase is used to activate t-RNA by attaching amino acid at 3′ end. Tryptophan synthetase is used to convert tryptophan amino acid to IAA.

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Site of enzyme action

All enzymes are produced in the living cells. About 3,000 enzymes have recorded. These are of two types with regard to the site where they act as :

Intracellular enzymes : Most of the enzymes remain and function inside the cells, They are called the intracellular enzymes or endoenzymes. Some of these enzymes are found in cytoplasmic matrix. Certain enzymes are bound to ribosomes, mitochondria and chloroplast etc.

Extracellular enzymes : Certain enzymes leave the cells and function outside them. They are called the extracellular enzymes or exoenzymes. They mainly include the digestive enzymes. *e.g.*, salivary amylase, gastric pepsin, lysozyme present in tears and nasal secretion.

Rennet tablets with enzyme rennin from calf's stomach are widely used to coagulate protein caseinogen for cheese (casein) formation.

Mechanism of enzyme action

Energy is required to bring the inert molecules into the activated state. The amount of energy required to raise the energy of molecules at which chemical reaction can occur is called **activation energy.** Enzymes act by decreasing the activation energy so that the number of activated molecules is increased at lower energy levels. If the activation energy required for the formation of the enzyme-substrate complex is low, many more molecules can participate in the reaction than would be the case if the enzyme were absent.

Mode of enzyme action

In 1913 Michaelis and Menten proposed that for a catalylic reaction to occur it is necessary that enzyme and substrate bind together to form an enzyme substrate complex.

$$\underset{\text{(Enzyme)}}{E} + \underset{\text{(Substrate)}}{S} \rightarrow \underset{\text{(Enzyme-substrate Complex)}}{E\text{-}S\ \text{Complex}}$$

$$E\text{-}S\ \text{Complex} \rightarrow \underset{\text{(Enzyme)}}{E} + \underset{\text{(Product)}}{P}$$

It is amazing that the enzyme-substrate complex breaks up into chemical products different from those, which participated in its formation (*i.e.*, substrates). On the surface of each enzyme there are many specific sites for binding substrate molecules called **active sites** or catalytic sites.

There are two views regarding the mode of enzyme action :

Lock and Key hypothesis (Template hypothesis) : The hypothesis was put forward by Emil Fisher (1894). According to this hypothesis the enzyme and its substrate have a complementary shape. The specific substrate molecules are bound to a specific site of the enzyme molecule.

The theory can be explained easily by the fact that a particular lock can be opened by a particular key specially designed to open it. Similarly enzymes have specific sites where a particular substrate can only be attached. The lock and key model accounts for enzyme specificity.

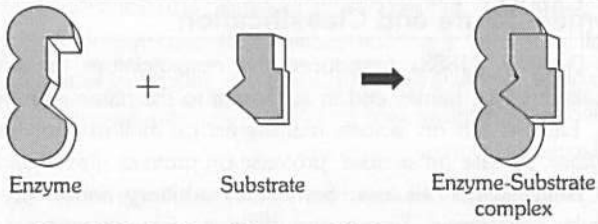

Fig : 3.2-1 Lock and key model of enzyme action

Induced fit hypothesis : This hypothesis was proposed by Daniel, E. Koshland (1959).

According to this view, active site is not rigid but static and it has two groups – buttressing group and catalytic group. Initially substrate bind to the buttressing group which induces the catalytic group to fit the substrate and catalytic group weaks the bonds of reactant or substrate by electrophilic and nucleophilic forces.

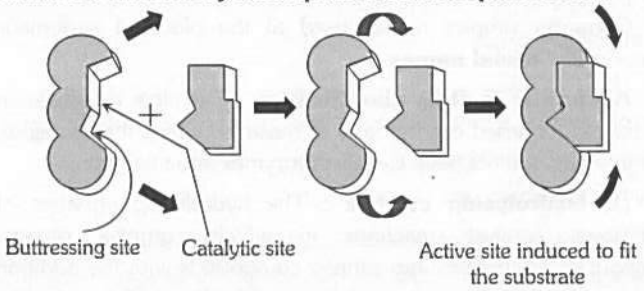

Fig : 3.2-2 Induced fit model of enzyme action

Properties of enzymes

Molecular weight : Enzymatic proteins are substances of high molecular weight. Bacterial ferredoxin one of the smaller enzymes has molecular weight of 6,000, where as pyruvic dehydrogenase one of the largest-has a molecular weight of 4600000.

Amphoteric nature : Each molecule of enzyme possess numerous groups which yield H^+ in slightly alkaline solutions and groups which yield OH^- ions in slightly acidic solutions. Unlike many other substances, therefore, the enzymatic protein is amphoteric, *i.e.*, capable of ionizing either as an acid or as a base depending upon the acidity of the external solution.

Colloidal nature : All enzymes are colloidal in nature and thus provide large surface area for reaction to take place. They posses extremely low rates of diffusion and form colloidal system in water.

Specificity of enzyme : Most of the enzymes are highly specific in their action. A single enzyme will generally catalyze only a single substrate or a group of closely related substrates. The active site possess a particular binding site which complexes only with specific substrate. Thus, only a suitable substrate fulfils the requirements of active site and closely fixes with it. The specificity of enzyme is determined by sequence of amino acids in the active sites.

Heat specificity : The enzymes are thermolabile *i.e.*, heat sensitive. They function best at an optimum temperature (20°C-40°C). Their activity decrease with decrease as well as increase in temperature and stops at 0°C and above 80°C.

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Catalytic properties : Enzymes are active in extremely small amounts, *e.g.*, one molecule of invertase can effectively hydrolyze 1,000,000 times its own weight of sucrose. One molecule of catalase is able to catalyze conversion of 5,000,000 molecules of hydrogen peroxide.

Reversibility of reaction : The enzyme-controlled reactions are reversible. The enzymes affect only the rate of biochemical reactions, not the direction. *e.g.*, Lipase can catalyse splitting of fat into fatty acids and glycerol as well as synthesis of fatty acids and glycerol into fats.

$$\text{Fat} \overset{\text{lipase}}{\rightleftharpoons} \text{Glycerol + Fatty acid}$$

***pH* sensitivity :** The enzymes show maximum activity at an optimum *pH* is 6 – 7.05(7 ± 1.05). Their activity slows with decrease and increase in *pH* till it stops. Each enzyme has its own different favourable *pH* value.

High efficiency : The effectiveness of an enzymatic reaction is expressed in terms of its turn over number or catalytic centre activity means number of substrate molecules on which one enzymes molecules acts in one minute.

Turn over number depends on the number of active sites of an enzyme. An active site is an area of the enzyme which is capable of attracting and holding particular substrate molecules by its specific charge, size and shape so as to allow the chemical change. Enzymes show 3-D structure. R (alkyl) groups of amino acids form active sites during folding polypeptide chains. Usually 3-12 amino acids form an active site.

Highest turn over number is of **carbonic anhydrase** (36 million/min or 600000 per second) and lowest is of lysozymes (30/min or 0.5 per second). So carbonic anhydrase is fastest enzyme. The lowest turn over number is of lysozymes.

Enzyme inhibition

Competitive inhibition : Substances (inhibitors) which are structurally similar to the substrates and competes for the active site of the enzyme are known as competitive inhibitors. Usually such inhibitors show a close structural resemblance to the substrates to the enzyme they inhibit. In such a case, inspite of enzyme substrate complex, enzyme inhibitor complex is formed and enzyme activity is inhibited.

$$\underset{\text{Enzyme}}{E} + \underset{\text{inhibitor}}{I} \rightarrow \underset{\text{Enzyme–inhibitor complex(EI)}}{EI}$$

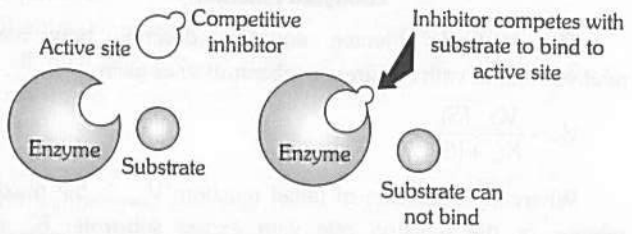

Fig : 3.2-3 Competitive inhibition

The concentration of EI complex depends on the concentration of free inhibitor. Because EI complex readily dissociates, the empty active sites are then available for substrate binding. The effect of a competitive inhibitor on activity is reversed by increasing the concentration of substrate. In it V_{max} remain constant and *Km* increases.

A classic example of competitive inhibition is succinic acid dehydrogenase which oxidises succinic acid to fumaric acid. If concentration of malonic acid, is added, the activity of succinic dehydrogenase decreases rapidly. Hence malonic acid acts as a competitive inhibitor since it has structural resemblance to succinic acid.

The competitive inhibition can be reversed by increasing the concentration of the substrate. Competitive inhibitors are used in control of bacterial pathogens.

Non-competitive inhibition : These substances (poisons) do not combine with active sites but attach somewhere else and destroy the activity of enzyme.

Both EI and ES complexes are formed. Inhibitor binding alters the three dimensional configuration of the enzyme and thus blocks the reaction. Non competitive inhibitor do not competes directly with the substrate for binding to the enzyme. In it V_{max} in lowered and *Km* is changed.

The non-competitive inhibition can not be reversed by increasing the concentration of the substrate *i.e.*, irreversible. *e.g.*, cyanide inhibits the mitochondrial enzyme cytochrome oxidase which is essential for cellular respiration. This kills the animals.

More AMP is a non competitive inhibitor of fructose biphosphate phosphatase, the enzyme that catalyzes the conversion of fructose 1, 6 biphosphate to fructose 6 phosphate.

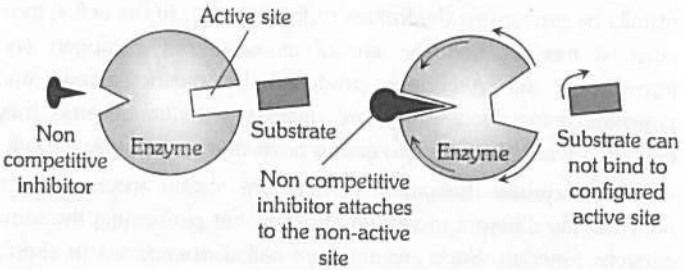

Fig : 3.2-4 Non-competitive inhibition

Feedback inhibition : In number of cases, accumulation of the final product of the reaction is capable of inhibiting the first step of reaction.

$$A \xrightarrow{E_1} B \xrightarrow{E_2} C \xrightarrow{E_3} D \xrightarrow{E_4} P$$

The product P checks the activity of enzyme which converts A into B. It is quite useful mechanism because it checks the accumulation of products.

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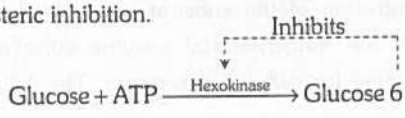
The phenomenon in which the end product of a metabolic pathway can regulate its own production by inhibition of the sort is called **feed back inhibition** or negative feed back inhibition. This type of inhibition can be shown in *Escherichia coli* bacterium which synthesises the amino acid isoleucine from a substrate threonine by a series of intermediate reactions (*i.e.*, α ketobutyrate threonine deaminase, α Aceto hydroxy butyrate, α keto β methyl valerate etc).

When isoleucine accumulates in amounts more than required, it stops its own production by inhibiting the activity of the enzyme. Threonine deaminase which catalyzes the first reaction of the series. This type of metabolic control in which the first enzyme of a series is inhibited by the end product, is known as end product inhibition.

Allosteric inhibition (Modulation) : Allosteric literally means 'another place'. Still other inhibitors join an enzyme at a specific site and change the form of the active site meant for the substrate. These inhibitors are known as modifiers or modulators and the sites where they fit in are called allosteric sites. Modulators are of two types-positive (activators) and negative (inhibitors).

Change of active site which prevent the binding of substrate to the enzyme and stops the reaction. The process is called allostery or allosteric inhibition, The enzyme with allosteric sites are called allosteric enzymes. Jacob and Monod have termed this phenomenon as allosteric transition.

An example of allosteric enzyme inhibition is hexokinase that converts glucose to glucose 6-phosphate. Glucose 6-phosphate causes allosteric inhibition of hexokinase. This is called feedback allosteric inhibition.



Some terms regarding enzymes

Zymogens or (Enzyme Precursors) : Certain enzymes are produced by the living cells in an inactive (non-functional) form. They are called the zymogens or proenzymes. It is then converted, usually by proteolysis (hydrolysis of the protein), to the active form when it has reached the site of its activity. Pepsinogen and trypsinogen are zymogens produced by gastric glands and pancreas respectively. They are necessary to life because they degrade dietary proteins into amino acids that are used by the cell.

Isoenzymes (Isozymes) **:** There are certain enzymes which have slightly different molecular structure but performing the same catalytic function. Such enzymes are called isoenzymes or simply isozymes. Isoenzyme of an enzyme differ from each another in their amino acid sequence, molecular weight, immunological and electrophoretic behaviours. Hence, they can be separated by electrophoresis.

More than 100 enzymes are known to have isoenzyme. A good example of isoenzyme is lactic dehydrogenase (LDH). It catalyzes change of pyruvate to lactate.

Inducible enzymes : An enzyme which is synthesized only in the presence of its substrate (inducer) is called inducible enzyme *e.g.*, β-galactosidase.

Constitutive enzymes (House keeping enzyme) : The enzyme which are found in constant amounts under different growth conditions (regardless of its metabolic states) are called constitutive enzyme *e.g.*, enzymes of sugar breakdown *i.e.*, glycolysis.

Repressible enzymes : The presence of a specific substance may inhibit continued production of specific enzyme (enzyme repressor) *e.g.*, glucokinase.

Ribozymes : Study of post transcriptional processing of RNA molecules has led to the most exciting discovery of the existence of some catalytic RNA molecules which have been called as RNA enzymes or ribozymes. All enzymes are not proteins as confirmed by Cech (1981) and Altman (1983). Ribozyme and RNAase-P are two non protein enzyme where RNA acts as catalyst. Ribozyme was reported from Tetrahymens (a protozoans) by Cech. The substrate for ribozyme is usually an RNA molecule. RNAase-P (Ribonuclease) was discovered by Altman.

Peptidyl transferase is also a non-proteinaceous enzyme, discovered by Noller.

Michaelis constant : Michaelis and Menten (1913) introduced a constant K_m (Michaelis constant).

It is a mathematical derivative or constant which indicates the substrate concentration at which the chemical reaction catalysed by an enzyme attains half its maximum velocity (V_{max}).

K_m indicates affinity of the enzyme for its substrate.

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

K_m value differs from substrate to substrate because different enzymes differ in their affinity towards different substrates. A high K_m indicates low affinity while a low K_m shows strong affinity. Protease acts on different proteins. So it's K_m value will differ from protein to protein.

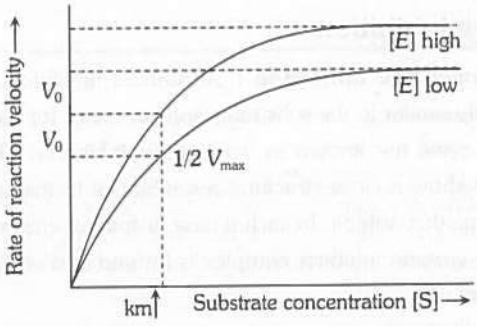


Fig : 3.2-5 Reaction velocity 'V' and substance concentration (S) for a typical enzyme catalysed reaction

The Michaelis Menten equation describe how reaction relatively varies with substrate concentration as given

$$V_0 = \frac{V_{max}[S]}{K_m + [S]}$$

Where V_0 is the rate of initial reaction; V_{max} is the maximum relative or the reaction rate with excess substrate; K_m is the Michaelis constant $= K_2 + K_3/K_1$; [S] is the substrate concentration.

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The above reaction shows that the greater the affinity between an enzyme and its substrate, the lower the K_m (in units moles per litre) of the enzyme substrate reaction. Stated inversely, $1/K_m$ is the measure of affinity of the enzyme for its substrate.

Enzyme-inhibitor dissociation constant (Ki) : It is dissociation constant of enzyme – inhibitor complex.

$$Ki = \frac{[E][I]}{[EI]}$$

Where, E is enzyme and I is concentration of inhibitor.

High Ki decreases enzyme activity while low Ki increases some, it is applicable to competitive inhibitors.

Factors affecting the enzyme activity

Substrate concentration : If there are more enzyme molecules than substrate molecules, a progressive increase in the substrate molecules increases the velocity of their conversion to products. However, eventually the rate of reaction reaches the maximum. At this stage the active sites of all the available enzyme molecules are occupied by the substrate molecules. Therefore, the substrate molecules occupy the active sites vacated by the products and cannot increase the rate of reaction further.

Enzyme concentration : The rate of reaction is directly proportional to enzyme concentration. An increase in enzyme concentration will cause a rise in the rate of reaction upto a point and them the rate of reaction will be constant. Increasing the enzyme concentration increases the number of available active sites.

Product concentration : Accumulation of the product of enzyme reaction lowers the enzyme activity. Enzyme molecules must be freed to combine with more substrate molecules. Normally the product are quickly removed from the site of formation and the reaction does not suffer.

Hydrogen ion concentration (*pH*) : Some enzyme act best in an acid medium, other in an alkaline medium, for every enzyme there is an optimum *pH* where its action is maximum *e.g.*, 2 for pepsin, 6.8 for salivary amylase, 8.5 for trypsin. Most enzyme show maximum activity in a *pH* range of about 6.0 to 7.5 *i.e.*, near neutral *pH* (endoenzymes). A shift to the alkaline or acid side rapidly decreases the enzyme activity and finally stops it altogether. This is due to denaturation of enzyme molecule *i.e.*, change in its physical structure.

Temperature : Within certain limits (5-40°C) the rate of an enzyme catalyzed reaction increases as the temperature increases. The Q_{10} of most enzymatic reactions is 2, *i.e.*, every 10°C rise in temperature doubles the rate of reaction. Most enzymes show maximum activity in a temperature range of 25 to 40°C. Beyond this temperature, there is sharp fall in the rate of reaction. Above 50°C they get denatured completely.

Modification in the physical form of the enzyme results in the loss of its catalytic activity. This change in structure is called **denaturation** of protein. This is the permanent change, and the denatured enzyme protein remains inactive even if the temperature is then brought down. The enzymes are not destroyed by freezing, and regain their lost activity if the temperature is raised to normal.

Deep freezing of food for preserving them for long periods is done not only to prevent the growth and multiplication of microorganisms but also to inactivate enzymes. It makes impossible for the microorganisms to digest the food. Below freezing point enzymes become inactive but do not get denatured.

Enzyme inhibitors : Certain chemical compounds inhibit activity of enzyme molecules either permanently or temporarily. Thus, diisopropyl flurophosphate (DFP) inhibits the action of various enzymes catalysing hydrolysis of ester linkage. Inhibition is permanent or irreversible.

Poisons and Radiation : Poisons such as cyanide and radiation destroy the tertiary structure of the enzymes, making them ineffective.

Tips & Tricks

- Most of the vitamins of B complex group act as coenzyme.
- Myosin a structural component of muscle. It has *ATPase* activity also.
- Synthesis of enzymes occur in polysome (aggregation of ribosomes).
- cAMP mediated cascade model of enzyme regulation was proposed by Sutherland.
- Competitive inhibitor increase Michaelis constant (K_m) but it has no effect on V_{max}.
- Regulators of metabolism are enzymes, vitamins and hormones.
- RNA polymerase enzyme form RNA from DNA and DNA polymerase is responsible for synthesis of DNA from DNA.
- Enzyme that catalyses the conversion of soluble proteins into insoluble ones, process is called enzyme coagulation.
- Albinism is caused by the deficiency of tyrosinase.
- Iron porphyrin coenzyme or cofactor is cytochrome.
- Nitrogenase enzyme is inactivated by oxygen.
- Nitrogenase enzyme is responsible for the reduction of molecular nitrogen to the level of ammonia in leguminous root nodule.
- Nitrate reductase enzyme is responsible for the formation of NO_2.
- Amylopsin acts upon polysaccharide in alkaline medium.
- Due to enzymatic transformations huge amount of starch is deposited in potato tubers.
- Tertiary structure of protein component of enzyme is destroyed by a number of factors like heat, high energy radiation and salts of heavy metals (*e.g.*, Ag^+, Hg^{2+}, As^+.)
- Some enzyme are active at very high temperature (70–80°C) called extermozyme *e.g.*, Taqe polymerase.
- Smallest enzyme is peroxidase and largest being catalase found in peroxisome.

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Ordinary Thinking

Objective Questions

Carbohydrates, Starch and Protein

1. Starch and cellulose are the compounds made up of many units of **[CPMT 1993, 2003, 09]**

(a) Simple sugar (b) Fatty acid
(c) Glycerol (d) Amino acid

2. Which one of the following is the sweetest sugar or laevo-rotatory sugar **[AFMC 2002; MP PMT 2007]**

Or

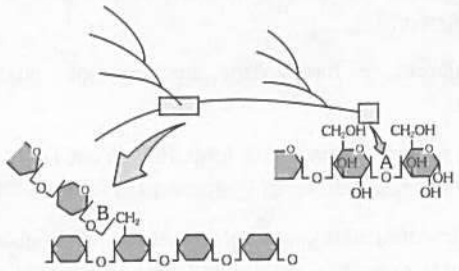
Inulin is a polymer of **[WB JEE 2011]**

(a) Fructose (b) Glucose
(c) Galactose (d) Sucrose

3. Which of the following is the characteristic of plants **[MP PMT 2003]**

(a) Glucose and cellulose (b) Pyruvic acid and glucose
(c) Cellulose and starch (d) Starch and pyruvic acid

4. Observe the following figure and identify A and B bonds in the diagrammatic representation of a portion of glycogen **[NCERT]**



(a) A = 1- 4 α - glycosidic bonds , B = 1- 4 α - glycosidic bonds
(b) A = 1-1 α - glycosidic bonds , B = 1 - 1 α - glycosidic bonds
(c) A = 1- 6 α - glycosidic bonds , B = 1 - 4 α - glycosidic bonds
(d) A = 1- 4 α - glycosidic bonds , B = 1 - 6 α - glycosidic bonds

5. Inulin found in plant cell is a **[Odisha PMT 2002; WB JEE 2012; AIIMS 2012]**

(a) Lipid (b) Protein
(c) Polysaccharide (d) Vitamin

6. Pentoses and hexoses are the most common **[BHU 2002]**

Or

The simple polyhydroxy ketone molecule containing 3–7 carbons is a **[Kerala PMT 2006]**

(a) Disaccharides (b) Monosaccharides
(c) Oligosaccharides (d) Polysaccharides

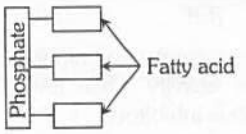
7. Corn is immersed in the boiling water. It is then cooled, the solution becomes sweet. It is due to **[AFMC 1999; JIPMER 2001]**

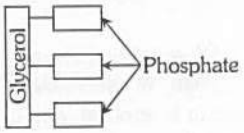
(a) Enzymes are inactivated in boiling water
(b) Disaccharides are converted to monosaccharides
(c) Monosaccharides are converted to disaccharides
(d) None of these

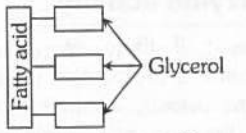
8. Cholesterol belongs to which of the following groups **[Odisha JEE 2008; J & K CET 2012]**

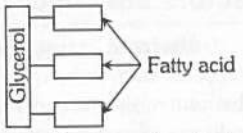
(a) Steroids (b) Neutral fats
(c) Waxes (d) Phospholipids

9. Which one of the following diagrams shows a molecule of simple lipid **[NCERT]**

(a) 

(b) 

(c) 

(d) 

10. The alpha helices and beta sheets are the example of which level of protein organization **[J & K CET 2012]**

(a) Primary structure (b) Secondary structure
(c) Tertiary structure (d) Quaternary structure

11. Sucrose, a common table sugar, is composed of **[Odisha JEE 2004; CPMT 2009]**

(a) Glucose + fructose (b) Glucose + galactose
(c) Fructose + galactose (d) None of these

12. Which is non-reducing sugar **[Odisha JEE 2004; Bihar CECE 2005; CBSE PMT 2014]**

(a) Glucose (b) Galactose
(c) Mannose (d) Sucrose

13. Sugar and amino acids are **[MHCET 2004]**

(a) Primary metabolites (b) Secondary metabolites
(c) Feed stock (d) Inoculum

14. A complex polysaccharide produced from sucrose by the bacterium *Leuconostoc mesenteroides* is **[BHU 2004]**

(a) Chitin (b) Starch
(c) Cellulose (d) Dextran

15. The chemical formula of starch is **[RPMT 2002]**

(a) $(C_6H_{10}O_5)_n$ (b) $(C_6H_{12}O_6)_n$
(c) $C_{12}H_{22}O_{11}$ (d) CH_3COOH

16. Oval shaped and eccentric starch particles are found in **[RPMT 1995]**

(a) Wheat (b) Maize
(c) Potato (d) Rice

17. Which one of the following . conjugate protein **[Odisha PMT 2002]**

(a) Globulin (b) Albumin
(c) Histone (d) Flavoprotein

18. Glycoproteins contain **[KCET 2000]**

(a) Protein and fat
(b) Protein and salt
(c) Protein and vitamin
(d) Protein and carbohydrates

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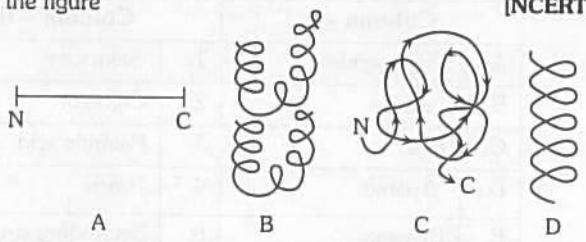
19. See the following figure and identify the structure of proteins in the figure **[NCERT]**



(a) A = 4° structure, B = 3° structure, C = 2° structure, D = 1° structure
(b) A = 1° structure, B = 4° structure, C = 3° structure, D =2° structure
(c) A = 4° structure, B = 2° structure, C = 3° structure, D = 1° structure
(d) A=1° structure, B = 2° structure, C = 3° structure, D = 4° structure

20. Which one of the following is a basic amino acid **[Odisha JEE 2012]**

(a) $NH_2-\underset{\displaystyle CH(CH_3)_2}{\overset{\displaystyle COOH}{\underset{|}{\overset{|}{C}}}}-H$ (b) $NH_2-\underset{\displaystyle (CH_2)_4NH_2}{\overset{\displaystyle COOH}{\underset{|}{\overset{|}{C}}}}-H$

(c) $NH_2-\underset{\displaystyle CH_2OH}{\overset{\displaystyle COOH}{\underset{|}{\overset{|}{C}}}}-H$ (d) $NH_2-\underset{\displaystyle CH_3}{\overset{\displaystyle COOH}{\underset{|}{\overset{|}{C}}}}-H$

21. Largest physical and chemical molecules are **[CBSE PMT 1996]**

Or

What are the most diversed molecules in the cell **[MP PMT 2000]**

Or

No cell could live without **[MP PMT 1997]**

(a) Carbohydrates (b) Lipids
(c) Proteins (d) Nucleic acids

22. Find out the wrongly matched pair **[Kerala PMT 2010]**

(a) Primary metabolite - Ribose
(b) Secondary metabolite - Anthocyanins
(c) Protein - Insulin
(d) Chitin - Polysaccharide
(e) Cellulose - Heteropolymer

23. Lipids are insoluble in water, because lipids molecules are **[CBSE PMT 2002]**

(a) Neutral (b) Zwitter ions
(c) Hydrophobic (d) Hydrophilic

24. Which one of the following statements is **wrong** **[NEET (Phase-I) 2016]**

(a) Sucrose is a disaccharide
(b) Cellulose is a polysaccharide
(c) Uracil is a pyrimidine
(d) Glycine is a sulphur containing amino acid

25. Which of the following is conjugated protein **[MHCET 2000]**

(a) Chromoproteins (b) Phosphoprotein
(c) Glycoprotein (d) All of the above

26. α-helical model of protein was discovered by **[BVP 2000; MHCET 2001]**

(a) Pauling and Correy (b) Watson
(c) Morgan (d) Berzelus

27. Which one of the following biomolecules is correctly characterised **[NCERT; CBSE PMT (Mains) 2012]**

(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

28. High content of lysine is present in **[MHCET 2003]**

(a) Wheat (b) Apple
(c) Maize (d) Banana

29. Example of a typical homopolysaccharide is **[WB JEE 2011]**

(a) Lignin (b) Suberin
(c) Inulin (d) Starch

30. Arachidonic acid is **[MHCET 2003]**

(a) Non-essential fatty acid (b) Essential fatty acid
(c) Polyunsaturated fatty acid (d) Both (b) and (c)

31. The two polypeptides of human insulin are linked together by **[NEET (Phase-I) 2016]**

(a) Hydrogen bonds (b) Phosphodiester bond
(c) Covalent bond (d) Disulphide bridges

32. Which of the following carbon is anomeric in glucose **[BHU 2012]**

(a) C_1 (b) C_2
(c) C_4 (d) None of these

33. During strenous exercise glucose is converted into **[BHU 2005]**

(a) Glycogen (b) Pyruvic acid
(c) Starch (d) Lactic acid

34. In which form does the food transported in plants **[BHU 2005]**

(a) Sucrose (b) Fructose
(c) Glucose (d) Lactose

35. Which of the following fatty acids is liquid at room temperature **[NCERT; AMU (Med.) 2012]**

(a) Palmitic acid (b) Stearic acid
(c) Oleic acid (d) Linoleic acid

36. Match the following and choose the correct combination from the options given

Column I (Organic Compound)	**Column II (Example)**
A. Fatty acid	1. Glutamic acid
B. Phospholipid	2. Tryptophan
C. Aromatic amino acid	3. Lecithin
D. Acidic amino acid	4. Palmitic acid

[NCERT; Kerala PMT 2012]

(a) A-1, B-2, C-3, D-4 (b) A-4, B-3, C-2, D-1
(c) A-2, B-3, C-4, D-1 (d) A-3, B-4, C-1, D-2
(e) A-4, B-3, C-1, D-2

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37. Which of the following amino acids is not optically active **[BHU 2005]**

(a) Glycine (b) Valine
(c) Leucine (d) Isoleucine

38. Paraffin wax is **[BHU 2006]**

(a) Ester (b) Acid
(c) Monohydric alcohol (d) Cholesterol

39. Match the items in column I with those in column II and choose the correct answer

Column I (Biomolecules)	Column II (Examples)
A. Carbohydrates	1. Trypsin
B. Protein	2. Cholesterol
C. Nucleic acid	3. Insulin
D. Lipid	4. Adenylic acid

[Kerala PMT 2012]

(a) A-3, B-1, C-4, D-2 (b) A-2, B-3, C-4, D-1
(c) A-3, B-4, C-1, D-2 (d) A-4, B-1, C-2, D-3
(e) A-1, B-2, C-3, D-4

40. Match the items in column I with items in column II and choose the correct answer

Column I		Column II	
A.	Triglyceride	1.	Animal hormones
B.	Membrane lipid	2.	Feathers and leaves
C.	Steroid	3.	Phospolipids
D.	Wax	4.	Fat stored in form of droplets

[Kerala PMT 2006]

(a) A – 4, B – 3, C – 1, D – 2
(b) A – 2, B – 3, C – 4, D – 1
(c) A – 3, B – 4, C – 1, D – 2
(d) A – 4, B – 1, C – 2, D – 3
(e) A – 4, B – 3, C – 2, D – 1

41. Given below is the chemical formula of

$$CH_3(CH_2)_{14}-\overset{O}{\overset{\|}{C}}-OH$$

[NCERT; Kerala PMT 2007]

(a) Palmitic acid (b) Stearic acid
(c) Glycerol (d) Galactose
(e) Fumaric acid

42. Find out the mis-matched pair **[Kerala PMT 2007]**

(a) Agar - Polymer of glucose and sulphur containing carbohydrates
(b) Chitin - Polymer of glucosamine
(c) Peptidoglycan - Polysaccharide linked to peptides
(d) Lipopolysaccharides - A complex of lipid and polysaccharide
(e) Glycogen - Polymer of glucose

43. Select the wrong statement **[Kerala PMT 2007]**

(a) The building blocks of lipids are amino acids
(b) Majority of enzymes contain a non-protein part called the prosthetic group
(c) The thylakoids are arranged one above the other like a stack of coins forming a granum
(d) Crossing-over occurs at pachytene stage of meiosis *I*
(e) Steroids are complex compounds commonly found in cell membranes and animal hormones

44. Match the following with correct combination

Column – I		Column – II	
A.	Triglycerides	1.	Galactose
B.	Lactose	2.	Glycerol
C.	*RNA*	3.	Palmitic acid
D.	β pleats	4.	Uracil
E.	Beewax	5.	Secondary structure

[Kerala PMT 2007]

(a) A – 4, B – 1, C – 5, D – 2, E – 3
(b) A – 5, B – 1, C – 4, D – 2, E – 3
(c) A – 3, B – 1, C – 4, D – 5, E – 2
(d) A – 2, B – 1, C – 4, D – 5, E – 3
(e) A – 3, B – 1, C – 4, D – 2, E – 5

45. Which of the following is not a disaccharide **[KCET 1999; DPMT 2007]**

(a) Maltose (b) Starch
(c) Sucrose (d) Lactose

46. What does the following equation denote? Amino acid + ATP → Aminoacyl AMP + PP **[DPMT 2007]**

(a) Elongation of chain (b) Chain termination
(c) Activation of amino acid (d) None of these

47. Which of the following is not a conjugated protein **[WB JEE 2010]**

(a) Peptone (b) Phosphoprotein
(c) Lipoprotein (d) Chromoprotein

48. Which of the following fats is least harmful for heart **[DPMT 2007]**

(a) Saturated fat (b) Cholesterol
(c) Polyunsaturated fat (d) Oils

49. Protein denaturation takes place by the activity of **[Odisha JEE 2008]**

Or

Enzymes are sensitive to **[MP PMT 1999]**

(a) Water (b) Heat
(c) Enzyme (d) Pressure

50. In a polysaccharide, the individual monosaccharides are linked by a **[AMU (Med.) 2011; Kerala PMT 2011]**

(a) Glycosidic bond (b) Peptide bond
(c) Ester bond (d) Phosphodiester bond
(e) Hydrogen bond

51. Select the incorrect statement **[Kerala PMT 2011]**

(a) Amino acids are substituent methanes
(b) Glycerol is a trihydroxy propane
(c) Lysine is a neutral amino acid
(d) Lecithin is a phospholipid
(e) Adenosine is a nucleoside

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52. Carbohydrates are commonly found as starch in plant storage organs. Which of the following five properties of starch (A-E) make it useful as a storage material

(A) Easily translocated
(B) Chemically non-reactive
(C) Easily digested by animals
(D) Osmotically inactive
(E) Synthesized during photosynthesis

The useful proeprties are : **[CBSE PMT 2008]**

(a) (A), (C) and (E) (b) (A) and (E)
(c) (B) and (C) (d) (B) and (D)

53. Which of the following promotes softening of fruits **[Kerala PMT 2008]**

(a) Polygalacturonase (b) Colchicine
(c) Polyethylene glycol (d) Cellulase
(e) Brazzein

54. Which of the following statements is/are not true

(A) Glycerol is a 3 carbon alcohol with 3 OH groups that serve as binding sites
(B) Waxes are esters formed between a long chain alcohol and saturated fatty acids
(C) The term protein was coined by Gerardus Johannes Mulder
(D) Agar is an indispensable polysaccharide and it is a complex polymer of glucose and sulphur-containing carbohydrates **[Kerala PMT 2008]**

(a) (A) and (C) only (b) (A) and (D) only
(c) (A), (B) and (D) only (d) (A), (C) and (D) only
(e) (D) only

55. Which is an organic compound found in most cells **[DUMET 2009]**

Or

Most common monomer of carbohydrate is **[Odisha JEE 2008]**

Or

The "repeating unit" of glycogen is **[WB JEE 2009]**

(a) Glucose (b) Water
(c) Sodium chloride (d) Oxygen

56. Quarternary structure of protein **[NCERT; WB JEE 2008]**

(a) Consists of four subunits
(b) May be either α or β
(c) Is unrelated to two function of the protein
(d) Is dictated by the primary structures of the individual subunits

57. Which of the following carbohydrates is not a disaccharide **[WB JEE 2008]**

(a) Maltose (b) Lactose
(c) Sucrose (d) Galactose

58. Chitin is a **[WB JEE 2010; NEET 2013]**

(a) Polysaccharide
(b) Nitrogenous polysaccharide
(c) Lipoprotein
(d) Protein

59. Which of the following is the least likely to be involved in stabilizing the three-dimensional folding of most proteins **[NEET (Phase-II) 2016]**

(a) Ester bonds (b) Hydrogen bonds
(c) Electrostatic interaction (d) Hydrophobic interaction

60. Which of the followings can bring about the denaturation of proteins **[WB JEE 2016]**

(a) Reaction to salts of heavy metals
(b) Reaction to acid and bases
(c) Reaction to inorganic neutral salts
(d) Preservation at a temperature below-5°C

Nucleotides and Nucleic acid

1. A ribose (but not deoxyribose) nucleotide is **[Kerala PMT 2004]**

(a) Cytosine — pentose sugar — phosphate
(b) Guanine — pentose sugar — phosphate
(c) Thymine — pentose sugar — phosphate
(d) Uracil — pentose sugar — phosphate

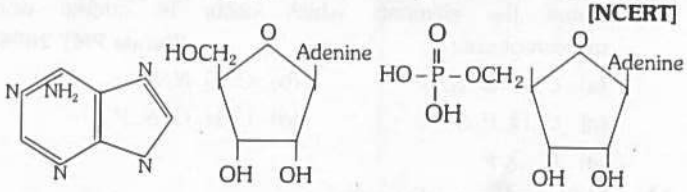
2. DNA is present in **[NCERT; MP PMT 1995, 96, 98; BVP 2000; RPMT 2001; MHCET 2001; AIIMS 2004]**

Or

Which one of the following has its own DNA **[CBSE PMT (Pre.) 2010]**

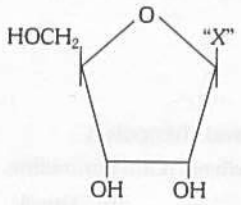
(a) Nucleus only (b) Mitochondrion only
(c) Chloroplast only (d) All the above

3. See the following figure and identify the correct combination **[NCERT]**



	A	B	C
(a)	Uracil	Adenosine (Nucleoside)	Adenylic acid (Nucleotide)
(b)	Adenosine (Nucleoside)	Adenylic acid (Nucleotide)	Adenine (N – base)
(c)	Adenine (N – base)	Adenosine (Nucleoside)	Adenylic acid (Nucleotide)
(d)	Adenine (N – base)	Adenosine (Nucleotide)	Adenylic acid (Nucleoside)

4. Given below is the diagrammatic representation of one of the categories of small molecular weight organic compounds in the living tissues. Identify the category shown and the one blank component "X" in it **[NCERT; CBSE PMT (Pre.) 2012]**



Category	Component
(a) Cholesterol	Guanin
(b) Amino acid	NH_2
(c) Nucleotide	Adenine
(d) Nucleoside	Uracil

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5. DNA is a polymer of **[CPMT 1998; BVP 2000]**

Or

Which is the ultimate unit of DNA molecule **[MH CET 2005]**

(a) Nucleotide (b) Nucleoside
(c) Amino acids (d) All of the above

6. How many nucleotides are present in one turn of DNA helix **[NCERT; MP PMT 1999, 2000; HPMT 2005; Odisha JEE 2011]**

(a) 4 pairs (b) 8 pairs
(c) 10 pairs (d) 9 pairs

7. ATP is **[Odisha PMT 2002; MP PMT 2004, 05]**

(a) Adenosine D-ribose three phosphate
(b) Adenosine L-ribose three phosphate
(c) Adenine D-ribose three phosphate
(d) Adenine L-ribose three phosphate

8. Which of the following is correct pair of pyrimidine bases **[MHCET 2015]**

(a) Adenine and Thymine (b) Adenine and Guanine
(c) Thymine and Cytosine (d) Guanine and Cytosine

9. Thymine is a

(a) Enzyme (b) Vitamin
(c) Pyrimidine (d) Purine

10. Name the elements which occur in nucleic acid macromolecule **[Kerala PMT 2006]**

(a) *C, H, O, N, S* (b) *C, O, N, S*
(c) *C, O, P, S* (d) *C, H, O, N, P*
(e) *H, O, P*

11. Nucleoside is made up of **[BHU 1995; BCECE 2001; Pb. PMT 2004]**

(a) Sugar only (b) Phosphate only
(c) Sugar and phosphate (d) Sugar and base

12. Strands of DNA are bonded by **[NECRT]**

(a) Hydrogen (b) Carbon
(c) Oxygen (d) Nitrogen

13. RNA and ATP contains **[KCET 1994, 2009; BVP 2000; CPMT 2003]**

(a) Hexose sugar (b) Deoxyribose sugar
(c) Dextrose sugar (d) Ribose sugar

14. Nucleic acid occurs in **[KCET 2007]**

(a) Golgi body
(b) Lysosomes
(c) Cytoplasm
(d) Mitochondria and chloroplast

15. Which of the following is not a pyrimidine **[MP PMT 2007]**

(a) Thymine (b) Uracil
(c) Guanine (d) Cytosine

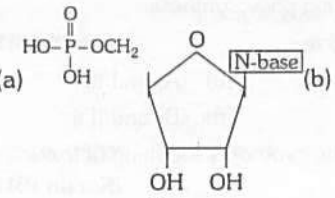
16. DNA is not present in one of the following **[MP PMT 2003]**

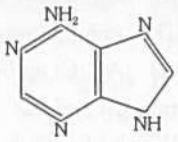
(a) Mitochondria (b) Chloroplast
(c) Bacteriophage (d) Tobacco mosaic virus

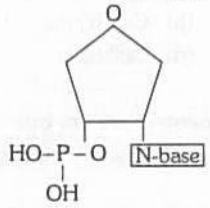
17. DNA strands are antiparallel because of the presence of **[Kerala PMT 2004]**

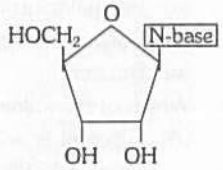
(a) H-bonds (b) Peptide bonds
(c) Disulphide bonds (d) Phosphate-diester bonds
(e) None of the above

18. Examine the following figures and select the right answer in which diagrammatic representation of a nucleotide is correctly shown **[NCERT]**

(a) 

(b) 

(c) 

(d) 

19. Which of the following bases is present in RNA in place of thymine **[NCERT; CPMT 1996, 2003; MP PMT 1998, 2001, 10; Pb PMT 2000; Odisha JEE 2004; J & K CET 2005, 08; Kerala PMT 2009, 11]**

(a) Uracil (b) Adenine
(c) Guanine (d) Water

20. Nucleic acids were discovered by **[MP PMT 1999]**

Or

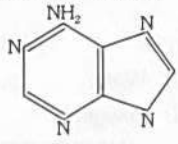
DNA was first discovered by **[CPMT 1994]**

(a) Watson and Crick (b) Khorana
(c) Wilkins (d) Miescher

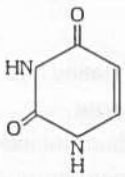
21. In DNA molecule, which of the following base pair is present **[MP PMT 1992]**

(a) Cytosine and adenine (b) Adenine and thymine
(c) Adenine and guanine (d) Cytosine and thymine

22. The given diagram shows the nitrogenous bases. Identify the correct combination **[NCERT]**



A



B

(a) A = Guanine; B = Uracil
(b) A= Adenine; B= Uracil
(c) A = Guanine; B = Thymine
(d) A = Adenine; B= Thymine

23. The transformation experiments on *Pneumococcus* showed that

(a) DNA can duplicate itself
(b) RNA is the genetic material
(c) DNA is the genetic material
(d) None of these

24. The base pairs of DNA are correctly shown as **[Bihar MDAT 1995; RPMT 1997; BHU 1998, 99, 2004; BVP 2000; MHCET 2003; MP PMT 2013]**

(a) $A \equiv T$ and $C = G$ (b) $A = T$ and $C = G$
(c) $A = T$ and $C \equiv G$ (d) $A \equiv T$ and $C \equiv G$

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25. Which one of the following is widely distributed in a cell **[MHCET 2000]**

(a) DNA (b) RNA
(c) Chloroplast (d) Chromoplast

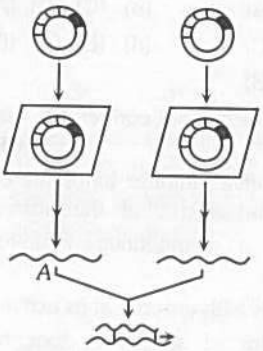
26. Which of the cell organelles are devoid of deoxy ribonucleic acid **[RPMT 1997]**

(a) Mitochondria and nucleus
(b) Chloroplast and mitochondria
(c) Nucleus and chloroplast
(d) Lysosome and dictyosome

27. The similarity between DNA and RNA is that both are **[KCET 1999, 2006]**

(a) Double stranded
(b) Having similar sugars
(c) Polymers of nucleotides
(d) Having similar pyrimidines

28. What indicated "A" in given figure **[GUJCET 2015]**



(a) Peptide bond (b) Glycosidic bond
(c) Disulfide bond (d) Hydrophobic bond

29. Which of the following biomolecules does have phosphodiester bond **[AIPMT 2015]**

(a) Monosaccharides in a polysaccharide
(b) Amino acids in a polypeptide
(c) Nucleic acids in a nucleotide
(d) Fatty acids in a diglyceride

30. Ultraviolet light absorbed by nucleic acid is **[RPMT 2000]**

(a) 26 *nm* (b) 75 *nm*
(c) 260 *nm* (d) 1500 *nm*

31. The length of DNA having 23 base pairs is **[Kerala PMT 2004; WB JEE 2009]**

(a) 70 Å (b) 78.4 Å
(c) 78.2 Å (d) 74.8 Å
(e) 74.2 Å

Introduction, properties, action and inhibition of enzyme

1. Who first used the term "enzyme" **[CPMT 2004]**

(a) J.B. Sumner (b) Kuhne
(c) Thompson (d) Garnier

2. Who coined the term zymase for enzymes in yeast **[BHU 2002]**

(a) Kuhne (b) Sumner
(c) Louis pasteur (d) Edward Buchner

3. Enzymes are basically **or** All enzymes contain **[NCERT; MP PMT 1995, 2000, 04, 05; CBSE PMT 2000; BVP 2002; MHCET 2003; Odisha JEE 2009]**

(a) Sugars (b) Proteins
(c) Fats (d) Vitamins

4. "*Enzymes are proteins*", it was suggested by

(a) Miller (b) Sumner
(c) Pasteur (d) Leeuwenhock

5. Who got the Nobel prize working on enzymes in the year 1978 **[MP PMT 1997]**

(a) W. Arber and D. Nathans
(b) Nass and Nass
(c) R. Misra
(d) H.G. Khorana

6. To explain the mechanism of enzymatic action, who proposed "*Lock and key hypothesis*" **[CPMT 1996; MP PMT 1998, 2010, 12; BHU 2000; RPMT 2002]**

(a) Fischer (b) Jacob
(c) Koshland (d) Sumner

7. Many of the hydrolytic reactions are **[BHU 2001]**

(a) Reversible (b) Irreversible
(c) Endothermic (d) Exothermic

8. The "lock and key" model of enzyme action illustrates that a particular enzyme molecule **[DUMET 2009, 10]**

(a) May be destroyed and resynthesized several times
(b) Interacts with a specific type of substrate molecule
(c) Reacts at identical rates under all conditions
(d) Forms a permanent enzyme-substrate complex

9. Enzymes were discovered for the first time in **[Pb. PMT 1995]**

(a) Yeast (b) Maize
(c) Bacteria (d) Algae

10. Who discovered 'co-enzymes'

(a) James Sumner (b) Fritz Lipmann
(c) Mayerhoff (d) Edward Buchner

11. A competitive inhibitor of succinic dehydrogenase is **[NCERT; CBSE PMT 2008]**

(a) α-ketoglutarate (b) Malate
(c) Malonate (d) Oxaloacetate

12. An example of feedback inhibition is **[Kerala PMT 2008]**

(a) Cyanide action on cytochrome
(b) Sulpha drug on folic acid synthesizer bacteria
(c) Allosteric inhibition of hexokinase by glucose 6-phosphate
(d) Reaction between succinic dehydrogenase and succinate
(e) The inhibition of succinic dehydrogenase by malonate

13. Who proposed the principal of "*Induced fit*" **[BHU 1998]**

(a) Jacob (b) Fischer
(c) Koshland (d) Laderberg

14. The molecules that are well recognized as biocatalysts in addition to enzymes are **[AFMC 2012]**

(a) Polysaccharides (b) Fatty acids
(c) RNAs (d) None of these

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15. Enzymes are the polymers of **[MP PMT 1994]**

Or

Which of the following is polymerized to form proteins **[MHCET 2003]**

Or

An enzyme can be synthesised by chemically bonding together molecules of **[AFMC 1994]**

(a) Hexose carbon (b) Fatty acids
(c) Amino acids (d) Inorganic phosphate

16. Telomerase is an enzyme which is a **[AIIMS 2005]**

(a) Simple protein (b) RNA
(c) Ribonucleoprotein (d) Repetitive DNA

17. Which one of the following statements is incorrect **[AIPMT (Cancelled) 2015]**

(a) In competitive inhibition, the inhibitor molecule is not chemically changed by the enzyme
(b) The competitive inhibitor does not affect the rate of breakdown of the enzyme-substrate complex
(c) The presence of the competitive inhibitor decreases the Km of the enzyme for the substrate
(d) A competitive inhibitor reacts reversibly with the enzyme to form an enzyme-inhibitor complex

18. An example of non-competitive inhibition is **[Kerala PMT 2009]**

(a) The inhibition of succinic dehydrogenase by malonate
(b) Cyanide action on cytochrome oxidase
(c) Sulpha drug on folic acid synthesizing bacteria
(d) The inhibition of hexokinase by glucose 6-phosphate
(e) Reaction of succinic dehydrogenase

19. Enzymes are absent in **[CBSE PMT 2000; AFMC 2003]**

(a) Algae (b) Fungi
(c) Bacteria (d) Virus

20. Feedback inhibition of enzymes is affected by which of the following **[WB JEE 2009]**

Or

Jacob and Monad named those enzymes *allosteric* whose activity is regulated by

(a) Enzyme (b) Substrate
(c) End products (d) Intermediate end products

21. Non-proteinaceous enzyme that acts as a catalyst for the formation of peptide bond is **[MHCET 2000; MP PMT 2007; AMU (Med.) 2010; NEET (Phase-II) 2016]**

Or

"All enzymes are proteins." This statement is now modified because an apparent exception to this biological truth is **[DUMET 2010]**

(a) Spliceosome (b) Ribozyme
(c) RNA poly I (d) RNA poly III

22. Which one of the following statements regarding enzyme inhibition is correct **[CBSE PMT 2005]**

(a) Competitive inhibition is seen when a substrate competes with an enzyme for binding to an inhibitor protein
(b) Competitive inhibition is seen when the substrate and the inhibitor compete for the active site on the enzyme
(c) Non-competitive inhibition of an enzyme can be overcome by adding large amount of substrate
(d) Non-competitive inhibitors often bind to the enzyme irreversibly

23. In which one of the following enzymes, is copper necessarily associated as an activator **[CBSE PMT 2004]**

(a) Lactic dehydrogenase (b) Tyrosinase
(c) Carbonic anhydrase (d) Tryptophanase

24. *Km* is related to **[BHU 2000]**

(a) Morphology (b) ABO blood group
(c) *ES* complex (d) Chromatography

25. Arrange the steps of catalytic action of an enzyme in order an choose the right option

(A) The enzyme releases the products of the reaction and the enzyme is free to bind to another substrate
(B) The active site of enzyme is in close proximity of the substrate and breaks the chemical bonds of the substrate
(C) The binding of substrate induces the enzyme to alter its shape fitting more tightly around the substrate
(D) The substrate binds to the active site of the enzyme fitting into the active site **[Kerala PMT 2010]**

(a) (D), (C), (B), (A) (b) (C), (B), (A), (D)
(c) (D), (B), (A), (C) (d) (B), (A), (D), (C)
(e) (C), (D), (A), (B)

26. Select the option which is not correct with respect to enzyme action **[CBSE PMT 2014]**

(a) A non-competitive inhibitor binds the enzyme at a site distinct from that which binds the substrate
(b) Malonate is a competitive inhibitor of succinic dehydrogenase
(c) Substrate binds with enzyme at its active site
(d) Addition of lot of succinate does not reverse the inhibition of succinic dehydrogenase by malonate

27. Inhibition of acetylcholine by DEP (Diisorpropyl-fluorophosphate) is an example of **[AMU (Med.) 2012]**

(a) Competitive inhibition
(b) Non-competitive inhibition
(c) Non-competitive irreversible inhibition
(d) Allosteric inhibition

28. The catalytic efficiency of two different enzymes can be compared by the **[CBSE PMT 2005]**

(a) Formation of the product
(b) The *pH* of optimum value
(c) The *Km* value
(d) Molecular size of the enzyme

29. Which one of the following enzyme contains *Mn* metallic ion as the prosthetic group **[BHU 2000]**

Or

Which of the following enzyme is not usd in making detergent **[DPMT 2007]**

(a) Phosphatase (b) Dehydrogenase
(c) Peptidase (d) Catalase

30. Three of the following statements about enzymes are correct and one is wrong. Which one is wrong **[CBSE PMT (Mains) 2010; NEET (Karnataka) 2013]**

(a) Enzymes require optimum pH for maximal activity
(b) Enzymes are denatured at high temperature but in certain exceptional organisms they are effective even at temperatures 80°-90°C
(c) Enzymes are highly specific
(d) Most enzymes are proteins but some are lipids

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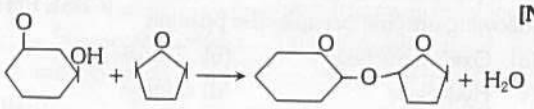
31. Which type of reaction is shown by the following figure **[NCERT]**



Or

Formation of both peptide and glycosidic bonds involves **[DUMET 2010]**

(a) Hydration (b) Denaturation
(c) Dehydration (d) Hydrolysis

32. Transition state structure of the substrate formed during an enzymatic reaction is **[NEET 2013]**

(a) Permanent and stable (b) Transient but stable
(c) Permanent but unstable (d) Transient and unstable

33. An organic substance bound to an enzyme and essential for its activity is called **[CBSE PMT 2006; AIIMS 2009]**

Or

Non-protein part of an enzyme is known as **[AFMC 1997; Odisha PMT 2002; BVP 2003]**

(a) Apoenzyme (b) Isoenzyme
(c) Coenzyme (d) Holoenzyme

34. An enzyme acts by **[MP PMT 1992; AIEEE Pharmacy 2003]**

(a) Reducing the energy of activation
(b) Increasing the energy of activation
(c) Decreasing the *pH*
(d) Increasing the *pH*

35. The protein part of enzyme is known as **[MP PMT 1996; AIIMS 2000; BVP 2000; Odisha JEE 2012; AFMC 2012]**

Or

The enzyme which combines with non-protein part to form a functional enzyme known as **[BHU 2004]**

(a) Holoenzyme (b) Apoenzyme
(c) Isoenzyme (d) All of the above

36. Which enzyme shows greatest substrate specificity **[CPMT 2005]**

(a) Nuclease (b) Trypsin
(c) Sucrase (d) Pepsin

37. Which one of the following statements is correct with reference to enzymes **[Odisha JEE 2009; KCET 2011; NEET 2017]**

(a) Apoenzyme = Holoenzyme + Coenzyme
(b) Holoenzyme = Apoenzyme + Coenzyme
(c) Coenzyme = Apoenzyme + Holoenzyme
(d) Holoenzyme = Coenzyme + Co-factor

38. Number of active sites in allosteric enzyme is **[CPMT 2000]**

(a) One (b) Two
(c) Three (d) Four

39. Which one value is required for better enzymatic action **[BHU 1995, 2000]**

(a) High Ki (b) Low Ki
(c) Low Km (d) High Km

40. Cofactor (prosthetic group) is a part of holoenzyme. It is **[CBSE PMT 1997; Odisha JEE 2011]**

(a) Loosely attached inorganic part
(b) Accessory non-protein substance attached firmly
(c) Loosely attached organic part
(d) None of these

41. The permeases are **[MP PMT 2003]**

(a) Structural membrane proteins
(b) Enzymatic membrane proteins
(c) Carrier membrane proteins
(d) None of these

42. Which one of the following is not true for enzymes **[WB JEE 2012]**

(a) They act on a specific substrate
(b) They are made up of fat and sugar
(c) They act at a specific temperature
(d) They act at a specific *pH*

43. Co-enzyme is **[BHU 1994; NEET 2013]**

(a) Always a protein
(b) Often a vitamin
(c) Always an inorganic compound
(d) Often a metal

44. Which of the following enzyme can form RNA from DNA **[MP PMT 1992]**

(a) Restriction enzyme (b) DNA polymerase
(c) RNA polymerase (d) Reverse transcriptase

45. Inhibitory effect of melonic acid on succinic dehydrogenase enzyme is **[NCERT; AIIMS 2003]**

(a) Competitive inhibition
(b) Non-competitive inhibition
(c) Feedback inhibition
(d) Inhibition due to end product

46. Lactose operon is considered to be glucose sensitive due to **[DPMT 2003]**

(a) Catabolite induction (b) Allosteric inhibition
(c) Anabolic inhibition (d) None of these

47. FAD or FMN is a coenzyme. Which vitamin is incorporated into its structure **[AIIMS 2009]**

(a) Vitamin C (b) Vitamin B_1
(c) Vitamin B_6 (d) Vitamin B_2 (Riboflavin)

48. Which of the following enzymes has/have haem as a prosthetic group

(i) Catalase (ii) Carboxypeptidase
(iii) Succinic dehydrogenase (iv) Peroxidase **[Kerala PMT 2011]**

(a) (i) Only (b) (i) and (ii)
(c) (ii) and (iii) (d) (iii) and (iv)
(e) (i) and (iv)

49. Which of the following is not a co-enzyme **[CPMT 2004; WB JEE 2010]**

(a) NAD (b) NADP
(c) FAD (d) ATP

50. Enzymes capable of changing their form are called **[DPMT 2003]**

(a) Apoenzyme (b) Holoenzyme
(c) Isoenzyme (d) Allosteric enzymes

51. Enzymes as they exist inside the cell are **[MP PMT 1993]**

(a) In solid form (b) In crystalline form
(c) In colloidal form (d) In solution form

52. Select the type of enzyme involved in the following reaction $\boxed{S-G+S' \rightarrow S+S'-G}$ **[Kerala PMT 2011]**

(a) Dehydrogenase (b) Transferase
(c) Hydrolase (d) Lyase
(e) Isomerase

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53. Template theory of enzyme action is supported by **[BVP 2003]**

(a) Enzymes occur in living beings and speed up certain reactions

(b) Enzymes speed up reaction

(c) Enzymes determine the direction of reaction

(d) Compounds similar to substrate inhibit enzyme activity

54. Decline in the activity of the enzyme hexokinase by glucose 6 - phosphate is caused by **[Kerala CET 2003]**

(a) Non-competitive (b) Competitive inhibitions

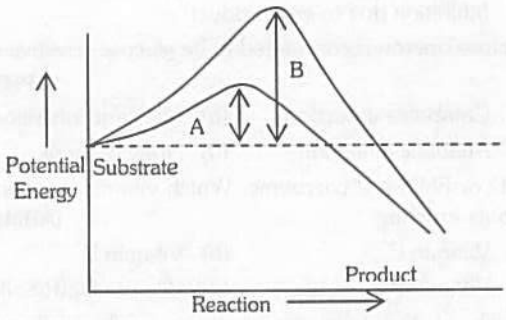
(c) Allosteric modulator (d) Denaturation of enzymes

55. During glycolysis enzyme hexokinase changes glucose to glucose–6– phosphate. Glucose–6–phosphate is inhibited by **[CBSE PMT 1996]**

(a) Feedback inhibition (b) Positive feedback

(c) Competitive inhibition (d) Non-competitive inhibition

56. Which of the following describes the given graph correctly **[NEET (Phase-II) 2016]**



(a) Exothermic reaction with energy A in absence of enzyme and B in presence of enzyme

(b) Endothermic reaction with energy A in presence of enzyme and B in absence of enzyme

(c) Exothermic reaction with energy A in presence of enzyme and B in absence of enzyme

(d) Endothermic reaction with energy A in absence of enzyme and B in presence of enzyme

Classification and factors affecting enzyme

1. Enzymes that catalyse inter-conversion of optical, geometrical or positional isomers are **[DUMET 2009]**

(a) Ligases (b) Lyases

(c) Hydrolases (d) Isomerases

2. Systematic approach of naming enzymes has been recommended by the Commission on Enzymes of the

(a) International Union of Physiology

(b) International Union of Biochemistry

(c) International Union of Biotechnology

(d) International Union of Genetic Engineering

3. Basically how many types of enzymes have been recognised by International Union of Biochemistry **[MHCET 2000]**

(a) 4 (b) 5

(c) 6 (d) 8

4. In the modern system of nomenclature which one of the following enzyme occupies 1st position

(a) Oxidoreductase (b) Transferase

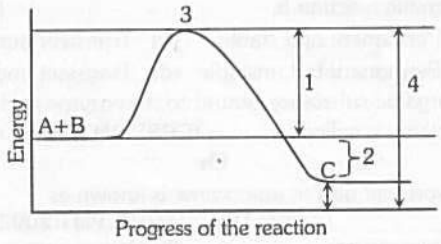
(c) Hydrolase (d) Ligase

5. The plant proteinases or endopeptidases enzyme is **[CPMT 1994]**

(a) Urease (b) Papain

(c) Pepsin (d) Trypsin

6. See the following figure and identify 1, 2, 3 and 4 from the list I to IV



I. Segment representing the energy of activation

II. Segment representing the amount of free energy released by the reaction

III. Transition state

IV. Segment would be the same regardless of whether the reaction were uncatalysed or catalysed. Which one is correct **[NCERT]**

	I	II	III	IV
(a)	1	2	4	3
(b)	1	3	2	4
(c)	1	2	3	2
(d)	1	3	2	4

7. Zymogens are

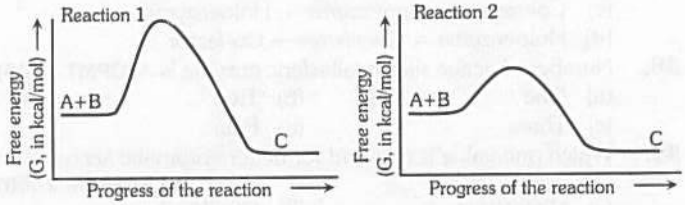
(a) Enzyme acting upon starch

(b) Group of zymase enzymes

(c) Inactive enzyme precursors

(d) None of the above

8. The two chemical reactions are showing in the following figure. Which statement is correct for reaction 1 **[NCERT]**



(a) Slower and more exergonic than 2

(b) Slower and more endergonic than 2

(c) Faster and more exergonic than 2

(d) Faster and more endergonic than 2

9. At the time of cotton seeds germination, the stored food is digested by **[CPMT 1996]**

Or

Which one of the following enzyme is composed of simple proteins

(a) Diastase (b) Maltase

(c) Lipase (d) Amylase

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10. Fat is hydrolysed by enzyme lipase to yield **[RPMT 2002; CBSE PMT 2004; MP PMT 2012]**

(a) Fatty acid and amino acids
(b) Glycerol and fatty acids
(c) Glycerine and water
(d) Glycerol and amino acids

11. Substrate of *amylase* enzyme is **[J & K CET 2005]**

(a) Protein (b) Fat
(c) Starch (d) Sucrose

12. Enzyme which hydrolyses starch to maltose is **[MP PMT 1999]**

(a) Lactase (b) Protease
(c) Maltase (d) Amylase

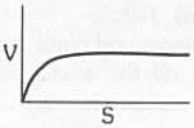
13. Which one is not an example for hydrolases **[Kerala PMT 2004]**

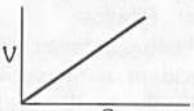
Or

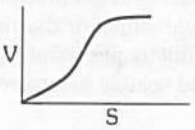
Hydrogen is removed from a substrate with the help of enzyme

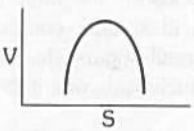
(a) Dehydrogenase (b) Protease
(c) Amylase (d) Esterase
(e) Sucrase

14. Which graph shows the relationship between the rate of an enzymatic activity and substrate conc.(S) **[NCERT]**

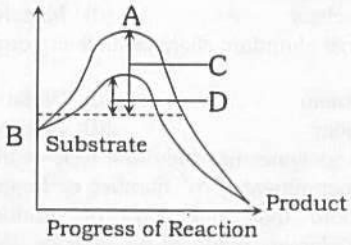
(a) 

(b) 

(c) 

(d) 

15. The figure given below shows the conversion of a substrate into product by an enzyme. In which one of the four options (a-d) the components of reaction labelled as A, B, C and D are identified correctly



Options **[NCERT; CBSE PMT (Mains) 2010]**

	A	B	C	D
(a)	Potential energy	Transition state	Activation energy with enzyme	Activation energy without enzyme
(b)	Transition state	Potential energy	Activation energy without enzyme	Activation energy with enzyme
(c)	Potential energy	Transition state	Activation energy with enzyme	Activation energy without enzyme
(d)	Activation energy with enzyme	Transition state	Activation energy without enzyme	Potential energy

16. Enzyme concerned with transfer of electrons are **[NCERT; MP PMT 1998, 2002, 03]**

(a) Hydrolase (b) Dehydrogenase
(c) Transaminase (d) Desmolase

17. Enzyme having different molecular arrangement but similar functions is **[BVP 2003, 04]**

Or

Enzymes which are slightly different in molecular structure but can perform identical activity are called

(a) Isoenzyme (b) Holoenzyme
(c) Apoenzyme (d) Co-enzyme

18. Allosteric modulation is due to the inhibition action of enzyme by **[Kerala PMT 2006]**

(a) Competitive inhibition (b) Substrate concentration
(c) Products of reaction (d) Enzyme concentration
(e) Non competitive inhibition

19. Which one of the following pairs is wrongly matched **[CBSE PMT 2009]**

(a) Detergents - lipase (b) Alcohol – nitrogenase
(c) Fruit juice - pectinase (d) Textile – amylase

20. Modern detergents contain enzyme preparations of **[CBSE PMT 2008]**

(a) Thermoacidophiles (b) Thermophiles
(c) Acidophiles (d) Alkaliphiles

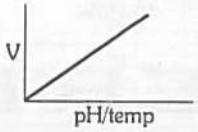
21. Signaling between cells usually results in the activation of protein **[DUMET 2009]**

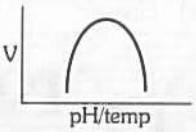
(a) Lipases (b) Kinases
(c) Proteases (d) Nucleases

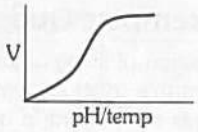
22. With reference to enzymes, turnover number means ..... **[KCET 2010]**

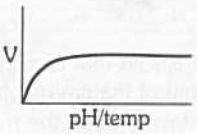
(a) The number of substrate molecules that a molecule of an enzyme converts into products per hour
(b) The number of substrate molecules that a molecule of an enzyme converts into products per second
(c) The number of substrate molecules that a molecule of an enzyme convert into products per minute
(d) The number of substrate molecules that a molecule of an enzyme converts into products per day

23. Which graph represents the effect of pH/temp on the velocity of a typical enzymatic reaction (V) **[NCERT]**

(a) 

(b) 

(c) 

(d) 

24. The effectiveness of an enzyme is affected least by **[DUMET 2009]**

(a) Temperature
(b) Concentration of the substrate
(c) Original activation energy of the system
(d) Concentration of the enzyme

25. The enzyme which converts glucose into ethyl alcohol (C_2H_5OH) is **[MP PMT 1998, 2003; AMU (Med.) 2006; BHU 2006]**

(a) Diastase (b) Maltase
(c) Zymase (d) Invertase

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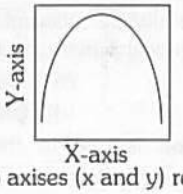
26. The enzymes ribulose biphosphate carboxylase-oxygenase and phosphoenol pyruvate carboxylase are activated by **[AMU (Med.) 2009]**

(a) *Mg* (b) *Zn*
(c) *Mo* (d) *Mn*

27. The curve given below show enzymatic activity with relation to three conditions (pH, temperature and substrate concentration)



What do the two axises (x and y) represent **[NCERT; CBSE PMT (Pre.) 2011]**

	X-axis	Y-axis
(a)	Enzymatic activity	Temperature
(b)	Enzymatic activity	pH
(c)	Temperature	Enzyme Activity
(d)	Substrate concentration	Enzymatic Activity

28. The nucleic acids are broken into nucleotides by..... enzymes **[J & K CET 2002]**

(a) Amylases (b) Nucleases
(c) Lipases (d) Proteases

29. Which one of the following is wrongly matched **[Kerala PMT 2009]**

(a) Fungi – Chitin
(b) Phospholipid – Plasma membrane
(c) Enzyme – Lipopolysaccharide
(d) ATP – Nucleotide derivative
(e) Antibody – Glycoprotein

30. As temperature changes from 3°C to 45°C, the rate of enzyme activity will **[MP PMT 1996]**

(a) Decrease and then increase (b) Increase and then decrease
(c) Increase only (d) Decrease only

31. Which enzyme helps in removing oil stains from clothes **[BHU 2008]**

Or

Which enzyme digests the stored food material of castor seeds

(a) Streptokinase (b) Trypsin
(c) Lipase (d) Amylase

NCERT Exemplar Questions

1. It is said that elemental composition of living organisms and that of inanimate objects (like earth's crust) are similar in the sense that all the major elements are present in both. Then what would be the difference between these two groups. Choose a correct answer from among the following **[NCERT]**

(a) Living organisms have more gold in them than inanimate objects
(b) Living organisms have more water in their body than inanimate objects
(c) Living organisms have more carbon, oxygen and hydrogen per unit mass than inanimate objects
(d) Living organisms have more calcium in them than inanimate objects

2. Many elements are found in living organisms either free or in the forms of compounds. One of the following is not, found in living organisms **[NCERT]**

(a) Silicon (b) Magnesium
(c) Iron (d) Sodium

3. Aminoacids, as the name suggests, have both an amino group and a carboxyl group in their structure. In addition, all naturally occurring aminoacids (those which are found in proteins) are called L-aminoacids. From this, can you guess from which compound can the simplest aminoacid be made **[NCERT]**

(a) Formic acid (b) Methane
(c) Phenol (d) Glycine

4. Many organic substances are negatively charged e.g., acetic acid, while others are positively charged e.g., ammonium ion. An aminoacid under certain conditions would have both positive and negative charges simultaneously in the same molecule. Such a form of aminoacid is called **[NCERT]**

(a) Positively charged form (b) Negatively charged form
(c) Neutral form (d) Zwitterionic form

5. Sugars are technically called carbohydrates, referring to the fact that their formulae are only multiple of $C(H_2O)$. Hexoses therefore have six carbons, twelve hydrogens and six oxygen atoms. Glucose is a hexose. Choose from among the following another hexose **[NCERT]**

(a) Fructose (b) Erythrose
(c) Ribulose (d) Ribose

6. When you take cells or tissue pieces and grind them with an acid in a mortar and pestle, all the small biomolecules dissolve in the acid. Proteins, polysaccharides and nucleic acids are insoluble in mineral acid and get precipitated. The acid soluble compounds include aminoacids, nucleosides, small sugars etc. When one adds a phosphate group to a nucleoside one gets another acid soluble biomolecule calle **[NCERT]**

(a) Nitrogen base (b) Adenine
(c) Sugar phosphate (d) Nucleotide

7. When we homogenise any tissue in an acid the acid soluble pool represents **[NCERT]**

(a) Cytoplasm (b) Cell membrane
(c) Nucleus (d) Mitochondria

8. The most abundant chemical in living organisms could be **[NCERT]**

(a) Protein (b) Water
(c) Sugar (d) Nucleic acid

9. A homopolymer has only one type of building block called monomer repeated 'n' number of times. A heteropolymer has more than one type of monomer. Proteins are heteropolymers made of aminoacids. While a nucleic acid like DNA or RNA is made of only 4 types of nucleotide monomers, proteins are made of **[NCERT]**

(a) 20 types of monomers (b) 40 types of monomers
(c) 3 types of monomers (d) only one type of monomer

10. Proteins perform many physiological functions. For example, some functions as enzymes. One of the following represents an additional function that some proteins discharge **[NCERT]**

(a) Antibiotics
(b) Pigment conferring colour to skin
(c) Pigments making colours of flowers
(d) Hormones

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11. Glycogen is a homopolymer made of **[NCERT]**
(a) Glucose units (b) Galactose units
(c) Ribose units (d) Aminoacids

12. The number of 'ends' in a glycogen molecule would be **[NCERT]**
(a) Equal to the number of branches plus one
(b) Equal to the number of branch points
(c) One
(d) Two, one on the left side and another on the right side

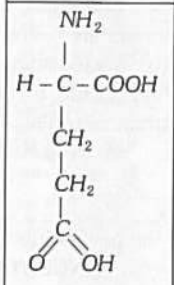
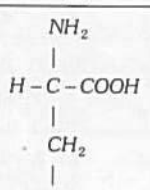
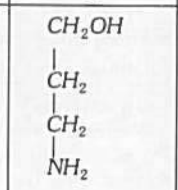
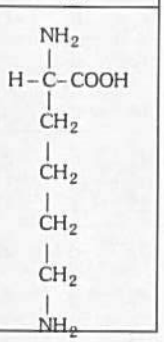
13. A pure protein should normally have **[NCERT]**
(a) Two ends (b) One end
(c) Three ends (d) No ends

14. Enzymes are biocatalysts. They catalyse biochemical reactions. In general they reduce activation energy of reactions. Many physico-chemical processes are enzyme mediated. Some examples of enzyme mediated reactions are given below. Tick the wrong entry **[NCERT]**
(a) Dissolving CO_2 in water
(b) Unwinding the two strands of DNA
(c) Hydrolysis of sucrose
(d) Formation of peptide bond

Critical Thinking

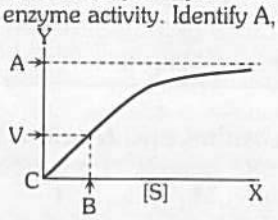
Objective Questions

1. Which one out of A-D given below correctly respresents the structural formula of the basic amino acid **[NCERT; CBSE PMT (Pre.) 2012]**

A	B	C	D
			

(a) C (b) D
(c) A (d) B

2. The given adjacent graph depicts the change in conc. of substrate on enzyme activity. Identify A, B and C **[NCERT]**



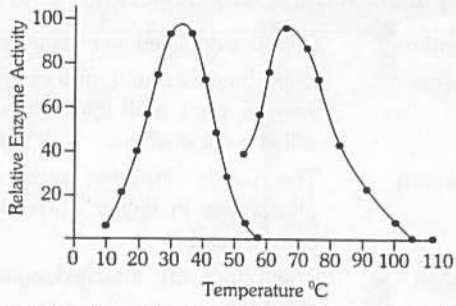
	A	B	C
(a)	K_m	V_{max}	$\frac{V_{max}}{2}$
(b)	V_{max}	K_m	$\frac{V_{max}}{2}$
(c)	$\frac{V_{max}}{2}$	K_m	Ki
(d)	Ki	K_m	V_{max}

3. Enzymes generally have
(a) Same *pH* and temperature optima
(b) Same *pH* but different temperature optima
(c) Different *pH* but same temperature optima
(d) Different *pH* and different temperature optima

4. Most of the biochemical reactions differ from those occuring in the non-living world in
(a) Requiring energy (b) Releasing energy
(c) Being enzymatic (d) Being spontaneous

5. A phosphoglyceride is always made up of **[NEET 2013]**
(a) A saturated or unsaturated fatty acid esterified to a phosphate group which is also attached to a glycerol molecule
(b) Only a saturated fatty acid esterified to a glycerol molecule to which a phosphate group is also attached
(c) Only a unsaturated fatty acid esterified to a glycerol molecule to which a phosphate group is also attached
(d) A saturated or unsaturated fatty acid esterified to a glycerol molecule to which a phosphate group is also attached

6. The given graph depicts the effect of temperature on the activity of the two enzymes A and B that catalyze the same reaction. Select the correct statement (s) for these results



A. The rate of reaction in each case increases with increase in temperature and declines at higher temperatures due to denaturation of the enzyme
B. Both the enzymes A and B are thermolabile
C. At higher temperature the reactants become highly energized and fail to interact with active site, thus decreasing the rate of reaction
D. The enzyme A is from a mesophilic organism, whereas the enzyme B is from a thermophilic organism **[NCERT]**
(a) A, B, D (b) C and D
(c) B and C (d) A and B

7. In the modern system of nomenclature which one of the following enzyme occupies 6th position
(a) Ligase (b) Isomerase
(c) Lyase (d) Hydrolase

8. The most important property of an enzyme is its
(a) Composition (b) Thermal denaturation
(c) Specificity (d) Solubility

9. The ratio of the enzyme to substrate molecule can be as high as
(a) 1 : 1000 (b) 1 : 1,00,000
(c) 1 : 10,00,000 (d) 1 : 50,000

10. Repressible enzymes are formed **[DPMT 2006]**
(a) In the absence of corepressor
(b) In the presence of corepressor
(c) In the presence of apressor
(d) All of the above

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11. The enzyme nitrogenase is extremely sensitive to **[WB JEE 2016]**

(a) Oxygen (b) Nitrogen
(c) Hydrogen (d) Helium

12. Which of the following are not polymeric **[NEET 2017]**

(a) Nucleic acids (b) Proteins
(c) Polysaccharides (d) Lipids

AR Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

(a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion
(b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion
(c) If the assertion is true but the reason is false
(d) If both the assertion and reason are false
(e) If the assertion is false but reason is true

1. Assertion : DNA is associated with proteins.
Reason : DNA binds around histone proteins that form a pool and the entire structure is called a nucleosome. **[AIIMS 2000]**

2. Assertion : The bonds attaching second and third phosphates in higher nucleotide are high energy bonds.
Reason : The bonds are attached against force of repulsion.

3. Assertion : Enzymes have active sites and substrates reactive sites, on their surfaces respectively.
Reason : Active and reactive sites push the enzyme and substrate molecules away from each other. **[AIIMS 1999]**

4. Assertion : Enzyme substrate complex remains throughout the reaction.
Reason : The greater the affinity of the enzyme for a substrate, the higher is the catalytic activity.

5. Assertion : Desmolysing enzymes are those which catalyse the reactions by hydrolysis.
Reason : Digestive enzymes are hydrolysing in nature.

6. Assertion : Coenzymes are also called prosthetic groups.
Reason : Coenzymes and prosthetic groups are cofactors.

7. Assertion : Enzymes are defined as biological proteins.
Reason : Chemically all enzymes are globular proteins. **[AIIMS 1997]**

8. Assertion : DNA molecules and RNA molecules are found in the nucleus of cell.
Reason : On heating, enzymes do not lose their specific activity. **[AIIMS 1994]**

9. Assertion : The higher the turn-over number the more efficient an enzyme is.
Reason : It is not dependent upon the number of active sites present over an enzyme.

10. Assertion : Allosteric enzymes show feed back inhibition.
Reason : The inhibitor is competitive.

11. Assertion : Enzyme becomes inactive below minimum temperature.
Reason : The inactivity of the enzymes is due to denaturation.

12. Assertion : Enzymes lower the activation energy.
Reason : A substrate molecule can be acted upon by a particular enzyme. **[AIIMS 2011]**

Answers

Carbohydrates, Starch and Protein

1	a	2	a	3	c	4	d	5	c
6	b	7	b	8	a	9	d	10	b
11	a	12	d	13	a	14	d	15	a
16	c	17	d	18	d	19	b	20	b
21	c	22	e	23	c	24	d	25	d
26	a	27	a	28	a	29	d	30	b
31	d	32	a	33	d	34	a	35	c,d
36	b	37	a	38	a	39	a	40	a
41	a	42	a	43	a	44	d	45	b
46	c	47	a	48	c	49	b	50	a
51	c	52	d	53	a	54	e	55	a
56	d	57	d	58	b	59	a	60	abc

Nucleotides and Nucleic acid

1	d	2	d	3	c	4	d	5	a
6	c	7	c	8	c	9	c	10	d
11	d	12	a	13	d	14	d	15	c
16	d	17	a	18	a	19	a	20	d
21	b	22	b	23	c	24	c	25	b
26	d	27	c	28	a	29	c	30	a
31	d								

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Introduction, properties, action and inhibition of enzyme

1	b	2	d	3	b	4	b	5	a
6	a	7	a	8	b	9	a	10	b
11	c	12	c	13	c	14	c	15	c
16	c	17	c	18	b	19	d	20	c
21	b	22	b	23	b	24	c	25	a
26	d	27	c	28	c	29	c	30	d
31	c	32	d	33	c	34	a	35	b
36	c	37	b	38	b	39	b	40	b
41	c	42	b	43	b	44	c	45	a
46	a	47	d	48	e	49	d	50	d
51	c	52	b	53	d	54	c	55	a
56	c								

Classification and factors affecting enzyme

1	d	2	b	3	c	4	a	5	b
6	c	7	c	8	a	9	d	10	b
11	c	12	d	13	a	14	a	15	b
16	b	17	a	18	c	19	b	20	d
21	b	22	c	23	b	24	c	25	c
26	a	27	c	28	b	29	c	30	b
31	c								

NCERT Exemplar Questions

1	c	2	a	3	b	4	d	5	a
6	d	7	a	8	b	9	a	10	d
11	a	12	a	13	a	14	d		

Critical Thinking Questions

1	b	2	b	3	c	4	c	5	d
6	a	7	a	8	c	9	c	10	a
11	a	12	d						

Assertion and Reason

1	a	2	a	3	c	4	e	5	e
6	e	7	a	8	d	9	c	10	c
11	c	12	b						

AS Answers and Solutions

Carbohydrates, Starch and Protein

1. (a) Simple sugar *i.e.*, monosaccharide. These are the simplest carbohydrates and are building units of complex carbohydrates. *i.e.*, Starch and cellulose.

2. (a) Fructose is the most common form of sugar. It is the sweetest among naturally occurring sugars. It has sweetening index of 170 (where as the sweetening index of glucose is 70).

5. (c) Inulin is homopolysaccharides, which is found in the root of dahlia plant.

6. (b) Pentoses and hexoses are the example of monosaccharides.

7. (b) Due to heating effect, disaccharides are dissociated into monosaccharides, which are sweet in nature.

11. (a) Sucrose is the common cane or table sugar which is composed of D-glucose and fructose attached together by the aldehyde and ketone carbon.

12. (d) The carbohydrates or sugar where free aldehyde or ketonic group is absent (utilized in glycosidic bond formation) can not reduce the above reagents are called non-reducing sugar *i.e.*, Sucrose, glycogen, starch.

14. (d) Dextran is a complex polysaccharide prepared either through partial hydrolysis of starch or polymerization of sucrose by the bacterium *Leuconostoc mesenteroides.*

17. (d) The non proteineous prosthetic group is FMN or FAD. The protein is flavoprotein, which is a type of conjugated protein.

18. (d) When protein adjoins with carbohydrates, is known as glycoprotein, which is a conjugated protein.

21. (c) No cell could live without protein because proteins are building block of the body.

28. (a) Lysine is an essential amino acid found in wheat. Which is not synthesized in the human body.

34. (a) The union makes sucrose more stable than other sugars because both its anomeric carbon atoms are protected from oxidative attack. It is because of this reason, sucrose is used for transporting carbohydrates in plants.

45. (b) Disaccharides composed of two unit of monosaccharides *e.g.* sucrose, maltose and lactose *etc.* Starch is the most common storage polysaccharide in plants.

47. (a) Peptone is a derived protein. Others are conjugated proteins.

48. (c) The fatty acids having more than one double bond are called polyunsaturated fatty acids. Fats having such fatty acids are termed polyunsaturated fats. The latter are commended by physicians for persons having cardiovascular disease as their use lowers the blood cholesterol level.

58. (b) Polymer of *N*-acetyleglucosamine $(C_8H_{13}O_5N)_n$ that forms exoskeleton of arthropods and cell wall of fungi.

59. (a) Ester bonds are formed in nucleic acids and lipids, but not proteins

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Nucleotides and Nucleic acid

12. (a) There is double hydrogen bond between adenine and thymine ($A = T$) and triple bond between cytosine and guanine ($C \equiv G$).

16. (d) Because plant viruses have RNA as genetic material.

17. (a) The two strands of DNA molecules run in opposite or antiparallel direction due to presence of hydrogen bond because two base i.e. one in each chain of DNA molecule, joined together by hydrogen bonds.

21. (b) Adenine and thymine; because *C* always attaches with *G* and *A* attaches with T.

25. (b) RNA is present both inside and outside the nucleus.

Introduction, properties, action and inhibition of enzyme

1. (b) The term enzyme was used by Willy Kuhne while working on fermentation.

2. (d) Zymase is complex of enzyme. It obtained from *yeast* cell by Edward Buchner.

3. (b) All enzymes are proteins but all proteins are not enzyme.

5. (a) Arber and Nathans got nobel prize in 1978 for the discovery of restriction endonucleases.

6. (a) *Lock and key theory* : Emil Fischer proposed this theory, according to which on the surface of enzymes a few elevations and ditches are found known as active sites and enzymes bind reactants on these sites to create reaction between them.

9. (a) First time fermentative enzymes were discovered from yeast.

15. (c) Because enzymes are made up of proteins which are basically polymers of amino acids.

17. (c) In competitive inhibition, km value increases.

19. (d) Viruses are acellular organisms.

24. (c) *Km* is a Michaelis Menten constant, which indicates the substrate concentration at which the chemical reaction catalysed by an enzyme attains half its maximum velocity.

26. (d) Inhibition of succinic dehydrogenase by malonate is an example of competitive inhibition. This is reversible reaction. On increasing the substrate (succinate) concentration the effect of inhibitor is removed and V_{max} remain same.

29. (c) Enzymes used as biological detergents

Application	Enzyme used	Uses
Biological detergents	Primarily Proteases, Produced in an extracellular form by bacteria.	Used for the pre-soak or main wash, break down protein stains on clothes; also used in dishwashers to remove food residues.
	Amylases	Remove starch stains from clothes; also used in dishwashers to remove resistant starch residues.
	Cellulase	Softens and brightens colour of cotton fabrics.

30. (d) Most enzymes are proteins but some are lipids.

33. (c) Coenzymes are loosely attached complex non-protein, low molecular weight, thermostable, organic or mettalo-organic groups. Which readily separate from the apoenzyme.

34. (a) In each and every molecule energy of activation is found, in which a few have more while others have less energy. Enzymes facilitates in between two molecules lowering their energy of activation.

35. (b) The proteinaceous part of an enzyme is called apoenzyme. The apoenzyme plus non proteinaceous part is called holoenzyme.

38. (b) One is active site and second is allosteric site.

41. (c) Permeases are found in the plasma membrane of the cell. Which take part in transportation of ions etc.

47. (d) Flavin mononucleotide (FMN), Flavin adenine dinucleotide (FAD) contains riboflavin (vitamin B_2).

49. (d) Co-enzymes are organic molecules which acts as co-factors, but unlike prosthetic groups they do not remain attached to the enzyme between reaction. NAD, NADP and FAD are co-enzymes whereas ATP is an energy carrier in cell.

53. (d) The best evidence of lock and key theory or template theory of enzyme action comes from the observation that compounds similar in structure to the substrate inhibit the reaction.

54. (c) The substance which causes change in allosteric sites are known as modulators. They are of two types activator and inhibitor. Hexokinase is the example of inhibitor modulator.

Classification and factors affecting enzyme

7. (c) *Zymogens* : These are inactive enzyme precursors which in need can be convert in enzymes.

9. (d) Amylase digest the stored food material of germinated cotton seed.

15. (b) Activation energy is required for overcoming the energy barrier which gets reduced in the presence of enzyme.

17. (a) *Isoenzymes* : A few enzymes are isomerically equal to others and are only differing in their molecular structure.

25. (c) $\underset{\text{Glucose}}{C_6H_{12}O_6} \xrightarrow[\text{Zymase}]{\text{Yeast}} C_2 \underset{\text{Alcohol}}{OH} + 2CO_2$.

27. (c) *X*-axis represent temp. ature and *Y*-axis represent enzyme activity. All enzymes act at an optimum temperature, above and below this temperature the enzyme activity declines.

30. (b) If temperature increases from 3°*C* to 45°*C*, firstly it reaches to optimum condition and later temperature conditions are not optimum for enzyme activity. Thus the rate of enzyme activity initially increases and then decreases.

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Critical Thinking Questions

3. (c) Each enzyme has its own different favourable *pH* value but same temperature optima.

4. (c) Biochemical reactions of living beings are different from non-living world because in non-living beings, catalysts of reactions are mostly inorganic metals.

8. (c) Because a particular enzyme can catalyse only a particular type of reaction.

9. (c) Enzymes show reversible reactions and act by lowering energy of activation by more than 50%. They work in milliseconds and rate of enzyme to substrate is as high as 1:1000000.

10. (a) Some enzymes are normally present in cell but their synthesis is ceased when the concentration of their end product become high, such enzymes are called **repressible enzymes** whereas the end product is called **corepressor.**

A regulator gene produces the aporepressor which unites with corepressor to form a functional repressor molecule. This repressor molecule inhibit mRNA synthesis by all genes specifying **enzymes.**

Assertion and Reason

1. (a) A chain of DNA has 140 base pairs, make $1\frac{3}{4}$ turns and twist around a histone octamer forming nucleosome. The core of nucleosome consists of 4 histones H_2A, H_2B, H_3 and H_4.

2. (a) Nucleotides having more than one phosphate group are called higher nucleotides. The second and third phosphates of higher nucleotides are attached against forces of repulsion between similarly charged phosphate radicals. Hence, the bonds attaching second and third phosphates are higher energy bonds.

3. (c) Enzyme has specific site for substrates called as active sites and substrate has reactive sites. These active and reactive sites help in making of substrates enzyme complex.

4. (e) The enzymes substrate complex is short lived. The substrate is changed into products. The products remain complexed with the active site of the enzyme for a brief period. They soon separate and the active site is free to perform another catalytic act. Enzymes activity depends upon their affinity of substrates. If turnover number of substrate is higher, then enzymes show high affinity towards substrate. The number of substrate molecules changed per minute by a molecule or enzyme is called turn over number.

5. (e) Desmolysing enzymes are those which catalyse reactions by the other methods other than hydrolysis, *e.g.*, aldolases, dehydrogenases, oxidases, etc. Digestive enzymes function by catalysing hydrolysis. Larger molecules are broken into smaller ones. They are grouped into three types – proteolytic (breaks protein molecule), amylolytic (breaks sugar molecule) and lipolytic (breaks lipid molecule).

6. (e) Cofactor may be inorganic or organic in nature. Organic cofactors are of two types, coenzymes and prosthetic groups. Coenzymes are easily separable nonprotein organic cofactors. Prosthetic groups are nonprotein organic cofactors firmly attached to apoenzymes (protein part of enzyme).

7. (a) We know that all biological reactions are catalysed by special catalysts called enzyme, thus enzymes are defined as biological proteins. We also know that enzymes are small organic molecules which are weakly held to the protein and can be easily seperated by dialysis. Therefore chemically all enzymes are globular proteins.

8. (d) We know that DNA molecules are found primarly in the nucleus of the cell but RNA molecules are found outside the nucleus. By heating, its special structural arrangement is changed irreversibly, this result in the conversion of enzyme into a fibrous or insoluble form. Due to this irreversible change, enzymes lose their specific activity when heated.

9. (c) The number of substrate molecules changed per minute by a molecule or enzyme is called turn over number. The higher the turn-over number, the more efficient an enzyme is. It depends upon the number of active sites present over an enzyme.

10. (c) Feed back inhibition is a type of reversible inhibition found in allosteric enzymes. The inhibitor is noncompetitive and is usually a low molecular intermediate or product of metabolic pathway having a chain of reactions involving a number of enzymes.

11. (c) Enzyme becomes inactive below minimum temperature. Low temperature preserves the enzymes in the inactive state. High temperature destroys enzymes by causing their denaturation.

12. (b) Activation energy is an external supply of energy which is needed for the initiation of the chemical reaction. Activation energy required for such a large number of reactions cannot be provided by living systems. Enzymes lower the activation energy required for a reaction. Enzymes are generally specific for their substrates.

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Biomolecules

SET Self Evaluation Test

1. Raphides are found in **[BHU 1995]**
(a) Dahlia (b) *Asparagus*
(c) Nut (d) Guava

2. Which level of protein structure is affected by DNA
(a) Primary structure (b) Secondary structure
(c) Tertiary structure (d) Quaternary structure

3. Insoluble carbohydrate inulin is commonly found in **[Odisha JEE 2009]**
(a) Root of beet (b) Stem of sugarcane
(c) Fruit of grapes (d) Roots of Dahlia

4. Ribose is a **[MP PMT 2011]**
(a) Monosaccharide (b) Disaccharide
(c) Polysaccharide (d) None

5. The unit of cellulose is **[MP PMT 2011]**
(a) Glucose (b) Fructose
(c) Mannose (d) Galactose

6. Which is true about enzymes
(a) Lower the energy of activation of a reaction
(b) Make the equilibrium more favourable for the organism
(c) Lower the energy of product and increases the energy of reactant
(d) Are altered permanently in the reaction they catalyse

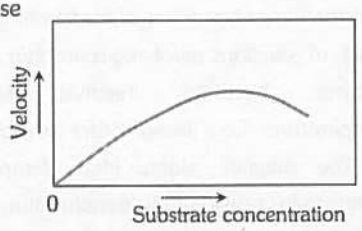
7. Papain produced from **[Odisha JEE 2009]**
(a) *Carica papaya* (b) *Glycine max*
(c) *Citrus* sp (d) *Ficus carica*

8. What enzymes do for a biochemical reaction
(a) Alter its rate (b) Alter its pattern
(c) Alter both (d) None of the above

9. The enzymes required to obtain protoplasts are **[AMU (Med.) 2006; Odisha JEE 2008]**
(a) Cellulase and proteinase (b) Cellulase and amylase
(c) Cellulase and pectinase (d) Amylase and pectinase

10. Enzymes have a very narrow optima for
(a) Light (b) Temperature
(c) *pH* (d) Humidity

11. The given graph shows the effect of substrate concentration on the rate of reaction of the enzyme green gram-phosphatase



What does the graph indicate **[AIIMS 2005, 08]**
(a) The rate of enzyme reaction is directly proportional to the substrate concentration
(b) Presence of an enzyme inhibitor in the reaction mixture
(c) Formation of an enzyme-substrate complex
(d) At higher substrate concentration the *pH* increase

12. Molecular weight of enzyme is
(a) Less than 5000
(b) 5000 to 10000
(c) 10000 to 20000
(d) More than 40000

13. The term 'feedback' refers to
(a) The effect of end product on the rate of enzymatic reaction
(b) The effect of substrate on the rate of enzymatic reaction
(c) The effect of an external compound on the rate of enzymatic reaction
(d) The effect of enzyme concentration on its rate of reaction

14. Pepsin is inactivated at *pH* **[BHU 2003]**
(a) Below 3 (b) Below 2
(c) Above 5 (d) Above 3

AS Answers and Solutions

1	b	2	a	3	d	4	a	5	a
6	a	7	a	8	a	9	c	10	c
11	b	12	d	13	a	14	c		

1. (b) Raphides are needle shaped structures of calcium oxalate. These are found in epidermal cells of *Asparagus, Eichhornia, Lemna* etc. Cell with raphides are called idioblasts.

3. (d) Inulin is called 'Dahlia starch' and found in roots.

6. (a) Enzyme act by decreasing the activation energy so that the number of activated molecules is increased at lower energy level.

10. (c) Each enzyme operates within a narrow range of *pH*. It is most effective at a particular point of this range which is called optimum *pH*.

12. (d) Peroxidase one of the smaller enzymes has molecular weight of 4,000, where as catalase one of the largest has a molecular weight of 250,000.

14. (c) All enzymes are temperature and *pH* specific in nature pepsin of gastric juice works well at *pH*2.

* * *

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