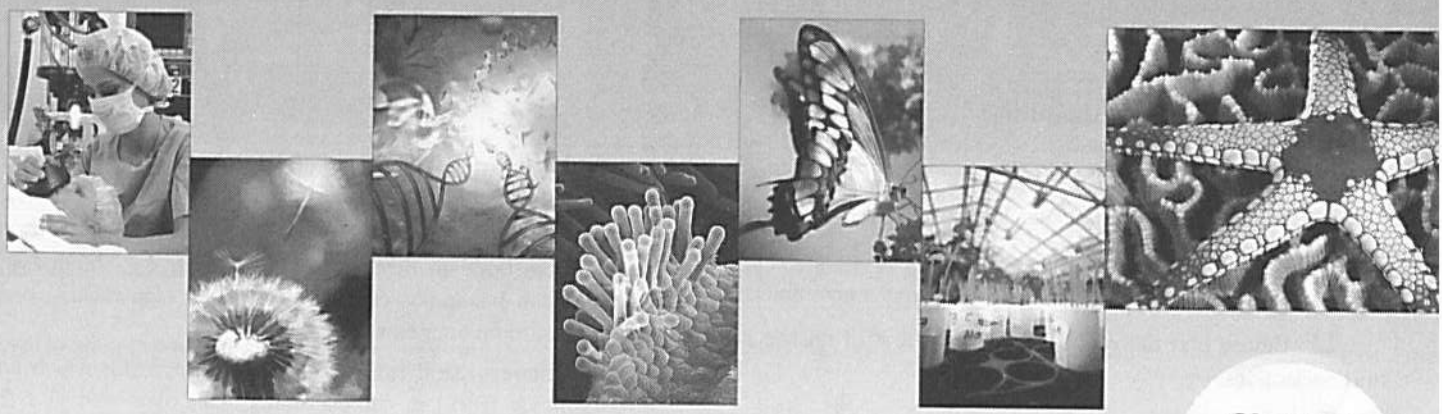


Chapter

# 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.

**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.

**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.

## 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 $\beta$-*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**

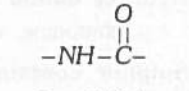
(i) Cellulose pectin and chitin are constituents in cell wall of higher plants but peptidoglycan in the cell wall of prokaryotes.

(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 ($\alpha$ – 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.

(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.

(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 |

## 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 4$^{th}$ 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.

## 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.

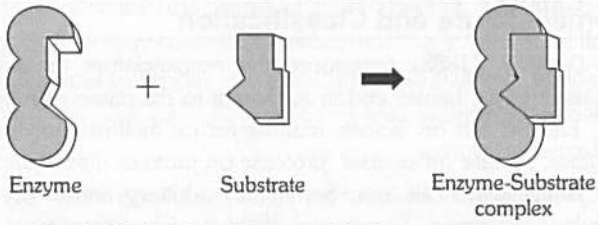



**Fig : 3.2-1 Lock and key model of enzyme action**

**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.

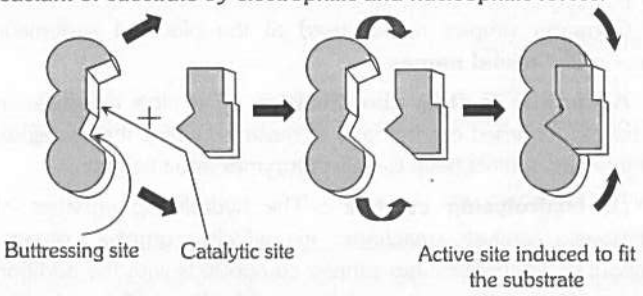



**Fig : 3.2-2 Induced fit model of enzyme action**

## 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.

**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.

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

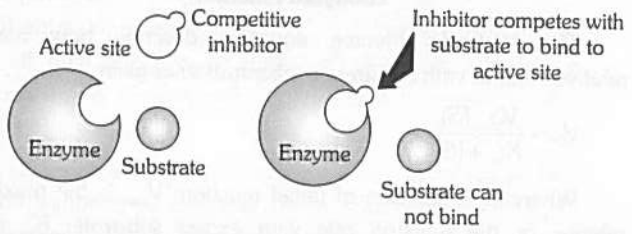



**Fig : 3.2-3 Competitive inhibition**

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.

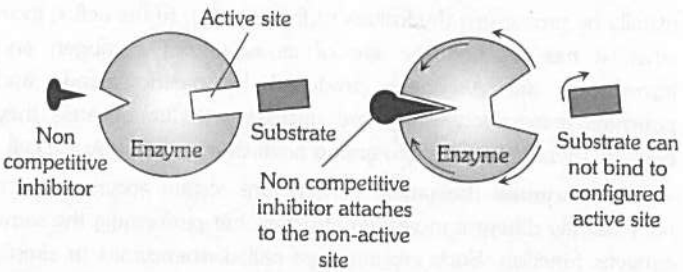
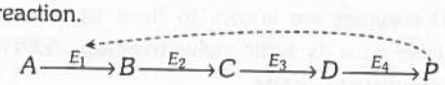



**Fig : 3.2-4 Non-competitive inhibition**

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




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.

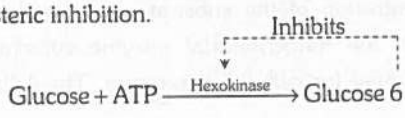
The phenomenon in which the end product of a metabolic pathway can regulate its own production by inhibition of the sort is called **feed back inhibition** or negative feed back inhibition. This type of inhibition can be shown in *Escherichia coli* bacterium which synthesises the amino acid isoleucine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

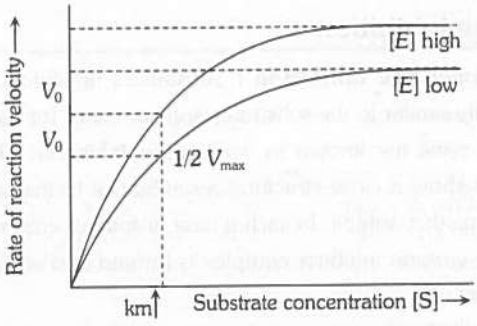



**Fig : 3.2-5 Reaction velocity 'V' and substance concentration (S) for a typical enzyme catalysed reaction**

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.

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.

# 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**

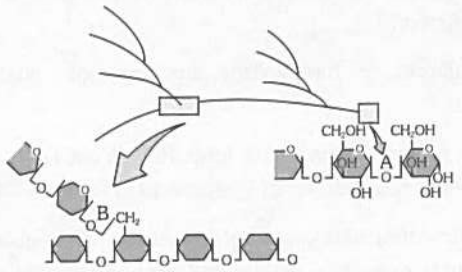
Inulin is a polymer of **[WB JEE 2011]**

(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

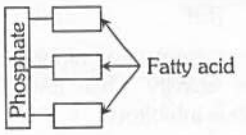
**7.** Corn is immersed in the boiling water. It is then cooled, the solution becomes sweet. It is due to **[AFMC 1999; JIPMER 2001]**

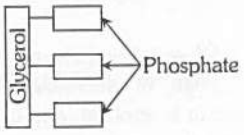
(a) Enzymes are inactivated in boiling water
(b) Disaccharides are converted to monosaccharides
(c) Monosaccharides are converted to disaccharides
(d) None of these

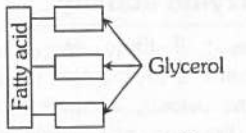
**8.** Cholesterol belongs to which of the following groups **[Odisha JEE 2008; J & K CET 2012]**

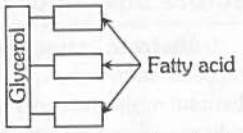
(a) Steroids (b) Neutral fats
(c) Waxes (d) Phospholipids

**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

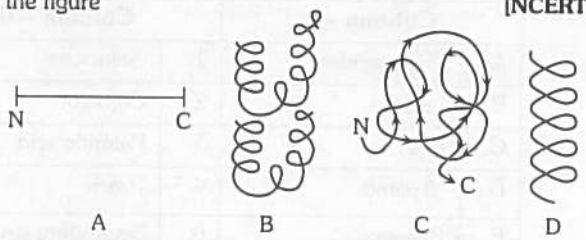
**17.** Which one of the following . conjugate protein **[Odisha PMT 2002]**

(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

**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) $NH_2-C(COOH)(CH(CH_3)_2)-H$
(b) $NH_2-C(COOH)((CH_2)_4NH_2)-H$
(c) $NH_2-C(COOH)(CH_2OH)-H$
(d) $NH_2-C(COOH)(CH_3)-H$

**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

**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

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

**[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. | $\beta$ 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

**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 $\alpha$ or $\beta$
(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

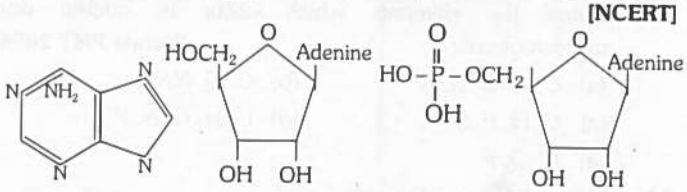
**2.** DNA is present in **[NCERT; MP PMT 1995, 96, 98; BVP 2000; RPMT 2001; MHCET 2001; AIIMS 2004]**

**Or**

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

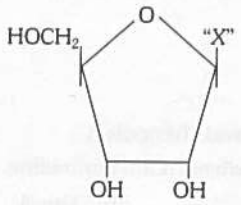
(a) Nucleus only (b) Mitochondrion only
(c) Chloroplast only (d) All the above

**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 |

**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

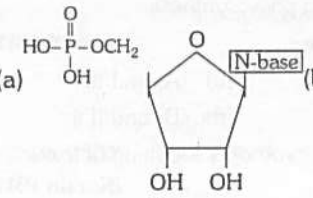
**16.** DNA is not present in one of the following **[MP PMT 2003]**

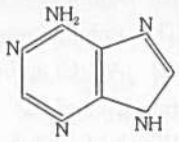
(a) Mitochondria (b) Chloroplast
(c) Bacteriophage (d) Tobacco mosaic virus

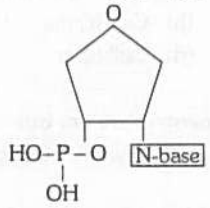
**17.** DNA strands are antiparallel because of the presence of **[Kerala PMT 2004]**

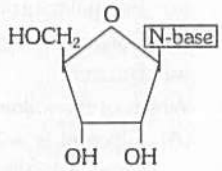
(a) H-bonds (b) Peptide bonds
(c) Disulphide bonds (d) Phosphate-diester bonds
(e) None of the above

**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**

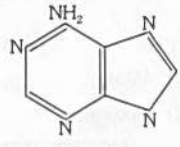
DNA was first discovered by **[CPMT 1994]**

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

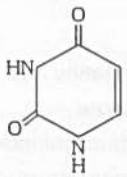
**21.** In DNA molecule, which of the following base pair is present **[MP PMT 1992]**

(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 $C \equiv G$

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

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

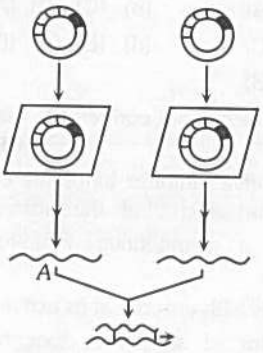
**26.** Which of the cell organelles are devoid of deoxy ribonucleic acid **[RPMT 1997]**

(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) $\alpha$-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

**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**

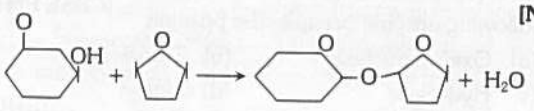
Which of the following enzyme is not usd in making detergent **[DPMT 2007]**

(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

**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

$$S-G+S' \rightarrow S+S'-G$$ **[Kerala PMT 2011]**

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

**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

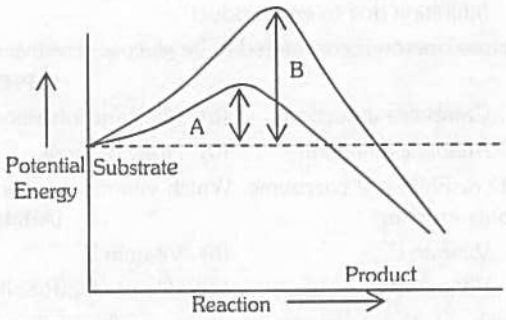
(c) Allosteric modulator (d) Denaturation of enzymes

**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

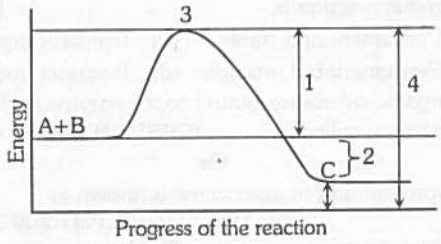
(c) Hydrolase (d) Ligase

**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

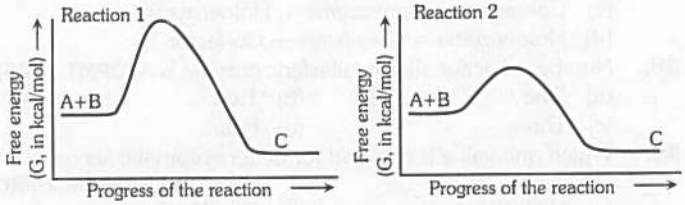
(a) Enzyme acting upon starch

(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

**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

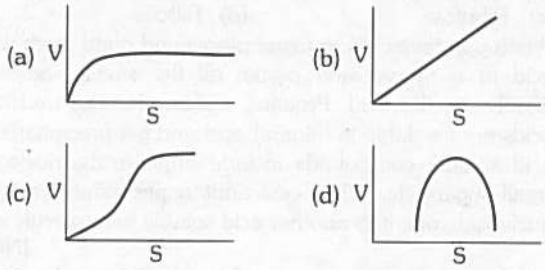
**13.** Which one is not an example for hydrolases **[Kerala PMT 2004]**

**Or**

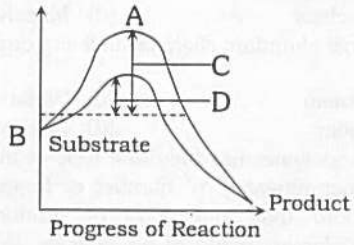
Hydrogen is removed from a substrate with the help of enzyme

(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]**




**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

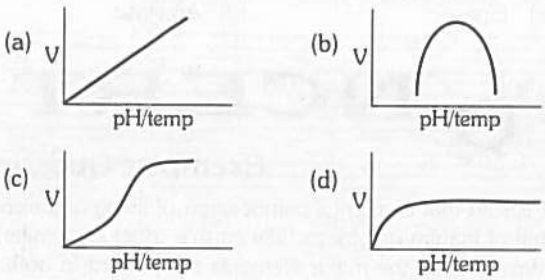
**21.** Signaling between cells usually results in the activation of protein **[DUMET 2009]**

(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]**




**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

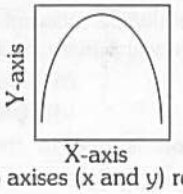
**25.** The enzyme which converts glucose into ethyl alcohol ($C_2H_5OH$) is **[MP PMT 1998, 2003; AMU (Med.) 2006; BHU 2006]**

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

**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

**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

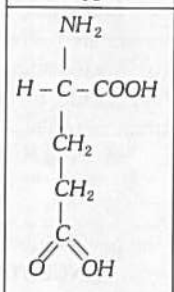
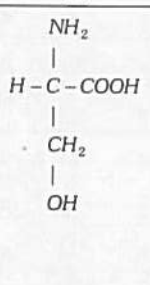
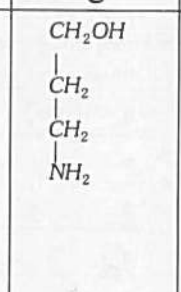
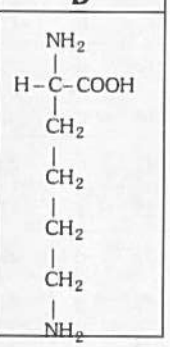
**13.** A pure protein should normally have **[NCERT]**
(a) Two ends (b) One end
(c) Three ends (d) No ends

**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

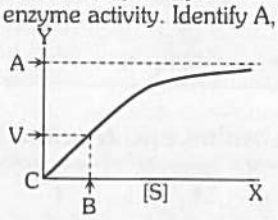
## Objective Questions

**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]**



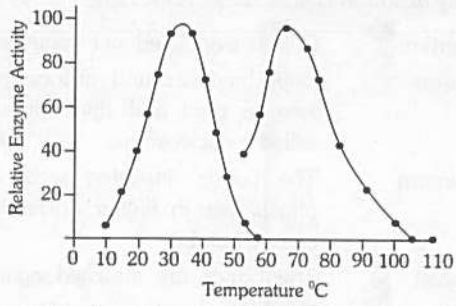

| | A | B | C |
|---|---|---|---|
| (a) | $K_m$ | $V_{max}$ | $\frac{V_{max}}{2}$ |
| (b) | $V_{max}$ | $K_m$ | $\frac{V_{max}}{2}$ |
| (c) | $\frac{V_{max}}{2}$ | $K_m$ | Ki |
| (d) | Ki | $K_m$ | $V_{max}$ |

**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

**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 | | | | | | | | |

## 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

## 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.

## 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.

# 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

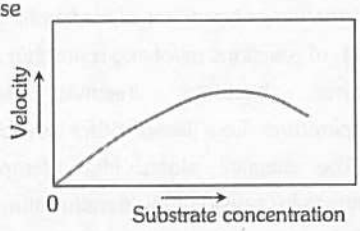
**7.** Papain produced from **[Odisha JEE 2009]**
(a) *Carica papaya* (b) *Glycine max*
(c) *Citrus* sp (d) *Ficus carica*

**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.

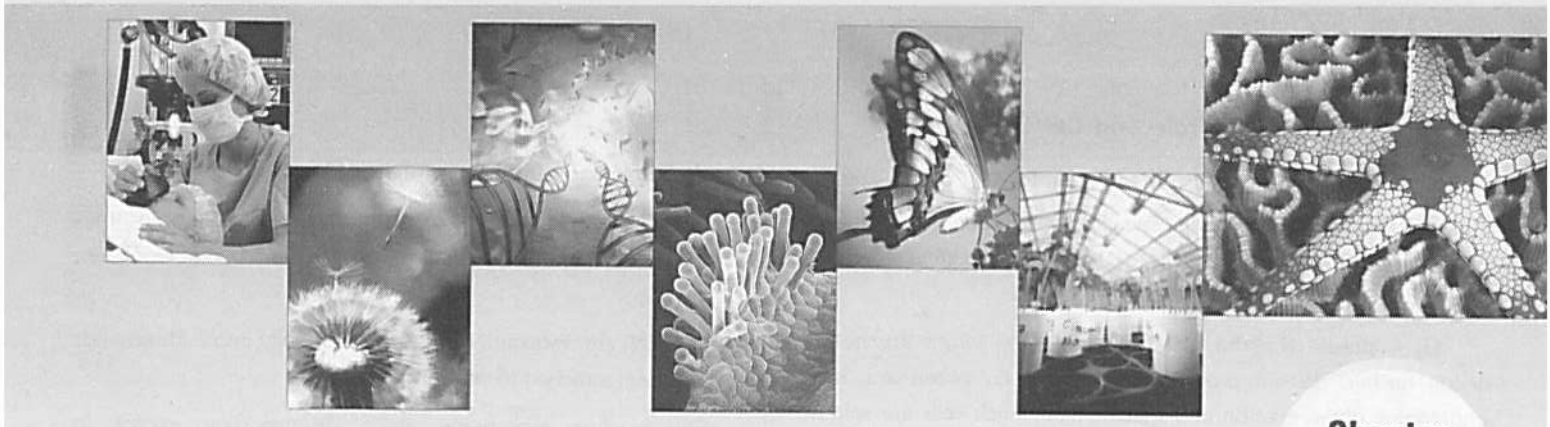
**6.** (a) Enzyme act by decreasing the activation energy so that the number of activated molecules is increased at lower energy level.

**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.

* * *



Chapter

3.3

# Cell Cycle and Cell Division

## Cell division / Cell reproduction / Cell cycle

It is the process by which a mature cell divides and f+orms two nearly equal daughter cells which resemble the parental cell in a number of characters.

In unicellular organisms, cell division is the means of reproduction by which the mother cell produces two or more new cells. In multicellular organism also, new individual develop from a single cell. Cell division is central to life of all cell and is essential for the perpetuation of the species.

**Discovery :** Prevost and Dumans (1824) first to study cell division during the cleavage of zygote of frog. Nageli (1846) first to propose that new cells are formed by the division of pre-existing cells.

Rudolf Virchow (1859) proposed "omnis cellula e cellula" and "cell lineage theory".

A cell divides when it has grown to a certain maximum size which disturb the karyoplasmic index (KI)/Nucleoplasmic ratio (NP)/Kernplasm connection.

**Cell cycle :** *Howard* and *Pelc* (1953) first time described it. The sequence of events which occur during cell growth and cell division are collectively called cell cycle. Cell cycle completes in two steps:

(1) Interphase, (2) *M*-phase/Dividing phase

(1) **Interphase :** It is the period between the end of one cell division to the beginning of next cell division. It is also called resting phase or not dividing phase. But, it is actually highly metabolically active phase, in which cell prepares itself for next cell division. In case of human beings it will take approx 25 hours. Interphase is completed into three successive stages.

**$G_1$ phase/Post mitotic/Pre-DNA synthetic phase/gap I$^{st}$ :** In which following events take place.

(i) Intensive cellular synthesis.

(ii) Synthesis of rRNA, mRNA ribosomes and proteins.

(iii) Metabolic rate is high.

(iv) Cells become differentiated.

(v) Synthesis of enzymes and ATP storage.

(vi) Cell size increases.

(vii) Decision for a division in a cell occurs.

(viii) Substances of G stimulates the onset of next S – phase.

(ix) Synthesis of NHC protein, carbohydrates, proteins, lipids.

(x) Synthesis of enzyme, amino acids, nucleotides etc. but there is no change in DNA amount.

***S*-phase/Synthetic phase**

(i) DNA replicates and its amount becomes double (2C - 4C).

(ii) Synthesis of histone proteins and NHC (non-histone chromosomal proteins).

(iii) Euchromatin replicates earlier than heterochromatin.

**$G_2$-phase/Pre mitotic/Post synthetic phase/gap-II$^{nd}$**

(i) Mitotic spindle protein (tubulin) synthesis begins.

(ii) Chromosome condensation factor appears.

(iii) Synthesis of 3 types of RNA, NHC proteins, and ATP molecule.

(iv) Duplication of mitochondria, plastids and other cellular macromolecular complements.

(v) Damaged DNA repair occur.

(2) ***M*-phase/Dividing phase/Mitotic phase :** It is divided into two phases, karyokinesis and cytokinesis.

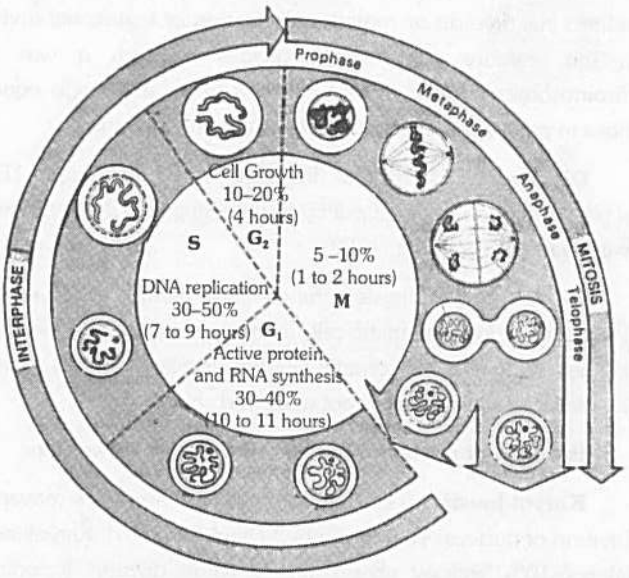



**Fig : 3.3-1 Different stages of cell cycle (Mitotic cycle)**

**Duration of cell cycle :** Time period for $G_1$, $S$, $G_2$ and $M$-phase is species specific under specific environmental conditions. *e.g.*, 20 minutes for bacterial cell, 8-10 hours for intestinal epithelial cell, and onion root tip cells may take 20 hours.

**$G_0$ – phase (Lajtha, 1963) :** The cells, which are not to divide further, do not proceed beyond the $G_1$ phase and start undergoing differentiation into specific type. Such cells are said to be in $G_0$ phase.

**Types of cell division :** It is of three types, Amitosis, Mitosis and Meiosis.

## Amitosis

Amitosis (Gk. *Amitos* = without thread; osis = state). It is also called as direct cell division. It was discovered by Remak (1855) in RBC of chick embryo. In this division there is no differentiation of chromosomes and spindle. The nuclear envelope does not degenerate.The nucleus elongates and constricts in the middle to form two daughter nuclei. This is followed by a centripetal constriction of the cytoplasm to form two daughter cells. It is primitive type of division occuring in prokaryotes, protozoans, yeasts, foetal membrane of mammals, cartilage of mammals etc.

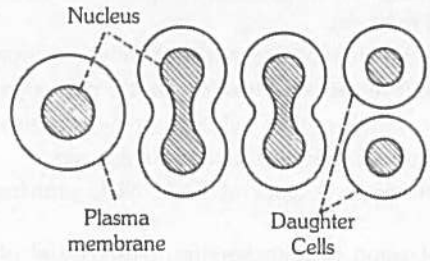



**Fig : 3.3-2 Amitosis division**

## Mitosis

Mitosis (Gk. *Mitos* = thread; *osis* = state). It is also called indirect cell division or somatic cell division or equational division. In this, mature somatic cell divides in such a way that chromosomes number is kept constant in daughter cells equal to those in parent cell. So it is called equational division.

**Discovery :** Mitosis was first observed by *Strasburger* (1875) in plant cell and in animal cell by *W.flemming* (1879). Term mitosis was given by Flemming (1882).

**Occurrence :** Mitosis is the common method of cell division. It takes place in the somatic cells in the animals and plants. Hence, it is also known as the somatic division. In plants mitosis occurs in the meristematic cells *e.g.*, root apex and shoot apex.

**Process of mitosis :** Mitosis is completed in two steps.

**Karyokinesis :** (Gk. *Karyon* = nucleus; *kinesis* = movement) Division of nucleus. Term given by *Schneider* (1887). Karyokinesis it takes 5-10% (shortest phase) time of whole division. It comprises four phases *i.e.*, Prophase, Metaphase, Anaphase, Telophase.

(1) **Prophase :** It is longest phase of karyokinesis.

(i) Chromatin fibres thicken and shorten to form chromosomes which may overlap each other and appears like a ball of wool. *i.e.*, Spireme stage.

(ii) Each chromosome divides longitudinally into 2 chromatids which remain attached to centromere.

(iii) Nuclear membrane starts disintegrating except in dinoflagellates.

(iv) Nucleolus starts disintegrating.

(v) Cells become viscous, refractive and oval in outline.

(vi) Spindle formation begins.

(vii) Cell cytoskeleton, golgi complex, ER, etc. disappear.

(viii) In animal cells, centrioles move towards opposite sides.

(ix) Lampbrush chromosomes can be studied well.

(x) Small globular structure (beaded) on the chromosome are called chromomeres.

(xi) Spindle is formed from centriole (in animal cells) or MTOC (microtubule organising centre) in plant cells successively called astral and anastral spindle.

(2) **Metaphase**

(i) Chromosomes become maximally distinct *i.e.*, size can be measured.

(ii) A colourless, fibrous, bipolar spindle appears.

(iii) Spindle fibre are made up of 97% tubulin protein and 3% RNA.

(iv) Chromosomes move towards equatorial plane of spindles called congression and become arranged with their arms directed towards pole and centromere towards equator.

(v) Spindle fibres attach to kinetochores.

(vi) Metaphase is the best stage for studying chromosome morphology (structure, size, number).

(vii) Spindle has two type of fibres :

(a) Continous fibre (run from pole to pole).

(b) Discontinous fibre (between pole to centromeres).

(3) **Anaphase**

(i) Centromere splits from the middle and two chromatids gets separated.

(ii) Both the chromatids move towards opposite poles due to repulsive force called anaphasic movement.

(iii) Anaphasic movement is brought about by the repolymerisation of continuous fibres and depolymerisation of chromosomal fibres. Formation and expansion of interzonal fibres.

(iv) Different shape of chromosomes (V, J, I or L shapes) become evident during chromosome movement viz. metacentric acrocentric etc.

(v) The centromere faces towards equator.

(vi) The chromatids are moved towards the pole at a speed of 1 *μm/minute*. About 30 ATP molecules are used to move one chromosome from equator to pole.

(vii) Shape of chromosome is best studied at anaphase.

(4) **Telophase**

(i) Chromosomes reached on poles by the spindle fibers and form two groups.

(ii) Chromosomes begin to uncoil and form chromatin net.

(iii) The nuclear membrane and nucleolus reappear.

(iv) Two daughter nuclei are formed.

(v) Golgi complex and ER etc., reform.

(vi) This phase is also known as reverse prophase.

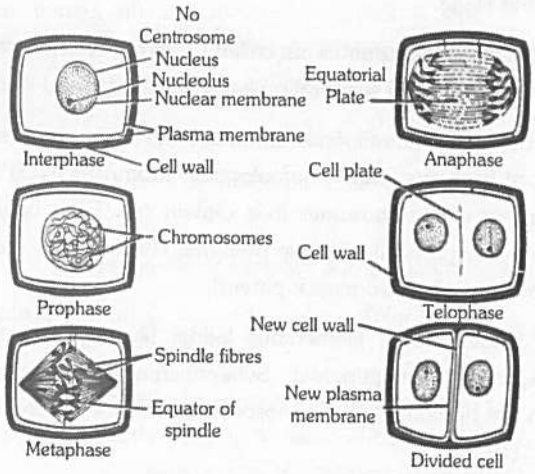



**Fig : 3.3-3 Various stages of mitosis**

**Cytokinesis** : (Gk –kitos = cell; kinesis = movement) Division of cytoplasm, Term given by *Whiteman* (1887). Division of cytoplasm into 2 equal parts.

Cytokinesis is by 2 methods :

(1) **Cell furrow method** : This is characteristic of animal cells. Due to absence of rigid cell wall here, the more flexible plasmamembrane forms the outer layer of cell. A **circular constriction** or invagination appears at centre or equator, which deepens gradually and finally two daughter cells are separated.

(2) **Cell plate method** : This is characteristic of plant cells. Here, vesicles provided by Golgi apparatus unite to form phragmoplasts, which join to form cell plate. Cell plate is first laid down in centre and then proceeds towards periphery (*i.e.*, centrifugal plate-formation). Cell wall materials are now laid down on both sides of cell plate and thus forming two daughter cells.

**Significance of mitosis**

(1) It keeps the chromosome number constant and genetic stability in daughter cells, so the linear heredity of an organism is maintained. All the cells are with similar genetic constituents.

(2) It provides new cells for repair and regeneration of lost parts and healing of the wounds.

(3) It helps in asexual reproduction by fragmentation, budding, stem cutting, etc.

(4) Somatic variations when maintained by vegetative propagation can play important role in speciation.

**Types of Mitosis**

(1) **Intranuclear or Promitosis** : In this nuclear membrane is not lost and spindle is formed inside the nuclear membrane *e.g.*, Protozoans (*Amoeba*) and yeast. It is so as centriole is present within the nucleus.

(2) **Extranuclear or Eumitosis** : In this nuclear membrane is lost and spindle is formed outside nuclear membrane *e.g.*, in plants and animals.

(3) **Endomitosis** : Chromosomes and their DNA duplicate but fail to separate which lead to polyploidy *e.g.*, in liver of man, both diploid (2N) and polyploid cells (4N) have been reported. It is also called endoduplication and endopolyploidy.

(4) **Dinomitosis** : In which nuclear envelope persists and microtubular spindle is not formed. During movement the chromosomes are attached with nuclear membrane.

**Mitotic poision** : The agents which inhibit cell division.

(1) **Azides and Cyanides** : Inhibit prophase.

(2) **Colchicine** : Inhibits spindle formation at metaphase.

(3) **Mustard gas** : Agglutinates the chromosomes.

(4) **Chalones** : These were first reported by Laurence and Bullough (1960). They are peptides and glycoproteins secreted by extracellular fluid of healthy cells and inhibit cellular division.

**Karyochoriosis** : A type of mitosis in fungi in which is intranuclear nucleus divides by furrow formation.

**Table : 3.3-1**

**Difference between animal and plant cells (Mitosis)**

| Animal cells | Plant cells |
|---|---|
| Centrioles present at spindle poles. | Centrioles lacking at spindle poles. |
| Asters are formed (amphiastral). | No asters are formed (anastral). |
| Cytokinesis by furrowing of cytoplasm. | Cytokinesis mostly by cell plate formation. |
| Furrow extends centripetally | Cell plate grows centrifugally. |

| | |
|---|---|
| Microfilament ring brings about cleavage. | Microfilaments have no role in cytokinesis. |
| Occurs nearly in all tissues. | Occurs mainly at meristems. |
| Cell becomes rounded and its cytoplasm more viscous at the time of mitosis. | Cell does not change form or nature at the time of mitosis. |
| Midbody is formed at the equator of the spindle. | Equator of the spindle changes into phragmoplast. |
| Intercellular spaces appear between the daughter cells. | Daughter cells remain adhered together by middle lamella. |
| Animal mitosis is controlled by certain mitogens. | Plant mitosis is usually controlled by a hormone cytokinin. |

## Meiosis

Meiosis (Gr. meio – to lessen, *osis* – state). *Meiosis is a much slower process than mitosis*. It is a double division that occurs in a mature diploid reproductive cell (2x) in which nucleus divides twice but chromosome (DNA) replicates only once to form four haploid cells, each having the half the number of chromosomes present in the parent cell. As it causes reduction in the number of chromosomes, it is known as **reduction division**. Meiosis in a cell occurs only once. The so formed haploid cells do not further undergo meiosis because there is no synaptinemal complex in haploid genome.

**Discovery :** It was first demonstrated by *Van Beneden* (1887) but was described by *Winiwarter* (1900). Term "meiosis" was given by Farmer and Moore (1905). Gregoire used the term meiosis I and II.

**Occurrence :** It is found in special types and at specific period. It is reported in diploid germ cells of sex organs (*e.g.*, primary spermatocytes of testes to form male gametes called spermotozoa and primary oocytes to form female gametes called ova in animals) and in pollen mother cells (microsporocytes) of anther and megasporocyte of ovule of ovary of flowers in plant to form the haploid spores. The study of meiosis in plants can be done in young flower buds.

**Process of meiosis :** Meiosis is completed in two steps, meiosis I and meiosis II

**Meiosis-I :** In which the actual chromosome number is reduced to half. Therefore, meiosis I is also known as reductional division or heterotypic division. It results in the formation of two haploid cells from one diploid cell. It is divided into two parts, karyokinesis I and cytokinesis I.

**Karyokinesis-I :** It involves division of nucleus. It is divided into four phases *i.e.*, prophase, metaphase, anaphase, telophase.

(1) **Prophase-I :** It is of longest phase of karyokinesis of meiosis. It is again divisible into five subphases *i.e.*, leptotene, zygotene, pachytene, diplotene and diakinesis.

(i) **Leptotene/Leptonema**

(a) Chromosomes are long thread like with chromomeres on it.

(b) Volume of nucleus increases.

(c) Chromatin network has half chromosomes from male and half from female parent.

(d) Chromosome with similar structure are known as homologous chromosomes.

(e) Leptonemal chromosomes have a definite polarization and forms loops whose ends are attached to the nuclear envelope at points near the centrioles, contained within an aster. Such peculiar arrangement is termed as *bouquet stage* (in animals) and *syndet knot* (in plants).

(g) Lampbrush chromosome found in oocyte of amphibians is seen in leptotene.

(ii) **Zygotene/Zygonema**

(a) Pairing or "synapsis" of homologous chromosomes takes place in this stage.

(b) Paired chromosomes are called bivalents, which by furthur molecular packing and spiralization becomes shorter and thicker.

(c) Pairing of homologous chromosomes in a zipper-fashion. Number of bivalents (paired homologous chromosomes) is half to total number of chromosomes in a diploid cell. Each bivalent is formed of one paternal and one maternal chromosome (*i.e.*, one chromosome derived from each parent).

(d) Under EM, a filamentous ladder like nucleoproteinous complex, called synaptinemal. Synaptinemal complex is seen between the homologous chromosomes which was discovered by "*Moses*" (1956).

(iii) **Pachytene/Pachynema**

(a) In the tetrad, two similar chromatids of the same chromosome are called sister chromatids and those of two homologous chromosomes are termed non-sister chromatids.

(b) Crossing over *i.e.*, exchange of segments between non-sister chromatids of homologous chromosome occurs at this stage.

It takes place by breakage and reunion of chromatis segments. Breakage called nicking, is assisted by an enzyme endonuclease and reunion termed annealing is added by an enzyme ligase. Breakage and reunion hypothesis proposed by *Darlington* (1937).

(c) Chromatids of pachytene chromosome are attached with centromere.

(d) A tetrad consists of two sets of homologous chromosomes each with two chromatids. Each tetrad has four kinetochore (two sister and two homologous).

(e) A number of electron dense bodies about 100 *nm* in diameter are seen at irregular intervals within the centre of the synaptonemal complex, known as recombination nodules.

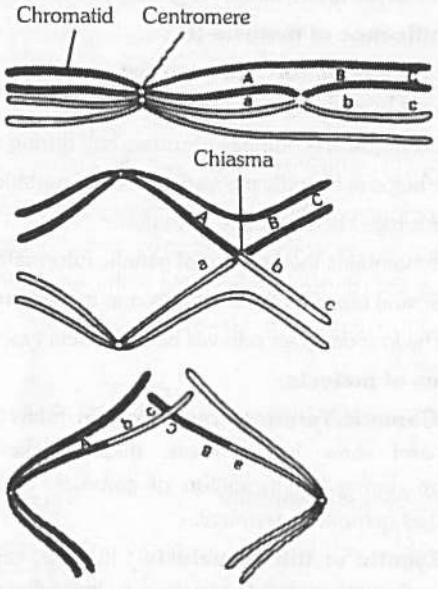



**Fig : 3.3-4 Crossing over during meiosis**

(f) DNA polymerase is responsible for the repair synthesis.

(iv) **Diplotene/Diplonema**

(a) At this stage the paired chromosomes begin to separate (desynapsis). Terminalisation starts.

(b) Cross is formed at the place of crossing over between non-sister chromatids.

(c) Homologous chromosomes move apart they remain attached to one another at specific points called chiasmata.

(d) At least one chiasma is formed in each bivalent.

(e) Chromosomes are attached only at the place of chiasmata.

(f) Chromatin bridges are formed in place of synaptonemal complex on chiasmata.

(g) This stage remains as such for long time.

(v) **Diakinesis**

(a) Terminalization completes.

(b) Nuclear membrane and nucleolus degenerates.

(c) Chromosome recondense and tetrad moves to the metaphase plate.

(d) Formation of spindle.

(e) Bivalents are irregularly and freely scattered in the nucleocytoplasmic matrix.

When the diakinesis of prophase-I is completed than cell enters into the metaphase-I.

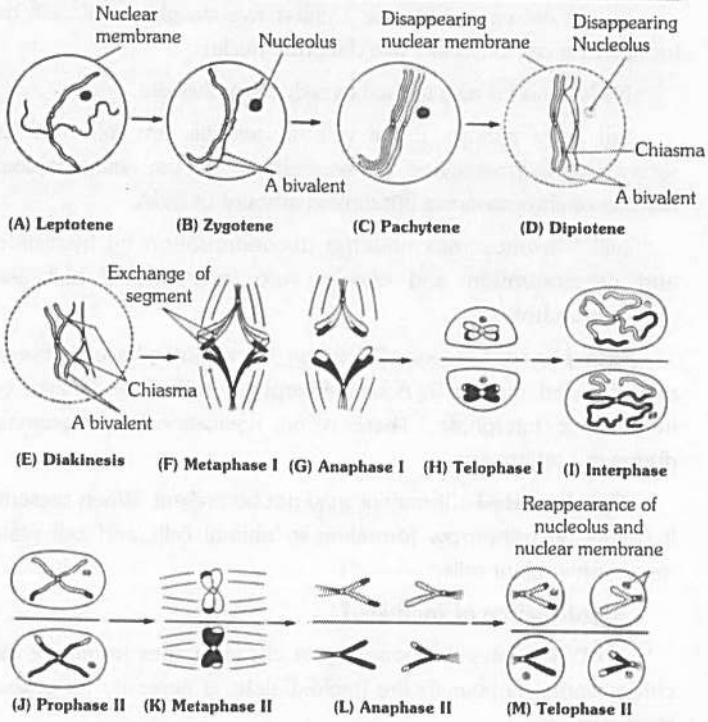



**Fig : 3.3-5 Different stages of meiotic cell division (meiosis)**

(2) **Metaphase-I**

(i) Chromosome come on the equator.

(ii) Bivalents arrange themselves in two parallel equatorial or metaphase plates. Each equatorial plate has one genome.

(iii) Centromeres of homologous chromosomes lie equidistant from equator and are directed towards the poles while arms generally lie horizontally on the equator.

(iv) Each homologous chromosome has two kinetochores and both the kinetochores of a chromosome are joined to the chromosomal or tractile fibre of same side.

(3) **Anaphase-I**

(i) It involves separartion of homologous chromosomes which start moving opposite poles so each tetrad is divided into two daughter dyads. So anaphase-I involves the reduction of chromosome number, this is called *disjunction*.

(ii) The shape of separating chromosomes may be rod or J or V-shape depending upon the position of centromere.

(iii) Segregation of Mendelian factors or independent assortment of chromosomes take place. In which the paternal and maternal chromosomes of each homologous pair segregate during anaphase-I which introduces genetic variability.

(4) **Telophase-I**

(i) Two daughter nuclei are formed but the chromosome number is half than the chromosome number of mother cell.

(ii) Nuclear membrane reappears.

(iii) After telophase I cytokinesis may or may not occur.

(iv) At the end of Meiosis I either two daughter cells will be formed or a cell may have two daughter nuclei.

(v) Meiosis I is also termed as reduction division.

(vi) After meiosis I, the cells in animals are reformed as secondary spermatocytes or secondary oocytes; with haploid number of chromosomes but diploid amount of DNA.

(vii) Chromosomes undergo decondensation by hydration and despiralization and change into long and thread like chromation fibres.

**Interphase :** Generally there is no interphase between meiosis-I and meiosis-II. A brief interphase called interkinesis, or intrameiotic interphase. There is no replication chromosomes, during this interphase.

**Cytokinesis-I :** It may or may not be present. When present, it occurs by cell-furrow formation in animal cells and cell plate formation in plant cells.

**Significance of meiosis-I**

(1) It separates the homologous chromosomes to reduce the chromosome number to the haploid state, a necessity for sexual reproduction.

(2) It introduces variation by forming new gene combinations through crossing over and random assortment of paternal and maternal chromosomes.

(3) It induces the cells to produce gametes for sexual reproduction or spores for asexual reproduction.

**Meiosis-II :** It is also called equational or homotypical division because the number of chromosomes remains same as after meiosis-I. It is of shorter duration than even typical mitotic division. It is also divisible into two parts, Karyokinesis-II and Cytokinesis-II.

**Karyokinesis-II :** It involves the separation of two chromatids of each chromosome and their movement to separate cells. It is divided in four phases *i.e.*, Prophase-II, Metaphase-II. Anaphase-II and Telophase-II.

Almost all the changes of Karyokinesis-II resembles to mitosis which involves.

(1) It starts just after end of telophase I.

(2) Each daughter cell (nucleus) undergoes mitotic division.

(3) It is exactly similar to mitosis.

(4) At the end of process, cytokinesis takes place.

(5) Four daughter cells are formed after completion.

(6) The sister kinetochores of one chromosome are separated.

(7) The four daughter cells receive one chromatid each of the tetravalent.

(8) Centromere split at anaphase II.

(9) Spindle fibres contract at prophase II.

**Cytokinesis-II :** It is always present and occurs by cell furrow formation in animal cell and cell plate formation in plant cell.

So by meiosis, a diploid parental cell divides twice forming four haploid gametes or sex cells, each having half the DNA amount than that of the parental cell and one-fourth of DNA present in the cell at the time of beginning of meiosis.

**Significance of meiosis-II**

(1) Constancy of chromosome number in successive generation is brought by process.

(2) Chromosome number becomes half during meiosis.

(3) It helps in introducing variations and mutation.

(4) It brings about gamete formation.

(5) It maintains the amount of genetic informative material.

(6) Sexual reproduction includes one meiosis and fusion.

(7) The four daughter cells will have different types of chromatids.

**Types of meiosis**

(1) **Gametic/Terminal meiosis :** In many protozoans, all animals and some lower plants, meiosis takes place before fertilization during the formation of gametes. Such a meiosis is described as gametic or terminal.

(2) **Zygotic or Initial meiosis :** In fungi, certain protozoan groups, and some algae fertilization is immediately followed by meiosis in the zygote, and the resulting adult organisms are haploid. Such a meiosis is said to be zygotic or initial. This type of life cycle with haploid adult and zygotic meiosis is termed the haplontic cycle.

(3) **Sporogenetic / Intermediate meiosis**

(i) Diploid sporocytes or spore mother cells of sporophytic plant, undergo meiosis to form the haploid spores in the sporangia.

(ii) Haploid spore germinates to form haploid gametophyte which produces the haploid gametes by mitosis.

(iii) Haploid gametes fuse to form diploid zygote which develops into diploid sporophyte by mitotic divisions. *e.g.*, In higher plants like pteridophytes, gymnosperms and angiosperms.

**Table : 3.3-2**

**Where does meiosis take place in different plant**

| Plant | Stage at which meiosis occurss |
|---|---|
| *Chlamydomonas* (alga) | In zygote |
| *Ulothrix* (alga) | In zygospore |
| *Spirogyra* (alga) | In zygospore |
| *Rhizopus* or Bread mould (fungus) | In zygospore |
| *Saccharomyces* or Yeast (fungus) | During formation of ascospores in ascus mother cell or ascus |
| *Riccia. Marchantia, Funaria,* etc. (Bryophytes) | In spore mother cell inside capsule of sporophyte. |
| Ferns (Pteridophytes) | In spore mother cell inside sporangium |
| Gymnosperms (*e.g., Cycas, Pinus,* etc.) | In microspore mother cells and megaspore mother cells inside |
| Angiosperms (Wheat, pea, etc.) | Microsporangia and megasporangia during formation of microspores (pollens) and megaspores. |

**Table : 3.3-3**

**Differences between Mitosis and Meiosis**

| Mitosis | Meiosis |
|---|---|
| **General** | |
| This division takes place in all kinds of cells and may continue throughout life. | It usually occurs in reproductive cells just before formation of gametes or spores in the life cycle of a plant |
| Nucleus undergoes a single division at the completion of division cycle. Similar is the case with chromosomes. | Nucleus undergoes two divisions, first is reductional while second is equational, at the completion of division cycle, while the chromosomes divide only once, *i.e.*, in anaphase II. |
| Two daughter cells are formed at the end of mitosis | Four daughter cells are formed at end. |
| The chromosome no. remains constant in daughter cells like parent cell, *i.e.*, daughter cells are **genetically identical** to parent cell. | The chromosome no. is reduced to half in daughter cells as compared to parent cells, *i.e.*, daughter cells are **genetically different** from parent cell. |
| Mitosis is much shorter. | Meiosis is much longer. |
| Mitosis may occur in diploid or haploid cells. | Meiosis always occurs in diploid cells (meiocytes). |
| **Prophase** | |
| Prophase is short and is without sub-stages. | Prophase 1 is prolonged with 5 different sub-stages as leptotene, zygotene, pachytene, diplotene and diakinesis. |
| There is no pairing of homologous chromosomes (synapsis) and hence no chance of **crossing over** and **chiasmata formation.** | Homologous chromosomes pair during **zygotene sub-stage** of prophase 1 and often **undergo crossing over** and hence **forming chiasmata.** |
| No synaptonemal complex (SC) is formed between chromosomes. | Synaptonemal complex (tripartite protein framework) is formed between pairing homologous chromosomes. |
| The chromosomes are longitudinally split into two sister chromatids during early prophase, *i.e.*, prophase chromosomes appear double from the very begining. | The chromosomes are **not longitudinally split** but appear as single thread, *i.e.*, prophase I chromosomes do not appear double in the beginning. |
| Chromosomes do not unfold and there is **no transcription** and **protein synthesis** in prophase. | Chromosomes unfold and there may occur transcription and protein synthesis during **diplotene** sub-stage of prophase I. |
| **Metaphase** | |
| All chromosomes form a single plate in metaphase. | Chromosomes form 2 parallel plates in metaphase I and one plate in metaphase II. |
| On equatorial plate, chromosomes appear two threaded. | On equatorial plate, chromosomes appear four threaded in metaphase I, while metaphase II is similar to metaphase of mitosis. |
| **Anaphase** | |
| Splitting of centromere of chromosomes and hence separation of 2 chromatids of each chromosome occurs at anaphase. | There is no splitting of centromeres in anaphase I and there is separation of homologous chromosomes in anaphase I. In anaphase II, splitting of centromeres and hence separation of chromatids occurs. |
| **Telophase** | |
| Telophase occurs in all cases. | In some cases, telophase I is omitted. |
| Daughter cells have same number of chromosomes as parent cell. | At the end of telophase I, chromosome number is reduced to half. |
| **Cytokinesis** | |
| **Karyokinesis** (division of nucleus) is usually followed by **cytokinesis** (wall formation). | Sometimes cytokinesis does not occur after telophase I or meiosis. I but it **always occurs** after meiosis II or telophase II, thus forming 4 cells simultaneously. |
| **Significance** | |
| Mitosis is responsible for growth, repair and healing. | Meiosis is responsible for maintaining chromosomes number constant from generation to generation, forms gametes or spores and also produces variations due to crossing over. |

## Tips & Tricks

- Interkinesis : Stage between meiosis I and meiosis II.
- Mitosis index is the ratio of dividing and non-dividing cells.
- Karyochoriosis : A type of mitosis in fungi in which is intranuclear nucleus divides by furrow formation.
- In mitosis, plectonemic coiling takes place, in which sister chromatids are tightly coiled upon each other and are not easily separable. Paranemic coiling found in meiosis.
- Brachymeiosis : Failure of meiosis-II. It is characteristic feature of fungi.
- Chiasmata first observed by Janssens (1909).
- To study mitosis root tips are fixed in 1: 3 acetic acid and methanol.
- Mitotic crossing over takes place in parasexual cycle.
- Cell cycle duration – 20 minutes in bacteria, 20 hours in root tip of onion. 2-3 hrs in yeast, 24- hrs man.

# OT Ordinary Thinking

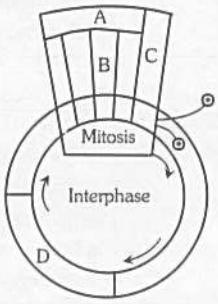
## Objective Questions

### Cell division

**1.** The term "meiosis" was coined by
(a) Hertwig and Van Bevedin
(b) Sutton and Boveri
(c) Hofmeister and Waldeyer
(d) Farmer and Moore

**2.** Coiling of chromatids in mitotic and meiotic division is **[MP PMT 2002]**
(a) Paranemic in both
(b) Plectonemic in both
(c) Paranemic in mitosis and plectonemic in meiosis
(d) Plectonemic in mitosis and paranemic in meiosis

**3.** Given below is a schematic break-up of the phases/stages of cell cycle




Which one of the following is the correct indication of the stage/phase in the cell cycle **[CBSE PMT 2009]**
(a) B-Metaphase (b) C-Karyokinesis
(c) D-Synthetic phase (d) A-Cytokinesis

**4.** Condensation of chromosomes occurs in **[AFMC 2002]**
(a) Prophase I (b) Prophase II
(c) Anaphase (d) Metaphase

**5.** Find the correctly matched pairs and choose the correct option

| | | |
|---|---|---|
| A. Leptotene | – | The chromosomes become invisible |
| B. Zygotene | – | Pairing of homologous chromosomes |
| C. Pachytene | – | Dissolution of the synaptonemal complex takes place |
| D. Diplotene | – | Bivalent chromosomes appear as tetrads |
| E. Diakinesis | – | Terminalization of chiasmata takes place |

**[AFMC 1995; Odisha JEE 2012; Kerala PMT 2012]**
(a) A and B are correct (b) B and D are correct
(c) B and E are correct (d) B and C are correct
(e) C and D are correct

**6.** The role of meiosis **[AFMC 2002]**
(a) Formation of gametes (b) Bringing haplophase
(c) Bringing diplophase (d) Completing life cycle

**7.** Which of the following events are not characteristic features of telophase
A. Chromosome material condenses to form compact mitotic chromosomes
B. Nucleolus, Golgi complex and ER reform
C. Nuclear envelope assembles around the chromosome clusters
D. Centromeres split and chromatids separate
E. Chromosomes cluster at opposite, spindle poles and their identity as discrete elements is lost **[Kerala PMT 2012]**
(a) A, B and D only (b) A and D only
(c) B and C only (d) C, D and E only
(e) A and B only

**8.** Which stage connecting link between Meiosis I and Meiosis II **[AFMC 2002; Kerala PMT 2011]**
(a) Interphase I (b) Interphase II
(c) Interkinesis (d) Anaphase I

**9.** Which of the following stage is affected by colchicum **[BVP 2001; AFMC 2002; Pb. PMT 2004; Odisha JEE 2011]**

**Or**

Spindle apparatus is formed during which stage of mitosis **[AFMC 1999]**
(a) Metaphase (b) Prophase
(c) Interphase (d) Anaphase

**10.** "$G_0$" state of cells in eukaryotic cell cycle denotes **[AIEEE Pharmacy 2003]**
(a) Check point before entering the next phase
(b) Pausing in the middle of a cycle to cope with a temporary delay
(c) Death of a cell
(d) Exit of cells from cell cycle

**11.** Three copies of chromosome – 21 in a child with Down's syndrome have been formed analysed using molecular biology technology to detect any possible DNA polymorphism with reference to different alleles located on chromosome – 21. Results showed that out of 3 copies 2 of the chromosomes of the child contain the same alleles as one of the mother's alleles. Based on this when did the non-disjunction event most likely occur **[KCET 2015]**
(a) Paternal meiosis – I (b) Maternal meiosis – I
(c) Paternal meiosis – II (d) Maternal meiosis – II

**12.** Mitosis occurs in **[RPMT 2002]**
(a) Haploid individuals (b) Diploid individuals
(c) Both (a) and (b) (d) In bacteria only

**13.** Which is not true for anaphase **[Odisha JEE 2004]**
(a) Golgi body and ER are reformed
(b) Chromosomes move to opposite poles
(c) Spindle poles move farther apart
(d) Centromeres split and chromatids separate

**14.** Cyclin is associated with which one of the following **[BHU 2000]**

**Or**

Diploid living organism develops from zygote by repeated cell divisions is called **[J & K C CET 2005]**
(a) Glycolysis (b) Cyclosis
(c) Haemolysis (d) Mitosis

**15.** For viewing diakinesis which one of the following would be a suitable material **[MP PMT 2002]**
(a) Onion root tip (b) Leaf of Dichanthium
(c) Rat tail (d) Flower bud

**16.** Which is not the character of mitosis **[MP PMT 2000]**
(a) Leptotene (b) Zygotene
(c) Pachytene (d) All of the above

**17.** Synaptonemal complex is formed during **[CBSE PMT 2001]**
(a) Meiosis (b) Amitosis
(c) Mitosis (d) Cytokinesis

**18.** Synaptonemal complex was discovered in **[BHU 2000]**
(a) 1956 (b) 1950
(c) 1935 (d) 1980

**19.** Recombinant nodules are found during which of the following **[BHU 2000]**
(a) Anaphase (b) Prophase
(c) Telophase (d) Metaphase

**20.** Four daughter cells formed after meiosis are **[MP PMT 2001]**
(a) Genetically similar (b) Genetically different
(c) Anucleate (d) Multinucleate

**21.** The term synaptonemal complex refers to site of **[BHU 2012]**
(a) Chromatid separation
(b) Spindle attachment
(c) Replication
(d) Chromosome alignment and recombination

**22.** Repulsion of homologous chromosomes takes place in **[MP PMT 2001]**
(a) Zygotene (b) Leptotene
(c) Diakinesis (d) Diplotene

**23.** Which cell division is found during cleavage **[RPMT 2001]**
(a) Amitosis (b) Mitosis
(c) Closed mitosis (d) Meiosis

**24.** A stage in mitosis that starts towards the middle of anaphase and is completed with the telophase is **[AFMC 2012]**

**Or**

Division of cytoplasm after completion of nuclear division is called **[MP PMT 2012]**
(a) Cytokinesis (b) Karyokinesis
(c) Crossing over (d) Interkinesis

**25.** How many ATP is required during anaphase to move chromosomes from equator to the poles **[BHU 2000]**
(a) 38 ATP (b) 5 ATP
(c) 30 ATP (d) 76 ATP

**26.** Mitosis is the process by which eukaryotic cells **[Pune CET 1998; CBSE PMT 2000; BHU 2000]**
(a) Expose the genes for protein synthesis
(b) Become specialized in structure and function
(c) Multiply
(d) Grow

**27.** In pachytene stage of meiosis the chromosomes appear **[MP PMT 1994; BHU 2002; Kerala PMT 2010]**
(a) Single stranded (b) Double stranded
(c) Three stranded (d) Four stranded

**28.** Microtubule depolymerizing drug such as colchicine is expected to **[AIIMS 2012]**
(a) Inhibit spindle formation during mitosis
(b) Inhibit cytokinesis
(c) Allow mitosis beyond metaphase
(d) Induce formation of multiple contractile rings

**29.** Recombination of genes occur at **[J & K CET 2002]**
(a) Prophase in mitosis (b) Prophase I in meiosis
(c) Prophase II in meiosis (d) Metaphase II in meiosis

**30.** The second division in meiosis is called **[KCET 1998]**
(a) Equational division (b) Reduction division
(c) Multiplied division (d) None of the above

**31.** Which stages of cell division do the following figures A and B represent respectively **[NCERT; CBSE PMT (Pre.) 2010]**


A


B

(a) Prophase – Anaphase
(b) Metaphase – Telophase
(c) Telophase – Metaphase
(d) Late Anaphase – Prophase

**32.** Select correct option

| | I | | I |
|---|---|---|---|
| (A) | Synapsis aligns homologous chromosomes | (i) | Anaphase-II |
| (B) | Synthesis of RNA and protein | (ii) | Zygotene |
| (C) | Action of enzyme recombinase | (iii) | $G_2$-phase |
| (D) | Centromeres do not separate but chromatids move towards opposite poles | (iv) | Anaphase-I |
| | | (v) | Pachytene |

**[AIPMT (Cancelled) 2015]**

| | (A) | (B) | (C) | (D) |
|---|---|---|---|---|
| (a) | (ii) | (iii) | (v) | (iv) |
| (b) | (i) | (ii) | (v) | (iv) |
| (c) | (ii) | (iii) | (iv) | (v) |
| (d) | (ii) | (i) | (iii) | (iv) |

**33.** Which of the following statements is incorrect about $G_0$ phase **[AIIMS 2012]**
(a) Mitosis occurs after $G_0$ phase
(b) Biocatalysts can be used to exit $G_0$ phase
(c) Cell volume keeps on increasing during this phase
(d) Cell metabolism occurs continuously in $G_0$ phase

**34.** A somatic cell that has just completed the S-phase of its cell cycle, as compared to gamete of the same species, has **[AIPMT (Cancelled) 2015]**

(a) Same number of chromosomes but twice the amount of DNA

(b) Twice the number of chromosomes and four times the amount of DNA

(c) Four time the number of chromosomes and twice the amount of DNA

(d) Twice the number of chromosomes and twice the amount of DNA

**35.** Arrange the following events of meiosis in correct sequence

(A) Crossing over

(B) Synapsis

(C) Terminalisation of chiasmata

(D) Disappearance of nucleolus **[AIPMT 2015]**

(a) (B), (A), (C), (D) (b) (A), (B), (C), (D)

(c) (B), (C), (D), (A) (d) (B), (A), (D), (C)

**36.** In Which stage of meiosis crossing over takes place **[Odisha JEE 2009]**

(a) Prophase - 1 (b) Prophase

(c) Metaphase (d) Anaphase

**37.** Beads on string like structures of **A** are seen in **B,** which further condense to form chromosomes in **C** stage of cell division. What are **A, B** and **C** **[AIIMS 2012]**

| | A | B | C |
|---|---|---|---|
| (a) | Chromonema | Chromatin | Metaphase |
| (b) | Chromatin | Chromatid | Metaphase |
| (c) | Chromonema | Chromosome | Anaphase |
| (d) | Chromonema | Chromatid | Anaphase |

**38.** The best stage to count the number of chromosomes during mitosis is or structure of chromosomes can be best seen at **[CPMT 2000; BHU 2001; CBSE PMT 2004; J & K CET 2008; MP PMT 2010]**

**Or**

In which phase of mitosis the chromosomes are arranged around the equator of the spindle **[Manipal MEE 1995; CPMT 1998; Kerala CET 2002; BVP 2002; RPMT 2005; MP PMT 2009]**

(a) Prophase (b) Metaphase

(c) Anaphase (d) Telophase

**39.** In 'S' phase of the cell cycle **[CBSE PMT 2014]**

(a) Chromosome number is increased

(b) Amount of DNA is reduced to half in each cell

(c) Amount of DNA doubles in each cell

(d) Amount of DNA remains same in each cell

**40.** Homologous pairing in prophase I of meiosis I is called **[MP PMT 2005]**

(a) Synapsis (b) Linkage

(c) Crossing over (d) Syndesis

**41.** In meiosis, the centromere divides during **[MP PMT 1996, 97, 2001, 11; CBSE PMT 2000; BVP 2002]**

(a) Prophase-I (b) Metaphase-I

(c) Anaphase-I (d) Anaphase-II

**42.** During interphase, RNA and proteins are synthesized in **[MP PMT 1997]**

(a) *S* phase

(b) $G_1$ phase

(c) $G_2$ phase

(d) In both $G_1$ and $G_2$ phases

**43.** Four chromatids and two centromeres which are homologous occurs in **[CPMT 1995]**

(a) Zygotene (b) Diplotene

(c) Diakinesis (d) Pachytene

**44.** The number of chromosome groups at the equatorial plate in metaphase–I of meiosis in a plant with $2n = 50$ shall be **[MP PMT 1995, 98]**

(a) 50 (b) 25

(c) 30 (d) 100

**45.** The significance of meiosis lies in **[NCERT; MP PMT 1995, 98; BVP 2003]**

(a) Reduction of the diploid number of chromosomes to haploid

(b) Maintaining constancy in the number of diploid chromosomes during sexual reproduction

(c) Production of genetic variability in the population of a species

(d) All the above

**46.** During which phase(s) of cell cycle amount of DNA in a cell remains at 4C level if the initial amount is denoted as 2C **[CBSE PMT 2014]**

(a) Only $G_2$ (b) $G_2$ and M

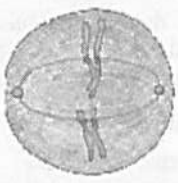
(c) $G_0$ and $G_1$ (d) $G_1$ and S

**47.** The given figure represent a sequence in cell division

The missing stage in the above sequence is **[NCERT]**

(a) 

(b) 

(c) 

(d) 

**48.** Identify the meiotic stage in which the homologous chromosomes separate while the sister chromatids remain associated at their centromeres **[NCERT; Odisha JEE 2009; CBSE PMT (Mains) 2012; PET (Pharmacy) 2013]**

**Or**

In which stage of meiosis homologous chromosomes are segregated **[WB JEE 2016]**

(a) Metaphase I (b) Metaphase II

(c) Anaphase I (d) Anaphase II

**49.** Which phase comes in between the $G_1$ and $G_2$ phase of cell cycle **[WB JEE 2010]**

**Or**

The formation of chromatid takes place in **[Odisha JEE 2011]**

(a) M-phase (b) $G_0$ – phase

(c) S-phase (d) Interphase

**50.** During mitosis ER and nucleolus begin to disappear at **[AFMC 1996; CBSE PMT (Pre.) 2010]**

(a) Early prophase (b) Late prophase

(c) Early metaphase (d) Late metaphase

**51.** Match List I and List II and select the correct answer using the code given below in the lists :

| List I (Phase of meiosis) | | List II (Event that occurs) |
|---|---|---|
| 1. | Prophase I | Crossing over occurs |
| 2. | Metaphase I | Sister chromatids migrate to opposite poles |
| 3. | Anaphase I | Homologous line up at equator in pairs |

**Code** **[MP PMT 1993]**

(a) 1, 2 and 3 are correct

(b) 1 and 2 are correct, 3 is false

(c) 1 is correct, 2 and 3 are false

(d) 1 and 3 are correct, 2 is false

**52.** Chromosome number is halved in meiosis during **[NCERT; RPMT 2006]**

(a) Metaphase-I (b) Anaphase-I

(c) Metaphase-II (d) Telophase-I

**53.** Yeast cell can progress through the cell cycle in about **[NCERT; AMU (Med.) 2012]**

(a) 30 minutes (b) 60 minutes

(c) 90 minutes (d) 120 minutes

**54.** Normal cellular activities, such as protein synthesis occur primarily during **[Pune CET 1998]**

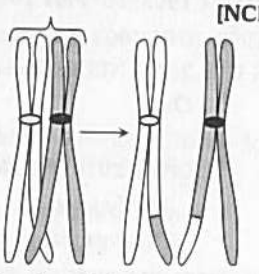
**Or**

Chromosome replicate in which stage of meiosis **[MP PMT 1994; BHU 2002; WB JEE 2008; Odisha JEE 2008]**

(a) Interphase (b) Anaphase

(c) Metaphase (d) Prophase

**55.** Given below is the representation of a certain event at a particular stage of a type of cell division. Which is this stage **[NCERT; CBSE PMT (Pre.) 2012]**



(a) Prophase I during meiosis

(b) Prophase II during meiosis

(c) Prophase of Mitosis

(d) Both prophase and metaphase of mitosis

**56.** In mitosis the movement of chromosomes requires **[CPMT 1993]**

(a) Presence of centromere (b) Plasmalemma

(c) Spindle fibres (d) Nucleotides

**57.** DNA replication occurs during **[MDAT Bihar 1995; MP PMT 2005; Odisha JEE 2010]**

**Or**

The replication of centrioles occurs during **[MP PMT 1994; BHU 2004; WB JEE 2016]**

**Or**

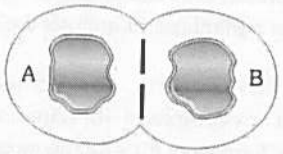
$G_1$, $G_2$ and S phases are seen in which phase of the cell cycle **[AFMC 2009]**

(a) Prophase (b) Metaphase

(c) Anaphase (d) Interphase

(e) Leptotene

**58.** The given diagram shows a cell




Which of the following statements related to the image is not correct **[NCERT]**

(a) The nuclear envelope is disappearing

(b) The cell furrow is forming

(c) It is an animal cell

(d) It is in telophase

**59.** Meiosis is found at **[MP PMT 2005]**

(a) Shoot apex (b) Reproductive part

(c) Leaves bud (d) Vegetative parts

**60.** During cell division, sometimes there will be failure of separation of sister chromatids. This event is called **[Kerala PMT 2004; WB JEE 2016]**

(a) Interference (b) Complementation

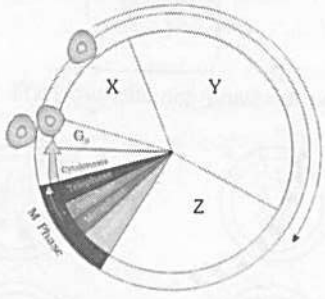
(c) Coincidence (d) Non-disjunction

**61.** If a cell has a chromosome number after first meiosis equal to 48. The chromosome number in the daughter cells after the completion of meiosis will be **[BHU 2001]**

(a) 48 (b) 24

(c) 12 (d) 36

**62.** The given diagram is of a typical cell cycle




Identify the parts labelled as X, Y and Z **[NCERT]**

(a) X - $G_1$; Y - $G_2$; Z - $G_0$ (b) X - $G_0$; Y - S; Z - $G_2$

(c) X - $G_2$; Y - S; Z - $G_1$ (d) X - $G_1$; Y - S; Z - $G_2$

**63.** Chiasmata formation takes place during **[CPMT 1994, 2004; RPMT 1995; MP PMT 2002, 03, 06, 11; AMU (Med.) 2010]**

(a) Prophase I (Diplotene) (b) Metaphase I
(c) Anaphase II (d) Telophase I

**64.** The given figure represents various stages of cell division. Identify them **[NCERT]**


(a) A - Metaphase I, B - Prophase, C - Anaphase
(b) A - Metaphase I, B - Prophase I, C - Anaphase I
(c) A - Metaphase, B - Prophase I, C - Anaphase I
(d) A - Metaphase, B - Prophase I, C - Anaphase

**65.** During the first metaphase of meiosis the centromeres **[MP PMT 1994]**

(a) Undergo division (b) Do not divide
(c) Divide but do not separate (d) Are not identical

**66.** During gamete formation, the enzyme recombinase participates during **[NCERT; CBSE PMT (Pre) 2012; CBSE PMT 2014]**

(a) Metaphase - I (b) Anaphase - II
(c) Prophase – I (Pachytene) (d) Prophase - II

**67.** Which of the following is unique to mitosis and not a part of meiosis **[DUMET 2009]**

(a) Homologous chromosomes behave independently
(b) Chromatids are separated during anaphase
(c) Homologous chromosomes pair and form bivalents
(d) Homologous chromosomes crossover

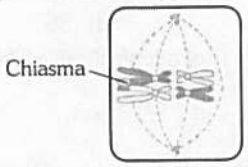
**68.** The protein for spindle fibre is **[AIIMS 2001; WB JEE 2011; Odisha JEE 2011]**

(a) Myosin (b) Actin
(c) Troponin (d) Myoglobin

**69.** 56 cells are produced in meiosis in which **[Odisha JEE 2011]**

(a) First division is reductional (b) First division is equational
(c) Second division is reductional (d) None of these

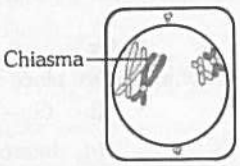
**70.** The given diagram of a cell undergoing meiosis, indicated that crossing over occurs only at the chiasma



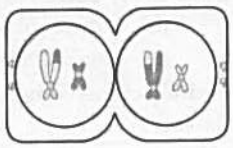
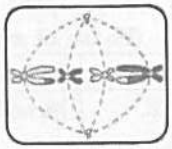

Which of the following gametes will NOT be formed from this cell **[NCERT]**

(a)  (b) 
(c)  (d) 

**71.** The given diagram shows a cell undergoing meiosis




Which diagram shows the next stage in the process **[NCERT]**

(a)  (b) 
(c)  (d) 

**72.** The process of mitosis is divided into 4 phases. Identify the correct order in which these phases appear in mitosis **[MP PMT 1993]**

(a) Anaphase, metaphase, telophase and prophase
(b) Telophase, anaphase, metaphase and prophase
(c) Metaphase, prophase, anaphase and telophase
(d) Prophase, metaphase, anaphase and telophase

**73.** Meiosis and mitosis differ from each other because in meiosis **[CPMT 1993]**

(a) The four nuclei formed are not similar to parental ones
(b) Homologous chromosomes pair are exchange parts
(c) Number of chromosomes gets halved
(d) All the above

**74.** Cell division is initiated by **[CBSE PMT 1993]**

(a) Centrosome (b) Centriole
(c) Centromere (d) Chromomere

**75.** "Endomitosis" refers to

(a) Division of nucleus without chromosomal division
(b) Division of chromosome without nuclear division
(c) Division of cytoplasm
(d) None of the above

**76.** The homologous chromosomes follow the process of synapsis in the stage **or** Pairing of homologous chromosome takes place in **[DPMT 1995; MP PMT 1996, 99, 2011; RPMT 1997; BHU 2003; Haryana PMT 2005; J & K CET 2010; NEET (Karnataka) 2013]**

**Or**

During which stage of meiosis, synaptonemal complex is formed **[CPMT 2010; Odisha JEE 2011]**

(a) Leptotene (b) Zygotene
(c) Diplotene (d) Pachytene

**77.** At metaphase, chromosomes are attached to the spindle fibres by their **[NCERT; Manipal 2005; CBSE PMT (Mains) 2011; NEET (Karnataka) 2013]**

(a) Kinetochores (b) Centromere
(c) Satellites (d) Secondary constrictions

**78.** The process of mitosis can be studied in **[CPMT 1998, 2009; MHCET 2001; CBSE PMT 2002]**
(a) Onion root tip (b) Garlic root tip
(c) Tendril tip (d) All of the above

**79.** Exchange of chromosome segments between maternal and paternal chromatids during meiosis is called **[CBSE PMT 2000]**

**Or**

In meiosis the daughter cells are not similar to that of parent because of **[AFMC 2005]**
(a) Linkage (b) Dominance
(c) Crossing over (d) DNA multiplication

**80.** Mitotic stages are not observed in **[KCET 2011]**
(a) *Cosmarium* (b) *E.coli*
(c) *Saccharomyces* (d) *Chlorella*

**81.** Period of active mitosis ranges from
(a) 10 minutes to a few hours (b) A few hours to a one day
(c) One day to a week (d) Less than a minute

**82.** Which is synthesized in $G_1$ phase **[CPMT 2004]**
(a) DNA polymerase (b) Histones
(c) Nucleolar DNA (d) Tubulin protein

**83.** How many meiotic divisions will be necessary to produce two hundred pollen grains **[MP PMT 1999]**
(a) 50 (b) 100
(c) 199 (d) 150

**84.** Prophase of reduction division is divided into number of stages. The correct chronological sequence is **[CMC Vellore 1993; CPMT 1996, 2000; KCET 1999; Odisha PMT 2002; HP PMT 2005]**
(a) Leptotene — pachytene — zygotene — diplotene — diakinesis
(b) Leptotene — diplotene — pachytene — zygotene — diakinesis
(c) Leptotene — zygotene — diplotene — pachytene — diakinesis
(d) Leptotene — zygotene — pachytene — diplotene — diakinesis

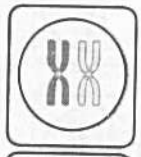
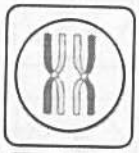
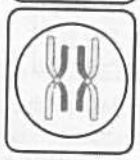
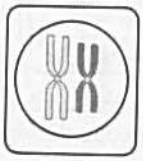
**85.** What is the correct sequence of the steps given here? Also work out the process depicted in the steps
i. Homologous chromosomes move toward opposite poles of the cell; chromatids do not separate
ii. Chromosomes gather together at the two poles of the cell and the nuclear membranes reform
iii. Homologous chromosomes pair and exchange segments
iv. Homologous chromosomes align on a central plate
v. The haploid cells separate completely **[AIIMS 2009]**
(a) The correct sequence is III → IV → I → II → V and the process is meiosis-I
(b) The correct sequence is II → I → V → IV → III and the process is mitosis
(c) The correct sequence is IV → I → III → II → V and the process is meiosis-I
(d) The correct sequence is II → V → IV → I → II and the process is mitosis

**86.** Regarding the sequence of cell cycle, which one is correct **[NCERT; MP PMT 1998; AIIMS 1999; CPMT 2002; RPMT 2005; WB JEE 2008, 12]**
(a) $G_1$, $G_2$, $S$ and $M$ (b) $S$, $G_1$, $G_2$, and $M$
(c) $G_1$, $S$, $G_2$ and $M$ (d) $G_2$, $S$, $G_1$, and $M$

**87.** If we ignore the effect of crossing over, how many different haploid cells arise by meiosis in a diploid cell having $2n=12$ **[AFMC 2006]**
(a) 8 (b) 16
(c) 32 (d) 64

**88.** In which of the following stage, the chromosome is thin and like long thread **[NCERT; AFMC 1997; MP PMT 2011; AMU (Med.) 2012]**
(a) Leptotene (b) Zygotene
(c) Pachytene (d) Diakinesis

**89.** Which figure correctly represents a pair of homologous chromosomes at the start of meiosis **[NCERT]**

(a) 
(b) 
(c) 
(d) 

**90.** Diploid cells have **[DUMET 2009]**
(a) Two chromosomes
(b) One set of chromosomes
(c) Two pairs of homologous chromosomes
(d) Two sets of chromosomes

**91.** Calcium dependent kinases can control **[AIIMS 2010]**
(a) Cell cycle activities (b) DNA replication
(c) Cell surface receptors (d) Membrane structure

**92.** $G_2$ phase of mitosis takes **[BVP 2003]**
(a) 50% time of cell cycle (b) 25 to 33% time of cell cycle
(c) 12 to 16% time of cell cycle (d) 4% time of cell cycle

**93.** Study the following lists

| List-I | | List-II | |
|---|---|---|---|
| (A) | Initiation of spindle fibres | (I) | Anaphase-I |
| (B) | Synthesis of RNA and protein | (II) | Zygotene |
| (C) | Action of endonuclease | (III) | $G_1$ phase |
| (D) | Movement of sister chromatids towards opposite poles | (IV) | Pachytene |
| | | (V) | Anaphase-II |

**[NCERT; AFMC 1995; Pb. PMT 2004; BHU 2005; CPMT 2009; EAMCET 2009]**

The correct match is

| | A | B | C | D |
|---|---|---|---|---|
| (a) | II | III | IV | V |
| (b) | III | II | I | V |
| (c) | I | III | V | IV |
| (d) | V | III | I | II |

**94.** What is not seen during mitosis in somatic cells **[DPMT 2006; NEET (Phase-I) 2016]**

(a) Spindle fibres
(b) Chromosome movement
(c) Disappearance of nucleolus
(d) Synapsis

**95.** The given figure shows a cell undergoing in Prophase I

Keeping the diagram in view which of the following diagram is correct for one of the cell at the end of meiosis **[NCERT]**

(a) 
(b) 
(c) 
(d) 

**96.** The microtubules from opposite poles of the spindle get attached to the kinetochores of sister chromatids in **[AMU (Med.) 2009]**

**Or**

At what phase of meiosis are there two cells, each with sister chromatids aligned at the spindle equator **[Pune CET 1998; BHU 1999]**

(a) Prophase II (b) Metaphase II
(c) Anaphase II (d) None of these

**97.** Prophase is longer in **[Manipal MEE 1995; CPMT 2001; MHCET 2001; WB JEE 2011]**

(a) Mitosis (b) Meiosis
(c) Equal in both (d) Amitosis

**98.** Which of the following characters is related with telophase **[MP PMT 2009]**

(a) Formation of nuclear membrane
(b) Formation of nucleolus
(c) Elongation of chromosome
(d) Formation of two daughter nuclei

**99.** In which stage of cell division chromosomes are most condensed **[WB JEE 2009; AIIMS 2010]**

(a) Prophase (b) Metaphase
(c) Anaphase (d) Telophase

**100.** Which of the following event takes place during Diplotene stage of prophase I of meosis **[DUMET 2010]**

(a) Compaction of chromosomes
(b) Formation of synaptonemal complexes
(c) Formation of recombinational nodules
(d) Dissolution of synaptonemal complex

**101.** The term "mitosis" was proposed by **[MP PMT 2011]**

(a) Flemming (b) Farmer
(c) Moore (d) Boveri

**102.** Root cells of wheat has $2n = 42$ chromosomes. Which one of the following is the basic chromosome number of wheat **[WB JEE 2010]**

(a) 42 (b) 21
(c) 7 (d) 14

**103.** Which of the following structure will not be common to mitotic cell of a higher plant **[CBSE PMT 1997]**

(a) Cell plate (b) Centromere
(c) Centriole (d) Spindle fibre

**104.** How many mitotic divisions are needed for a single cell to make 128 cells **[CBSE PMT 1997; AFMC 1999, 2002; Odisha JEE 2010]**

(a) 7 (b) 14
(c) 28 (d) 32

**105.** Which one of the following forms the spindle apparatus during cell division **[Kerala CET 2002]**

(a) Chromosome (b) Centrosome
(c) Ribosome (d) Chondriosome

**106.** During cell division in apical meristem nuclear membrane reappears in **[CBSE PMT 1997]**

(a) Interphase (b) Telophase
(c) Prophase (d) S phase

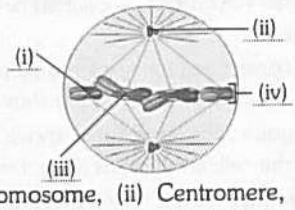
**107.** Cell in $G_0$ phase of cell cycle **[WB JEE 2009]**

(a) Exit cell cycle (b) Enter cell cycle
(c) Suspend cell cycle (d) Terminate cell cycle

**108.** How many reduction divisions are necessary for the formation of 200 grains of wheat **[MHCET 2002]**

(a) 250 (b) 150
(c) 200 (d) 360

**109.** See the following figure and identify marked lines (i), (ii), (iii) and (iv) **[NCERT]**




(a) (i) Chromosome, (ii) Centromere, (iii) Centriole, (iv) Chromatid
(b) (i) Chromatid, (ii) Centromere, (iii) Centriole, (iv) Chromosome
(c) (i) Chromosome, (ii) Centriole, (iii) Centromere, (iv) Chromatid
(d) (i) Chromatid, (ii) Centriole, (iii) Centromere, (iv) Chromosome

**110.** The non-sister chromatids twist around and exchange segments with each other during **or** In meiosis crossing over is initiated at **[Kerala PMT 2009; WB JEE 2011; NEET (Phase-I) 2016]**

(a) Diplotene (b) Diakinesis
(c) Leptotene (d) Pachytene
(e) Zygotene

**111.** During mitosis chromosomes go to their poles in a stage called **[CPMT 1994; MP PMT 2001; DPMT 2003; BHU 2004]**

**Or**

The shape of chromosome is clearly visible at **[Odisha JEE 2009]**

(a) Prophase (b) Metaphase
(c) Anaphase (d) Telophase

**112.** The number of mitotic cell division required to produce 256 cells from single cell would be **[KCET 2007]**

(a) 10 (b) 12
(c) 6 (d) 8

**113.** DNA replication takes place in **[MP PMT 2009; AFMC 2010; WB JEE 2016]**

**Or**

DNA molecule of each chromosome become double in **[NCERT; CPMT 1996, 2001, 10; MP PMT 1994, 99, 2001, 02, 06, Kashmir MEE 1995; CBSE PMT 1996, 2001; RPMT 1997; Pb. PMT 1999; Kerala PMT 2006]**

**Or**

DNA and histone proteins are synthesized during the following phase of cell cycle **[DPMT 2004; CBSE PMT 2005; NEET (Phase-II) 2016]**

(a) $G_1$ phase (b) $G_2$ phase
(c) S phase (d) Mitotic phase

**114.** During the meiotic division the **[BHU 2005]**

(a) Homologous chromosomes are separated
(b) The linkage is disturbed
(c) The homologous chromosomes do not segregate
(d) All of the above

**115.** The number of chromosomes after I phase of meiotic division in reduction division **[CPMT 1994]**

(a) Remain unchanged (b) Become doubled
(c) Become halved (d) None of the above

**116.** Meiosis can be observed in **[MP PMT 1992, 96; CPMT 1994; WB JEE 2008]**

(a) Root tips (b) Cambium
(c) Anther (PMC) (d) Pollen grains

**117.** Select the correct match

| | | | |
|---|---|---|---|
| A. | *S* phase | - | *DNA* replication |
| B. | Zygotene | - | Synapsis |
| C. | Diplotene | - | Crossing over |
| D. | Meiosis | - | Both haploid and diploid cells |
| E. | Gap 2 phase | - | Quiescent stage |

**[Kerala PMT 2011]**

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

**118.** During meiosis, the alleles of the parental pair separate or segregate from each other. How many allele(s) are then transmitted to a gamete **[Kerala PMT 2011]**

(a) Four (b) Two
(c) Six (d) One
(e) Eight

**119.** In meiosis *I*, a bivalent is an association of **[NCERT; Kerala PMT 2007]**

(a) Four chromatids and four centromeres
(b) Two chromatids and two centromeres
(c) Two chromatids and one centromere
(d) Two chromatids and four centromeres
(e) Four chromatids and two centromeres

**120.** Cell division can not be stopped in which phase of the cell cycle **[WB JEE 2010]**

(a) $G_1$ – phase (b) $G_2$ – phase
(c) $S$ – phase (d) Prophase

**121.** Cell plate is referred as **[MP PMT 1994; MHCET 2001; JIPMER 2002; Odisha JEE 2004]**

(a) Germplast (b) Idioblast
(c) Phragmoplast (d) Middle lamella

**122.** In which phase proteins for spindle fibre formation are synthesized **[Odisha JEE 2004]**

(a) $G_1$ phase (b) $G_2$ phase
(c) S-phase (d) Anaphase

**123.** Karyokinesis differ from cytokinesis because it involves **[MP PMT 1994, 2003]**

(a) Division of cytoplasm
(b) Division of the nucleus and cytoplasm
(c) Division of the nucleus
(d) Division of the cell

**124.** Differentiated cell arrests at which stage **[DPMT 2007]**

(a) $G_1$ (b) $H_2$
(c) $G_0$ (d) $U$

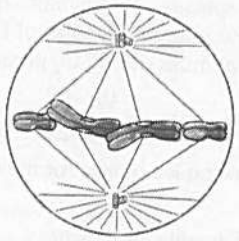
**125.** The nuclear membrane disappears in **[CPMT 1993; MP PMT 1995, 98; J & K CET 2002]**

(a) Metaphase (b) Early prophase
(c) Late prophase (d) Anaphase

**126.** Chromonemata start associating into bivalent chromosomes during **[MP PMT 1997; J & K CET 2002]**

(a) Zygotene (b) Leptotene
(c) Pachytene (d) Diplotene

**127.** Select the correct option with respect to mitosis



**[CBSE PMT (Pre.) 2011; NEET (Karnataka) 2013]**

(a) Chromosomes move to the spindle equator and get alingned along equatorial plate in metaphase
(b) Chromatids separate but remain in the centre of the cell in anaphase
(c) Chromatids start moving towards opposite poles in telophase
(d) Golgi complex and endoplasmic reticulum are still visible at the end of prophase

**128.** Which one of the following precedes re-formation of the nuclear envelope during *M* phase of the cell cycle **[NCERT; CBSE PMT 2004; AIIMS 2008]**

(a) Formation of the contractile ring, and formation of the phragmoplast
(b) Formation of the contractile ring, and transcription from chromosomes
(c) Decondensation of chromosomes, and reassembly of the nuclear lamina
(d) Transcription from chromosomes, and ressembly of the nuclear lamina

**129.** In an organism, if the normal diploid number of chromosomes is 8, how many chromatids are present in each daughter cell at the end of meiosis I **[MP PMT 1993]**

(a) 2 (b) 4
(c) 8 (d) 16

**130.** In eukaryotic cell cycle, cell fusion experiments show that **[AIEEE Pharmacy 2004]**

(a) When an S-phase cell is fused with a $G_1$-phase cell, $G_1$-phase cell is stimulated to synthesize DNA
(b) When an S-phase cell is fused with a $G_2$-phase cell, DNA synthesis is induced in $G_2$-phase cell.
(c) When a $G_1$-phase cell is fused with a $G_2$-phase cell, DNA synthesis is induced in both $G_1$ and $G_2$ phase cells
(d) When a $G_1$-phase cell is fused with an M-phase cell both $G_1$ and *M* phase cells are stimulated to synthesise DNA

**131.** The points at which crossing over has taken place between homologous chromosomes are called **[Pune CET 1998; BHU 2001]**

**Or**

Visible expression of the genetic phenomenon of crossing over is called **[KCET 2012]**

(a) Protein axis (b) Synaptonemal complexes
(c) Chiasmata (d) Centromeres

**132.** How many meiotic division would be required to produce 101 female gametophytes in an angiosperm **[Pb. PMT 1997]**

(a) 101 (b) 26
(c) 127 (d) None of these

**133.** Mitotic spindle have main protein **[BHU 2006; MP PMT 2007]**

(a) Tubulin (b) Myosin
(c) Tropomyocin (d) Dynein

**134.** Cells of certain species of animals have six pairs of chromosomes. How many molecules of DNA will remain in a nucleus of these animals during $G_2$ phase **[WB JEE 2016]**

(a) 12 (b) 48
(c) 6 (d) 24

**135.** Which of the following is not true for meiosis **[WB JEE 2016]**

(a) Production of genetic variability
(b) Maintaining constancy of chromosome number during sexual reproduction
(c) Reduction of chromosome number to one half
(d) Production of diploid cell

**136.** Which of the following is used as the mitotic spindle poison **[WB JEE 2016]**

(a) $Ca^{++}$ (b) $Mg^{++}$
(c) Tubulin (d) Colchicine

**137.** Progression of cell cycle is regulated by the concentration of which type of molecule **[WB JEE 2016]**

(a) Centrosomes (b) Cyclin-dependent kinases
(c) Cyclins (d) Microtubules

**138.** When cell has stalled DNA replication fork, which checkpoint should be predominantly activated **[NEET (Phase-II) 2016]**

(a) Both $G_2$/M and M (b) $G_1$/S
(c) $G_2$/M (d) M

**139.** Match the stages of meiosis in **Column-I** to their characteristic features in **Column-II** and select the correct option using the codes given below **[NEET (Phase-II) 2016]**

| **Column-I** | **Column-II** |
|---|---|
| (A) Pachytene | (i) Pairing of homologous chromosomes |
| (B) Metaphase I | (ii) Terminalization of chiasmata |
| (C) Diakinesis | (iii) Crossing-over takes place |
| (D) Zygotene | (iv) Chromosomes align at equatorial plate |

| **Codes** | **(A)** | **(B)** | **(C)** | **(D)** |
|---|---|---|---|---|
| (a) | (iv) | (iii) | (ii) | (i) |
| (b) | (iii) | (iv) | (ii) | (i) |
| (c) | (i) | (iv) | (ii) | (iii) |
| (d) | (ii) | (iv) | (iii) | (i) |

**140.** Anaphase promoting Complex (APC) is a protein degradation machinery necessary for proper mitosis of animal cells. If APC is defective in a human cell, which of the following is expected to occur **[NEET 2017]**

(a) Chromosomes will not condense
(b) Chromosomes will be fragmented
(c) Chromosomes will not segregate
(d) Recombination of chromosome arms will occur

**141.** Which of the following options gives the correct sequences of events during mitosis **[NEET 2017]**

(a) Condensation → nuclear membrane disassembly → crossing over → segregation → telophase
(b) Condensation → nuclear membrane disassembly → arrangement at equator → centromere division → segregation → telophase
(c) Condensation → crossing over → nuclear membrane disassembly → segregation → telophase
(d) Condensation → arrangement at equator → centromere division → segregation → telophase

## NCERT Exemplar Questions

**1.** Select the correct statement about G 1 phase **[NCERT]**

(a) Cell is metabolically inactive
(b) DNA in the cell does not replicate
(c) It is not a phase of synthesis of macromolecules
(d) Cell stops growing

**2.** At which stage of meiosis कबमे the genetic constitution of gametes is finally decided **[NCERT]**
(a) Metaphase I (b) Anaphase II
(c) Metaphase II (d) Anaphase I

**3.** Meiosis occurs in organisms during **[NCERT]**
(a) Sexual reproduction
(b) Vegetative reproduction
(c) Both sexual and vegetative reproduction
(d) None of the above

**4.** During anaphase-I of meiosis **[NCERT]**
(a) Homologous chromosomes separate
(b) Non-homologous autosomes separate
(c) Sister chromatids separate
(d) Non-sister chromatids separate

**5.** Mitosis is characterised by **[NCERT]**
(a) Reduction division
(b) Equal division
(c) Both reduction and equal division
(d) None of the above

**6.** Identify the wrong statement about meiosis **[NCERT]**
(a) Pairing of homologus chromosomes
(b) Four haploid cells are formed
(c) At the end of meiosis the number of chromosomes are reduced to half
(d) Two cycle of DNA replication occurs

**7.** Cells which are not dividing are likely to be at **[NCERT]**
(a) G 1 (b) G 2
(c) G o (d) S phase

**8.** Which of the events listed below is not observed during mitosis **[NCERT]**
(a) Chromatin condensation
(b) Movement of centrioles to opposite poles
(c) Appearance of chromosomes with two chromatids joined together at the centromere.
(d) Crossing over

## CT Critical Thinking

### Objective Questions

**1.** Pick out the correct statements
(A) Mitosis takes place in the somatic cells and meiosis takes place in the germ cells
(B) During mitosis, the DNA replicates once for one cell division and in meiosis the DNA replicates twice for two cell divisions
(C) Mitosis and meiosis occur both in sexually and asexually reproducing organisms **[Kerala PMT 2008]**
(a) (A) only (b) (B) only
(c) (C) only (d) (A) and (B) only
(e) (B) and (C) only

**2.** The number of DNA in chromosome at $G_2$ stage of cell cycle **[RPMT 2002]**
(a) One (b) Two
(c) Four (d) Eight

**3.** While working in a lab, a student forgot to add colchicine while karyotyping through blood culture technique, Then what will happen **[GUJCET 2014]**
(a) Mitosis will be arrested at metaphase
(b) Chromosomal division will continue and each chromosome will have four arms
(c) Chromosomal division will continue
(d) Mitosis will be arrested at telophase

**4.** Which one of the following pairs is correctly matched **[MP PMT 1993]**
(a) Anaphase I – Homologous chromosomes are separated
(b) Metaphase I – Pairing of maternal and paternal homologous chromosomes takes place
(c) Interphase – A nuclear envelope encloses each haploid set of chromosomes
(d) Prophase I – Non-homologous chromosomes are separated

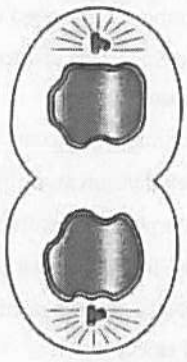
**5.** Chromosome start separating at which stage of mitosis **[AFMC 1996]**
(a) Early metaphase (b) Late metaphase
(c) Early anaphase (d) Early telophase

**6.** The number of chromatids in a chromosome at anaphase is **[CBSE PMT 1992; BHU 1994; AFMC 1995]**
(a) 2 in mitosis and 1 in meiosis
(b) 1 in mitosis and 2 in meiosis
(c) 2 each in mitosis and meiosis
(d) 2 in mitosis and 4 in meiosis

**7.** The major event that occurs during the anaphase of mitosis, which brings about the equal distribution of chromosomes, is **[KCET 2006]**
(a) Replication of the genetic material
(b) Splitting of the chromatids
(c) Splitting of the centromeres
(d) Condensation of the chromatin

**8.** In the somatic cell cycle **[CBSE PMT 2004]**
(a) A short interphase is followed by a long mitotic phase
(b) $G_2$ phase follows mitotic phase
(c) In $G_1$ phase DNA content is double the amount of DNA present in the original cell
(d) DNA replication takes place in S-phase

**9.** A stage in cell division is shown in the figure. Select the answer which gives correct identification of the stage with its characteristics



**[NEET 2013]**

| | | |
|---|---|---|
| (a) | Telophase | Endoplasmic reticulum and nucleolus not reformed yet |
| (b) | Telophase | Nuclear envelop reforms, Golgi complex reforms |
| (c) | Late anaphase | Chromosomes move away from equatorial plate, Golgi complex not present |
| (d) | Cytokinesis | Cell plate formed, mitochondria distributed between two daughter cells |

**10.** Meiosis takes place in **[NEET 2013]**
(a) Megaspore (b) Meiocyte
(c) Conidia (d) Gemmule

**11.** The complex formed by a pair of synapsed homologous chromosomes is called **[NEET 2013]**
(a) Axoneme (b) Equatorial plate
(c) Kinetochore (d) Bivalent

**12.** DNA replication in bacteria occurs **[NEET 2017]**
(a) During S phase (b) Within nucleolus
(c) Prior to fission (d) Just before transcription

## 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 : Synthesis of DNA takes place in the S-phase of interphase.
Reason : Every chromosome, during metaphase, has two chromatids. **[KCET 2010]**

**2.** Assertion : Reduction division occurs in anaphase-I. So there is no need of meiosis.
Reason : Meiosis-II occurs to separate homologous chromosomes. **[AIIMS 2009]**

**3.** Assertion : Karyokinesis occurs in M-phase.
Reason : Cell division stops in M-phase.

**4.** Assertion : Interphase is resting stage.
Reason : The interphase cell is metabolically inactive.

**5.** Assertion : DNA synthesis occurs in $G_1$ and $G_2$ periods of cell cycle.
Reason : During $G_1$ and $G_2$ phase the DNA contents become double.

**6.** Assertion : Mitosis maintains the genetic similarity of somatic cells.
Reason : Chromosomes do not undergo crossing over.

**7.** Assertion : Chiasmata is formed during diplotene.
Reason : Chiasmata are formed due to deposition of nucleoproteins.

**8.** Assertion : During zygotene, chromosomes show bivalent stage.
Reason : Bivalent is half the number of chromosomes.

**9.** Assertion : Meiosis takes place in pollen mother cells.
Reason : Each pollen mother cell produce 4 haploid pollen grains. **[AIIMS 1996]**

**10.** Assertion : Meiotic division results in the production of haploid cells.
Reason : Synapsis occurs during zygotene of meiosis. **[AIIMS 1998]**

## Answers

### Cell division

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | d | 2 | d | 3 | c | 4 | a | 5 | c |
| 6 | b | 7 | b | 8 | c | 9 | a | 10 | d |
| 11 | d | 12 | c | 13 | a | 14 | d | 15 | d |
| 16 | d | 17 | a | 18 | a | 19 | b | 20 | b |
| 21 | d | 22 | d | 23 | c | 24 | a | 25 | c |
| 26 | c | 27 | d | 28 | a | 29 | b | 30 | a |
| 31 | d | 32 | a | 33 | a | 34 | b | 35 | a |
| 36 | a | 37 | a | 38 | b | 39 | c | 40 | a |
| 41 | d | 42 | d | 43 | a | 44 | b | 45 | d |
| 46 | a | 47 | c | 48 | c | 49 | c | 50 | a |
| 51 | c | 52 | b | 53 | c | 54 | a | 55 | a |
| 56 | c | 57 | d | 58 | a | 59 | b | 60 | d |
| 61 | a | 62 | d | 63 | a | 64 | b | 65 | b |
| 66 | c | 67 | a | 68 | b | 69 | a | 70 | a |
| 71 | c | 72 | d | 73 | d | 74 | a | 75 | b |
| 76 | b | 77 | a | 78 | d | 79 | c | 80 | b |
| 81 | a | 82 | a | 83 | a | 84 | d | 85 | a |
| 86 | c | 87 | d | 88 | a | 89 | a | 90 | d |
| 91 | a | 92 | c | 93 | a | 94 | d | 95 | c |
| 96 | b | 97 | b | 98 | d | 99 | b | 100 | d |
| 101 | a | 102 | c | 103 | c | 104 | a | 105 | b |
| 106 | b | 107 | c | 108 | a | 109 | d | 110 | d |
| 111 | c | 112 | d | 113 | c | 114 | a | 115 | c |
| 116 | c | 117 | a | 118 | d | 119 | e | 120 | c |
| 121 | c | 122 | a | 123 | c | 124 | c | 125 | c |
| 126 | a | 127 | a | 128 | c | 129 | c | 130 | b |
| 131 | c | 132 | a | 133 | a | 134 | d | 135 | d |
| 136 | d | 137 | b | 138 | b | 139 | b | 140 | c |
| 141 | b | | | | | | | | |

## NCERT Exemplar Questions

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | b | 2 | d | 3 | a | 4 | a | 5 | a |
| 6 | d | 7 | c | 8 | d | | | | |

## Critical Thinking

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

## Assertion and Reason

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | a | 2 | b | 3 | d | 4 | c | 5 | d |
| 6 | a | 7 | c | 8 | b | 9 | a | 10 | a |

# AS Answers and Solutions

## Cell division

**4.** (a) Condensation of chromosomes occurs in the prophase-I. After that chromosome moves toward the poles.

**6.** (b) The most important role of meiosis is to maintain haploid phase.

**9.** (a) Colchicine is obtained from colchicum autumnale plant, which inhibits the formation of spindle fibers in metaphase.

**10.** (d) When cells are not to divide after $G_1$ phase and start undergoing differentiation into specific types of cells such cells are said to be in $G_0$ phase/$G_0$ state.

**14.** (d) Cyclin is a protein, which participates in cell division.

**15.** (d) Diakinesis is the stage of meiosis. For the study of meiosis young flower bud is the best material.

**16.** (d) Leptotene, zygotene, pachytene, diplotene and diakinesis all are successive stages of meiosis.

**17.** (a) Synaptonemal complex is formed during meiotic prophase first.

**18.** (a) Synaptonemal complex is formed in meiotic prophase-I, which was first observed by Moses in 1956.

**19.** (b) Knot like structure 'Chromomeres' found in the stage leptotene of prophase first of meiosis.

**20.** (b) During meiosis, daughter cells has the half number of chromosomes with respect to parent cells. Therefore daughter cell will be genetically different.

**22.** (d) In meiosis, crossing over takes place in pachytene, after that chromosome get repulsion in diplotene.

**23.** (c) During cleavage, cell divides mitotically without taking any gap, so that is known as closed mitosis.

**27.** (d) During the pachytene, chromosomes get crossed with each other and forms a four stranded or tetrad appearance.

**29.** (b) The crossing over of homologous chromosome occurs in Pachytene of prophase first of meiosis. It is known as recombination.

**34.** (b) Gamete is haploid while somatic cell is diploid. After S-phase it will contain twice the number of chromosomes and four times the amount of DNA.

**35.** (a) In prophase I of meiosis I, the correct sequence of events are
B – synapsis in Zygotene
C –crossing over in pachytene in diakinesis
D – disappearance of nucleolus in diakinesis

**38.** (b) Because in metaphase, chromosomes are present in bivalent form on equator. Chromosomes are much condense and well visible.

**39.** (c) S or synthesis phase marks the period where DNA synthesis takes place. During this time the amount of DNA per cell doubles.

**41.** (d) In meiosis II division is equational division; thus centromere divides and chromatid move towards the pole during anaphase-II.

**44.** (b) One chromosome forms one chromosome group in metaphase-I after splitting of tetravalent condition.

**46.** (a) In M=phase, both 4C and 2C of DNA are present in different stages.

**49.** (c) The sequence of interphase (I-Phase) is $G_1 \rightarrow S \rightarrow G_2$.

**55.** (a) Diagrame first represents crossing over that takes place in pachytene stage of prophase I during meiosis.

**56.** (c) Because they are thread like structures, which contract to pull the chromosome towards pole.

**57.** (d) Because interphase is the growth phase of cell. Centrioles replicate in $G_2$ of interphase of cell cycle but some authors reported this duplication in early prophase.

**66.** (c) Crossing over is an enzyme-mediated process and the enzyme involved is called recombinase.

**73.** (d) All the above; four nuclei formed are not similar to parent ones because they are haploid in nature. Homologous chromosome pairs are exchange parts because in crossing over exchange of chromatid arms takes place and number of chromosomes gets halved.

**76.** (b) In zygotene of prophase of meiosis, chromosomes pairing occurs for crossing over.

**83.** (a) Because one cell produces 4 daughter cells after meiotic division, thus 50 cells produce $50 \times 4 = 200$ daughter cells.

**85.** (a) III-Prophase, IV-Metaphase, I-Anaphase (I), II-Telophase (I), V-Telophase (III)

**87.** (d) The number of different haploid cells arise by meiosis can be calculated by $2^n$
$n$ = number of haploid chromosome.

**88.** (a) Leptotene is a stage in the prophase I of meiosis. In this stage chromosome appears thin and long.

**91.** (a) Calcium Dependent Kinases (CDKs) have the ability to control cell cycle activities during cell division.

**94.** (d) Synapsis is the pairing of homologous chromosomes during zygotene stage of prophase I of meiotic division-I. The homologous chromosomes come from the mother and father.

**102.** (c) For wheat, $2n = 6x = 42$.

$\therefore x = 7$

'x' represents basic or genomic number.

**103.** (c) Centrioles are organelles important in spindle formation during nuclear division. These are found commonly in most animal cells and some lower plant cells.

**104.** (a) A single mitotic division results in the production of two cells from a single one.

**108.** (a) For the formation of 100 grains of wheat 100 pollen grains and 100 megaspores are required. Each microspore mother cell produces 4 microspores (pollen grains) as a result of reduction division. Hence for the formation of 100 pollen grains, $\frac{100}{4} = 25\ PMC$ are needed and each will undergo one reduction division. Each megaspore mother cell will produce 4 megaspores in which one become functional and other three degenerate. Thus each MMC produces one megaspore. So 100 MMC are required to produce 100 megaspores.

Total number of reduction divisions to produce 100 grains is 100 + 25 = 125.

**112.** (d) Mitotic cells division is equational division where a mother cell divides to form 2 daughter cells. So to produce 256 cells from a single cell, 8 mitotic divisions will occur which can be represented as $1 \rightarrow 2 \rightarrow 4 \rightarrow 8 \rightarrow 16 \rightarrow 32 \rightarrow 64 \rightarrow 128 \rightarrow 256$.

**115.** (c) Because first phase of meiosis includes reduction division while second phase exhibits mitotic divisions.

**116.** (c) As a result of it pollen grains formed.

**120.** (c) The check points are basically present in the interphase.

**126.** (a) Pairing between the homologous chromosomes takes place in zygotene stage of prophase-I.

**129.** (c) Because each chromosome bears two chromatids and at the end of meiosis–I chromosome number becomes halved *i.e.*, 4 and number of chromatids are $4 \times 2 = 8$.

**134.** (d) $G_1 \rightarrow 6$ pairs or 12 chromosomes or 12 chromatids or 12 DNA molecules. After S or $G_2 \rightarrow 6$ pairs or 12 chromosomes or 24 chromatids or 24 DNA molecules.

**135.** (d) As a result of meiosis only haploid cells are produced.

**136.** (d) Spindle depolymerization is caused by Colchicine.

**138.** (b) DNA replication occurs in S-phase of cell cycle.

## Critical Thinking

**2.** (b) The duplication of DNA takes place in 'S' stage of interphase after that cell reaches in $G_2$ phase. That is why the strand of DNA in $G_2$ phase will be two.

**3.** (c) In absence of colchicines mitotic division will be continued in normal way.

**8.** (d) In the somatic cell cycle S-phase is a stage of replication of each chromosome by synthesis of a new DNA molecule on the template of existing DNA.

## Assertion and Reason

**1.** (a)

**2.** (b) Anaphase-I involves separation of homologous chromosomes into different daughter cells. So, meiosis I is a reductional division. But each chromosome is still formed of two sister chromatids joined at the common centromers. Anaphase-I results in reduction in number of chromosomes but each chromosome has double amount of DNA, so, meiosis-II occurs, during, which chromatids of each chromosome separate into different cells. Main aim of meiosis II is to separate genetically modified chromatids of each homologous chromosome formed during crossing over in meiosis-I

**3.** (d) M-phase represents the phase of actual division. It consists of karyokinesis (The division of nucleus) followed by cytokinesis (The division of cytoplasm). Cell divisions stop after M-phase.

**4.** (c) Previously interphase is called resting stage because there is no apparent activity related to cell division. The interphase cell is metabolically quite active. Interphase consist of three subphases ($G_1$, $G_2$ and S). Synthesis of DNA occurs in S phase. $G_1$ is the period between the end of mitosis and the start of S phase. $G_2$ is the interval between S phase and start of mitosis. As the synthesis of DNA occurs in S phase so it is considered as metabolically active phase.

**5.** (d) The synthesis of DNA occurs only in a restricted portion of the interphase during S period, which is preceded and followed by two "gap" periods of interphase ($G_1$ and $G_2$) in which there is no DNA synthesis. $G_1$ is the period between the end of mitosis and the start of DNA synthesis. S is the period of DNA synthesis and $G_2$, the interval between the end of DNA synthesis and the start of mitosis. During $G_2$ a cell contains two times (4C) the amount of DNA present in the original diploid cell (2C). Following mitosis the daughter cell again enter the $G_1$ period and have a DNA content equivalent to 2C.

**6.** (a) Mitosis keeps all the somatic cells of an organism genetically similar, resembling the fertilized egg. Mitosis involves replication and equitable distribution of all the chromosomes so that all the cells of a multicellular organism have the same number and type of chromosomes. This helps in proper co-ordination among different cells.

**7.** (c) The points of attachment between the homologous chromosomes after the partial dissolution of nucleoprotein complex are called chiasmata. It occurs during diplotene substage of prophase I.

**8.** (b) During zygotene, because of the pairing of the homologous, the nucleus contains half the number of chromosomes. Each unit is a bivalent composed of two homologous chromosomes.

**9.** (a) Meiosis occurs in pollen mother cells. All pollen mother cells are diploid and produce haploid pollen grains after meiosis.

**10.** (a) Diploid cell produce haploid cell by meiosis. It occurs due to synapsis. A chromosome has two chromatids, hence a bivalent has 4 chromatids.

# Cell Cycle and Cell Division

## SET Self Evaluation Test

1. Bivalents in meiosis are **[RPMT 2001]**
   (a) Tetrad
   (b) Pairs of non-homologous chromosomes
   (c) Pairs of several chromatids
   (d) Pairs of homozygous chromosomes

2. Which type of cell division occurs in the gonads **[RPMT 2001]**
   (a) Mitosis only (b) Meiosis
   (c) Both (a) and (b) (d) Amitosis and meiosis

3. The spindle fibre contracts in **[KCET 1998]**
   (a) Metaphase I (b) Anaphase II
   (c) Prophase II (d) Telophase II

4. If there were 4 chromosomes present during prophase, how many chromosomes are there in each cell at the end of anaphase II **[Pune CET 1998]**
   (a) 16 (b) 4
   (c) 2 (d) 8

5. Which is not characteristic of meiosis **[AIIMS 2011]**
   (a) Two stages of DNA replication, first before meiosis I and second before meiosis II
   (b) Recombination and crossing over
   (c) Sister chromatids separate during anaphase II
   (d) Nuclear membrane disappears towards end of prophase

6. Cell division in blue-green algae is more or less similar to that in **[MP PMT 1994]**
   (a) Red algae (b) Green algae
   (c) Brown algae (d) Bacteria

7. Which out of the following is not a divisional stage
   (a) Telophase (b) Interphase
   (c) Metaphase (d) Prophase

8. Crossing over is advantageous because it brings about
   (a) Variation (b) Linkage
   (c) Inbreeding (d) Stability

9. Cellular structure always disappears during mitosis is
   (a) Cell wall (b) Cell membrane
   (c) Nucleolus (d) All the above

10. Anastral mitosis is found in **[MHCET 2001]**
    (a) Animals (b) Higher plants
    (c) Bacteria (d) Cyanobacteria

* * *

## AS Answers and Solutions

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | a | 2 | c | 3 | b | 4 | c | 5 | a |
| 6 | d | 7 | b | 8 | a | 9 | c | 10 | b |

1. (a) Bivalent formation occurs in pachytene of meiosis, In this stage, two chromatids of homologous chromosome (Bivalent) later on forms a cross and now showing a tetravalent or tetrad stage.

2. (c) Mitosis and meiosis both type of cell division occurs in gonads. Mitosis during growth and development and meiosis during gametogenesis.