Biomolecules

Quick Revision

- Living organisms are made up of elements like carbon, hydrogen, oxygen and several others.
- All the carbon compounds that we get from living tissues can be called as **biomolecules**.
- Living tissues also contain inorganic elements and compounds. If this tissue is fully burnt, all the carbon compounds will get oxidised to gaseous form (e.g. CO_2, water vapour) and are thus removed. The remaining is called 'ash' which contains inorganic elements (like calcium, magnesium, etc).
- Water is the most abundant chemical, found in living organisms about 70-90% of total cellular mass.
- The biomolecules are of two types, i.e. small micromolecules with simple structures and large macromolecules with complex structures.

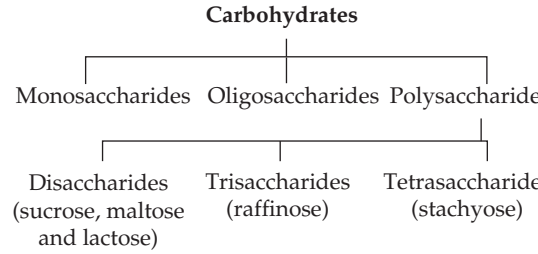
Biomicromolecules

- These are with low molecular weight (18-800 Da), highly soluble and have simple molecular conformation.
- These include inorganic compounds, i.e. water, minerals and gases, as well as organic compounds, *viz* sugars (monosaccharides and disaccharides), lipids, amino acids and nucleotides.

1. Carbohydrates (Saccharides)

- About 3% of the total cell content is made up of carbohydrates. These are biomolecules consisting of C, H and O atoms.
- The carbon forms chains or rings with two or more hydroxyl groups and an aldehyde or ketone group, forming aldoses or ketoses. They have a general formula, $C_nH_{2n}O_n$.

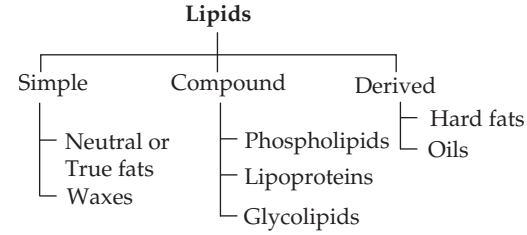
These are of following types



- Reducing sugars possess free aldehyde or ketone group and can reduce cupric ions of Benedict's or Fehling's solution to cuprous ions, e.g. lactose.
- Non-reducing sugars do not possess free aldehyde or ketone groups and cannot reduce cupric ions of Benedict's or Fehling's solution to cuprous ions, e.g. sucrose.

2. Lipids

- These are esters of fatty acids and alcohol, form 2% of the cell contents. Important lipids are as follows



Fatty Acids

- These are water insoluble long chain hydrocarbons (4-36 carbon long) with one carboxyl (–COOH) group. These are the simplest constituents of lipids.
- There are two types of fatty acid chains as follows
  - **Saturated fatty acids** ($C_n H_{2n}O_{2n}$) These do not possess any double bond in their hydrocarbon chain and are solid at room temperature. These have high melting point, e.g. lauric acid (12 C), palmitic acid (16 C), stearic acid (18 C), arachidic acid (20 C), etc.
  - **Unsaturated fatty acids** ($C_nH_{2n-2x}O_2$) These possess one or more double bonds in their hydrocarbon chain and are liquid at room temperature due to the presence of double bond in them. These have low melting points, e.g. oleic acid (18 C), linoleic acid (18 C), etc.

3. Amino Acids

- These are organic compounds containing an amino group and an acidic group as a substituent on the same carbon, i.e. the α carbon. Hence, they are called **α-amino acids**.
- They are substituted methanes. There are four substituent groups occupying the four valency positions → hydrogen, carboxyl group, amino group and a variable group designated as *R* group.
- Based on the nature of *R* group, there are many amino acids. However, 20 amino acids occur in protein.
- General formula is

$$NH_2—\underset{\displaystyle R}{\underset{|}{CH}}—COOH$$

Classification of Amino Acids

Amino acids can be classified as follows

- **On the basis of synthesis in living organism**, amino acids are classified into following three categories
  - **Essential amino acids** cannot be synthesised by any organism in the body and are to be obtained from dietary sources.
  - **Non-essential amino acids** can be synthesised by an organism and thus, is not required as dietary component.
  - **Semi-essential amino acids** required essentially by an organism during particular phase of body growth and lactation period (in pregnant mothers).
- **On the basis of chemical nature**, amino acids are as follows
  - **Neutral** (contains one amino group and one carboxyl group), e.g. glycine (simple amino acid), alanine, valine, leucine and isoleucine.
  - **Acidic** (contains additional carboxylic group), e.g. aspartic acid, glutamic acid, aspargine and glutamine.
  - **Basic** (contains additional amino group), e.g. arginine and lysine.
- In a neutral solution, the amino acid molecules exist as a dipolar **zwitter ion**, i.e. a molecule containing both positive and negative ionic groups.

4. Nucleotides and Nucleosides

- These are five types of nitrogenous bases, i.e. adenine, guanine (both purines), cytosine, thymine and uracil (pyrimidines). When these bases found attached to a sugar they are called **nucleosides**. If a phosphate group is also found esterified to the sugar they are called **nucleotides**.
- Adenosine, guanosine, thymidine, uridine and cytidine are nucleosides.
- Adenylic acid, thymidylic acid, guanylic acid, uridylic acid and cytidylic acid are nucleotides. Nucleic acids like DNA and RNA consist of nucleotides only.

Primary and Secondary Metabolites

Metabolites are organic biomolecules present in cells and used in metabolic reactions.

- **Primary metabolites** These are found in animal tissue and are directly involved in normal growth, reproduction and development of animals, e.g. amino acids, proteins, etc.
- **Secondary metabolites** These are generally found in plant, fungal and microbial cells as a byproduct of major metabolic reactions, e.g. rubber, essential oils, antibiotics, etc. These are ecologically important, but role or functions of all secondary metabolites are not known yet.

Biomacromolecules

- These are large in size with higher molecular weight, i.e. above 10,000 daltons.
- These molecules (i.e. polymers) are formed by linking number of micromolecules called **monomers**, e.g. proteins, polysaccharides, nucleic acids and lipids (lipids are not strictly macromolecules).

1. Proteins

- These are polypeptides. These are long chain of amino acids joined by peptide bond. Each protein is a heteropolymer of amino acids.
- In a polypeptide, the first amino acid is called as N-terminal amino acid. The last amino acid is called the C-terminal amino acid.

Some Proteins and their Functions

Proteins	Functions
Collagen	Intercellular ground substance
Trypsin	Enzyme
Insulin	Hormone
Antibody	Fight infections against
Receptors	Sensory reception (smell, taste, hormone, etc.)
GLUT-4	Enables glucose transport into cells

- Collagen is the most abundant protein in the animal world.
- Ribulose Bisphosphate Carboxylase-Oxygenase (RuBisCO), is the most abundant protein in the whole of biosphere.

Structural Level of Proteins

There are four structural levels in proteins

- **Primary structure** The sequence of amino acids, i.e. the positional information in a protein, which is the first amino acids, which is second and so on is called the primary structure.
  - Protein is imagined as a line in which the left end is represented by the first amino acid also called as **N-terminal amino acid**.
  - Right end represented by last amino acid also called as **C-terminal amino acid**.
  - A protein thread does not exist throughout as an extended rigid rod.
  - The thread is folded in the form of a helix. Some portions are folded as helix.
- **Secondary structure** There are three types of secondary structures, i.e. α-**helix**, β-**pleated sheet** and **collagen helix**. The turns of helices and sheets are attached by hydrogen bond.
- **Tertiary structure** Long protein chain is folded upon itself like a hollow woolen ball, giving rise to tertiary structure. It is stabilised by several types of bonds, i.e. hydrogen bonds, ionic bonds, i.e. van der Waals interaction, covalent bonds and hydrophobic bonds. It gives 3 D conformation to protein molecule.
- **Quaternary structure** Some proteins are an assembly of more than one polypeptide or subunits. The manner in which these individuals folded polypeptides or sub-units are arranged with respect to each other is the architecture of protein, referred as quaternary structure of a protein.

Classification of Proteins

- On the basis of composition, proteins are classified into following two classes
  - **Fibrous proteins** formed when the polypeptide chains run parallel and are held together by hydrogen and disulphide bonds, e.g. keratin, fibroin, collagen and myosin.
  - **Globular proteins** In these, polypeptide chains are coiled about themselves which result in a spherical molecule, e.g. enzymes, hormones such as insulin and haemoglobin, etc.
- On the basis of components of molecules, proteins are classified into following three classes
  - **Simple proteins** (made up of amino acids only), e.g. collagen, albumin, etc.
  - **Conjugated proteins** (made up of protein molecules joined to non-protein part), e.g. haemoglobin, casein, etc.
  - **Derived proteins** (formed by partial breakdown of natural proteins), e.g. peptones, insulin, fibrin, etc.

2. Polysaccharides

- Polysaccharides (Gr. *Poly*–many; *saccharon*–sugar) are usually employed to polymers containing minimum of ten monosaccharide units. Polysaccharides are of following two types
  - **Homopolysaccharides or Homoglycans** They have only one type of monosaccharide units in

them. Some of the better known homoglycans are starch, cellulose, chitin, etc.

- **Heteropolysaccharides or Heteroglycans** They have at least two types of monosaccharide units in them, e.g. chitin, pectin, peptidoglycan.

- Major polysaccharides are discussed below
  - **Starch** $(C_6H_{10}O_5)_n$ It is a polymer of D-glucopyranose units linked by α-1, 4-glycosidic linkages. It consists of a mixture of **amylose** and **amylopectin**.
  - **Glycogen** About 5000-15000 glucose units make up glycogen $(C_6H_{10}O_5)_n$.
  - **Cellulose** It is a linear polymer of β-D-glucose units connected through β -1, 4-glycosidic linkage.
  - **Chitin** It is the second most abundant polysaccharide, comprising of linear unbranched structural heteropolysaccharide of β-1,4-linked chains of N-acetylglucosamine.

3. Nucleic Acids

- These are **biomacromolecules** and are **polymeric** compounds of **nucleotides**, i.e. polynucleotides.
- A nucleic acid which contains deoxyribose sugar is **DNA**, while that which contains ribose is called **Ribonucleic Acid** (RNA).
- **Deoxyribonucleic Acid** (DNA) is right-handed double helix model (structure) of two parallel polynucleotide chains given by **Watson** and **Crick** having a major and minor groove. The outline of **Watson** and **Crick** model of DNA is as follows
  - DNA molecule consists of two helically twisted strands connected together by base pairs, which align themselves in antiparallel or in opposite direction. A DNA double helix is 20Å wide and its one complete turn is 34Å wide, having 10 base pairs.
  - The two strands are interwined in a clockwise direction, i.e. in the form of a right-handed helix and have antiparallel arrangement.
  - Each strand consists of a backbone made up of alternating deoxyribose sugar and phosphate. The phosphate joins the two sugars through a **phosphodiester bond**.
  - The nitrogenous bases are stacked inside the helix and paired with the base of the opposite strand through **hydrogen bonds** (H-bonds). There are two H-bonds between A and T and three H-bonds between G and C.

Note *The right-handed form of DNA is called **B-DNA** (found in humans) and left-handed form is called **Z-DNA** (found in nucleosome).*

- **Ribonucleic Acid** (RNA) The other nucleic acid present in the cell is RNA, i.e. ribose nucleic acid.
- It is mostly present in single-stranded form though some viruses like retrovirus and wound tumour virus has double-stranded RNA.
- RNA can be of following three types
  - Messenger RNA or *m*RNA or template RNA
  - Ribosomal RNA or *r*RNA
  - Soluble-RNA or transfer-RNA (*s* or *t*RNA)

Nature of Bond Linking Monomers in Polymer

The polymers are formed by combination of one or more types of monomer units *via* bonds. These are

- **Peptide bonds** These are formed when the carboxyl (—COOH) group of one amino acid reacts with the amino (—NH_2) group of the next amino acid with the elimination of a water moiety (the process is called dehydration).
- **Glycosidic bond** This bond ions carbon atoms of two adjacent monosaccharides with the removal of water molecule.
- **Phosphodiester bond** In a nucleic acid, a phosphate moiety links the 3′-carbon of one sugar of one nucleotide to the 5′-carbon of the sugar of the succeeding nucleotide. The bond between the phosphate and hydroxyl group of sugar is an ester bond. As there is one such ester bond on either sides, it is called phosphodiester bond.

Enzymes

- Almost all enzymes are proteins. Some nucleic acids that behave like enzymes are called **ribozymes**.
- These are organic catalysts which catalyse biochemical reactions without being utilised themselves.
- An enzyme like any protein has the secondary and tertiary structures. This tertiary structure has

backbone of the protein chain folded upon itself, also the chain *criss-crosses* itself and hence, many crevices or pockets are made. One such pocket is the **active site**.

- An active site of an enzyme is a crevice or pocket into which the substrate fits. Thus, enzymes through their active site, catalyse reactions at a high rate.

Properties of Enzymes

Enzymes show the various important properties. These are as follows

- They enhance the rate of a chemical reaction without themselves being changed or used.
- Enzymes are efficient in very small amounts.
- Enzymes are highly specific, as each of them catalyses only a specific reaction, e.g. maltase acts only on maltose.
- Enzymes can be denatured by heat (thermolabile or heat sensitive) human enzymes are active at 35-40°C, denature at 50-55°C. The enzymes of bacteria living in hot springs have optimal temperature of 70°C.

Working of Enzymes

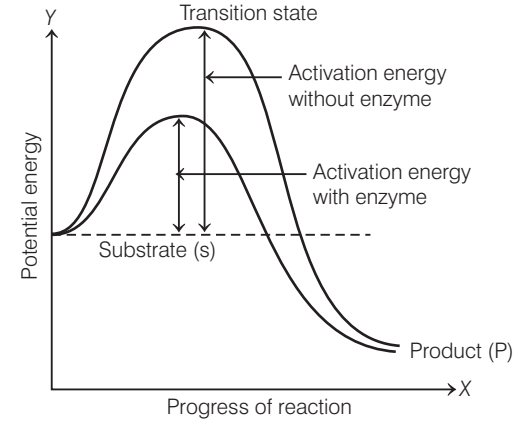
- **Substrate** (S) Chemical which is converted into a product.
- **Enzyme**, i.e. Proteins with three dimensional structures including an active site convert a **substrate** (S) into a **product** (P).

$$S \rightarrow P$$

- The substrate has to diffuse towards the 'active site'. There is thus, an obligatory formation of an 'ES' complex. This complex formation is a transient phenomenon.
- During this state, a new structure of the substrate called **transition state structure** is formed.
- After bond making/breaking is completed, the product is released from the active site.
- There could be many more 'altered structural states' between the stable substrate and the product.

Concept of Activation Energy

- Activation energy is the least possible energy required to start a chemical reaction or the amount of energy available in a chemical system for a reaction to take place.
- It can be understood with the given graph as follows



Y-axis = Potential energy

X-axis = Progression of the structural transformation or states through transition state.

- The features to notice
  - If 'P' is at a lower level than 'S', the reaction is an exothermic reaction (no supply of energy is needed to form the product).
  - The difference in average energy content of 'S' from that of the transition state is activation energy.

Nature of Enzyme Action

- Each enzyme (E) has a substrate (S) binding site in its molecule so that highly reactive enzyme-substrate complex (ES) is produced.

$$\underset{\text{Enzyme}}{E} + \underset{\text{Substrate}}{S} \rightleftharpoons \underset{\substack{\text{Enzyme - Substrate} \\ \text{complex}}}{ES} \longrightarrow \underset{\substack{\text{Enzyme - Product} \\ \text{complex}}}{EP} \longrightarrow \underset{\text{Enzyme}}{E} + \underset{\text{Product}}{P}$$

- The catalytic cycle of an enzyme action can be described in the following steps
  - Substrate binds to the active sites of the enzyme.
  - Binding induces enzyme to alter its shape fitting more tightly around the substrate.
  - Active site of enzyme breaks the chemical bonds of the substrate and the new enzyme-product complex is formed.
  - Enzyme releases products of the reaction and the free enzyme is ready to bind to another molecule of the substrate and run through the catalytic cycle once again.

Enzyme Inhibition

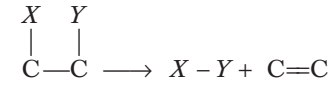
Reduction or stoppage of enzyme activity due to the certain adverse conditions or chemicals is called enzyme inhibition and the chemicals which interfere or inhibit the process are called **inhibitor**.

Enzyme inhibition can be of following types

- **Competitive inhibition** It is a reversible process due to the substrate or enzyme analogue in which K_m increases, but V_{max} remains the same.
- **Non-competitive inhibition** In this, inhibitor forms a complex with enzyme other than the active site and V_{max} decreases.
- **Feedback inhibition** Where the end product or intermediates functions as temporary inhibitor which combines with a regulatory site (also known as allosteric site) of the enzyme and thus, functions as negative modulator. This is also called **allosteric modulation**.

Classification and Nomenclature of Enzymes

- **Oxidoreductases/Dehydrogenases** catalyse oxidoreduction between two substrates, i.e. S and S′, e.g. S (reduced) + S′ (oxidised) → S (oxidised) + S′ (reduced)
- **Transferases** catalyse transfer of a group G (other than hydrogen) between a pair of substrate S and S′, e.g. S – G + S′ → S + S′ – G.
- **Hydrolases** catalyse hydrolysis of ester, ether peptide glycosidic C–C, C–halide or P–N.
- **Lyases** catalyse removal of groups from substrates mechanisms other than hydrolysis leaving double bonds.



- **Isomerases** catalyse inter-conversion of optical, geometric or positional isomers.
- **Ligases** catalyse linking together of two compounds, e.g. enzymes which catalyse joining of C–O, C–S, C–N, P–O, etc., bonds.

Objective Questions

Multiple Choice Questions

1. After doing the chemical analysis of organic compounds found in living organisms, two fractions were observed namely
(a) acid soluble pool and acid insoluble pool
(b) carbon pool and hydrogen pool
(c) inorganic pool and organic pool
(d) aqueous pool and non-aqueous pool

2. All the carbon compounds obtained from living tissues are called
(a) biomolecules (b) inorganic compounds
(c) organic compounds (d) Only DNA

3. Identify the term 'ash' in terms of living tissue sample analysis from the statements given below.
(a) Organic compounds oxidised to gaseous form (CO_2 and water vapour) after burning of the tissue
(b) The material left after burning the tissue, which contains inorganic elements such as calcium, magnesium, etc.
(c) Compounds removed in the form of gases
(d) Compounds which may be soluble in intracellular fluid

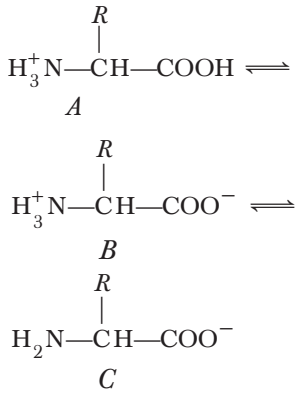
4. Amino acids are organic compounds and are called α-amino acids. Why?
(a) Amino acids are organic compounds containing an amino group and acidic group as substituents on two different carbons
(b) Amino acids are organic compounds containing an amino group and an acidic group as substituents on the same carbon
(c) Amino acids are inorganic compounds containing an amino group and acidic group as substituents on two different carbons
(d) Amino acids are inorganic compounds containing an amino group and acidic group as substituents on the same carbon

5. Most abundant organic compound on earth is
(a) protein (b) cellulose
(c) lipids (d) steroids

6. Which of the following can synthesise all of the amino acids?
(a) Animals (b) Plants
(c) Both (a) and (b) (d) None of these

7. Which of the following is not an amino acid?
(a) Uracil (b) Glycine
(c) Tryptophan (d) Lysine

8. Identify the zwitter ionic form in the given reversible reaction.



Choose the correct option.
(a) *A* (b) *C*
(c) *B* (d) None of these

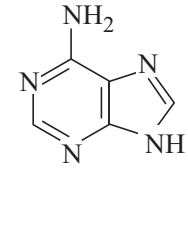
9. Which one of the following statements is wrong?
I. Sucrose is a disaccharide.
II. Cellulose is a polysaccharide.
III. Uracil is a pyrimidine.
IV. Glycine is a sulphur containing amino acid.
(a) Both I and II (b) I, II and IV
(c) II and III (d) Only IV

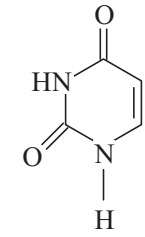
10. Which of the following organic compounds is the main constituent of lecithin?
(a) Arachidonic acid
(b) Phospholipid
(c) Cholesterol
(d) Phosphoprotein

11. Most abundant lipid in a cell membrane is glycolipid.
(a) True
(b) False
(c) Cannot say
(d) Partially true or false

12. A nucleoside having a phosphate group forms a
(a) nucleotide (b) triglyceride
(c) lipid (d) nitrogen base

13. Identify *A* and *B*.





A *B*

A	*B*
(a) Cytosine	Uracil
(b) Adenine	Thymine
(c) Adenine	Uracil
(d) Guanine	Thymine

14. Match the following columns.

Column I (Small molecules)		Column II (Large molecules)	
A.	Amino acids	1.	Proteins
B.	Fatty acids, glycerol	2.	Lipids
C.	Nucleotides	3.	Polysaccharides
D.	Simple sugars	4.	Nucleic acids

Codes

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

15. Primary metabolites
(a) include glucose and fructose
(b) present in all living tissues
(c) plays known roles in all physiological process
(d) All of the above

16. Sugar and amino acids are secondary metabolites.
(a) True (b) False
(c) Cannot say (d) Partially true or false

17. Secondary metabolites can be observed in
(a) plant cells (b) fungal cells
(c) microbial cells (d) All of these

18. Choose the correct option.
(a) Pigments – Carotenoids, anthocyanins
(b) Alkaloids – Monoterpenes
(c) Toxins – Morphine
(d) Polymeric substances – Ricin

19. Which of the following secondary metabolites belong to the group of drugs?
I. Morphine II. Curcumin
III. Codeine IV. Vinblastin
V. Abrin
(a) I and II (b) I and V
(c) II and III (d) II and IV

20. What is the common feature in all the compounds found in the acid soluble pool?
(a) They have molecular weights ranging from 18 to around 800 daltons (Da) approximately
(b) They have molecular weights ranging from 18 to around 80 daltons (Da) approximately
(c) They have molecular weights ranging from 80 to around 800 daltons (Da) approximately
(d) None of the above

21. The least abundant chemical component in living organisms is proteins.
(a) True
(b) False
(c) Cannot say
(d) Partially true or false

22. Match the following columns.

Column I		Column II	
A.	Water	1.	10-15%
B.	Proteins	2.	70-90%
C.	Carbohydrates	3.	5-7%
D.	Lipids	4.	3%
E.	Nucleic acids	5.	2%
F.	Ions	6.	1%

Codes

	A	B	C	D	E	F
(a)	1	3	5	6	2	4
(b)	3	2	6	5	4	1
(c)	2	1	4	5	3	6
(d)	6	2	3	4	5	1

23. Proteins are formed by the condensation of
(a) fatty acids (b) carbohydrates
(c) amino acids (d) Both (b) and (c)

24. Name the most abundant protein in animal world.
(a) RuBisCO
(b) Carboxylase-oxygenase
(c) Collagen
(d) Cellulose

25. Identify the correct pair.

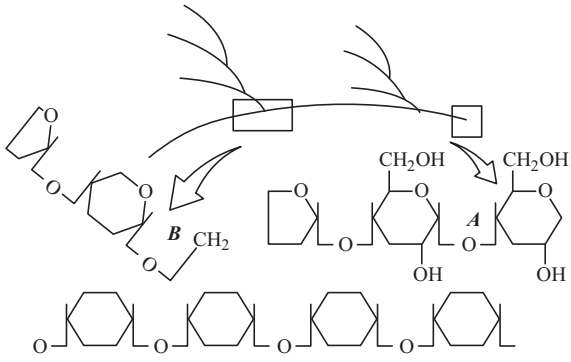
	Proteins	Functions
(a)	Collagen	Hormone
(b)	Antibody	Fights infectious agents
(c)	Insulin	Intercellular ground substance
(d)	Trypsin	Enables glucose transport in cell

26. Identify the correct statement pertaining to polysaccharides.

I. The polysaccharides are found as a part of acid insoluble pellet.
II. They are long chains of sugars.
III. They are threads containing different monosaccharides as building blocks.

(a) All statements are correct
(b) All statements are correct except II
(c) Only statement III is correct
(d) Only statement II is correct

27. Identify *A* and *B* bonds in the following diagrammatic representation of a portion of glycogen.



Choose the correct option.

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

28. Which of the following statements is/are incorrect?

I. Left end of a polysaccharide is called non-reducing end, while right end is called reducing end.
II. Starch and glycogen are branched molecules.
III. Starch and glycogen are the reserve food materials of plant and animals, respectively.
IV. Starch can hold iodine molecules in its helical secondary structure, but cellulose being non-helical, cannot hold iodine.

(a) I and II
(b) All statements are incorrect
(c) Only IV
(d) None of the above

29. Match the following columns and choose the correct combination from the options given below.

	Column I (Chemical compounds)		**Column II** (Examples)
A.	Nitrogen base	1.	RNA
B.	Nucleoside	2.	Thymidylic acid
C.	Nucleotide	3.	Cytidine
D.	Nucleic acid	4.	Uracil

Codes

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

30. Name the heterocyclic compounds, which are known as nitrogenous bases.

Choose the most appropriate option.

(a) Adenine, guanine, uracil, cytosine and thymine
(b) Adenine, guanine, uracil and thymine
(c) Adenine, guanine, cytosine, uracil
(d) None of the above

31. Which one of the following reactions result in the conversion of amino acids to proteins?
(a) Condensation (b) Phosphorylation
(c) Deamination (d) Transamination

32. The following statements describe three orders of structure of the insulin molecule.
I. The molecule consists of two polypeptide chains joined and folded around one another.
II. The sequence and number of amino acids in each polypetide chain is known.
III. The amino acids in each chain are coiled into a helix and held in position by hydrogen bonds.
Which order is described by each statement?

	Statement I	Statement II	Statement III
(a)	Primary	Secondary	Tertiary
(b)	Primary	Tertiary	Secondary
(c)	Secondary	Tertiary	Primary
(d)	Quaternary	Primary	Secondary

33. A peptide bond is formed between
(a) an aldehyde group and an amino group
(b) an aldehyde group and a carboxyl group
(c) an aldehyde group and an ester group
(d) a carboxyl group and an amino group

34. A nitrogenous base is linked to the pentose sugar through
(a) hydrogen bond
(b) glycosidic bond
(c) phosphate diester bond
(d) peptide bond

35. According to Watson and Crick model of DNA
(a) DNA exists as a double helix
(b) The two strands of polynucleotide are antiparallel to each other
(c) The backbone is formed by sugar and nucleic base
(d) Both (a) and (b)

36. Length of one turn of the helix in β-form DNA is approximately
(a) 3.4 nm (b) 2 nm
(c) 0.34 nm (d) 20 nm

37. Catabolic and anabolic pathways are often coupled in cell because
(a) Both the paths have the same energy
(b) the free energy released from one pathway is used to drive other
(c) the intermediates of a catabolic pathway are used in the anabolic pathway
(d) their enzymes are controlled by their same activators and inhibitors

38. Choose the correct statements.
I. Bond energy (ATP) is utilised for biosynthesis, osmotic and mechanical work that we perform.
II. When glucose is degraded into lactic acid in our muscles, energy is liberated.
III. Assembly of a protein from amino acid requires energy.
IV. Majority of metabolic reactions can occur in isolation.
V. There are many examples of uncatalysed metabolic reactions.
(a) IV and V (b) I and III
(c) I, II and III (d) None of these

39. Living state cannot reach equilibrium due to insufficiency of biomolecules.
(a) True
(b) False
(c) Cannot say
(d) Partially true or false

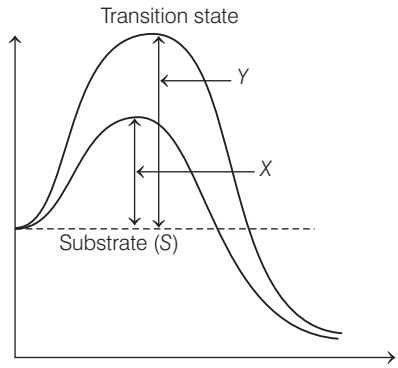
40. Those nucleic acids, which behave like enzymes are known as
(a) ribozymes (b) pepzymes
(c) ribose (d) Both (a) and (b)

41. Which of the following statements is true?
(a) All enzymes are protein
(b) All proteins are enzyme
(c) All enzymes are not protein
(d) All enzymes and hormones are protein

42. An enzyme can be synthesised by chemically bonding the molecules of
(a) carbohydrates (b) amino acids
(c) lipases (d) CO_2

43. Enzyme catalysts differ from inorganic catalysts in which way?
(a) Enzyme catalysts are smaller in size and lesser in weight in comparison to that of inorganic catalysts
(b) Inorganic catalysts can work efficiently at high temperature, but enzyme catalysts cannot (except few enzymes)
(c) Inorganic catalysts can work efficiently at high pressure, but enzyme catalysts cannot
(d) Both (b) and (c)

44. Identify *X* and *Y* in the given graph.



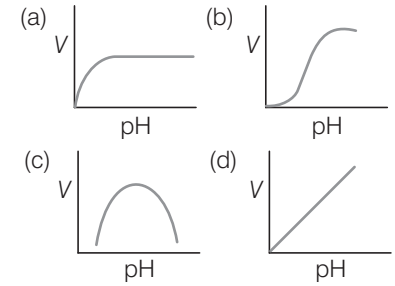
(a) *X*–Activation energy without enzyme, *Y*–Activation energy with enzyme
(b) *X*–Activation energy with enzyme, *Y*–Activation energy without enzyme
(c) *X*–Substrate concentration with enzyme, *Y*–Substrate concentration without enzyme
(d) *X*–Substrate concentration without enzyme, *Y*–Substrate concentration with enzyme

45. Properties defining enzyme activity include the
(a) correct folding at primary level of organisation
(b) presence or absence of optimum temperature and pH
(c) presence of substrate concentration that increases initially and then attains V_{max}
(d) All of the above

46. Lock and key concept explains the interaction of a particular enzyme molecule with a specific substrate molecule.
(a) True (b) False
(c) Cannot say (d) Partially true or false

47. Michaelis-Menten constant (K_m) is equal to
(a) the rate of enzymatic activity
(b) the rate of reaction
(c) substrate concentration at which the rate of the reaction attains half of its maximum velocity
(d) substrate concentration at which the rate of reaction is maximum

48. Identify the correct graph displaying the effect of pH on the velocity of a typical enzymatic reaction (V)?



49. When the binding of the chemical shuts off enzyme activity, the process is called ... *A* ....and the chemical is called ... *B*..... .
Fill in the blanks with the correct options.
(a) *A*–inhibition, *B*–inhibitor
(b) *A*–competition, *B*–inhibitor
(c) *A*–initiation, *B*–promoter
(d) None of the above

50. In competitive inhibition, which of the following is true?
(a) $E + I \rightleftharpoons EI$
(b) $E + I \rightleftharpoons EI + S \rightleftharpoons EIS$
(c) $S + I \rightleftharpoons SI$
(d) $E S + I \rightleftharpoons ESI$

Assertion-Reasoning MCQs

Direction *(Q. Nos. 51-60) Each of these questions contains two statements Assertion (A) and Reason (R). Each of these questions also has four alternative choices, any one of which is the correct answer. You have to select one of the codes (a), (b), (c) and (d) given below.*

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true, but R is not the correct explanation of A
(c) A is true, but R is false
(d) A is false, but R is true

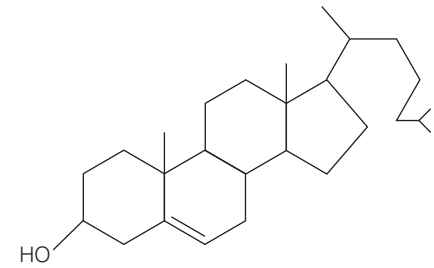
51. **Assertion** (A) In the solutions of different pH, structure of amino acids changes.
Reason (R) It is because of the ionisable nature of —NH_2 and —COOH groups.

52. **Assertion** (A) Eight amino acids are referred to as essential amino acids for humans.
Reason (R) These are synthesised in the human body.

53. **Assertion** (A) Arachidic acid is an unsaturated fatty acid.
Reason (R) There are one or more variable double bonds between carbon atoms in unsaturated fatty acids.

54. **Assertion** (A) Secondary metabolites are produced in small quantities and their extraction from the plant is difficult and expensive.
Reason (R) Secondary metabolites can be commercially produced by using tissue culture technique.

55. **Assertion** (A) The structure given is the most important animal steroid which is insoluble in water and chemically unreactive.



Reason (R) It is important because it is a structural component of cell.

56. **Assertion** (A) Starch is a polymer of glucose.
Reason (R) It is made of several glucose units.

57. **Assertion** (A) Enzymes lower down the activation energy of the reactant molecule to make its transition into product easier.
Reason (R) Enzymes are highly substrate specific catalysts.

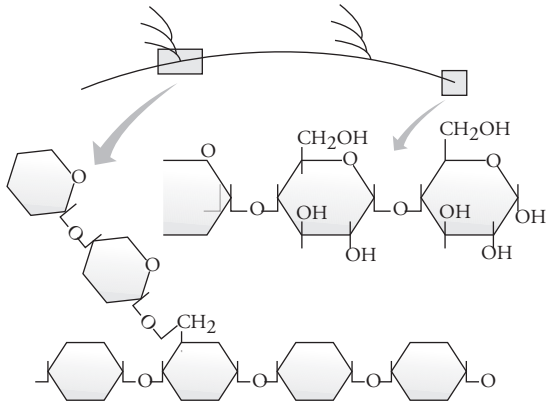
58. **Assertion** (A) Enzymes are not divided into different classes.
Reason (R) All enzymes catalyse the different reactions.

59. **Assertion** (A) Competitive inhibitor is also called substrate analogue.
Reason (R) It resembles the enzymes in structure.

60. **Assertion** (A) An example of non-competitive inhibitor is cyanide.
Reason (R) Cyanide kills animals by inhibiting cytochrome oxidase.

Case Based MCQs

61. Identify the molecular structure of the given polysaccharide and answer the questions that follow



(i) Chooose the correct characteristics about the polysaccharide molecule shown above.

I. It is a storage polysaccharide in animal cells only.

II. It gives red colour on reaction with iodine.

III. It is a branched homopolysaccharide.

IV. It contains repeating units of fructose only.

(a) I and IV (b) II, III and IV
(c) Only III (d) I, II and III

(ii) All the listed polysaccharides are homopolymers except

(a) starch (b) glycogen
(c) chitin (d) cellulose

(iii) Inulin is a polymer of

(a) glucose
(b) fructose
(c) glucose + sucrose
(d) fructose + galactans

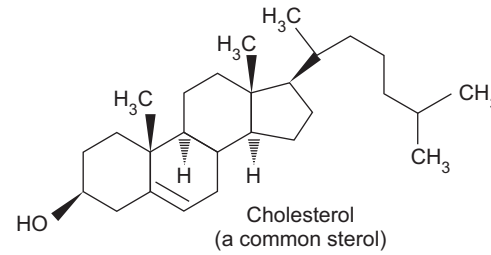
(iv) A polysaccharide found in the exoskeleton of crabs is

(a) cellulose (b) pectin
(c) murein (d) chitin

(v) Murein is a heteropolysaccharide like

(a) araban (b) xylan
(c) hyaluronic acid (d) agar

62. Identify the molecular structure of lipid molecule and answer the questions that follow



(i) Choose the incorrect characteristic about the lipid molecule shown above

I. It is a common sterol molecule.

II. It is the precursor of steroid hormones.

III. The given molecule has a steroid nucleus, a hydrocarbon side chain, and a hydroxyl group.

IV. Cholesterol is soluble in blood and thus transport through bloodstream easily.

(a) Only IV (b) III and IV
(c) I and II (d) Only II

(ii) Lipids mainly consist of

(a) carbon only
(b) carbon, hydrogen and nitrogen
(c) carbon, hydrogen and oxygen
(d) hydrogen only

(iii) Saturated fatty acids contain

(a) double bond
(b) carboxyl group
(c) Both (a) and (b)
(d) None of the above

(iv) An example of unsaturated fatty acid is

(a) oleic acid (b) stearic acid
(c) linoleic acid (d) Both (a) and (c)

(v) Among the given options, non-polymeric molecule is

(a) nucleic acid (b) proteins
(c) lipids (d) polysaccharide

63. **Direction** *Read the following and answer the questions that follow*

Proteins are most abundant intracellular organic biomolecules. These are polypeptides having chains of amino acids that are linked by peptide bonds. These amino acids are either essential or non-essential on the basis of their utility. Proteins are the heteropolymers and their structure exist at four different levels *viz,* primary, secondary, tertiary and quaternary. These four levels differ in the degree of complexity in the polypeptide chain. On the basis of structural function in animal body, proteins are either fibrous or globular.

Depending upon these structural characteristics proteins perform various functions linked to immune system, blood clotting, muscle movement, etc.

(i) An essential amino acid is
(a) leucine (b) proline
(c) serine (d) All of these

(ii) An example of globular protein is
(a) keratin (b) collagen
(c) albumin (d) All of these

(iii) In an alkaline solution, amino acids become
(a) positively charged
(b) negatively charged
(c) neutral
(d) zwitter ion

(iv) The type of bond that forms the α-helix secondary structure of protein is
(a) glycosidic bond
(b) disulphide bond
(c) phosphodiester bond
(d) hydrogen bond

(v) **Assertion** (A) Lipoprotein is a type of conjugated protein.

Reason (R) Conjugated proteins are exclusively made up amino groups.

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true, but R is not the correct explanation of A
(c) A is true, but R is false
(d) Both A and R are false

64. **Direction** *Read the following and answer the questions that follow*

Enzymes are organic macromolecules which are mostly proteinaceous in nature with few exceptions. These are water soluble compounds and required for catalysing biochemical reactions in living cells.

They are highly specific and efficient in very small amounts. Each enzyme has a substrate binding site in order to bind and forms complex with a specific substrate. Few compounds closely resemble substrate and can inhibit the activity of enzyme.

These are known to function under specific temperature, pH and substrate concentration.

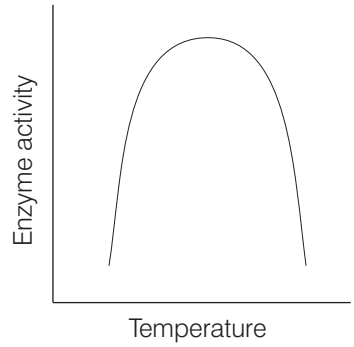
(i) The enzymes that catalyse the hydrolysis of ester bonds are
(a) hydrolases
(b) lyases
(c) transferases
(d) ligases

(ii) A competitive inhibitor of enzyme is
(a) penicillin (b) malonate
(c) cyclosporin (d) Both (b) and (c)

(iii) The factor that activates the activity of enzymes are
(a) Mg^{2+} (b) HCl
(c) Ca^{2+} (d) All of these

(iv) Lyases are the enzymes which catalyse
(a) cleavage of covalent bonds
(b) formation of bonds with ATP cleavage
(c) transfer of functional group
(d) Both (a) and (b)

(v)



Identify the correct conclusions about the graph shown above.

I. At optimum temperature, enzyme activity is maximum.

II. At low temperature, the enzyme is inactives.

III. At high temperature, enzymes get denatured.

Codes

(a) Only I (b) Only III (c) Only II (d) I, II and III

ANSWERS

Multiple Choice Questions

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

Assertion-Reasoning MCQs

51. (a)	*52. (c)*	*53. (d)*	*54. (b)*	*55. (b)*	*56. (a)*	*57. (b)*	*58. (d)*	*59. (c)*	*60. (b)*

Case Based MCQs

61. (i) *(d),* (ii) *(c),* (iii) *(b),* (iv) *(d),* (v) *(c)*

62. (i) *(a),* (ii) *(c),* (iii) *(b),* (iv) *(d),* (v) *(c)*

63. (i) *(a),* (ii) *(c),* (iii) *(b),* (v) *(d),* (v) *(c)*

64. (i) *(a),* (ii) *(b),* (iii) *(d),* (iv) *(a),* (v) *(d)*

EXPLANATIONS

1. (a) After performing the chemical analysis of organic compounds found in living organisms, two types of organic compounds were observed. They were the filtrate fraction or the acid soluble pool and the retentate fraction or the acid insoluble pool.

2. (a) All the carbon compounds obtained from living tissues are called as biomolecules.

3. (b) After burning the dry tissue, all the organic compounds are oxidised to gaseous form (CO_2 and water vapour) and are removed. The material left which contains inorganic elements (e.g. calcium, magnesium, etc.) is termed 'ash'.

4. (b) Amino acids are said to be organic compounds which contain an amino group and an acidic group as substituents on the same carbon, i.e. the α-carbon. Hence, these are also called α-amino acids.

5. (b) Cellulose is the most abundant organic compound, most abundant polysaccharide and most abundant bipolymer found on earth.

6. (b) In plants, photosynthesis plays a vital role in amino acid synthesis due to carbohydrate metabolism. Therefore, bacteria, yeast, mould and plants are unique because they are able to produce all needed amino acids by themselves.

7. (a) Amino acids are building blocks of proteins. Uracil is a pyrimidine base found in RNA and is not an amino acid.

8. (c) *B* is the zwitter ion form because a zwitter ion is a dipolar ion with both positive and negative ion groups.

9. (d) All statements are correct except statement IV. Incorrect statement can be corrected as
Glycine is the simplest amino acid, which is devoid of sulphur content.

10. (b) Phospholipids are the main constituents of lecithin. These molecules are composed of choline and inositole. It is found in all living cells and serves as a major component of cell membrane.

11. (b) The most abundant membrane lipids are the phospholipids. These have a polar head group and two hydrophobic hydrocarbon tails.

12. (a) Nucleotides are formed when a phosphate group is esterified to the sugar molecule of a nucleoside. In simple words, a nucleoside with a phosphate group forms a nucleotide.

15. (d) Primary metabolites are present in all living tissues. These include amino acids, sugars (e.g. glucose, fructose) etc. They play a major role in different physiological processes of the body including growth, development and reproduction.

16. (b) Sugar and amino acids are primary metabolites. Sugars are building blocks of starch, glycogen, etc., while amino acids are the building blocks of proteins.

18. (a) Option (a) contains the correct information. Rest are incorrect and can be corrected as
- Alkaloids – Morphine
- Toxins – Abrin, ricin
- Polymeric substances – Rubber, gums, cellulose

19. (d) Secondary metabolites are organic compounds which are not involved in primary metabolism and seem to have no direct function in growth and development of plants. Curcumin and vinblastin are drugs. Others are explained as
Morphine and codeine are alkaloids and abrin is aoxin.

20. (a) There is a common feature in all the compounds found in the acid soluble pool. They have molecular weights ranging from 18 to around 800 dalton (Da) approximately.

23. (c) Proteins are formed by the condensation of amino acids.

25. (b) Option (b) contains the correct match. Rest of the matches are incorrect and can be corrected as

Proteins	**Functions**
Collagen	Intercellular ground substance
Trypsin	Enzyme
Insulin	Hormone

27. (d) *A* represents 1, 4 α-glycosidic bonds as the glucose residues in glycogen are linked by this bond.
B represents 1, 6 α-glycosidic bonds as this bond creates branches in glycogen.

31. (a) In proteins, amino acids are linked together by peptide bonds, which are formed between the amino group of one amino acid and the carboxyl group of another. This association of amino acids to form proteins occurs by condensation.

32. (d) Polypeptides can be divided into various levels of organisation. The primary structure refers to the linear arrangement of amino acid residues along a polypeptide chain.
The secondary structure refers to the folding of parts of these chains into regular structure.
The tertiary structure includes the folding of regions within the same polypeptide and quaternary structure refers to two or more polypeptide chains joined and wound around one another.

33. (d) The peptide bond is the chemical bond that connects 2 amino acids in a polymer. It is formed between the amino group of one amino acids and the carboxyl group of another through the process of condensation.

34. (b) The bond which connects a nitrogenous base and a pentose sugar is a glycosidic bond. It leads to the formation of nucleoside which is a part of nucleotide.

35. (d) Both options (a) and (b) are correct with respect to the structure of DNA elucidated by Watson and Crick.
Option (c) is incorrect and can be corrected as
The backbone of DNA is formed by the sugar phosphate chain.

36. (c) Length of one turn of DNA helix is 34Å.

$$1\text{Å} = 10^{-1} \text{ nm}$$

Therefore, 34 Å $= 0 \cdot 34$ nm

38. (c) Statements I, II and III are correct. Statements IV and V are incorrect and can be corrected as

- Majority of the metabolic reactions do not occur in isolation, they are always linked to some other reactions.
- There are many examples of catalysed metabolic reactions.

39. (b) System at equilibrium cannot perform work. As living organisms work continuously, they make a constant effort to prevent the state of equilibrium.

41. (c) Option (c) is true statement as all enzymes are not proteins. Ribozyme is a nucleic acid having enzymatic properties.

42. (b) Biochemically enzymes are proteinaceous. These can be synthesised by chemically bonding of the amino acids, which are building blocks of proteins.

43. (d) Both options (b) and (c) are correct. As inorganic catalyst works efficiently at high temperature and pressure, while enzymes gets damaged at high temperature (say above 40°C). However few enzymes isolated from thermophilic organisms works at up to 80°-90°C. Other incorrect statement can be corrected as

Enzyme catalysts are larger in size and higher in weight in comparison to that of inorganic catalyst.

44. (b) The amount of activation energy in the presence of an enzyme is very less as compared to the amount, which is needed in the absence of enzymes. Thus, *X*–Activation energy with enzyme and *Y*–Activation energy without enzyme.

45. (d) Option (d) is correct as

Enzyme activity is influenced by the presence or absence of optimum pH and temperature, substrate concentration and the folding of their protein structure. Enzyme activity increases in the presence of substrate whose concentration increases initially and then reaches V_{max} and decreases in the absence of such substrate concentration.

Further, enzyme activity is maximum at optimum pH and temperature and is minimum beyond or above the optimum value. Also, any misfolding at the primary level may generate a malfunctioning enzyme.

47. (c) Michaelis-Menten constant (K_m) is equal to the substrate concentration at which the velocity of the reaction is half of the maximum velocity. It is inversely proportional to the enzyme activity.

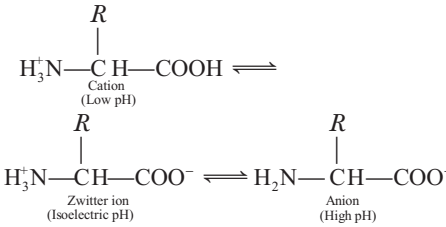
48. (c) Some enzymes act best in acid medium and others in an alkaline medium. For every enzyme, there is an optimum pH where its action is maximum. Most enzymes show activity in a pH range of about 6.0 to 7.5, i.e neutral pH. A shift towards the alkaline or acid side rapidly decreases the enzyme activity and finally stops it altogether. Thus, graph (c) shows the effect of pH on the velocity of enzymatic reactions.

49. (a) The activity of an enzyme is also sensitive to the presence of specific chemicals that bind to the enzyme. When the binding of the chemical shuts off enzyme activity, the process is called inhibition (*A*) and the chemical is called an inhibitor (*B*).

51. (a) Both A and R are true and R is the correct explanation of A.

Amino acids have a particular property, i.e. the ionisable nature of $-NH_2$ and —COOH groups. Hence, in solutions of different pH, the structure of amino acids changes.

In a neutral solution, the amino acid molecule exists as a dipolar ion (zwitter ion) having both positive and negative ion groups. The charge on this ion changes with the pH. In acid solutions (low pH), the amino group of amino acid picks up H^+ ions and becomes positively charged. On the other hand, in alkaline solution (high pH), the amino acid donates H^+ ions to the medium and becomes negatively charged.



52. (c) A is true, but R is false because

Eight amino acids are referred to as the essential amino acids for humans. These must be ingested through diet, since they are not synthesised in the human body.

53. (d) A is false, but R is true and A can be corrected as

Arachidic acid is a saturated fatty acid found in peanut oil. It is with 20 carbon chain.

54. (b) Both A and R are true, but R is not the correct explanation of A.

Secondary metabolites are biosynthetically derived from primary metabolites, but more limited in distribution in plant kingdom, being restricted to a particular taxonomic group. Secondary metabolites are accumulated by plant in smaller quantities than primary metabolites. Also, they are synthesised in specialised cell types and at distinct developmental stages, making their extraction and purification difficult and expensive. By culture media, using tissue culture techniques, secondary metabolites can be produced on a large scale.

55. (b) Both A and R are true, but R is not the correct explanation of A.

The given structure is of cholesterol. It is one of the most important animal steroid which is insoluble in water and chemically unreactive. Cholesterol is useful since it is a structural component of cells. It is synthesised from acetyl Co-A or acetate (C_2) in the liver.

56. (a) Both A and R are true and R is the correct explanation of A.

Starch is a homopolysaccharide made up of several glucose monomer units.

57. (b) Both A and R are true, but R is not the correct explanation of A.

Enzymes are able to lower the activation of the reactant molecule by binding to and placing the substrate in close proximity to other substrates and catalytic groups, so that less energy is required to enable interaction between them.

Another way is that enzymes may provide charged side groups in their amino acid structure to help stabilise transition states between the initial and final products.

58. (d) A is false, but R is true. A can be corrected as

Enzymes, mostly have been categorised into six different classes on the basis of the reactions they catalyse.

The six classes of enzymes are oxidoreductases, transferases, hydrolases, lyases, ligases and isomerases.

59. (c) A is true, but R is false and R can be corrected as

Competitive inhibitor resembles the substrate in structure.

60. (b) Both A and R are true, but R is not the correct explanation of A.

Cyanide is an example of non-competitive inhibitor as it can attach to the enzyme at a region other than the active site and inhibits its activity.

61. (i) (d) I, II and III are correct. The given diagram is of glycogen which contains repeating units of glucose only.

(ii) (c) Chitin is a heteropolysaccharide.

(iii) (b) Inulin is a homopolymer of fructose.

(iv) (d) Chitin is found in the exoskeleton of arthropods like prawns and crabs.

(v) (c) Both murein and hyaluronic acid are heteropolysaccharides. Araban, xylan and agar are homopolysaccharides.

62. (i) (a) Only statement IV is incorrect because Cholesterol is insoluble in blood and thus transported in conjugation with proteins.

(ii) (c) Lipids are the heterogeneous compounds of carbon, hydrogen and oxygen.

(iii) (b) Fatty acids are long hydrocarbon chains containing one carboxyl group. Saturated fatty acids do not contain any double bond in their chains. Unsaturated fatty acids contain one or more double bonds.

(iv) (d) Examples of unsaturated fatty acids are oleic acid and linoleic acid.

(v) (c) Lipids are non-polymeric compounds. These are not biomacromlecules.

63. (i) (a) Leucine is essential amino acids that is not synthesised in animal body.

(ii) (c) Albumin is globular protein.

(iii) (b) Amino acids contain both amino and carboxylic group. In an alkaline solution, the amino acid donates H^+ ions to the medium and becomes negatively charged.

(iv) (d) In the secondary structure of proteins, hydrogen bonding occurs between — C ═ O and — NH groups.

(v) (c) A is true, but R is false because Conjugated proteins are those containing non-amino prosthetic groups like metals or ions, e.g. phosphoproteins, lipoproteins, etc.