9 Biomolecules

There are numerous types of biomolecules that occur naturally in your body, such as proteins. To keep your biological proteins balanced, however, you must include protein-rich foods in your diet. Whether you eat meat or are a strict vegan, beans and legumes are a great plant based source of protein.

Topic Notes

- *Metabolites and Biomacromolecules*
- *Proteins*
- *Enzymes*

METABOLITES AND BIOMACROMOLECULES 1

TOPIC 1
CHEMICAL COMPOSITION

Chemical Analysis of Biomolecules

To study the various biomolecules that are found in living tissues, we perform a chemical analysis.

Procedure of chemical analysis

Living tissue (a piece of liver or a vegetable, etc.) is grounded in trichloroacetic acid (CCl_3COOH) with the help of a mortar and a pestle, to obtain a thick slurry. This slurry is then strained through a cheesecloth or cotton and two fractions were obtained. One is called the filtrate or Acid soluble pool whereas the other fraction is called the retentate or the acid-insoluble pool. Filtrate consists of lower molecular weight compounds whereas retentate consists of compounds like proteins, nucleic acids, polysaccharides, etc., which have high molecular weight. Later on, the compounds are extracted using various separation techniques from filtrate and retentate. It finally leads to the complete isolation of a particular compound from all other compounds. All these carbon compounds that we get from living tissues are called biomolecules.

Ash analysis

Apart from organic compounds, living organisms also have inorganic elements and compounds in their body. To analyse the inorganic elements in the body of living organisms, we use a technique called Ash analysis.

In this technique, we take a small amount of living tissue, which is weighed and dried. All the water evaporates and the remaining material gives dry weight. This tissue is then fully burnt (the remaining are called ash) and the carbon compounds present in them are oxidised to gaseous forms like carbon dioxide, and water vapour and are removed and the remaining material is called ash. This ash contains many inorganic elements like calcium, magnesium, sodium, potassium, etc. Inorganic compounds like sulfate and phosphate are also present in the acid-soluble fraction.

Component	Formula
Sodium	$Na^{\oplus}$
Potassium	$K^{\oplus}$
Calcium	$Ca^{2\oplus}$
Magnesium	$Mg^{2\oplus}$

Component	Formula
Water	H_2O
Compounds	NaCl, $CaCO_3$, H_3PO_4 , H_2SO_4

List of Inorganic Constituents of Living Tissues

Functional groups such as aldehydes, ketones, aromatic molecules, and others can be identified based on chemistry. However, we will divide them into amino acids, nucleotide bases, fatty acids, and other biological categories.

Example 1.1: What are macromolecules? Give examples. [NCERT]

Ans. Macromolecules are polymers that are formed by combining simpler micromolecules. They have high molecular weight and come under acid-insoluble pools. Examples: Proteins, Polysaccharides, DNA, etc.

Important

➥ *The acid-insoluble fraction has only four types of organic compounds that are protein, nucleic acid, polysaccharides and lipids. These classes of compounds with the exception of lipids have molecular weights in the range of ten thousand daltons and above. For this reason, biomolecules, i.e. chemical compounds found in living organisms are of two types:*

(1) Biomolecules that have a molecular weight less than 1000 Da are usually known as micromolecules or simple biomolecules.

(2) Biomolecules which are found in the acid fraction are called macromolecules or biomacromolecules.

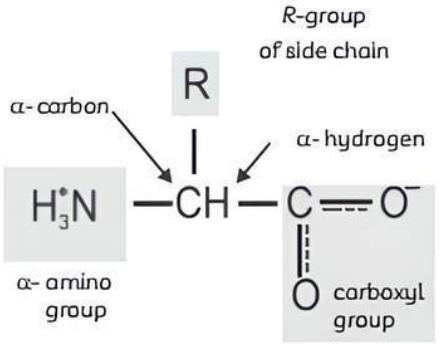
Biomacromolecules

The biomacromolecules present in living organisms are Monosaccharides, Amino acids, Fatty acids, and Nucleotides.

They have a molecular weight of around 18 to 800 daltons (Da) approximately.

Amino acids

Amino acids are a type of biomolecule that contains a carboxyl and an amino group attached to the same carbon (α-carbon) as substituents. That's why they are called α-amino acids. The four valency positions of α-carbon are occupied by four substituent groups, which are hydrogen, amino group, carboxyl group, and a variable *R*-group.



Basic structure of amino acid

(1) Amino acids are classified into various groups based on the nature of the *R*-group. For example, when the *R*-group is hydrogen, then the amino acid is called glycine. When the *R*-group is a methyl group ($-CH_3$) then the amino acid is called alanine.

(2) The proteins in the human body are made up of 20 different types of amino acids.

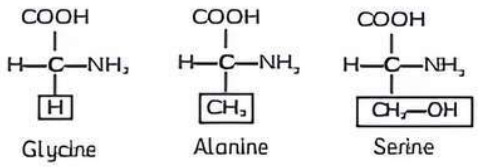
(3) The amino group, carboxyl group, and *R*-functional group determine the chemical and physical properties of amino acids.

(4) Based on the number of amino and carboxyl groups, amino acids are classified into three types:

(i) Acidic amino acid: An amino acid in which the number of the carboxyl groups is greater as compared to amino groups, *e.g.* glutamic acid.

(ii) Basic amino acid: An amino acid in which the number of the amino group is more than the number of the carboxyl group, *e.g.* lysine.

(iii) Neutral amino acid: An amino acid in which the number of amino and carboxyl groups are the same, *e.g.* valine.

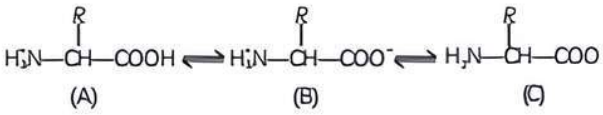


Amino acids

(5) Similarly, there are aromatic amino acids (amino acids whose structure contains an aromatic ring, *e.g.*, phenylalanine, tyrosine, tryptophan).

(6) Amino acids show a property in which $-NH_2$ and $-COOH$ are ionisable. Therefore, the structure of amino acids changes in solutions of different pH.

(7) Amino acids form zwitter ion (a molecule that contains an equal number of positively and negatively charged functional groups).



(B) is called zwitter ionic form.

Zwitter ionic form of amino acid

Lipids

Lipids are water-insoluble and soluble in non-polar solvents (Benzene, chloroform), whose basic unit is a fatty acid. A fatty acid consists of a carboxyl group attached to an *R*-group, where the *R*-group could be a methyl ($-CH_3$) or ethyl ($-C_2H_5$) or a higher number of $-CH_2$ groups.

Lipids = fatty acid + glycerol

Types of fatty acids are based on the presence of a double bond between two carbon atoms. They are:

Saturated fatty acid: A fatty acid in which there is no double bond between two carbon atoms. They have high melting and boiling point and exist in solid form at room temperature. *E.g.* Palmitic acid (16:0), Stearic acid (18:0) and Arachidic acid (20:0).

Unsaturated fatty acid: A fatty acid in which there is one or more than one double bond between two carbon atoms. They have low melting and boiling point and exist in liquid form at room temperature. *E.g.* Palmitoleic acid, oleic acid, linoleic acid, arachidonic acid, etc.

Fatty acids can also be classified as:

Simple lipids: These are esters of fatty acids with various kinds of alcohol. *E.g.* Triglycerides, suberin, wax, etc.

Compound lipids: These are esters of fatty acids containing groups in addition to alcohol and fatty acid. *E.g.* Phospholipids, glycolipids, lipoprotein, etc.

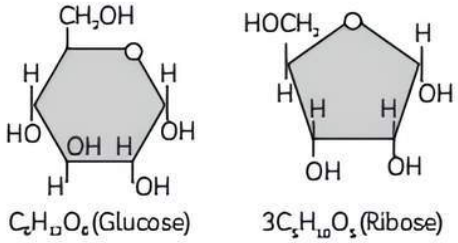
Derived lipids: Fatty acids which are produced by hydrolysis of simple and compound lipids. *E.g.* Steroids, prostaglandin, *etc.*

Nucleotides

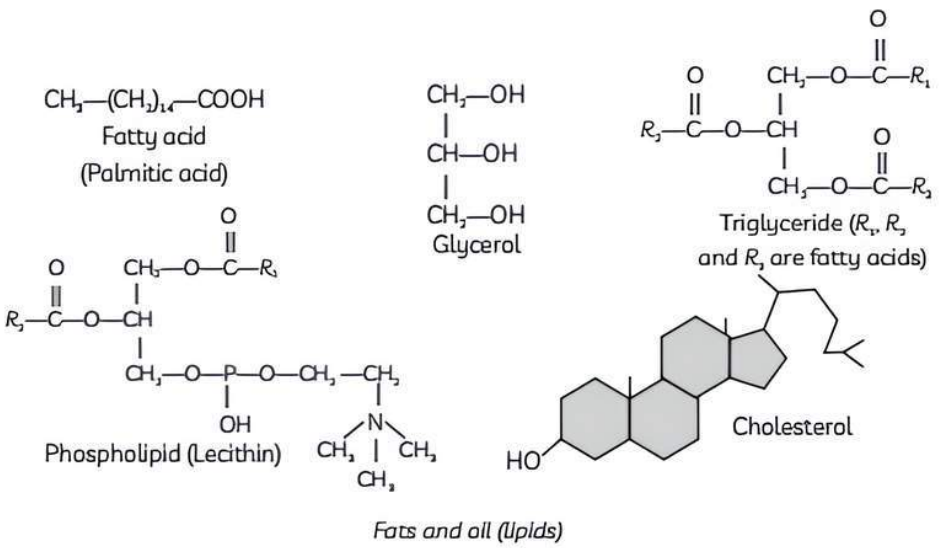
Nucleic acids are a type of biomolecule found in living organisms that are composed of basic units called nucleotides.

A nucleotide consists of ribose sugar, nitrogenous base, and phosphoric acid. A nucleoside consists of ribose sugar and nitrogenous base only. The nitrogenous base includes adenine, guanine, cytosine, uracil, and thymine. Adenosine, guanosine, thymidine, uridine, and cytidine are nucleosides.

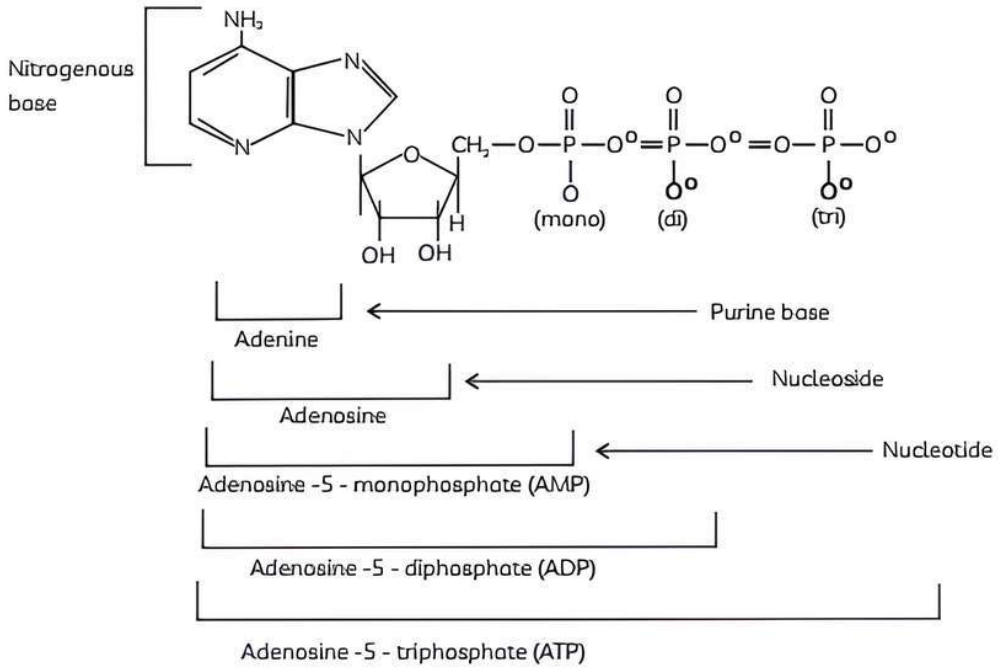
Nucleotides are–Adenylic acid, guanylic acid, thymidylic acid, uridylic acid, and cytidylic acid. Nucleic acids are present in DNA and RNA which function as genetic material.



Sugars (Carbohydrates)



Fats and oil (lipids)



Primary and Secondary Metabolites

Metabolites are intermediate or end products of metabolism. Since every living organism shows metabolism, the products formed during the process of metabolism or after it, are called metabolites. There are two types of metabolites:

Primary metabolites

It is required for basic metabolic activities like respiration, photosynthesis, lipids and protein metabolism, *etc.* It is produced in large quantities and its extraction is very easy. It is almost the same in all plants. *Eg.* Enzymes, amino acids, vitamins, etc.

Secondary metabolites

It has no direct function in the growth and development of living organisms. It is produced in small quantities and extraction is difficult. It is unique to different plant species. *Eg.* pigments, antibiotics, drugs, alkaloids, rubber, flavonoids, essential oils, scents, gums, spices, etc.

Table : Some Secondary Metabolites.

S. No.	Category	Secondary Metablite
(1)	Pigments	Carotenoids, Anthocyanins, etc.
(2)	Alkaloids	Morphine, Codeine, etc.
(3)	Terpenoides	Monoterpenes, Diterpenes, etc.
(4)	Essential oils	Lemon grass oil, etc.
(5)	Toxins	Abrin, Ricin
(6)	Lectins	Concanavalin A, etc.
(7)	Drugs	Vinblastin, curcumin, etc.
(8)	Polymeric substances	Rubber, gums, cellulose

TOPIC 2

POLYSACCHARIDES

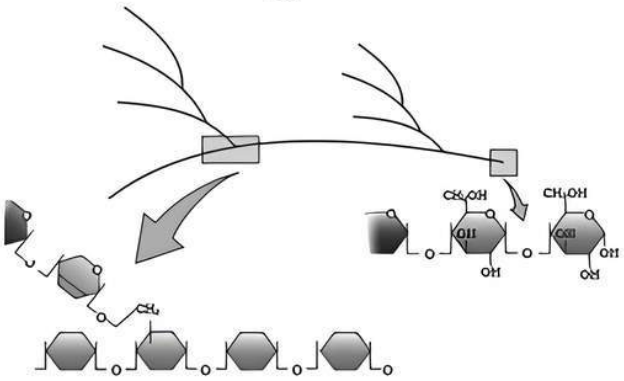
Polysaccharides are chains of polymers of monosaccharides. Monosaccharides are simple sugars or carbohydrates which cannot be further hydrolysed into smaller components. Monosaccharides are composed of 3-7 carbon atoms. Polysaccharides are composed of more than 10 monosaccharides. These polysaccharides contain different monosaccharides and can be branched or unbranched. The individual monosaccharides are joined by a glycosidic bond in a polysaccharide.

There are two types of polysaccharides:

Homopolysaccharides

They are made up of only one type of monosaccharide, *i.e.* all the monosaccharide units are the same. *E.g.* Starch, glycogen, inulin, cellulose, etc.

(1) **Glycogen:** Branched homopolysaccharide formed by glucose α–1,4 linkage at unbranched part and α–1,6 linkage at branching points. When reacted with iodine it gives red colour. It is the storehouse of energy in animal cells.



Diagrammatic representation of a portion of glycogen

(2) **Starch:** Its structure is the same as glycogen, but shows less branching frequency than glycogen. It acts as the storehouse of energy in plant cells. It forms helical secondary structures in which iodine molecules get trapped and gives blue colour.

(3) **Cellulose:** They are the structural component of plants, and these do not form helices, so they can not hold iodine molecules.

(4) **Inulin:** This is a polymer of fructose. The metabolism of inulin does not occur in the human body so it gets filtered out through the kidney. Due to this, they are used in the testing of kidney function.

(5) **Chitin:** This is a polymer of Nitrogen-containing glucose derivative called N-acetyl glucosamine. It is found in the exoskeleton of arthropods.

Heteropolysaccharide

They are made up of more than one type of monosaccharide, *i.e.*, monosaccharide units are different. *E.g.* Peptidoglycans, hyaluronic acid, etc.

Example 1.2: Find out how much cellulose is made by all the plants in the biosphere and compare it with how much of it is manufactured by man and hence what is the consumption of plant material by man annually. [NCERT]

Ans. About 100 billion tons of cellulose is produced by the biosphere out of which, paper-making consumes 0.5 billion wood. Food, medicines, wood, spices, and other products are all made from trees. A total of 1.5 billion tonnes of food is estimated to be required. Approximately 2 billion tonnes of wood are required for various reasons. As a result, estimating man's annual consumption of plant material is difficult. As a result, the usage of cellulose resulted in a significant loss of vegetation.

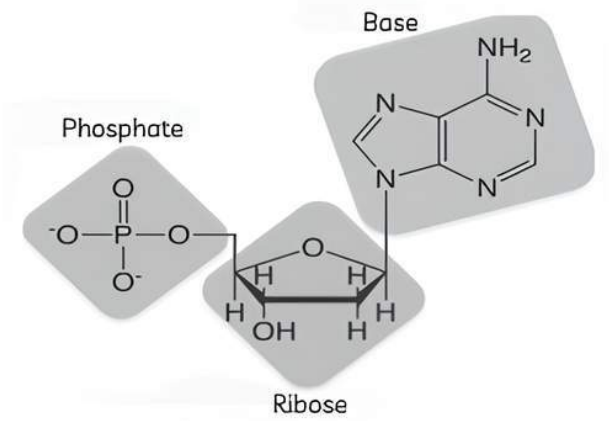
TOPIC 3

NUCLEIC ACIDS

Nucleic acids are polymers of nucleotides. There are two types of nucleic Acids in nature, *i.e.* Deoxyribonucleic Acid (DNA) and Ribonucleic Acid (RNA). A nucleotide is composed of a phosphate group, a five-carbon sugar or pentose sugar, and a nitrogenous base. A nucleoside is composed of pentose sugar and nitrogenous base only. The nitrogenous base is joined with pentose sugar *via* a glycosidic bond. The bond between the hydroxyl group of sugar and phosphate group is called an ester bond. Since there is one such ester bond on either side, it is called a phosphodiester bond.

⚠ Caution

➥ *Students usually get confused between nucleotides and nucleosides. They both are different. Nucleosides are shorter than nucleotides.*

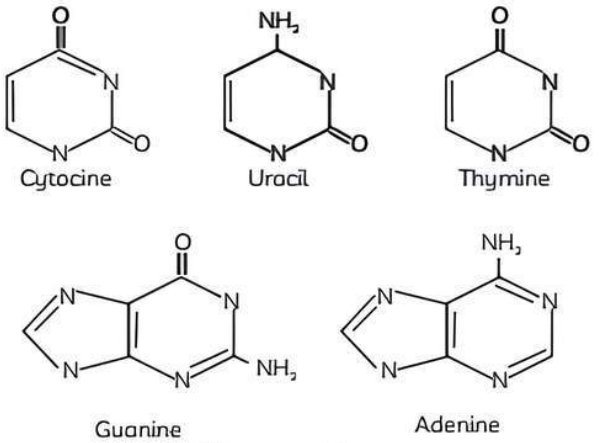


Structure of a nucleotide containing phosphate group, pentose sugar, and nitrogenous base

Nitrogenous bases are of 5 types—Adenine, Guanine, Thymine, Cytosine, and Uracil. Adenine and Guanine are purines, whereas Thymine, Cytosine, and Uracil are pyrimidines. Uracil is absent in DNA and thymine is absent in RNA. In DNA, the sugar is deoxyribose sugar, and in RNA, the sugar is ribose sugar.

Important

- *DNA contains – Adenine, Guanine, Cytosine and Thymine.*
- *RNA contains – Adenine, Guanine, Cytosine and Uracil.*



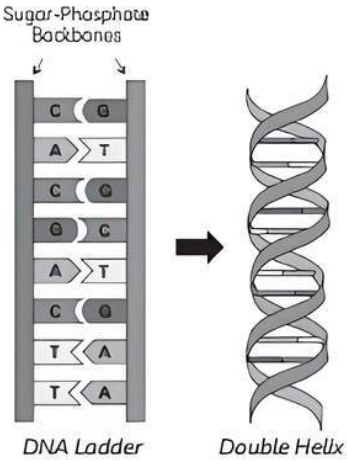
Nitrogenous Bases

Caution

- *Pay attention to the spelling of 'Thymine'. Thymine is a pyrimidine, whereas Thiamine is Vitamin B.*

Example 1.3: Case Based:

What makes DNA "the molecule of life"? DNA, or deoxyribonucleic acid, is the molecule that carries all the genetic information of an organism (except for some RNA viruses). It can be thought of as a blueprint containing the instructions that govern the production of proteins and other molecules essential to cell function. The collection of these instructions is called a genome. The informational units of the genome are called genes. Genes are translated into proteins via the genetic code, which defines the protein sequence. This translation process is central to life.



(A) What type of molecules are DNA and RNA?
(a) Micromolecule (b) Macromolecule
(c) Nucleic acids (d) Both (b) and (c)

(B) Which organism has RNA as its genetic material?
(a) Retrovirus (b) Human
(c) *E. coli* (d) Viroid

(C) What is the key difference between DNA and RNA?

(D) Write the full form of DNA and RNA.

(E) Assertion (A): RNA is formed from DNA by the process called transcription.
Reason (R): It takes place in the cytoplasm of the eukaryotic cell.
(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true and R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true.

Ans. **(A)** *(d) Both (b) and (c)*

Explanation: DNA and RNA both are macromolecules and nucleic acids. Nucleic acids are a type of macromolecule.

(B) *(a) Retrovirus*

Explanation: Retrovirus has RNA as its genetic material. Humans and *E. coli* both have DNA as genetic material.

(C) DNA has two strands, whereas RNA has one strand. The sugar in DNA is deoxyribose, whereas ribose sugar is present in RNA.

(D) DNA: Deoxyribonucleic acid
RNA: Ribonucleic acid

(E) *(c) A is true but R is false.*

Explanation: RNA is formed from DNA by the process called transcription inside the nucleus of the eukaryotic cell.

OBJECTIVE Type Questions

[1 mark]

Multiple Choice Questions

1. It is said that the elemental composition of living organisms and that of inanimate objects (like the 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?

(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.

[NCERT Exemplar]

Ans. *(c) Living organisms have more carbon, oxygen, and hydrogen per unit mass than inanimate objects.*

Explanation: In living beings, the relative amount of carbon, hydrogen, and oxygen concerning other elements is higher than in non-living things. The amount of gold, water, and calcium is more in inanimate objects than in living organisms.

2. Many elements are found in living organisms either free or in the form of compounds. Which of the following is not found in living organisms?

(a) Silicon **(b) Magnesium**

(c) Iron **(d) Sodium solution**

[NCERT Exemplar]

Ans. *(a) Silicon*

Explanation: Silicon is not found in the body of living organisms as it has no role in any metabolic process. Magnesium, iron, and sodium solutions are found in a considerable amount in living organisms as they take part in various physiological functions.

3. When you take cells or tissue pieces and grind them with an acid in a mortar and pestle, all the small molecules dissolve in the acid. Proteins, polysaccharides, and nucleic acids are insoluble in mineral acid and get precipitated. The acid-soluble compounds include amino acids, nucleosides, small sugars, etc. When one adds a phosphate group to a nucleoside, one gets another acid-soluble molecule called:

(a) Nitrogenous base

(b) Adenine

(c) Sugar phosphate

(d) Nucleotide **[NCERT Exemplar]**

Ans. *(d) Nucleotide*

Explanation: Nucleotides are formed by the phosphorylation of nucleosides. Nucleotides are also a part of acid-soluble biomolecules.

Caution

Adenine is a nitrogenous base. Adding a phosphate group to it won't change anything because it needs phosphate sugar to form nucleotides. So both options (a) and (b) are incorrect. By adding phosphate to sugar phosphates, the only thing that it will do is the formation of more phosphate bonds. Sugar phosphate needs a nitrogenous base to form a nucleotide which comes in an acid-soluble pool. So option (c) is also incorrect.

4. Glycogen is a homopolymer made of:

(a) Glucose units **(b) Galactose units**

(c) Ribose units **(d) Amino acids**

[NCERT Exemplar]

Ans. *(a) Glucose units*

Explanation: Glycogen is a branched homopolysaccharide formed by glucose α–1,4 linkage at the unbranched part and α–1,6 linkage at branching points. Since, homopolymer is made of only one type of basic unit, which is glucose.

5. Upon hydrolysis of nucleic acid which of the following will not be obtained?

(a) Phosphoric acid

(b) Pentose sugar

(c) Nitrogenous base

(d) α-D-glucose **[Diksha]**

Ans. *(d) α-D-glucose*

Explanation: The basic unit of nucleic acid is nucleotides, which are made up of pentose sugar, nitrogenous base, and phosphoric acid. Thus, hydrolysis will produce pentose sugar, nitrogenous base, and phosphoric acid but not α-D-glucose.

6. Which statement is true regarding the 5' end of a DNA molecule?

(a) The 5^{th} carbon of the pyrimidine base is free.

(b) The 5^{th} carbon of pentose sugar is free.

(c) The 5^{th} carbon of the purine base is free.

(d) Both (a) and (c)

Ans. *(b) The 5th carbon of pentose sugar is free.*

Explanation: The 5' end of a DNA molecule means the 5th carbon of pentose sugar is free. So, the 5th carbon of the pyrimidine base, and 5th carbon of the purine base options are incorrect. Pyrimidine and purine bases are attached to the pentose sugar, so they do not form the backbone of the DNA molecule. Therefore, the 5' end of a DNA molecule does not concern them.

7. The similarity between nucleotides and nucleosides is:

(a) They both have a pentose sugar.
(b) They both have a phosphate group.
(c) They both have a nitrogenous base.
(d) Both (a) and (c)

Ans. *(d) Both (a) and (c)*

Explanation: Nucleotides and nucleosides both contain pentose sugar and a nitrogenous base. Unlike nucleotides, nucleosides do not have phosphate groups.

8. The exoskeleton of arthropods is made up of:

(a) Cellulose **(b) Glycogen**
(c) Chitin **(d) Both (b) and (c)**

Ans. *(c) Chitin*

Explanation: The exoskeleton of arthropods is made up of chitin which is a homopolysaccharide. Glycogen acts as storage food in animals, whereas cellulose is found in the plant cell walls especially.

Assertion-Reason (A-R)

Given below are two statements labelled as Assertion (A) and Reason (R). Select the most appropriate answer from the options given below:

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

9. Assertion (A): **Starch gives a blue-black colour in the presence of Iodine.**
Reason (R): **Iodine gets trapped in the helix-like structure of starch.**

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

Explanation: Starch gives a positive iodine test because its structure is helix-like in which iodine gets trapped.

Related Theory

Starch is a homopolysaccharide, which is made up of glucose units.

10. Assertion (A): **Palmitic acid is a saturated fatty acid**
Reason (R): **Palmitic acid does not contain any double bond between two carbon atoms.**

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

Explanation: Saturated fatty acids do not contain any double bond between two carbon atoms, *e.g.* Palmitic acid.

11. Rubber based products are essential commodities in the present day market. Natural rubber, being renewable with its unique qualities, plays a critical role in rubber product manufacture. Most natural rubber are produced in tropical Asian countries and their processing seems to be material and energy-intensive, hence challenged by cost-ineffectiveness and various environmental issues.

Assertion (A): **Rubber is the primary metabolite.**
Reason (R): **Primary metabolites are directly involved in physiological function in the body of a living organisms.**

Ans. *(d) A is false but R is true.*

Explanation: Rubber is a secondary metabolite. Secondary metabolites do not take part in physiological functions in the body of a living organism.

12. Assertion (A): **Glucose comes under the acid-soluble pool.**
Reason (R): **Its molecular weight is more than 1000 Dalton.**

Ans. *(c) A is true but R is false.*

Explanation: The molecules under the acid-soluble pool have a molecular weight between 18 to 800 Dalton.

Related Theory

➥ *The acid-insoluble pool contains macromolecules, which means they have high molecular weight.*

CASE BASED Questions (CBQs)

[**4** & **5** marks]

Read the following passages and answer the questions that follow:

13. *Jatin is experimenting in his lab where he is grinding living tissues with the help of mortar and pestle. He wants to find various biomolecules found in living tissues.*

(A) What chemical is used to grind living tissues in chemical analysis?
- **(a) Trichloroacetic acid**
- **(b) Ethanol**
- **(c) Benzene**
- **(d) Both (a) and (b)**

(B) What are the fractions found by performing the chemical analysis of living tissues?
- **(a) Acid-soluble pool**
- **(b) Acid-insoluble pool**
- **(c) Both (a) and (b)**
- **(d) None of the above**

(C) What is the technique called for the analysis of inorganic constituents in living tissues?
- **(a) Oxidative phosphorylation**
- **(b) Ash analysis**
- **(c) Centrifugation**
- **(d) None of the above**

(D) Which among the following comes under filtrate?
- **(a) Monosaccharides**
- **(b) Nucleoside**
- **(c) Proteins**
- **(d) Disaccharides**

(E) What are some of the inorganic constituents found in living tissues?
- **(a) Sodium** **(b) Potassium**
- **(c) Calcium** **(d) All of these**

Ans. (A) *(a) Trichloroacetic acid*

Explanation: Trichloroacetic acid is used to grind living tissues in chemical analysis. Ethanol and benzene are not used here. Ethanol and Benzene both are just a non-polar solvents, which do not contribute to the grinding of living tissues.

(B) *(c) Both (a) and (b)*

Explanation: There are two fractions found by performing the chemical analysis of living tissues. These are acid-soluble pools and acid-insoluble pools.

(C) *(b) Ash analysis*

Explanation: For analysis of inorganic constituents in living tissues, we perform a method called ash analysis. Oxidative phosphorylation has no relation with this chemical analysis.

(D) *(a) Monosaccharides*

Explanation: Monosaccharides and nucleotides are small molecules so they come under filtrate. Protein is a macromolecule that comes under retentate.

(E) *(d) All of these*

Explanation: Sodium, potassium, and calcium, all are inorganic elements found in living tissues.

14. *Rekha sends his 13-year-old daughter Rita to bring vegetable oil from the market. Rita brings home ghee. Her mother then told her to return ghee back to the shop and bring back sunflower oil. Rita asks her mother why ghee and oil do different works. Then Rekha told her that sunflower oil is much healthier than ghee.*

(A) What type of oil is vegetable oil?

(B) Rita observed that ghee in her home gets frozen in cold weather but vegetable oil remains liquid. Why?

(C) Which type of oil should one consume and why?

Ans. (A) Vegetable oil is unsaturated oil or fatty acid.

(B) The unsaturated fatty acid has low melting and boiling point, whereas saturated fatty acid has high melting and boiling point. Ghee is saturated, so its melting point is high, thus it remains frozen in cold weather. But vegetable oil has a low melting point, so it remains liquid in cold weather.

(C) One should consume unsaturated oils because unsaturated fats are an essential component of a balanced diet. These fats aid in the prevention of heart disease and the reduction of cholesterol levels.

VERY SHORT ANSWER Type Questions (VSA)

[1 mark]

15. What is an acid-insoluble pool? Give examples.

Ans. It consists of macromolecular organic compounds which are insoluble in acid. They have high molecular weight. *Eg.* proteins, nucleic acids, carbohydrates, etc.

16. Medicines are either man-made *(i.e.* synthetic) or obtained from living organisms like plants, bacteria, animals, etc., and hence the latter are called natural products. Sometimes natural products are chemically altered by man to reduce toxicity or side effects. Write against each of the following whether they were initially obtained as a natural product or as a synthetic chemical.

(A) Penicillin **(B) Sulfonamide**
(C) Vitamin C **(D) Growth hormone**
[NCERT Exemplar]

Ans. (A) **Penicillin:** a natural product.

(B) **Sulfonamide:** synthetic chemical.

(C) **Vitamin C:** a natural product.

(D) **Growth hormone:** a natural product.

17. Write the name of any one amino acid, sugar, nucleotide, and fatty acid.
[NCERT Exemplar]

Ans. (1) **Amino acid:** Alanine.

(2) **Sugar:** Galactose.

(3) **Nucleotide:** Adenosine monophosphate.

(4) **Fatty acid:** Palmitic acid.

18. Why do oils generally remain in a liquid state even in winter?
[Delhi Gov. QB 2022]

Ans. Oils are unsaturated lipids, hence have lower melting points. So, they remain in a liquid state even in winter.

19. Starch, cellulose, glycogen and chitin are polysaccharides found among the following.

(A) Cotton fibre

(B) Exoskeleton of cockroach

(C) Liver

(D) Peeled potato

Choose the one appropriate and write against each. **[NCERT Exemplar]**

Ans. (A) **Cotton fibre:** Cellulose.

(B) **Exoskeleton of cockroach:** Chitin.

(C) **Liver:** Glycogen.

(D) **Peeled potato:** Starch.

SHORT ANSWER Type-I Questions (SA-I)

[2 marks]

20. Rahul is given ash analysis to perform as an experiment. What is it?

Ans. Ash analysis is a technique where we take a small amount of living tissue, which is weighed and dried. All the water evaporates and the remaining material gives dry weight. This tissue is fully burnt and the carbon compounds present in them are oxidised to gaseous forms like carbon dioxide and water vapour, and are removed and the remaining material is called ash. This ash contains many inorganic elements like calcium, magnesium, sodium, potassium, etc.

21. Nucleic acids exhibit secondary structure. justify with an example. **[NCERT Exemplar]**

Ans. DNA and RNA are examples of nucleic acids which exist in the form of a helix. DNA forms a double-stranded helix whereas RNA forms a single-stranded helix. Since the helix is a secondary structure, we can say that nucleic acid exhibits a secondary structure.

22. Both starch and cellulose are polymers of glucose, but starch gives a blue-black colour with iodine whereas no such colour is obtained with cellulose. Why? **[Diksha]**

Ans. Starch forms a helix-like structure due to which iodine gets trapped inside the starch molecule. Whereas cellulose does not show a helix-like structure, so it is not able to trap iodine in it. That is why starch gives a blue-black colour with iodine whereas no such colour is obtained with cellulose.

23. Raghav is testing the presence of starch in his school lab. Name any two substances which will give a positive iodine test and another two substances which will give a negative iodine test.

Ans. Cotton fibre and paper contain cellulose which gives negative results for Iodine tests.

Potatoes and wheat both contain starch which gives a positive iodine test.

24. Why do physicians recommend vegetable oils rich in poly-unsaturated fat for persons suffering from cardiovascular diseases?

[Delhi Gov. QB 2022]

Ans. Physicians recommend vegetable oils rich in poly-unsaturated fat for persons suffering from cardiovascular diseases because polyunsaturated oils contain fatty acids having one or more double bonds which does not clog arteries due to high proportion of polyunsaturated fatty acids.

SHORT ANSWER Type-II Questions (SA-II)

[3 marks]

25. Write two points about each one of them: glycogen, starch, and cellulose.

Ans. Glycogen:

(1) Branched homopolysaccharide formed by glucose α-1,4 linkage at unbranched part and α-1,6 linkage at branching points.

(2) When reacted with iodine it gives red colour. It is the storehouse of energy in animal cells.

Starch:

(1) Its structure is the same as glycogen, but shows less branching frequency than glycogen. It acts as the storehouse of energy in plant cells.

(1) It forms helical secondary structures in which iodine molecules get trapped and give blue colour.

Cellulose:

(1) They are the structural component of plants.

(2) They do not form helices, so they can not hold Iodine molecules.

26. Write the differences between primary and secondary metabolites.

Ans.

Primary metabolite	Secondary metabolite
They are directly involved in the physiological function in the body of a living organism.	They are not directly involved in the physiological function inside the body of a living organism.
Produced in very large quantities.	Produced in small quantities.
E.g. Carbohydrates, proteins, lipids, etc.	*E.g.* Alkaloids, steroids, rubber, etc.

27. Differentiate between saturated and unsaturated fatty acids.

Ans.

Saturated fatty acid	Unsaturated fatty acid
A fatty acid that does not contain a double bond between two carbon atoms.	A fatty acid that has one or more than one double bond between two carbon atoms.
They have high melting and boiling points.	They have low melting and boiling points.
Exist in solid form at room temperature.	Exist in liquid form at room temperature.
E.g. Palmitic acid, Stearic acid, etc.	*E.g.* Palmitoleic acid, Linoleic acid, etc.

28. A student was given a group of compounds and asked to separate them as acid-insoluble and acid-soluble pools. But he doesn't know the difference between these two. Help him by giving a few points of differences.

Ans.

Acid insoluble pool	Acid soluble pool
They contain macromolecular organic compounds.	They contain micromolecular organic compounds.
The molecules found in this pool have molecular weight greater than 10,000 Da.	The molecules found in this pool have molecular weight between 18 to 800 Da.
E.g. Proteins, carbohydrates, nucleic acids, etc.	*E.g.* Amino acids, monosaccharides, nucleotides, etc.

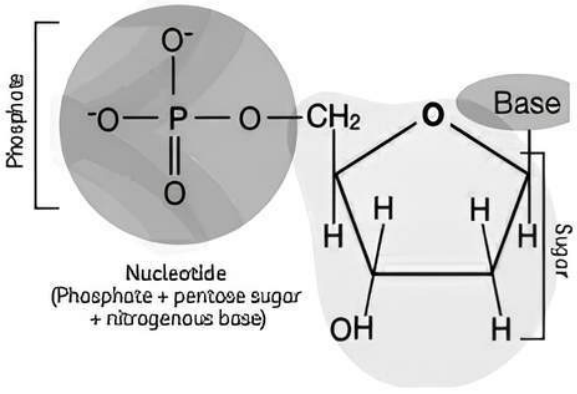
LONG ANSWER Type Questions (LA)

[4 & 5 marks]

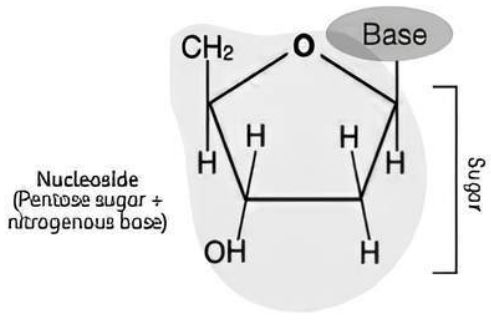
29. Write the differences between nucleotide and nucleoside with examples and structure.

Ans.

Nucleotide	Nucleoside
It consists of a nitrogenous base, pentose sugar, and phosphate.	It consists of a nitrogenous base and a pentose sugar.
It is formed by the phosphorylation of nucleosides.	It is a component of nucleotides.
It is acidic due to the presence of phosphoric acid.	It is slightly basic.
E.g. AMP, GMP, CMP, dTMP, and UMP. AMP- Adenosine monophosphate dTMP- deoxythymidine monophosphate.	*E.g.* Adenosine, guanosine, thymidine, uridine, and cytidine.



Nucleotide



Nucleoside

30. How to analyse organic and inorganic compounds present in living tissues? Describe both processes.

Ans. To analyse organic compounds:

(1) Living tissue is ground into trichloroacetic acid with the help of a mortar and a pestle, to obtain a thick slurry.

(2) This slurry is then strained through a cheesecloth or cotton and gives two fractions. One is called the filtrate or Acid soluble pool whereas the other fraction is called the retentate or the acid-insoluble pool.

(3) Filtrate consists of lower molecular weight compounds whereas retentate consists of compounds like proteins, nucleic acids, polysaccharides, etc., which have high molecular weight.

(4) Later on, the compounds are extracted using various separation techniques from filtrate and retentate.

(5) It finally leads to the complete isolation of a particular compound from all other compounds.

To analyse inorganic compounds:

(1) To analyse the inorganic elements in the body of living organisms, we use a technique called Ash analysis.

(2) In this technique, we take a small amount of living tissue, which is weighed and dried. All the water evaporates and the remaining material gives dry weight.

(3) This tissue is fully burnt and the carbon compounds present in them are oxidised to gaseous forms like carbon dioxide and water vapour, and are removed and the remaining material is called ash.

(4) This ash contains many inorganic elements like calcium, magnesium, sodium, potassium, etc.

PROTEINS 2

TOPIC 1

PROTEIN AND ITS STRUCTURE

Protein is an essential biomolecule made up of monomers of amino acids. Amino acids are joined together by a peptide bond and hence proteins are also called polypeptides, meaning a molecule made up of a number of peptide molecules. The amino acids are joined by peptide bonds when arranged in a linear fashion give rise to the basic structure of protein.

There are many amino acids present in nature, but only a few are essential that need to be taken through the diet which cannot be synthesised by the human body or organisms themselves. Such amino acids are called essential amino acids like histidine, isoleucine, leucine, lysine, methionine, etc. Essential amino acids must be taken in a diet for proper growth and development of cells and hence are also called dietary proteins.

The non-essential amino acids are not important to be taken in the diet as the body can synthesise them as per its need.

Proteins are found everywhere in the environment in various forms and they have many essential roles in the biosystem and ecosystem.

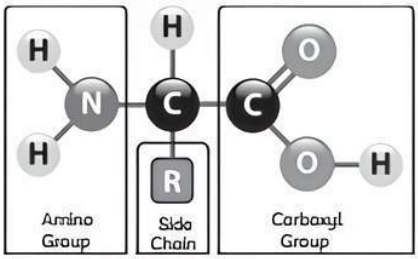
Proteins have various functions and are abundant in nature. The most abundant protein on the earth is called Ribulose Bisphosphate Carboxylase-Oxygenase (RuBisCO) present in plants. Similarly, collagen is abundantly found in animals and is the most abundant protein among animals.

Example 2.1: Can you describe what happens when milk is converted into curd or yoghurt, from your understanding of proteins?

Ans. Lactic acid bacteria are added to milk. Lactic acid is formed when lactose, a sugar found in milk, is converted into lactic acid. Lactic acid denatures the globular milk protein casein, causing it to denature and become fibrous. The protein fibres produce a reticulum that traps milk fat, causing milk to curdle or yoghurt.

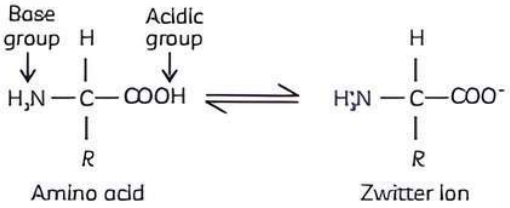
Structure

The amino acid contains a central carbon atom linked with an amino group (positively charged group), a carboxyl group (negatively charged group), a hydrogen atom and an '*R*'-group. There are 20 amino acids which have a similar structure but only vary in their '*R*'-group. The *R*-group can be acidic, basic, polar, non-polar, neutral, aliphatic or aromatic and it decides the nature of amino acids.



Structure of a simple amino acid

The amino acids in the aqueous environment are present in zwitter ion form. The hydrogen from the carboxyl group moves to the basic amino group making carboxyl group negative and amino group positive and yet, the overall charge on the zwitter ion remains zero and is only determined by distinct '*R*'-group.



Structure of a Zwitter Ion.

Example 2.2: Find out and make a list of proteins which are used as therapeutic agents. Find other applications of proteins (*e.g.* Cosmetics, etc.).

Ans. Proteins used as therapeutic agents are:

(1) Antigen/Antibody is the basis on which blood is transfused and many allergic and immunologic responses occur in the human body.

(2) Renin is used in regulating blood pressure and maintains osmoregulation.

(3) Insulin has the function of maintaining glucose levels in the blood serum.

(4) Thrombin and fibrinogen are used in blood clotting.

(5) Certain soluble proteins like wheat gluten protein and insoluble proteins like fibrous collagen are used in cosmetic products such as face masks, makeup kits, lotions, gels, etc., because they provide the capacity to recover quickly and flexibility to the skin cells.

Table: List of amino acids

Nature of side-chains of Amino acid	Type of Amino acids
Acidic	Aspartic acid
	Glutamic acid
Basic	Histidine
	Lysine
	Arginine
Aliphatic	Glycine
	Alanine
	Valine
	Leucine
	Isoleucine
	Proline
Amide	Asparagine
	Glutamine
Sulphur-containing	Methionine
	Cysteine
Polar neutral	Serine
	Threonine
Aromatic	Phenylalanine, Tyrosine, Tryptophan

Example 2.3: **Case Based:**

Rohit decided to buy some protein dietary sources from the supermarket. Reaching the supermarket, he saw there were so many options for protein dietary supplements. An entire section of food was dedicated to protein food materials like eggs, pulses, fish, poultry meat, etc. Rohit brought some eggs and decided to boil them for breakfast. A pan was heated with water in it to the point where the water started boiling and then eggs were added to the boiling water for some minutes. The boiling of the egg made its structure harder and changed its natural characteristics. Cooking protein can change the physical and chemical structure of protein due to temperature and these changes are usually irreversible meaning that once the protein loses its characteristics in cooking, it can never be regained later.

(A) Among the following biomolecules, which one of them is most versatile in nature?

(a) Carbohydrates **(b) Proteins**

(c) Lipids **(d) Nucleic acids**

(B) What protein is present in the eggs?

(a) Tubulin **(b) Renin**

(c) Keratin **(d) Albumin**

(C) In which part of the egg, protein is found?

(D) Which factors are responsible for the denaturation of proteins?

(E) Assertion (A): **Proteins are essential for life.**
Reason (R): **Protein carries important biochemical functions to sustain life.**

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

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

(c) A is true but R is false.

(d) A is false but R is true.

Ans. **(A)** *(b) Proteins*

Explanation: Proteins' versatility stems from their many different structures. Proteins are created by joining amino acids together, and each protein has its own distinct amino acid sequence.

(B) *(d) Albumin*

Explanation: The main protein in egg albumin is called "Ovalbumin," and this is the only protein in the albumin that has free –SH groups.

(C) Egg whites are especially renowned for their high yolk and contain more on a gram for gram basis. Compared to egg white, egg yolk contains less protein. A large egg contains about 6.3 gm of protein in which egg white contains 4.4 gm of protein whereas the egg yolk contains only 2.7 gm of protein.

(D) The denaturation of proteins is a result of heat, pH changes and organic solvents. This denaturation of proteins leads to the transformation of protein's secondary, tertiary and quaternary structure into a more basic and simpler one.

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

Explanation: Proteins have functions like building structures, providing energy, transportation and signalling. It plays an important role in biochemical reactions as enzymes for carrying out metabolic reactions in the body.

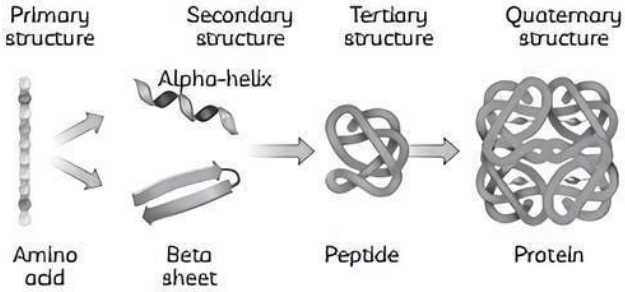
Taking a long rope with numerous knots might give an idea of the actual structure of protein's primary structure. The knots represent the amino acids, the knots may vary in shape and size which represent the different amino acids and the length of rope in between two knots represents the bond which is present in between the amino acids to join them. The amino acids when bound to one another in a linear fashion through peptide bonds make up the primary structure of protein.

(1) The first amino acid has a free amino group and hence is called N-terminus whereas the last amino acid has a free carboxyl group and is hence called C-terminus.

(2) When the linear amino acid chain turns into a right-handed helix then the secondary structure of protein is formed. It is mainly due to the presence of hydrogen bonds within them. The linear chain can be turned so that amino acids at some distance can have hydrogen bonding to make an alpha-helix or two polypeptide chains can be linked to one another through hydrogen bonding, forming beta-pleated sheets.

(3) When the linear structure of protein is folded into a stable three-dimensional structure due to other forces of interactions like sulphide bonds, Van der Waal forces of interaction, hydrophobic bonds, etc., the structure is called tertiary structure of protein like globular proteins.

(4) Also, when two or more polypeptides interweave with each other to form a complex structure, it is called quaternary structure of protein, like haemoglobin is made up of four polypeptide chains or subunits; two alpha and two beta.



Different levels of structure of proteins

Example 2.4: Proteins have a primary structure. If you are given a method to know which amino acid is at either of the two termini (ends) of a protein can you connect this information to purity or homogeneity of a protein?

Ans. We may utilise the information given in the question to estimate the purity of a protein if we are provided with a way to determine the sequence of proteins because it is very well understood that the precise sequence of an amino acid is critical for the proper functioning of a protein.

Example 2.5: Case Based:

Proteins are the building blocks of life and these are composed of small monomers, arranged into different groups. These monomers are linked together by the formation of bonds and form a polypeptide chain, which folds into a three dimensional (3D) structure to constitute a functional protein. These proteins are essential biomolecules, which are involved in the maintenance and metabolic processes of living organisms. In our body, protein is present in several forms. One such example of it is keratin protein which comes under the family of structural fibrous proteins also known as scleroproteins. Alpha-keratin (α-keratin) is a type of keratin found in vertebrates. It is the key structural material in these organisms. If the complete structure of a protein can be described, then it is described according to four different levels of complexity, i.e. primary, secondary, tertiary and quaternary structure.

(A) The monomers of proteins which synthesize entire biomolecules are called:

(a) Saccharides (b) Nucleotides
(c) Nucleosides (d) Amino acids

(B) What is the function of keratin protein?

(a) Helps in maintaining osmoregulation
(b) Maintaining the structure
(c) Lining the surfaces of the body
(d) All of the above

(C) Name the most abundant protein found in animals.

(D) Which bond is present in the primary structure of proteins?

(E) Assertion (A): Proteins are made up of amino acids.

Reason (R): Ten different types of amino acids combine to make a protein.

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

Ans. **(A)** *(d) Amino acids*

Explanation: Saccharides are sugars whereas nucleotides and nucleosides are the constituents of nucleic acids. Amino acids are the monomers of protein.

(B) *(c) Lining the surfaces of the body*

Explanation: Keratin is a type of protein present on the inside and exterior surfaces of the body's epithelial cells. Keratin helps in the formation of hair, nail, and skin's outer layer tissues.

(C) Collagen is the most abundant protein found in animals. Collagen is the main structural protein of the various connective tissue in animals. As the main component of connective tissue, it is the most abundant protein in mammals, makes up 25 to 35% of the whole-body protein.

(D) Peptide bonds are present in the primary structure of the protein. Within a protein, multiple amino acids are linked together by peptide bonds, thereby forming a long chain. Peptide bonds are formed by a biochemical reaction that extracts a water

molecule as it joins the amino group of one amino acid and the carboxyl group of a neighbouring amino acid.

(E) *(c) A is true but R is false.*

Explanation: Proteins are made up of hundreds or thousands of smaller units called amino acids, which are attached to one another in long chains. There are twenty different types of amino acids that can be combined to make a protein.

Example 2.6: Attempt titrating an amino acid against a weak base and discover the number of dissociating (ionisable) functional groups in the amino acid.

Ans. When a neutral or basic amino acid is titrated against a weak base, only one functional group is dissociated, however, when an acidic amino acid is titrated against a weak base, two or more functional groups are dissociated.

OBJECTIVE Type Questions

[1 mark]

Multiple Choice Questions

1. The *R*-group on an amino acid contains:

(a) water
(b) carbon dioxide
(c) any organic molecule
(d) fatty acid

Ans. *(c) any organic molecule*

Explanation: The *R*-group of an amino acid is what makes the various amino acids different from each other. *R*-groups can be acidic, basic, polar, non-polar, etc.

2. Proteins perform many physiological functions. For example, some function as enzymes. Which of the following represents an additional function that some proteins discharge?

(a) Antibiotics
(b) Pigment conferring colour to skin
(c) Pigments making colours of flowers
(d) Hormones **[NCERT Exemplar]**

Ans. *(d) Hormones*

Explanation: Hormones can be formed and secreted directly in the bloodstream through the endocrine glands following endocrine system whereas another contrasting, regulating system called exocrine, releases its products/substances using ducts and hence glands following exocrine pathway commonly called duct glands and glands following endocrine pathway are also called ductless glands.

Related Theory

Hormones are required in a trace amount to carry out various functions such as growth, thermal regulation, metabolic activities, etc. Some hormones are proteinaceous, e.g. insulin (regulates sugar metabolism), growth hormone of pituitary, parathormone of parathyroid gland (regulates calcium and phosphate transport).

3. A nucleotide is made up of the following constituent(s):

(a) Sugar **(b) Base**
(c) Phosphate **(d) All of these**

Ans. *(d) All of these*

Explanation: A nucleotide is made up of pentose sugar, nitrogenous base and phosphate group. They are the monomer units of nucleic acids.

4. Which structure of the protein is formed due to hydrogen bonding?

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

Ans. *(b) Secondary structure*

Explanation: In the secondary structure of proteins, the hydrogen bonding in protein gives rise to folding due to which alpha-helix and beta-pleated sheets are formed.

5. The primary structure of a protein molecule has:

(a) two ends **(b) one ends**
(c) three ends **(d) no end**
[NCERT Exemplar]

Ans. *(a) two ends*

Explanation: The primary structure of the protein is linear which ends with C-terminus (carboxyl terminal end) on one end and an N-terminus (amino terminal end) on the other.

6. The amino acid with no net charge is:

(a) glycine **(b) histidine**
(c) cysteine **(d) aspartic acid**

Ans. *(a) glycine*

Explanation: Glycine has an H-atom as its *R*-group which carries no charge. The negative charge of the carboxyl group is neutralised by the positive charge of the amino group and hence glycine has no charge.

Related Theory

Neutral Amino acids are glycine, alanine, leucine, isoleucine, valine, phenylalanine, proline, methionine, serine, threonine, tyrosine, cysteine, glutamine, asparagine, tryptophan. While, acidic amino acids are aspartic acid, glutamic acid and basic amino acids are lysine, histidine and arginine.

7. **Globular proteins follow which level of structure of protein arrangements?**

(a) Primary structure

(b) Secondary structure

(c) Tertiary structure

(d) Quaternary structure

Ans. *(c) Tertiary structure*

Explanation: Globular proteins are used in transportation and they are formed due to sulphide bonds, van der Waal forces, hydrophobic forces, etc.

Related Theory

Spherical ("globe-like") proteins, also known as globular proteins or spheroproteins, are one of the most frequent protein forms. Unlike fibrous or membrane proteins, globular proteins are relatively water soluble by forming colloids in water). Globular proteins are actually tertiary structures of proteins.

8. **Among the following which is not a non-polar amino acid?**

(a) Glycine **(b) Alanine**

(c) Valine **(d) Serine**

Ans. *(d) Serine*

Explanation: Serine is a polar amino acid whereas glycine, alanine and valine are non-polar.

9. **A transparent liquid was given to the students. The students were not allowed to smell, taste or perform any chemical reaction on the liquid. They were given the task of identifying whether the liquid contains protein or not. How will they do that?**

(a) By physically shaking the bottle.

(b) By incubating it in the presence of light.

(c) By incubating it in the presence of radiation.

(d) None of the above

Ans. *(a) By physically shaking the bottle.*

Explanation: On vigorous physical shaking of liquid, the amino acids in proteins can be broken which when interact with air forms bubbles and foam.

Assertion-Reason (A-R)

Given below are two statements labelled as Assertion (A) and Reason (R). Select the most appropriate answer from the options given below:

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

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

(c) A is true but R is false.

(d) A is false but R is true.

10. **Assertion (A):** **The group of amino acids that can be supplied by an organism under a defined condition are the non-essential amino acids.**

Reason (R): **Non-essential amino acids are those amino acids which can be synthesised by the body.**

Ans. *(b) Both A and R are true and R is not the correct explanation of A.*

Explanation: Non-essential amino acids are those amino acids which can be synthesised by the body in sufficient amounts. These are total eleven in number, *i.e.* alanine, arginine, asparagine, aspartic acid, cysteine, glutamic acid, glutamine, glycine, proline, serine, and tyrosine. Out of these, six (arginine, cysteine, glycine, glutamine, proline, and tyrosine) are considered as conditional amino acids. These are usually not essential, except in times of illness and stress. Thus, this group of amino acids can be supplied by an organism under a defined condition.

11. **Assertion (A):** **Protein interacts and assembles with other proteins.**

Reason (R): **The interaction or assembly provide multifunctional activity and specificity.**

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

Explanation: Protein interacts and assembles with other proteins through a combination of hydrophobic bonding, van der Waals forces, and salt bridges at specific binding domains on each protein. These domains can be small binding clefts or large surfaces and can be just a few peptides long or span hundreds of amino acids. Thus, on interaction or assemblage, new functions and specificity become available. These protein interactions provide multifunctional activity and specificity.

12. **Assertion (A):** ATP is an example of a nucleotide. It is also known as the energy currency of a cell.

Reason (R): The energy is stored in phosphate bonds.

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

Explanation: ATP (stands for adenosine triphosphate) is an example of nucleotide. The ATP molecules are the high energy molecules which store energy in their phosphate bonds and whenever energy is needed for any chemical reaction, these bonds are broken and energy is released.

13. **Assertion (A):** Essential amino acids cannot be synthesised by the human body and must be ingested for the mature formation of proteins.

Reason (R): These are nine essential amino acids, histidine, isoleucine, asparagine, lysine, methionine, glutamic acid, threonine, tryptophan, and proline.

Ans. *(c) A is true but R is false.*

Explanation: Essential amino acids are also known as indispensable amino acids. These are nine in number, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. These amino acids cannot be synthesised by the human body and therefore they must be taken from the diet. On the other hand, asparagine, glutamic acid, and proline are the non-essential amino acids.

CASE BASED Questions (CBQs)

[**4** & **5** marks]

Read the following passages and answer the questions that follow:

14. *Rohini is a kid who has been feeling lazy and tired. She went to her doctor. Her doctor told her to take a good amount of protein in her diet. She is suffering from a condition of low protein in her body. Hopefully, according to the doctor, she will feel all good and better. Answer the following questions based on the situation.*

(A) What is the name of the disease from which Rohini is suffering?

(a) Kwashiorkor (b) Anemia

(c) Diabetes (d) Both (a) and (b)

(B) What is the basic unit of proteins?

(a) Monosaccharides

(b) Nucleotide

(c) Amino acids

(d) None of the above

(C) What is the role of protein in the human body?

(a) Body repair

(b) New cell formation

(c) Both (a) and (b)

(d) Body degradation

(D) Which of the following is a property of amino acids?

(a) Having low metting and boiling points.

(b) having a high molecular weight.

(c) Organic solvents are insoluble in it.

(d) All of the above

(E) **Assertion (A):** There are 20 essential amino acids.

Reason (R): Essential amino acids are those amino acids that are not synthesised inside the human body.

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

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

(c) A is true but R is false.

(d) A is false but R is true.

Ans. (A) *(a) Kwashiorkor*

Explanation: Kwashiorkor is a disease that occurs in children suffering from protein deficiency.

(B) *(c) Amino acids*

Explanation: Amino acids are the basic unit of proteins whereas monosaccharide is the basic unit of carbohydrates and nucleotides are the basic unit of nucleic acid.

(C) *(c) Both (a) and (b)*

Explanation: Every cell in the human body is made up of proteins. Proteins are the building block so we need proteins for body repair and the formation of new cells. Proteins are an important source of energy also.

(D) *(d) All of the above*

Explanation: The properties of amino acids are:

(a) They have low melting and boiling points.

(b) They are crystalline white liquids having a high molecular weight.

(c) A pleasant, flavourless, or bitter flavour is shown by a few of the amino acids.

(d) Organic solvents are insoluble in most amino acids, which are soluble in water.

(E) *(d) A is false but R is true.*

Explanation: There are 9 essential amino acids, which cannot be synthesised inside the human body, so we need to take them from our food.

Related Theory

The nine essential amino acids are histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine.
The rest of the eleven amino acids that are considered as non-essential amino acids are alanine, arginine, asparagine, aspartic acid, cysteine, glutamic acid, glutamine, glycine, proline, serine and tyrosine.

15. *The proteins are composed of amino acids. They are organic compounds containing nitrogen, carbon, hydrogen, and oxygen and also a variable side chain group. For the efficient growth and operation of the many organs in the human body, 20 essential amino acids are required. Nine of the 20 are considered to be the most significant amino acids.*

Amino acids, the molecules' building blocks, are the components of proteins. By holding cells together, they provide many of a cell's structural components and help in tissue formation.

(A) On the basis of side chains, amino acids are differentiated into how many types?

(B) What is the importance of amino acids especially for human beings?

(C) Write about any two functions which are performed by essential amino acids.

Ans. (A) There are seven types of amino acids differentiated on the basis of side chains present.

Related Theory

The seven types of amino acids are:

(1) Acidic *(2) Basic*
(3) Aliphatic *(4) Amide*
(5) Sulfur-containing *(6) Polar neutral*
(7) Aromatic

(B) Amino acid is the compound that forms the building blocks of proteins. Proteins are essential components that make up 75% of the human body and are responsible for the overall development.

(C) In the human body, 9 essential amino acids are required. The functions performed by them are:

(1) Essential amino acids like phenylalanine, valine, and threonine help in maintaining the nervous system, promote muscle growth and strengthen the immune system.

(2) Essential amino acid, tryptophan is involved in the production of vitamin B_3 and serotonin hormones that play a vital role in regulating sleep, boosting mood, and in maintenance of appetite.

VERY SHORT ANSWER Type Questions (VSA)

[1 mark]

16. Define the role played by the amino acid isoleucine in the human body.

Ans. Isoleucine amino acid plays a vital role in the formation of haemoglobin along with stimulating the pancreas to synthesise insulin and helps transportation of oxygen in the human body.

Related Theory

Isoleucine is an essential amino acid which cannot be synthesised by human body. In fact, its requirement is completed by the diet.

17. Which is the most abundant protein found in the biosphere?

Ans. Ribulose bisphosphate Carboxylase-Oxygenase (RuBisCO).

18. What is the charge present in a zwitter ion?

Ans. No charge.

Related Theory

No charge on amino acid means no acidic or alkaline nature of amino acid. At pH 7, there should be no acidic or basic nature but the only amino acid that is zwitterionic at pH 7 is glutamine. At a specific pH value, an amino acid's structure permits it to act as both an acid and a base.

19. Glycine and Alanine are different with respect to one substituent on the carbon. What are the other common substituent groups? [NCERT Exemplar]

Ans. The common substituent groups are carboxyl group (–COOH), amino group ($–NH_2$) and hydrogen (–H) atom.

20. The chemical nature of an amino acid is decided by which one of the four groups?

Ans. The *R*-group.

21. The amino acids are present in which form in an aqueous solution?

Ans. Zwitter ion form.

SHORT ANSWER Type-I Questions (SA-I)

[2 marks]

22. Describe about the solubility of amino acids in water as well as in organic solvents.

Ans. Amino acids often dissolve in water but not in non-polar organic solvents like hydrocarbons. This confirms the reappearance of zwitter ions. The ionic attractions between the ions in the solid amino acid are replaced by the potent ionic interactions between polar water molecules and the zwitter ions in water.

23. Write the functions performed by non-essential amino acids.

Ans. The functions performed by non-essential amino acids are:

(1) Non-essential amino acids like alanine, cysteine, and glutamine help in the production of glucose and other amino acids.

(2) These provide resistance to certain diseases.

(3) Helps in promoting a healthy brain function.

(4) Helps in maintaining the regular processes in the body and promotes growth.

24. Proteins perform various functions in our body. Mention few.

Ans. Proteins have various functions:

(1) They provide energy for growth and maintenance of cells.

(2) Act as a biosignaling molecule.

(3) Act as a transporter molecules.

(4) Maintains homeostasis.

(5) Act as an enzymes with catalytic power.

(6) Make up the structure of cell.

(7) Carry out the important vital cellular functions of cell.

25. Provide an answer by explaining the importance of the *R*-group in amino acids.

Ans. The *R*-group determines the nature of amino acids. The *R*-group can have different chemical properties.

R - acidic (Aspartate)

R - basic (Lysine)

R - sulphur-containing (Cysteine)

R - aliphatic (Alanine)

R - polar neutral (Serine)

R - amide (Asparagine)

R - aromatic (Tryptophan)

26. What does turnover of biomolecules mean?

Ans. It means that biomolecules undergo many chemical reactions to transform themselves from one form to another and it is the basis of all the chemical reactions inside the body.

SHORT ANSWER Type-II Questions (SA-II)

[3 marks]

27. (A) Following is the given list of some amino acids. Observe them carefully.

Arginine, Glutamine, Histidine, Proline, Lysine, Isoleucine, Tryptophan

Which of the above amino acid(s) is/are not synthesised by the body and why?

(B) Name the amino acids that have non-polar aliphatic 'R'-group.

Ans. (A) From the above given list of amino acids, Histidine, Lysine, Isoleucine and Tryptophan are not synthesised by the body because these all are essential amino acids. As a result, they must be obtained through the consumption of food.

(B) Amino acids that have aliphatic non-polar or hydrophobic *R*-group are:

(1) Glycine (Gly, G): –H

(2) Alanine (Ala, A): CH

(3) Valine (Val, V): $(CH_3)_2CH$

(4) Leucine (Leu, L): $(CH_3)_2CHCH_2$

(5) Isoleucine (Ile, I): $CH_3CH_2CH(CH_3)$

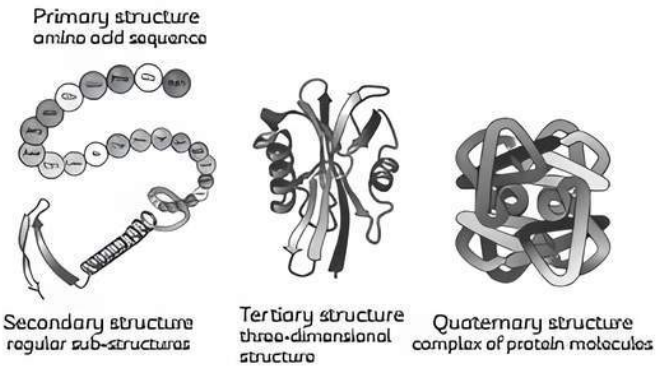
(6) Proline (Pro, P): $-CH_2CH_2CH_2$ cyclised onto the amine.

28. (A) Define Zwitter ion.

(B) Draw the diagrams of primary, secondary, tertiary and quaternary structures of protein.

Ans. (A) Zwitter ion is the ionic form of amino acids found in an aqueous environment. The hydrogen from the carboxyl group moves to the amino group making the carboxyl group negative and amino group positive. The overall charge of zwitterion remains zero.

(B) The diagrams of primary, secondary, tertiary and quaternary structures of protein are:



LONG ANSWER Type Questions (LA)

[**4** & **5** marks]

29. Give details of the levels of structures of proteins.

Ans. There are four types/levels of structure in proteins:

(1) Primary structure of proteins: The amino acids join together by peptide bonds in a linear fashion.

(2) Secondary structure of proteins: The hydrogen bonding within the linear structure of protein gives rise to right-handed helix and when hydrogen bonding is present in between two polypeptide chains adjacent to each other, then beta pleated sheets are formed.

(3) Tertiary structure of proteins: The interactions like sulphide bonds, hydrogen bonds, hydrophobic bonds and Van der Waal force of attraction give rise to three-dimensional structure of protein.

(4) Quaternary structure of proteins: Two or more polypeptide chains or subunits interlinked to one another to form a complex four dimensional structure of protein.

30. (A) Differentiate proteins on the basis of their shape.

(B) Describe one function of each one of them: collagen, trypsin, insulin and GLUT-4.

Ans. (A) On the basis of shape, proteins generally are of two types:

(1) **Fibrous:** In this, spiral secondary polypeptide chains wound around each other.

(2) **Globular:** These are spherical in shape.

Related Theory

Proteins are the polypeptides, having linear chains of amino acids which are linked together with the help of peptide bonds. These bonds are formed when the –COOH group of one amino acid reacts with the $–NH_2$ group of next amino acid by releasing a molecule of water.

(B) Proteins perform several functions such as:

(1) **Collagen:** It is the most abundant protein in the animal world which acts as an intercellular ground substance. Due to its rigidity and resistance to stretching, it is the perfect matrix for skin, tendons, bones, and ligaments.

(2) **Trypsin:** It acts as an enzyme that helps us digest protein. In the small intestine, it breaks down proteins, continuing the process of digestion that began in the stomach.

(3) **Insulin:** It acts as a hormone which regulates the blood sugar level.

(4) **GLUT-4:** It enables glucose transport into the cell that is responsible for insulin-regulated glucose uptake into fat and muscle cells.

31. Different types of amino acids are found in nature. Give a few examples.

Ans.

Types of amino acids	Examples
Non-polar amino acids with aliphatic groups.	Glycine Alanine Valine Leucine Proline Isoleucine
Polar amino acids with uncharged groups.	Serine Threonine
Sulphur-containing amino acids.	Cysteine Methionine
Amino acids with amide side-chains.	Asparagine Glutamine
Positively charged amino acids.	Lysine Arginine Histidine
Negatively charged amino acids.	Aspartate Glutamate
Non-polar amino acids with aromatic group.	Phenylalanine Tyrosine Tryptophan

32. Differentiate between the primary, secondary and tertiary structures of proteins.

Ans. The differences between the primary, secondary and tertiary structures of proteins are:

Primary Structure	Secondary Structure	Tertiary Structure
In this, a linear sequence of amino acids is seen.	Folding of the peptide chain into α-helix and β-pleated sheet.	Three-dimensional structure of a protein is formed.
Linear in shape.	Either an α-helix or β-pleated sheet.	Globular shaped.
Composed of peptide bonds which are formed between amino acids.	Encompasses hydrogen bonds.	Encompasses disulphide bridges, salt bridges and hydrogen bonds.
It is formed during the process of translation.	It forms collagen, elastin, actin, myosin and keratin-like fibres.	It includes enzymes, hormones, albumin, globulin and haemoglobin.
This structure of protein is involved in the post-translational modifications.	This structure of protein is involved in the formation of structures such as ligaments, cartilages and skin.	This structure of protein is involved in the metabolic functions of the body.

ENZYMES 3

TOPIC 1

ENZYMES

Many complicated reactions occur in the human body at temperatures of 37.5°C. Food digestion is an example of this, as it involves progressive oxidation producing CO_2 and water, as well as energy generation. Because of the existence of particular compounds known as enzymes, these processes take place in such benign circumstances. They serve as biochemical catalysts in living cells. Almost every enzyme is a globular protein.

Even some nucleic acids have enzyme-like properties. These are known as ribozymes. An enzyme, like any other protein, has a fundamental structure, which is the amino acid sequence. An enzyme, like any other protein, has secondary and tertiary structures.

Chemical Reactions

There are two sorts of modifications that occur in chemical compounds. A physical change is merely a deformation that does not involve the breaking of connections. This is a physical procedure. One physical process could be a change in states of matter, such as evaporation and fusion of substances. Whenever bonds are formed or broken during transformation, this is referred to as a chemical reaction. An example of this is represented as follows:

$$Ba(OH)_2 + H_2SO_4 \longrightarrow BaSO_4 + 2H_2O$$

(This represents a neutralisation reaction: H_2SO_4 is an acid while $Ba(OH)_2$ is a base. This is a precipitation process, and the precipitate created is $BaSO_4$).

This is an example of a chemical process that takes place in an inorganic environment. Similarly, starch breakdown into glucose is the result of an organic chemical process. The rate of a physical or chemical process depends on the quantity of product created per unit time. It may be expressed as follows:

$$\text{Rate} = \frac{\delta \text{ (product)}}{\delta \text{ (time)}} \text{ or } \left(R = \frac{\delta p}{\delta t}\right)$$

The rate of the reaction is the place where the products of a chemical reaction are created from the reactants. It provides some information about the time range wherein the reaction can be accomplished. To provide an example, the combustion of cellulose is an extremely rapid reaction; it only takes a few seconds. A general guideline is that for every 10°C shift in either direction, the rate doubles or reduces by half. Catalysed processes have been observed to proceed at significantly faster rates than uncatalysed ones. When enzyme-catalysed reactions are seen, the rate is much higher than the identical but uncatalysed process. An example of this is shown as follows:

In the absence of an enzyme, processes can be very inefficient, producing just around 200 molecules of H_2CO_3 each hour. However, by utilising a cytoplasmic enzyme called carbonic anhydrase, the reaction is speed up substantially, with around 600,000 molecules generated every second. The enzyme has thus increased the rate of the reaction by about 10 million times.

A metabolic pathway is a multistep chemical process in which each step is regulated by an enzyme (or a combination of them).

$$\underset{\text{Glucose}}{C_6H_{12}O_6} + O_2 \xrightarrow{\text{Cytoplasm}} \underset{\text{Pyruvate}}{2C_3H_4O_3} + 2H_4O$$

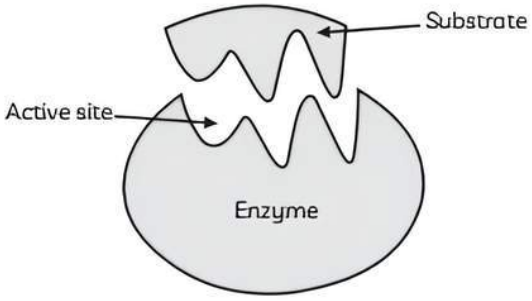
This reaction is part of a metabolic pathway that allows the conversion of glucose into energy in the human body. It is a step-by-step reaction, involving specific conditions as well as enzymes that serve as catalysts.

Example 3.1: The enzymes are made up of which biomolecule?

Ans. Enzymes are proteinaceous substances, hence they are made up of protein.

How do Enzymes bring about such High Rates of Chemical Conversions?

When a protein chain's backbone folds upon itself, the chain crisscrosses itself, and many crevices or pockets are formed, the protein is then said to possess a tertiary structure. The 'active site' is one such pocket. An enzyme's active site is a socket into which the substrate fits. Thus, enzymes catalyse processes at a rapid pace *via* their active site. In many aspects, enzyme catalysts vary from inorganic catalysts, but one key distinction stands out. Inorganic catalysts perform well at high temperatures and pressures, but enzymes are destroyed at high temperatures (over 40°C).



Active site of ezyme-substrate

Enzymes obtained from organisms that ordinarily live at extreme temperatures (*e.g.*, heat vents and sulphur springs) are more stable and keep their catalytic potency even at high temperatures (up to 80°C - 90°C). Thermal stability is therefore a critical property of enzymes derived from thermophilic species. For example, *Taq* polymerase enzyme is present in *Thermus aquaticus*.

Properties of Enzymes

(1) Enzymes can accelerate biological processes up to 10 million times faster than uncatalysed reactions.

(2) Enzyme catalysed processes reach equilibrium quickly.

(3) Human enzymes work best in dilute aqueous solutions at moderate temperatures and pH.

(4) Their impact on substrates is exceedingly particular and selective.

(5) Enzymes are very efficient and are only required in trace amounts.

(6) In addition to the protein structure, most active enzymes are linked to a non-protein component essential for their function, known as a coenzyme. For example, nicotinamide adenine dinucleotide (NAD) is a coenzyme that is involved in the activity of several dehydrogenation enzymes.

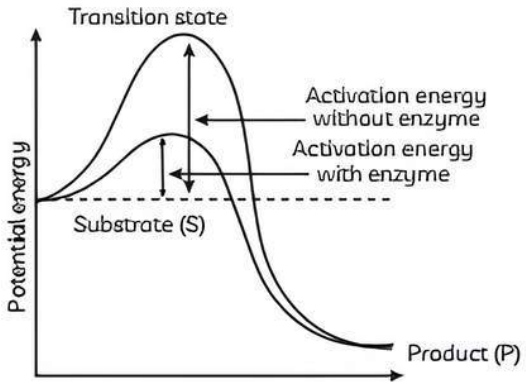
Action of Enzymes

A reaction is defined as a chemical or metabolic change. A 'substrate' is a chemical that is transformed into a product. As a result, enzymes, which are mostly proteins with three-dimensional structures that include an 'active site,' transform a substrate (S) into a product (P). This can be represented symbolically as:

It is now known that the substrate 'S' must bind the enzyme at its 'active site' within a specific socket. The substrate must diffuse to the 'active site.' As a result, the establishment of a 'ES' complex is unavoidable. The letter E stands for the enzyme. This complicated structure is a passing occurrence. When the substrate is attached to the active site of the enzyme, a new structure of the substrate known as the transition state structure is produced. The product is removed from the active location as soon as the planned bond breaking/making is finished. The substrate structure is changed into the product structure(s).

There are two things you would notice. The difference in energy levels between S and P. When 'P' is smaller than 'S,' the reaction is exothermic. There is no need to supply energy (through heating) in order to create the product, the substrate (S) must pass through a much higher energy state. This is also called the transition stage.

The gap in mean energy content between the substrate and this transition is known as 'activation energy.' It is here that enzymes finally break through this energy barrier, allowing the shift from substrate (S) to product (P) easier.



Example 3.2: Which constituent remains unchanged after the completion of a chemical reaction?

Ans. A catalyst or enzyme remains unchanged chemically at the end of the reaction. It takes part in the reaction mechanism. It may be consumed in the first step of the reaction and regenerated in the second step of the reaction.

Nature of Enzyme Action

Each enzyme (E) contains a substrate (S) binding domain in its molecule, allowing a substrate to attach to the enzyme. This results in the formation of a reactive enzyme-substrate complex (ES).

$$E + S \rightarrow ES$$

This complex has a brief lifetime and decomposes into its final product(s) (P) and the unmodified enzyme with intermediate enzyme-product complex (EP). The formation of the 'ES' complex is absolutely essential for the process of catalysis.

$$ES \rightarrow EP \rightarrow E + P$$

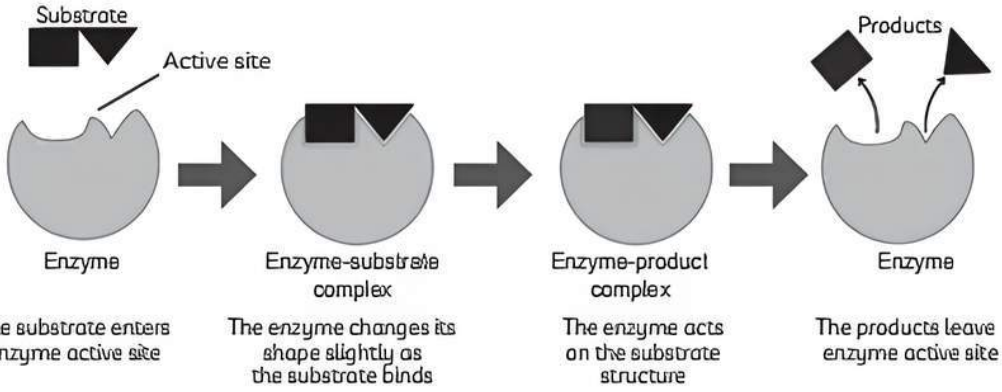
The following stages explain the catalytic cycle of an enzyme action:

(1) The substrates attach to the enzyme's active site, fitting into it.

(2) This binding of the substrate causes the enzyme to change shape, causing it to fit more closely around the substrate.

(3) The enzyme's active site, which is now in close vicinity to the substrate, destroys the chemical bonds of the substrate, resulting in the formation of a new enzyme-product complex.

(4) The enzyme releases the reaction products, and the free enzyme is ready to attach to some other molecule of the substrates and repeat the catalytic cycle.



Enzyme-catalysed reaction

Example 3.3: Enzymes exhibit variable properties on the basis of their structure. Describe. [NCERT]

Ans. All enzymes are generally made up of protein. The following are some of the most important features of enzymes:

(1) They are complex macromolecules with a larger molecular weight.

(2) They aid in the breakdown of bigger molecules into simpler ones or the joining of two smaller molecules to generate a larger one by catalysing metabolic processes in the cell.

(3) Enzymes do not start a process; rather, they speed it up.

(4) They have an effect on the rate of a biological process but have no effect on the reaction's direction.

(5) They are action-oriented.

(6) The efficiency of a process increases as the turnover of enzymes increases. The majority of enzymes have a high turnover rate.

(7) Temperature has an impact on enzymes. Enzymatic activity reduces as the temperature rises. At 30-40 degrees Celsius, maximum activity is recorded.

(8) At pH levels of 6-8, maximum activity of enzymes is recorded.

(9) The enzyme velocity increases as the substrate concentration rises, eventually reaching maximum velocity.

Example 3.4: Case Based:

The combustion of cellulose happens to be an extremely rapid reaction, often taking very little time. You must have observed how quickly paper burns upon being exposed to fire or high temperatures. This however, is not a catalysed reaction. Catalysed processes have been observed to proceed at even faster rates than uncatalysed ones. When enzyme-catalysed reactions are seen, the rate is much higher than the identical but uncatalysed process.

(A) Which of the following is not a true example of an enzyme catalysed reaction in the human body?

(a) Preliminary processing of sugar

(b) Secondary processing of sugar

(c) Processing of fat

(d) Processing of cellulose

(B) Which of the following mathematical operations can give us an idea of the catalytic activity of an enzyme?

(a) $\frac{\delta(\text{substrate})}{\delta(\text{time})}$

(b) $\frac{\delta(\text{product})}{\delta(\text{time})}$

(c) $\frac{\delta(\text{enzyme consumed})}{\delta(\text{time})}$

(d) None of these describe catalytic activity.

(C) What change in the catalytic activity would you expect to see upon an increase of temperature by 10°C?

(D) "When enzyme catalysed reactions are seen, the rate is much higher than the identical but uncatalysed process." Justify using an example.

(E) Assertion (A): Catalysed processes have been observed to proceed at even faster rates than uncatalysed ones.

Reason (R): Enzymes (Catalysts) reduce activation energy, and thus make the reaction thermodynamically favourable.

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

Ans. (A) *(d) Processing of cellulose*

Explanation: The human body does not have enzymes to digest or break down cellulose in any manner. This means that the processing of cellulose is not enzyme catalysed.

(B) *(b)* $\frac{\delta(product)}{\delta(time)}$

Explanation: The rate of a physical or chemical process depends on the quantity of product created per unit time. It may be expressed as follows:

$$\text{Rate} = \frac{\delta(\text{product})}{\delta(\text{time})}$$

This is used to predict the rate of the reaction, and thus, the activity of the enzyme.

Related Theory

➥ *The amount of enzyme consumed may be a tempting option. Enzymes are measured on the basis of their effect upon products because enzymes are catalysts that do not directly participate in the reaction.*

(C) The catalytic activity might reduce or increase by around half, by the general thumb rule.

Related Theory

➥ *A general guideline is that for every 10°C shift in either direction, the rate doubles or reduces by half. Catalysed processes have been observed to proceed at significantly faster rates than uncatalysed ones. When enzyme catalysed reactions are seen, the rate is much higher than the identical but uncatalysed process.*

(D) When enzyme catalysed reactions are seen, the rate is much higher than the identical but uncatalysed process. An example of this is shown as follows:

In the absence of an enzyme, processes can be very inefficient, producing just around 200 molecules of H_2CO_3 each hour. However, by utilizing a cytoplasmic enzyme called carbonic anhydrase, the reaction is speed up substantially, with around 600,000 molecules are generated every second. The enzyme has thus increased the rate of the reaction by about 10 million times.

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

Explanation: Catalysed processes have been observed to proceed at even faster rates than uncatalysed ones due to the activity of enzymes. Enzymes act as catalysts, reduce activation energy, and thus make the reaction thermodynamically favourable. This makes both Assertion and Reason true and thus, Reason is the correct explanation of Assertion.

OBJECTIVE Type Questions

[1 mark]

Multiple Choice Questions

1. The energy currency molecule of the living system is called:
(a) Lipid
(b) Adenine
(c) Protein
(d) Adenosine triphosphate

Ans. *(d) Adenosine triphosphate*

Explanation: The energy currency molecule of the living system is called Adenosine triphosphate (ATP).

2. Choose the incorrect statement:
(a) Initially, the pace of the enzyme reaction increases as the substrate concentration increases.
(b) An enzyme's activity can be influenced by changes in environmental circumstances, which can modify the protein's tertiary structure.
(c) A metabolic route is a multistep chemical process in which each step is regulated by an enzyme.
(d) In the absence of an enzyme, any process tends to be very inefficient.

Ans. *(d) In the absence of an enzyme, any process tends to be very inefficient.*

Explanation: In the absence of an enzyme, any process tends to be very inefficient. For example, just around 200 molecules of H_2CO_3 produces each hour in the absence of an enzyme.

3. What was the enzyme that was first isolated and purified in the form of crystals?
(a) Urease
(b) Carbonic anhydrase
(c) Salivary amylase
(d) Succinic dehydrogenase

Ans. *(a) Urease*

Explanation: Urease was first isolated and purified in the form of crystals.

4. Which of the following represents the function that some proteins perform?

(a) Antibiotics

(b) Pigment conferring colour to skin

(c) Pigments making colours of flowers

(d) Act as hormones

Ans. *(d) Act as hormones*

Explanation: Some proteins function as hormones that are essential for performing physiological functions of the human body. For example, Insulin, glucagon, thyrocalcitonin, pituitary hormones, and hypothalamic hormones. These all are proteinaceous hormones. They are also known as polypeptide hormones.

5. Which of the following terms is/are correct about enzymes?

(a) Proteins **(b) Dinucleotides**

(c) Nucleic acids **(d) All of these**

[NCERT Exemplar]

Ans. *(a) Proteins*

Explanation: Enzymes comprise protein molecules that function as biocatalysts for chemical processes in the body.

6. Enzymes speed up the process by reducing the activation energy. The statement is:

(a) True **(b) False**

(c) Can't say **(b) Can't be determined**

Ans. *(a) True*

Explanation: The gap in free energy between reactants and the transition state is referred to as activation energy. Enzymes decrease the activation energy as well as pass the transition state to accomplish a reaction.

7. In the context of an organic reaction, what does V_{max} stand for?

(a) The maximum velocity of an enzymatically catalysed reaction, when the enzyme is saturated with its substrate.

(b) The velocity of an enzymatically catalysed reaction at half the concentration of initial substrate.

(c) The velocity of an enzymatically catalysed reaction at half the concentration of the final product.

(d) None of the above

Ans. *(a) The maximum velocity of an enzymatically catalysed reaction when the enzyme is saturated with its substrate.*

8. Choose the correct statement.

(a) The combustion of cellulose is a relatively slow reaction.

(b) An enzyme's active site is a fissure or pocket into which the product fits.

(c) Pepsin operates in the stomach's extremely acidic environment.

(d) Enzymes operate within wise ranges of temperature and pH.

Ans. *(c) Pepsin operates in the stomach's extremely acidic environment.*

Explanation: Pepsin is a stomach enzyme that serves to digest proteins found in ingested food. Gastric chief cells secrete pepsin as an inactive zymogen called pepsinogen. Parietal cells within the stomach lining secrete hydrochloric acid that lowers the pH of the stomach. A low pH (1.5 to 2) activates pepsin.

9. Lyase carries out which of the following functions?

(a) Separation of bonds

(b) Joining of bonds

(c) Adding phosphorus to molecules

(d) Removing phosphorus from molecules

Ans. *(a) Separation of bonds*

Explanation: In biochemistry, a lyase refers to an enzyme that catalyses the separation of various chemical bonds.

Caution

Students often get confused between lyases and lipases. Lipase is an enzyme that facilitates the joining of DNA strands together by catalysing the formation of a phosphodiester bond. Lyases are general enzymes that separate chemical bonds.

Assertion-Reason (A-R)

Given below are two statements labelled as Assertion (A) and Reason (R). Select the most appropriate answer from the options given below:

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

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

(c) A is true but R is false.

(d) A is false but R is true.

10. Assertion (A): Each enzyme possesses an appropriate pH where it performs best.

Reason (R): Trypsin and pepsin are digestive enzymes that break down protein chains present in food into smaller pieces.

Ans. *(b) Both A and R are true and R is not the correct explanation of A.*

Explanation: Each enzyme possesses an appropriate pH where it shows maximum activity, but this is not explained by the fact that trypsin and pepsin are digestive enzymes that break down protein chains in food into smaller pieces.

11. **Assertion (A):** **Proteins which have the high catalytic power are called enzymes.**

Reason (R): **Amino acids are also considered as they have no charge.**

Ans. *(c) A is true but R is false.*

Explanation: The monomeric unit of protein is amino acids and when amino acids are present in the aqueous environment then, they are called zwitter ion which possesses no charge.

12. **Assertion (A):** **When a protein chain's backbone folds upon itself, the chain criss-crosses itself, and many crevices or pockets are formed.**

Reason (R): **This protein is said to possess a tertiary structure.**

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

13. **Assertion (A):** **Trypsin functions best in the small Intestine.**

Reason (R): **This is because trypsin can only function at a low pH.**

Ans. *(c) A is true but R is false.*

Explanation: Trypsin functions in the small intestine, and is functional only in alkaline conditions, *i.e.* high pH.

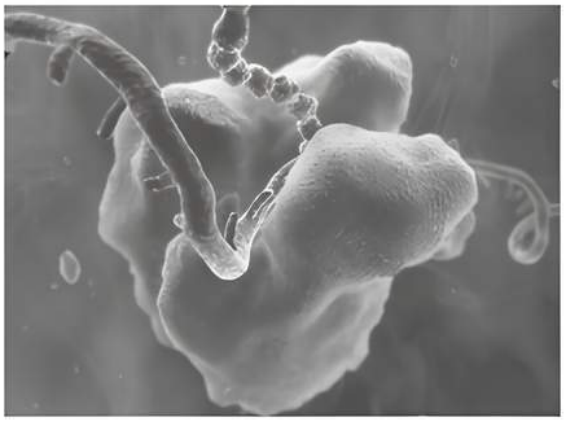
14. **Assertion (A):** **The reaction eventually achieves a maximum velocity (V_{max}) that is not exceeded by any additional increase in the concentration of the substrate.**

Reason (R): **V_{max} is achieved at the velocity where substrate is reduced to half of its concentration.**

Ans. *(c) A is true but R is false.*

Explanation: V_{max} refers to the maximum velocity of the reaction. This does not increase or decrease with the addition of more substrate.

15. **Enzymes have become one of the major industrial products of biotechnology. Growth of the enzyme market has been dramatic over the last 20 years and its expansion continues, new growth being often initiated from unusual and unexpected sources.**



Assertion (A): **Enzymes are very sensitive towards changes in pH and temperature.**

Reason (R): **Enzymes are only made up of proteins.**

Ans. *(c) A is true but R is false.*

Explanation: Enzymes are made up of proteins but they may also contain non-protein parts like organic or metallic groups in them. Due to the presence of proteins, enzymes are susceptible towards changes in the environment and such changes can affect their function and physiological structure.

16. **Assertion (A):** **Proteins with catalytic power are called enzymes.**

Reason (R): **Enzymes perform chemical reactions at a fast pace.**

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

Explanation: Enzymes are made up of proteins and they catalyse the chemical reactions to speed up the metabolism.

CASE BASED Questions (CBQs)

[**4** & **5** marks]

Read the following passages and answer the questions that follow:

17. *Enzymes are proteins that act as biological catalysts (biocatalysts). Almost all enzymes are proteins. Some Nucleic acids behave like enzymes. They are called ribozymes. Enzymes have tertiary structures and many crevices called 'active sites'. Enzymes act upon substrates and change them into products.*

Substrate binds to the active sites of enzymes. Like all catalysts, enzymes increase the rate of reaction by lowering their activation energy.

Some enzymes are used commercially, for example, synthesis of antibiotics, smart detergent to remove fat stains on clothes, in biscuit factories and in meat tenderizer process. **[Delhi Gov. QB 2022]**

(A) Which enzyme is used by the biscuit manufacturers to lower the protein level of flour?

(a) Amylases **(b) Proteases**

(c) Cellulases **(d) Xylases**

(B) Which of the following statements is/are correct about enzymes?

(a) An enzyme is a protein which acts as a biocatalyst to accelerate the rate of reaction.

(b) Life would not exist without the presence of enzymes in cells.

(c) Enzymes participate in various cellular metabolic processes.

(d) All of the above

(C) A protein having both structural and enzymatic properties is:

(a) Collagen **(b) Trypsin**

(c) Myosin **(d) Actin**

(D) The diagram shows a metabolic pathway:

$$A \xrightarrow{\text{Enzyme 1}} B \xrightarrow{\text{Enzyme 2}} C \xrightarrow{\text{Enzyme 3}} D$$

What would happen to the rate of production of 'D', if enzyme 1 was not present?

(a) It would stop.

(b) It would be increased.

(c) It would be decreased.

(d) No effect.

(E) Assertion (A): All enzymes are not proteins.

Reason (R): RNA molecules that possess catalytic activity are called ribozymes.

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

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

(c) A is true but R is false.

(d) A is false but R is true.

Ans. (A) *(b) Proteases*

Explanation: Proteases are used by biscuit manufacturers to lower the protein level of flour. Trypsin is used to pre-digest baby foods.

(B) *(d) All of the above*

Explanation: Biochemical reactions are sped up by enzymes, which operate as biological catalysts. The most popular explanation proposes that enzymes bind to the substrate molecule and create a transition state. An energy barrier that the substrates must pass separates the products from the substrates as the reaction progresses. The activation energy is the name given to this energy barrier. In contrast to the activation energy barrier in the absence of enzymes, the activation energy barrier in the case of a transition state is significantly lower. Because a transition state is formed and less activation energy is needed, processes catalysed by enzymes proceed at a higher rate. This modification is the result of what appears to be an increase in substrate molecule energy level.

(C) *(c) Myosin*

Explanation: Myosin is structural as well as functional protein. Myosin is also a functional protein as it has a specific function and is involved in muscle contraction and in various motility processes.

Related Theory

Structural protein is that protein that provides scaffolding or that gives the cell or one of its organelles its shape, while an enzymatic protein is a protein that catalyses a reaction of some kind. Structural protein includes actin, myosin, microtubules etc. Functional proteins include various enzymes like kinases and ATPases.

(D) *(a) It would stop.*

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

18. *Enzymes are important to the human body because they facilitate important chemical reactions that allow our body to function properly. Their productivity can be influenced by factors such as temperature and pH (how acidic or basic a substance is). There are various practical applications of enzymes in medical situations, such as in the emergency room, when a reaction must occur quickly in the body for the health of the patient. Certain medicines also act as catalysts in the same sense, speeding up chemical reactions that need to occur faster in the body. Overall, enzymes are important in situations where a chemical reaction must occur within a certain time frame.*

(A) Give examples of slow and fast reactions.

(B) What is the active site of an enzyme?

(C) Illustrate the lock and key hypothesis of enzyme action by using a diagram.

Ans. (A) Examples of slow reactions are rusting of a water pipe, a piece of newspaper turning yellow and so forth.

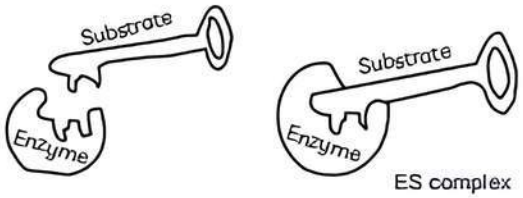
Examples of fast reactions are striking a match, burning of petrol in the car engine and so forth.

Caution

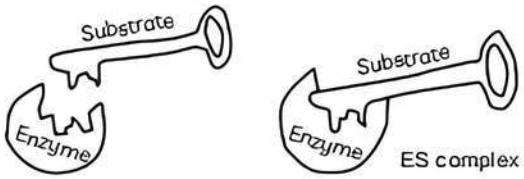
Students usually get confused between slow and fast reactions. The slow reaction is defined as the reaction which takes longer time to complete. The slow reaction possesses a low rate of reaction. They possess higher activation energy. The fast reaction is defined as the reaction which takes a shorter time to complete. The fast reaction possesses a high rate of reaction. They possess smaller activation energy.

(B) An active site is a crevice on the enzyme molecule into which a substrate molecule fits.

(C)



Lock and Key model



Induced fit model

19. *Richa was curious about enzymes working in our bodies. Our cells use a myriad of enzymes to do basically everything from replication to energy production. Following are a couple of examples of some other catalysts.*

Enzymes are probably still the most common catalysts you come in contact with in your daily life since they are used in both laundry and dishwasher detergents. Mostly they are proteases used to get rid of protein stains like an egg yolk that is otherwise hard to dislodge, but other enzymes are added as well. Fun fact - most of the detergent enzymes are produced in a surprisingly small number of factories, meaning that all those different brands of detergents competing with each other in the market place actually use the same active ingredients produced by the same few companies.

(A) Enzymes are made up of:

(a) fats **(b) proteins**

(c) nucleic acids **(d) vitamins**

(B) Which statement about enzymes is true?

(a) Enzymes accelerate reactions by lowering the activation energy

(b) Enzymes are proteins whose three-dimensional form is key to their function

(c) Enzymes do not alter the overall change in free energy for a reaction

(d) All of the above

(C) Enzyme activity decreases at higher temperature because:

(a) new bonds are formed

(b) of reformation of proteins

(c) denaturation of its active site occurs

(d) proteins denature at high temperature

(D) Enzyme-driven metabolic pathways can be made more efficient by:

(a) grouping enzymes into multienzyme free-floating complexes

(b) concentrating enzymes with specific cellular compartments

(c) fixing enzymes into membranes so they are adjacent to each other

(d) all of the above

(E) Diastase takes part in digestion of which one:

(a) protein **(b) starch**

(c) amino acids **(d) fat**

Ans. (A) *(b) proteins*

Explanation: The enzymes are the tertiary and quaternary structures of the protein, the only exception to it is the presence of the catalytic RNA molecules.

(B) *(d) All of the above*

Explanation: Enzymes catalyse the biochemical reaction, they increase the rate of reaction by lowering the activation barrier. They are generally tertiary and quaternary proteins, they are not consumed in the reaction.

(C) *(d) proteins denature at high temperature*

Explanation: Enzymes are proteins. Proteins get denatured at higher temperatures. Hence, the activity of enzymatic proteins also decreases at higher temperatures.

(D) *(d) all of the above*

Explanation: Enzyme-driven metabolic pathways can be made more efficient by concentrating enzymes within specific cellular compartments, grouping enzymes into free-floating, multienzyme complexes and fixing enzymes into membranes so that they are adjacent to each other.

(E) *(b) starch*

Explanation: Any set of enzymes that catalyse the breakdown of starch into maltose is known as diastase. Urine diastase is effective in detecting ambiguous abdominal situations, particularly when pancreatitis, stones in the common bile

duct, jaundice, and ruling out postoperative pancreatic damage are suspected; provided the diastase level is associated with clinical symptoms of the patient.

VERY SHORT ANSWER Type Questions (VSA)

[1 mark]

20. What does an enzyme do in terms of the energy requirement of a reaction?
[Delhi Gov. QB 2022]

Ans. An enzyme lowers the activation energy of reaction.

21. Which enzyme is secreted by the pancreas?

Ans. A proteolytic enzyme, trypsin is secreted by the pancreas.

22. "Many coenzymes' key chemical components include vitamins". Provide an example.

Ans. The coenzymes Nicotinamide adenine dinucleotide (NAD) and NADP contain the vitamin niacin.

23. Where does the substrate bind to an enzyme?

Ans. Substrate binds the enzyme at its 'active site' within a specific cleft or pocket.

SHORT ANSWER Type-I Questions (SA-I)

[2 marks]

24. (A) What is the difference between inorganic catalysts and enzymes?
(B) Briefly describe the modifications that may occur in a chemical compound.

Ans. (A) Inorganic catalysts perform well at high temperatures and pressures, but enzymes are destroyed at high temperatures (over 40°C).

(B) There are two sorts of modifications that occur in chemical compounds. A physical change is merely a deformation that does not involve the breaking of connections. Whenever bonds are formed or broken during transformation, this is referred to as a chemical reaction.

Related Theory
Forces like hydrogen bonding tend to be disrupted as a result of physical or chemical change, during which globules unfold, and helix uncoils to produce a thread-like molecule. As a result, protein secondary and tertiary structures lose all or part of their biological function. This is referred to as protein denaturation.

25. What would happen when salivary amylase which acts on starch in the mouth enters the stomach? [Delhi Gov. QB 2022]

Ans. In the mouth, salivary amylase changes starch into maltose. If this salivary amylase reaches the stomach, its action will stop as it cannot act in an acidic medium of the stomach.

SHORT ANSWER Type-II Questions (SA-II)

[3 marks]

26. (A) Do metals have a role in biochemical processes? Elaborate in the context of enzymes.
(B) Write the expression used for the rate of a physical or chemical process.
(C) Define activation energy.

Ans. (A) Metal Ions are required for the activity of a variety of enzymes, which engage with side chains at the active site while also forming one or more coordination bonds with the substrate. For example, zinc is a cofactor for carboxypeptidase.

(B) The rate of a physical or chemical process

$$= \frac{\delta P}{\delta T}$$

(C) The difference in the average energy content of a substrate from its transition state is called activation energy.

27. (A) Provide an example of a multi-step, metabolic reaction.
(B) Inhibitor binds to the active site of the enzyme, hence blocking the reaction. Whose example is this?

Ans. (A) A metabolic route is a multistep chemical process in which each step is regulated by an enzyme (or a combination of them). This involves several steps of multi-stage reactions, shown as follows:

$$\underset{\text{glucose}}{C_6H_{12}O_6} \xrightarrow{\text{cytoplasm}} \underset{\text{pyruvate}}{C_3H_4O_3}$$

$$\underset{\text{pyruvate}}{C_3H_4O_3} \xrightarrow{\text{oxygen}} CO_2 + H_2O + \text{energy}$$

(B) This is an example of competitive inhibition as when the substrate binds to the active site of the enzyme, it completes the reaction. When an inhibitor binds to the active site of the enzyme, it blocks the reaction.

LONG ANSWER Type Questions (LA)

[**4** & **5** marks]

28. (A) "Catalysed processes have been observed to proceed at significantly faster rates than uncatalysed ones." Justify the statement with an example.

(B) The living state is a non-equilibrium steady state to be able to perform work. Comment.

(C) Name the coenzyme of riboflavin (B_2) and state the nature of an enzyme.

Ans. (A) When enzyme catalysed reactions are seen, the rate is much higher than the identical but uncatalysed process. An example of this is shown as follows:

In the absence of an enzyme, the processes become very inefficient, producing just around 200 molecules of H_2CO_3 each hour. However, by utilizing a cytoplasmic enzyme called carbonic anhydrase, the reaction is sped up substantially, with around 600,000 molecules generated every second. The enzyme has thus increased the rate of the reaction by about 10 million times.

(B) Living entities exist in a steady state that is characterised by the concentration of every biomolecule, which is in metabolic flux. Any physical or chemical phenomena move parallell to the equilibrium. Living entities work continuously hence they cannot reach equilibrium. Thus living state is in a non-equilibrium steady-state to be able to perform work that is attained via energy provided by metabolism.

(C) The coenzymes of riboflavin (B_2) are FAD and FMN. The nature of enzymes is proteinaceous.

29. Formation of the enzyme-substrate complex (ES) is the first step in catalysed reactions. Describe the other steps until the formation of the product. [NCERT Exemplar]

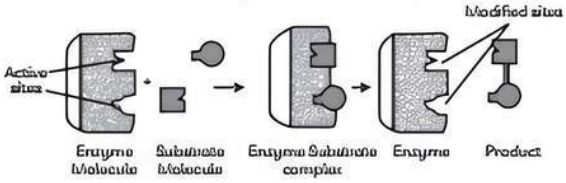
Ans. Each enzyme molecule has a particularly active site where substrate molecules can be bound. Enzymes function by changing the reaction's activation energy. The following is a description of an enzyme's catalytic site:

(1) The development of the Enzyme Substrate (ES) complex is caused by the substrate binding, which causes the enzymes to change their structure.

(2) The development of the Enzyme Substrate (ES) complex is caused by the substrate binding, which causes the enzymes to change their structure.

(3) The substrate is now in close proximity to the enzyme's active site, which breaks its chemical bonds and causes the formation of a new enzyme product complex.

(4) The enzyme discharges the reaction's products, and the free enzyme is prepared to attach to a different molecule of substrate and repeat the catalytic cycle.



30. How do enzyme catalysed reactions take place?

Ans. (1) Enzymes are proteins with catalytic effciency.

(2) Enzymes show specificity towards the binding of substrate, i.e., no other enzyme can catalyse the same reaction involving the same substrate molecule.

(3) Enzymes bind with substrate at a specific site called active site.

(4) A conformational change occurs in the enzyme which causes the strong interaction between enzyme and substrate.

(5) An enzyme-substrate complex is formed.

(6) Product is formed by breaking old bonds and making new ones within the active site.

(7) Product is released from enzyme molecules and enzyme remains unchanged and ready for another substrate catalysis reaction.