UNIT 07

Enzymes

Descriptive Questions

Metabolism

Q.1 Define metabolism. Differentiation between catabolism and anabolism? 09407001

Ans. Definition

Metabolism is the sum of all chemical reactions that occur within an organism to sustain life.

Types

There are two sub-sets of metabolism i.e., catabolism and anabolism

1. **Catabolism**

   Definition

   It involves the breakdown of complex molecules into simpler ones, releasing energy in the process.

Examples

i. Cellular respiration i.e. oxidation of food (glucose) into CO_2 and H_2O to get energy.
ii. Lipolysis i.e., break-down of lipids (fats) into fatty acids and glycerol, which can be used for energy production.

2. **Anabolism**

   Definition

It involves building up complex molecules from simpler ones. This process consumes energy.

Examples

i. Photosynthesis i.e. conversion of carbon dioxide and water into glucose and oxygen using sunlight.
ii. Protein synthesis i.e., formation of proteins from amino acids, which are vital for cell structure and function.

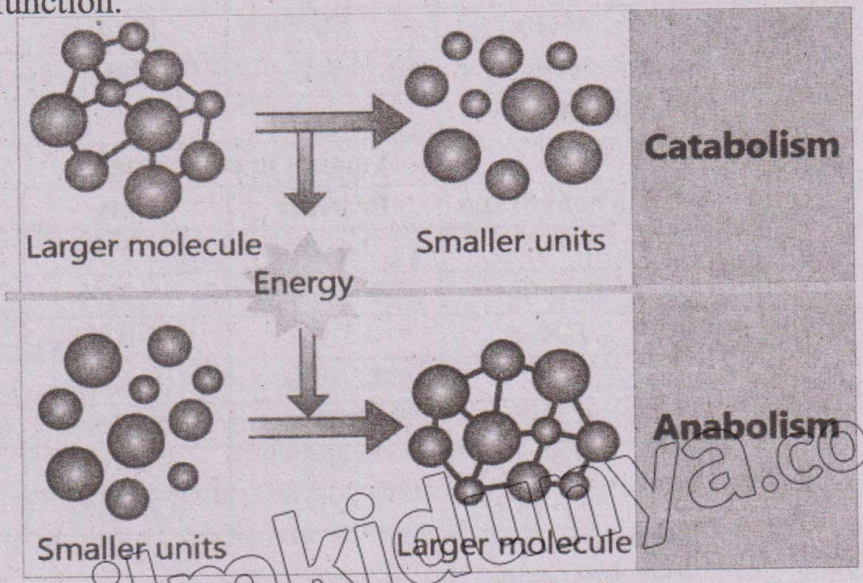


Figure 7.1: Types of Metabolism

Q.2 Describe the characteristics of enzymes. 09407002

Ans. Introduction

Enzymes are biological catalysts that speed up chemical reactions in living organisms without being consumed in the process.

Nature of Enzymes

i. They are primarily proteins and are highly specific to their substrates (the molecules that undergo enzyme- controlled reactions).

ii. Some RNA molecules also act as enzymes. Such RNA is called ribozyme. Ribozymes are primarily found in ribosome. They are also found in specific viruses and bacteria.

iii. Most enzymes can speed up reactions millions of times faster than uncatalyzed reactions.

Characteristics of Enzymes

i. **Chemical Nature of Enzymes:** Enzymes are predominantly proteins. Typically, they contain 100 to 1,000 amino acids.

ii. **Globular Structure (Active sites):** Enzymes possess a three dimensional globular structure. This structure allows them to form active sites that can bind specifically to substrates.

iii. **Specificity of Enzymes:** Enzymes are highly specific to the reaction they catalyse they are also very specific for the nature of substrate.

Example: Enzyme amylase specifically catalyses the breakdown of starch into simple sugars.

iv. **Intracellular and Extracellular Enzymes:** Enzymes can be classified based on the location where they function.

a) **Intracellular Enzymes** operate within cells e.g., enzymes of cellular respiration.

b) **Extracellular Enzymes** are secreted outside the cells to catalyse reactions e.g., enzymes secreted by the cells of stomach walls into stomach cavity for the digestion food.

v. **Cofactors of Enzymes**

Definition

Many enzymes require additional non-protein molecules to be fully active. Such non-protein molecules are called cofactors.

Main Groups

There are two main groups of cofactors. i.e., inorganic cofactors and organic cofactors.

a) **Inorganic cofactors** include metal ions like iron and magnesium ions.

b) The **organic cofactors** are of two types.

- **Prosthetic Groups** tightly bind with the enzymes. Examples are certain vitamins (e.g., biotin) and the haem group.
- **Coenzymes** loosely bind to the enzyme and may be released during the reaction. Examples include many vitamins and nucleotides (NAD and NADP).

vi. **Enzyme Actions in Complex Metabolic Reactions:** Enzymes often function in pathways. Multiple enzymes work in a sequence to carry out a series of reactions. Each enzyme in the pathway catalyses a specific step. After speeding up the reaction the product is passed on the next enzyme for further reaction.

vii. **Use of Enzymes in Different Industries:** Enzymes have extensive applications in various industries. **For example**

- **Food Industry:** Enzymes that break starch into simple sugars are used in production of white bread, buns and rolls. Enzymes are also used for the production of cheese.
- **Paper Industry:** Enzymes degrade starch to lower its viscosity that aid in making paper.
- **Biological Detergent:** Protease enzymes are used for removal of protein stains from clothes. Amylase enzymes are used in dish washing to remove resistant starch residues.
- **Fermentation Industry:** Enzymes degrade starch and proteins to produce simple sugar, amino acids and peptides that are used by yeast for fermentation.

Mechanism of Enzyme Action

Q.3 Describe the mechanism of enzyme action. **09407003**

Ans. Introduction

An enzyme has one or more pockets or clefts on its surface called active site. The active sites are directly involved in catalysis. Two models have been proposed to explain the mechanism of enzyme action.

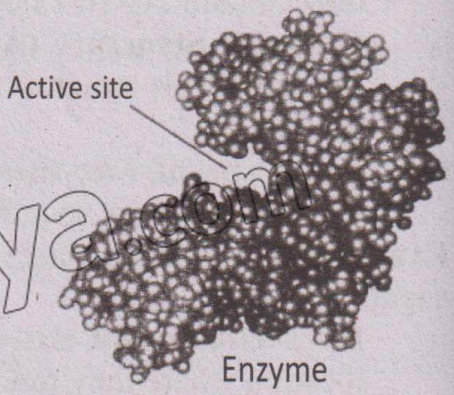


Figure 7.2: Active site of enzyme

1. Lock and Key Model of Enzyme Action

Introduction

The model was proposed by a German chemist Emil Fischer in 1894.

Explanation

According to it, the active site of an enzyme has fixed structure. The substrate molecule fits precisely into it to form an **enzyme-substrate complex.** The enzyme catalyzes the reaction and substrate is transformed into product/s. Then, the product is released from the enzyme.

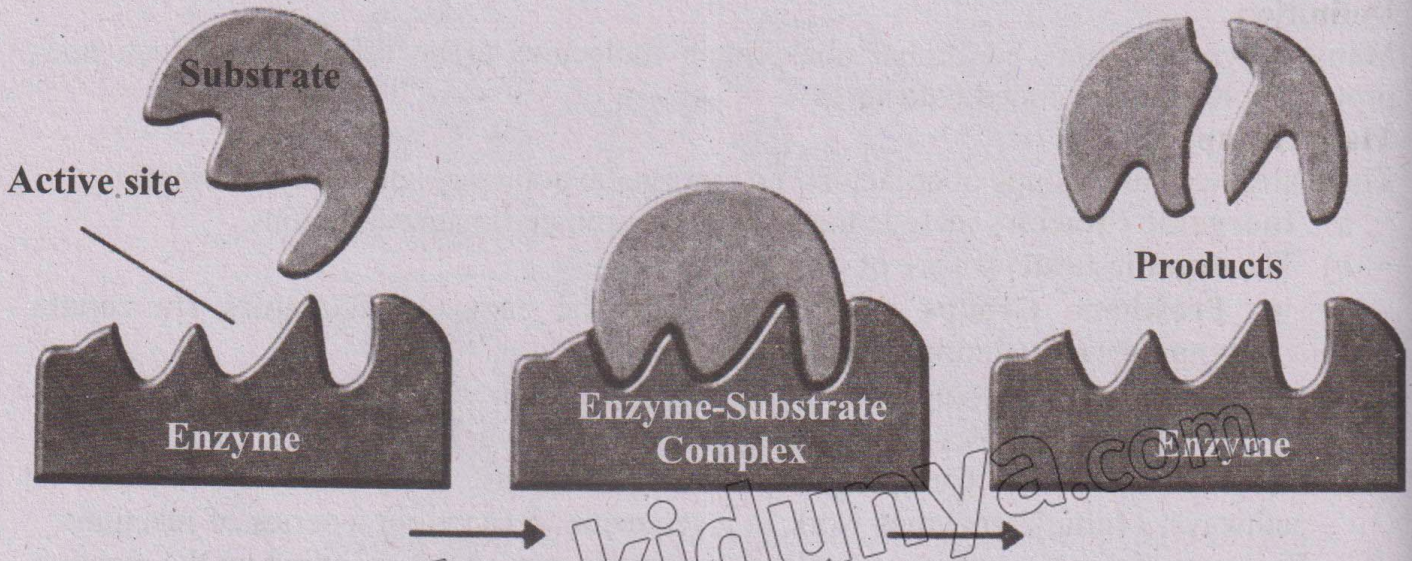


Figure 7.2: Lock and Key Model of Enzyme Action

2. Induced Fit Model

Introduction

This model was proposed by an American biologist Daniel Koshland in 1958.

Explanation

According to this model, the active site of an enzyme is not rigid. When substrate interacts with the enzyme, its active site is reshaped to perform its function.

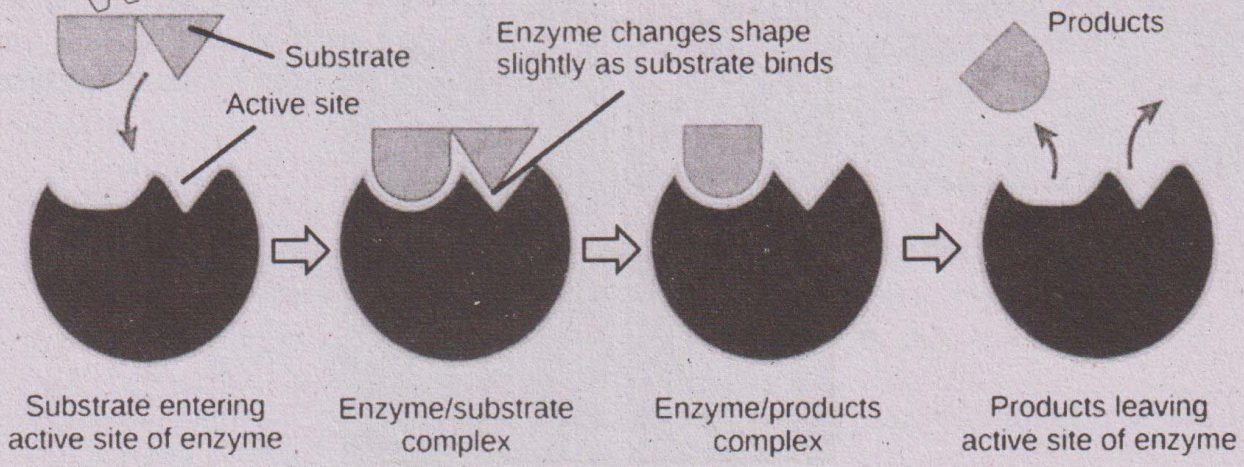
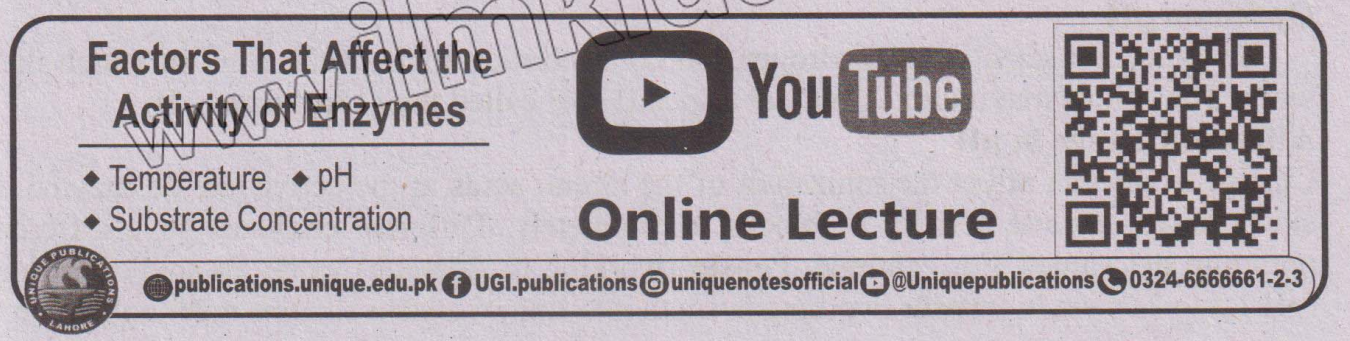


Figure 7.3: Induced Fit Model of Enzyme Action.

Factors That Affect the Activity Of Enzymes



Q.4 Describe factors affecting enzyme activity? **09407004**

Ans. Enzymes are sensitive to their environment. The activity of an enzyme is affected by the following factors.

1. Temperature / Describe how temperature extremes can inhibit enzyme activity and lead to enzyme denaturation?

Optimum Temperature

Each enzyme works at maximum rate at a specific temperature called optimum temperature.

Optimum Temperature for Human Enzymes

The optimum temperature for most of the human enzymes is 37°C.

Denaturation of Enzymes

When temperature rises to a certain limit, the heat adds in the movement of molecules. So, the rate of enzyme action increases. But when temperature is raised well above the optimum temperature, heat breaks the bonds in enzyme molecule. In this way the globular structure of enzyme is lost. This is called **denaturation** of enzyme. It results in a rapid decrease in the rate of enzymes action.

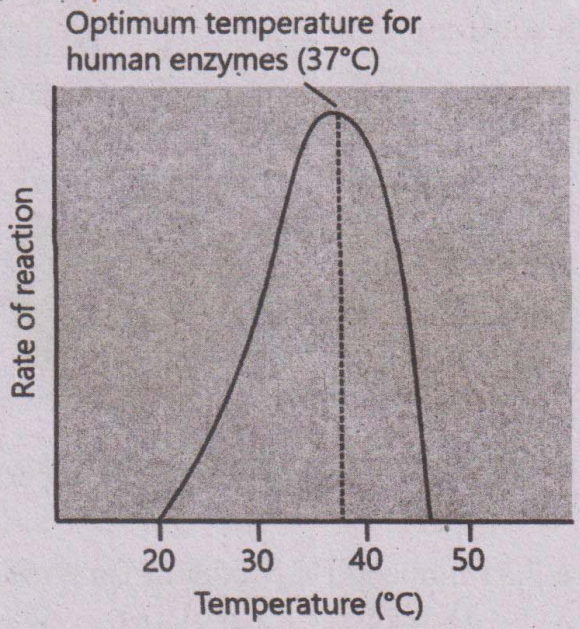


Figure 7.4: Effect of temperature on enzyme activity

2. pH / How does pH affect enzyme activity?

Optimum pH

Enzymes are sensitive to hydrogen ion concentration (pH) of the fluid in which they work. They show maximum activity at a specific pH called their **Optimum pH.**

Affect of Change in pH

Change in pH can affect the ionization of the amino acids at the active site of enzyme. It slows down enzyme activity or blocks it completely. Different enzymes have different optimum pH values. For example, **Pepsin** (working in stomach) works in acidic medium (pH 1.5 to 2.0) while **trypsin** (working in small intestine) works in alkaline medium(pH 7 to 8).

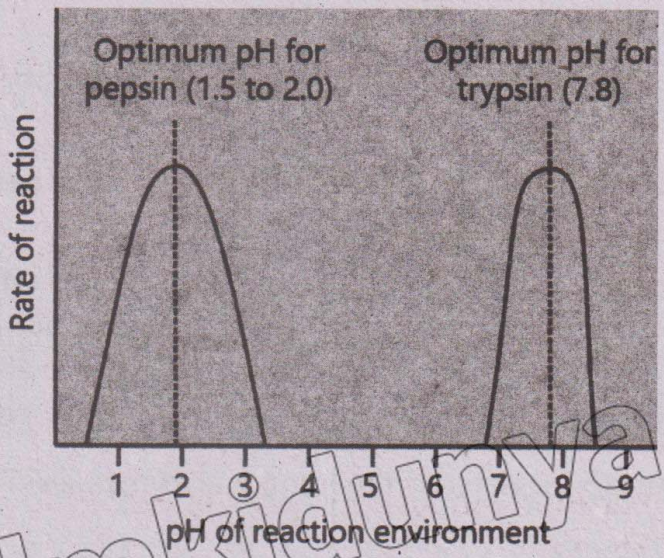


Figure 7.5: Effect of pH on enzyme activity

3. Substrate Concentration

An increase in substrate concentration increases the rate of reaction.

Saturation of Active Sites

At high substrate concentration, all active sites of the enzymes are occupied.

In this condition, any more substrate molecules do not find free active sites. This state is called **saturation** of active sites and reaction rate does not increase.

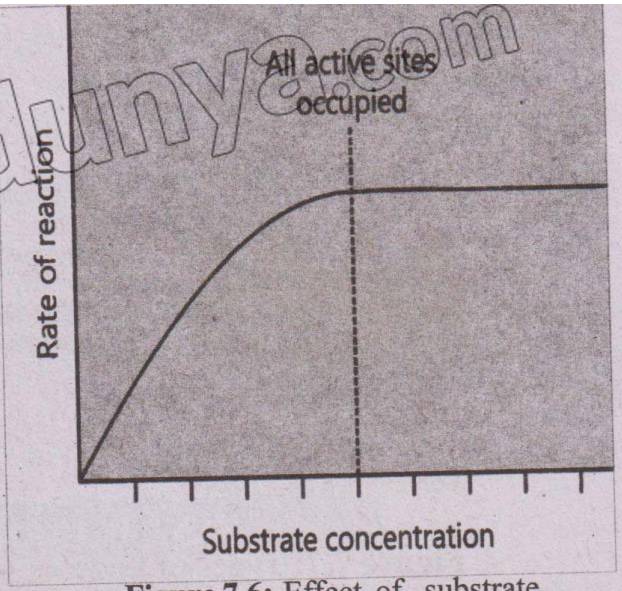


Figure 7.6: Effect of substrate concentration on enzyme activity

Enzyme Inhibition

Q.5 What is enzyme Inhibition? Differentiate between competitive and non-competitive Inhibition. 09407005

Ans. Introduction

Certain substances, called enzyme inhibitors, bind to enzyme and decrease its activity. This phenomenon is known as enzyme inhibition.

Types of Enzyme Inhibition

1. Competitive Inhibition

Introduction

Some inhibitors resemble the enzyme's substrate. They compete with the substrate to attach to the active site of enzyme. When the inhibitor is attached to the active site, it blocks it and does not allow the substrate to attach.

Examples

Examples of competitive inhibitors are antibiotics. The antibiotic molecules compete with the substrates of bacterial enzymes. They attach to bacterial enzymes and inhibit them.

2. Non- Competitive Inhibition

Introduction

Some enzyme inhibitors do not have similarity to the substrate. They do not attach to the active site of enzyme. Rather, they attach to some other location of enzyme. This attachment changes the overall shape of enzyme and also the shape of active site. So, this changed active site does not fit substrate and enzyme is inhibited.

Examples

Heavy metals like mercury and certain drugs used in cancer therapy.

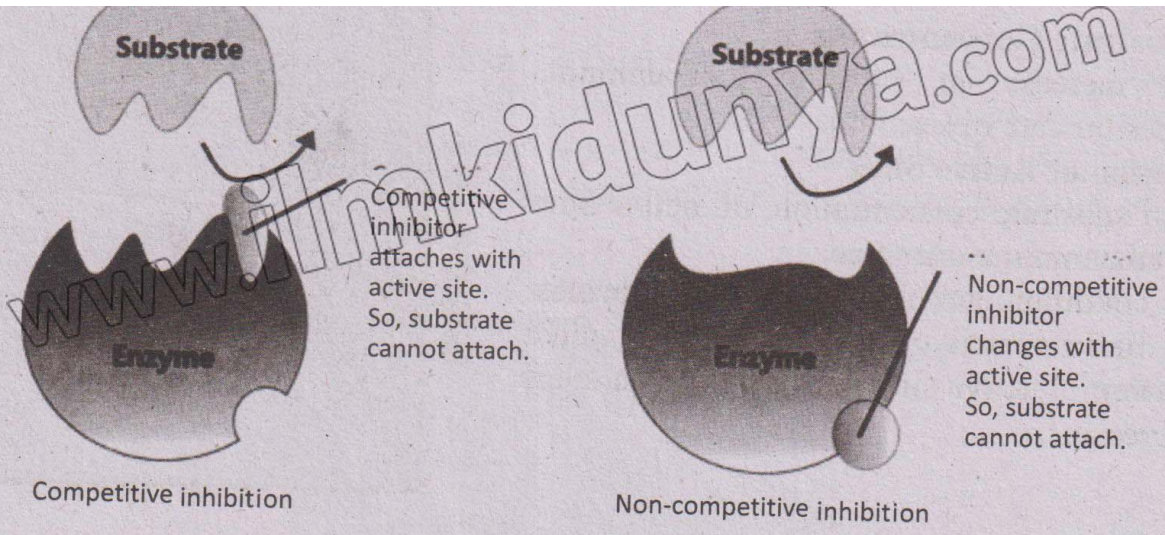


Figure 7.7: Types of Enzyme inhibition **(HQ picture is available on Pg # 211)**

Multiple Choice Questions (Exercise)

1. **Primarily, all enzymes are;** 09407006
   a) Nucleic acids b) Proteins
   c) Carbohydrates d) Lipids
2. **Which best defines an enzyme?** 09407007
   a) A chemical that breaks down food.
   b) A hormone that regulates metabolism.
   c) A Protein that speeds up reactions.
   d) A molecule that stores energy.
3. **What can happen if an enzyme is exposed to temperature that is higher than its optimal temperature?** 09407008
   a) Enzyme activity rate will increase.
   b) Enzyme's shape will change, potentially reducing its activity.
   c) Enzyme will speed up the reaction and remain stable.
   d) Enzyme will become a substrate itself.
4. **Enzymes are specific in their action because:** 09407009
   a) Their active sites fit specific substrates.
   b) They are always proteins.
   c) They are consumed in reactions.
   d) They work only at high temperatures.
5. **Prosthetic groups are:** 09407010
   a) Required by all enzymes.
   b) Proteins in nature.
   c) Loosely attached with enzymes.
   d) Tightly bound to enzyme.
6. **How does increasing temperature affect enzyme activity?** 09407011
   a) Increases activity to a point
   b) Always decreases activity
   c) Makes enzymes non-functional
   d) No effect on enzyme
7. **How does competitive inhibitor affect enzyme action?** 09407012
   a) Attaches with the substrate.
   b) Changes enzyme shape.
   c) Attaches and blocks the active site.
   d) Blocks the cofactors.
8. **An enzyme works best at a pH of 7.4. It is placed in an acidic solution with a pH of 4.0. How will this affect the enzyme?** 09407013
   a) The active site will be modified, reducing substrate binding.
   b) The enzyme will catalyse reactions faster due to increased H ions.
   c) The enzyme will gain additional active sites.
   d) The substrate will become inactive in an acidic environment.

9. **What is TRUE according to the induced fit model of enzyme action?** 09407014

a) Enzyme's active site change shape to bind the substrate.
b) Substrate must fit the enzyme perfectly before binding.
c) No shape changes occur during binding.
d) Enzyme is inactivated during the process.

10. **What is true about the optimum pH values of the following enzymes of digestive system?** 09407015

(a) Pepsin works at low pH while trypsin works at high pH
(b) Both work at high pH
(c) Both work at low pH
(d) Pepsin works at high pH while trypsin works at low pH

Multiple Choice Questions (Additional)

Metabolism

11. **Set of biochemical reactions that occur in living organisms in order to maintain life is called?** 09407016

(a) Catabolism (b) Anabolism
(c) Metabolism (d) Mutualism

12. **The biochemical reactions in which larger molecules are synthesized are called:** 09407017

(a) Anabolism
(b) Metabolism
(c) Catabolism
(d) Digestive reactions

13. **The biochemical reactions in which larger molecules are broken down are called:** 09407018

(a) Metabolism (b) Catabolism
(c) Anabolism (d) Mutualism

14. **Which does yield energy?** 09407019

(a) Anabolism (b) Catabolism
(c) Metabolism (d) None

15. **Which does consume energy?** 09407020

(a) Metabolism (b) Anabolism
(c) Both a and b (d) Catabolism

Enzymes

16. **Which is true about enzyme?** 09407021

(a) All enzymes are not protein
(b) All enzymes are vitamins
(c) All enzymes are proteins
(d) All proteins are enzyme

17. **What is true about cofactors?** 09407022

(a) Break hydrogen bond in proteins
(b) Help facilitate enzyme activity
(c) Increase activation energy
(d) Are composed of proteins

18. **The catalytic region on enzyme recognizes and binds the substrate and carries the reaction. This region is called as:** 09407023

(a) Cofaetor (b) Activator
(c) Inhibitor (d) Active site

19. **If you add more substrate to already occurring enzymatic reaction and it has no effect on the rate of reaction, what is the form given to this situation?** 09407024

(a) Saturation (b) Denaturation
(c) Desaturation (d) Inhibition

20. **The active site of an enzyme:** 09407025

(a) Never changes
(b) Forms no chemical bond with substrate
(c) Determines by its structure the specificity of the enzyme
(d) Looks like a lump projecting from the surface of an enzyme

21. **Ionization of amino acids at the active site is affected by?** 09407026

(a) Change in temperature
(b) Change in substrate concentration
(c) Change in pH
(d) Change in temperature and substrate concentration

22. **In the presence of enzymes, reactions proceed at a:** 09407027
(a) Slower rate (b) Faster rate
(c) Medium rate (d) Very slow rate

23. **Which of the following are not changed during the biochemical reactions?** 09407028
(a) Substrate (b) Products
(c) Enzymes (d) ES complex

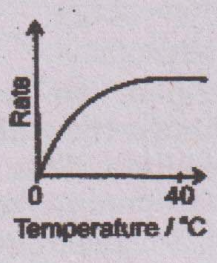
24. **Enzymes convert the substrate into different molecules called:** 09407029
(a) Reactants (b) Products
(c) Inhibitors (d) Biomolecules

Mechanism of Enzyme Action

25. **Lock and key hypothesis of enzyme action supports that:** 09407030
(a) Active sites are flexible
(b) Active sites are rigid
(c) Active site efficiency increases
(d) Active site can change its shape

Factors Affecting Activity of Enzyme

26. **Which graph shows how temperature affects the rate of an enzyme-controlled reaction?** 09407031

A)


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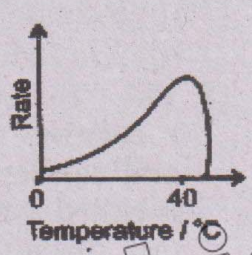

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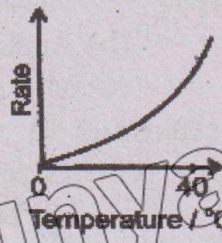
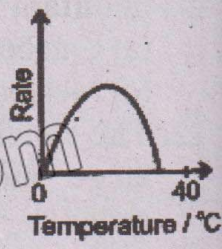


D)


27. **Change in pH can alter the active site by affecting the:** 09407032
(a) Ionization of amino acids
(b) Shape of substrate
(c) Ionization of cofactor
(d) Ionization of coenzyme

28. **Enzyme pepsin in the stomach has an optimum pH of about:** 09407033
(a) 3
(b) 4
(c) 2
(d) 5

29. **Pepsin enzyme works in:** 09407034
(a) Stomach (b) Large intestine
(c) Small intestine (d) Heart

30. **Increase or decrease in temperature beyond the optimum temperature will:** 09407035
(a) Increase the rate of reaction
(b) Decrease the rate of reactions
(c) Not affect the rate of reaction
(d) Denature the enzyme

Answer Key

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

Short Answer Questions (Exercise)

Q.1. Define metabolism. Differentiate between catabolism and anabolism. 09407036

Ans. Metabolism

Definition

Metabolism is the sum of all chemical reactions that occur within an organism to sustain life.

Catabolism	Anabolism
Definition It involves the breakdown of complex molecules into simpler ones, releasing energy in the process. **Example** i) Cellular respiration i.e. oxidation of food (glucose) into CO_2 and H_2O to get energy. ii) Lipolysis i.e., break-down of lipids (fats) into fatty acids and glycerol, which can be used for energy production.	**Definition** Involves building up complex molecules from simpler ones. This process consumes energy. **Examples** i) Photosynthesis i.e. conversion of carbon dioxide and water into glucose and oxygen using sunlight. ii) Protein synthesis i.e., formation of proteins from amino acids, which are vital for cell structure and function.

Q.2. Which type of metabolism demands input of energy? Give an examples. 09407037

Ans. Anabolism demands input of energy. Photosynthesis i.e., conversion of carbon dioxide and water into glucose and oxygen using sunlight.

Q.3. Define an enzyme. What is its role in metabolism? 09407038

Ans. Definition

Enzymes are biological catalysts that speed up chemical reactions in living organisms without being consumed in the process. They are primarily proteins and highly specific to their substrates.

Role

Enzymes play an important role in controlling cellular metabolism. An enzyme functions by lowering the activation energy of a chemical reaction inside the cells. Activation energy is the minimum amount of energy needed to form or break chemical bonds and convert reactants to products.

Q.4. What is the active site of enzyme? State its importance in enzyme specificity. 09407039

Ans. Only a small portion of enzyme molecule is directly involved in catalysis. This catalytic region is known as active site. It recognizes and binds substrates and then carries out biochemical reactions.

Q.5. Provide an example of a specific enzyme substrate pair. 09407040

Ans. The enzyme protease (which breaks peptide bonds in proteins) will not work on starch (which is broken down by an enzyme amylase).

Q.6. How does pH affect enzyme activity? 09407041

Ans. Enzymes are sensitive to hydrogen ion concentration (pH) of the fluid in which they work. They show maximum activity at a specific pH called their **Optimum pH.**

Affect of change in pH

Change in pH can affect the ionization of the amino acids at the active site of enzyme. It slows down enzyme activity or blocks it completely. Different enzymes have different optimum pH values. For example, **Pepsin** (working in stomach) works in acidic medium (pH 1.5 to 2.0) while **trypsin** (working in small intestine) works in alkaline medium (7.8).

Q.7. Provide two examples of enzymes that operate optimally at specific pH. 09407042

Ans. Pepsin (working in stomach) works in acidic medium (pH 1.5 to 2.0) While trypsin (Working in small intestine) works in alkaline medium (7.8).

Q.8. What do you mean by optimum temperature and pH? 09407043

Ans. Optimum temperature

Each enzyme works at maximum rate at a specific temperature called optimum temperature. The optimum temperature for most of human enzymes in 37°C.

Optimum pH

Optimum pH is a measure of how acidic or basic a substance or solution is. It is measured on pH scale of 0 to 14 with 7 being neutral.

Enzymes show maximum activity at a specific pH, called their **optimum pH.**

Q.9. Which type of enzyme inhibitors inhibit the enzymes without attaching to the active site? 09407044

Ans. Definition

Non-competitive inhibitors do not attach to the active site of an enzyme. Rather, they attach to some other location of enzyme.

Q.10. Differentiate between competitive and non-competitive inhibition. 09407045

Ans.

i. Competitive Inhibition

Introduction

Some inhibitors resemble the enzyme's substrate. They compete with the substrate to attach to the active site of enzyme. When the inhibitor is attached to the active site, it blocks it and does not allow the substrate to attach.

Examples

Examples of competitive inhibitors are antibiotics. The antibiotic molecules compete with the substrates of bacterial enzymes. They attach to bacterial enzymes and inhibit them.

ii. Non- Competitive inhibition

Introduction

Some enzyme inhibition do not have similarity to the substrate. They do not attach to the active site of enzyme. Rather, they attach to some other location of enzyme. This attachment changes the overall shape of enzyme and active site. So, this changed active site does not fit substrate and enzyme is inhibited.

Examples

Heavy metals like mercury and certain drugs used in cancer therapy.

Short Answer Questions (Additional)

Enzymes

Q.11. Why enzymes are called biological catalyst? 09407046

Ans. Enzymes are known as biocatalysts because they speed up and regulate the metabolic pathways in living organisms. Enzymes are mostly proteins that catalyze a chemical reaction in our body. They function as a catalyst that speed up the reaction by lowering the activation energy.

Q.12. Why are enzyme specific and why can't each one speed up many different reactions? 09407047

Ans. Each enzyme is specific to a chemical reaction as it contains an active site which is the area of an enzyme that has specific shape which differs from one enzyme to another.

Q.13. Why small quantity of enzyme is enough for catalysing large number of substrate molecules into products? 09407048

Ans. Because enzymes have high capability to convert giant quantities of substrate into product. Enzymes increase the rate of reaction and remain unaffected by reaction which is being catalyzed.

Q.14. Define co-factors. Gives two examples. 09407049

Ans. Some enzymes require non-protein molecules or ions to work, these molecules or ions are called cofactors. Cofactors can

either be inorganic e.g. metal ions or organic e.g. Flavin and haem.

Q.15. What do you mean by saturation of active sites? 09407050

Ans. When all the active sites of the enzymes are occupied (at high substrate concentration) and adding more substrate molecule do not find free active sites, this state is called saturation of active sites and the reaction rate does not increase.

Q.16. Write the difference between: 09407051

a) Catalyst and enzyme

b) Intracellular and extracellular enzymes.

Ans. a) Catalyst and Enzyme

Catalyst	Enzyme
Catalyst is a substance that increases rate of a chemical reaction without itself undergoing any permanent chemical change.	Enzymes are proteins that speed up biochemical reactions and are not changed during the reaction.

b) Intracellular and extracellular enzymes.

Intracellular Enzymes	Extracellular Enzymes
•Enzymes which remain inside the cell to speed up the reaction are called intracellular enzymes. **Example:** Enzymes of glycolysis working in cytoplasm.	•Enzymes that work outside the cell are called extracellular enzymes. **Example:** Pepsin enzyme working in the stomach cavity.

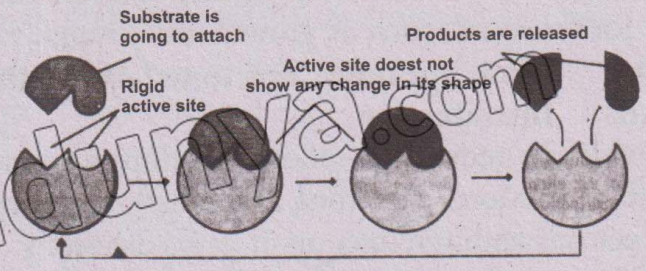
Mechanism of Enzyme Action

Q.17. According to induced fit model, the active site is flexible. Does it mean that any substrate can attach with this flexible active site? If not, then explain. 09407052

Ans. Enzymes are very specific for the substrate. One enzyme can act on a particular substrate because active sites possess specific geometric shapes that fit with specific substrates. According to induced fit model, the active site is slightly flexible but not flexible enough that any substrate can attach with active site.

Q.18. Describe lock and key model of enzyme action. 09407053

Ans. Emil Fischer proposed the lock and key model of enzyme action. The active site has particular rigid shape into which the specific substrate fits exactly. The substrate is imagined being like a key whose shape is complementary to the enzyme or lock. Once the product is formed no longer fits into the active site and escapes into the surrounding medium. The active site is free to combine again with another substrate molecule.



Fischer's "Lock and key" hypothesis of enzyme action

Factors of Affecting Activity of Enzymes

Q.19. Name the factors affecting enzyme activity. 09407054

Ans.

(1) Temperature

(2) Substrate Concentration

(3) pH

Q.20. What happens to an enzyme when it is frozen below 0°C? 09407055

Ans. At very low temperature (below 0°C) enzyme remain inactive due to fall in available activation energy.

Q.21. Which protein digesting enzyme functions in acidic medium? 09407056

Ans. Pepsin is a protein digesting enzyme which functions in acidic medium.