Unit 05

# Enzymes

## STUDENTS LEARNING OUTCOMES (SLO's)

*After studying this unit, the students will be able to*

- Identify the role and component parts of the active site of an enzyme.
- Differentiate among the three types of co-factors i.e., in organic ions, prosthetic group and co-enzymes, with examples.
- Explain the mechanism of enzyme action through the Induced Fit Model, including comparing it with Lock and Key Model.
- Explain enzyme catalysis with example of specific reactions.
- Define energy of activation and discuss through graph how an enzyme speeds up a reaction by lowering the energy of activation.
- Explain the effect of temperature on the rate of enzyme action with example of human and thermophilic bacteria
- Investigate the effect of pH on enzyme activity Compare the optimum pH of different enzymes like trypsin, pepsin, papain.
- Demonstrate that the concentration of enzyme affects the rate of enzyme action.
- Describe enzymatic inhibition, its types and its significance with examples.
- Name the molecules which act as inhibitors,
- Categorize inhibitors into competitive and non-competitive inhibitors.
- Explain feedback inhibition.
- Classify enzymes on the basis of the reactions catalyzed (oxidoreductases, transferases, hydrolases, isomerases, and ligases).
- Classify enzymes on the basis of the substrates they use (lipases, diastase, amylase, proteases etc.

We know that the life of living organisms is a reflection of what is going on in their bodies.

**Metabolism**

The sum of all biochemical reactions / activities occurring in living organisms is called **metabolism**& all the biochemical reactions / activities are carried out with the help of enzymes.

## 5.1 - ENZYMES

**1. What are enzymes? Describe their origin and occurrence in the cell?**

**Ans.** The specific globular proteins that speed up specific chemical reactions by lowering the required activation energy without themselves being used up are called **enzymes**.

- Enzymes are also known as **biocatalysts**.
- Rates of enzyme-catalysed reactions may be **$10^3$ to $10^8$ times** greater than the rates of corresponding uncatalyzed reactions.
- All cells do not have the same set of enzymes. The chemical reactions going on in red blood cells are very different from those going on within a nerve cell because red blood cells and nerve cells contain different sets of enzymes. **So,the difference in enzyme-sets makes the base of division of labour among cells.**

**Origin of Enzymes**

All enzymes are synthesized inside cells by the protein synthesizing machinery of ribosomes, mRNAs and tRNAs. So, we can say that **ribosomes are the factories of enzymes (proteins) synthesis**. After their synthesis, either they stay and work inside the cell or they are secretedout for functioning at other sites.

> **Point to Ponder**
> A reaction that is catalysed by an enzyme and is completed in 30 minutes, would take one year to get completed without being catalysed by enzyme. Thus, we can say that without enzymes there would have been no life at all.

**Occurrence of Enzymes**

**A. Cytoplasm**

Many enzymes are dissolved in cytoplasm.

- **For example**, the enzymes of **glycolysis** (the process in which breakdown of glucose takes place).

**B. Membranes of Organelles**

Many enzymes are tightly bound to membranes of certain organelles.

- **For example**, the enzyme of **Calvin cycle** and **Krebs cycle** (both processes are involved in the production of energy in the form of ATP).

**C. On the Ribosomes**

Some enzymes are integral part of **ribosomes** (factories of protein synthesis).

- **For example**, the enzymes involved in the process of protein synthesis.

> **Point to Ponder**
> Some enzymes are potentially damaging and may prove harmful, if become active at wrong place or at wrong time. For example; pepsin is a protein digesting enzyme and it can destroy protein-made structures present inside cells where it is synthesized. That is why it is produced in inactive form (pepsinogen) in membrane bounded lysosomes, and is secreted out of cells. When it reaches its target site of action, it is activated (pepsin).



### MCQs

1. **What are enzymes?**
   A) Structural proteins that build tissues
   B) Hormones that regulate metabolism
   C) Globular proteins that lower activation energy ✓
   D) Lipids that provide energy
2. **Enzymes are also known as:**
   A) Coenzymes B) Substrates
   C) Biocatalysts ✓ D) Metabolites
3. **What is the rate increase in enzyme-catalysed reactions compared to uncatalyzed reactions?**
   A) 10 to 100 times B) $10^2$ to $10^4$ times
   C) $10^3$ to $10^8$ times ✓ D) $10^6$ to $10^9$ times
4. **Why do red blood cells and nerve cells carry out different chemical reactions?**

A) They use the same enzymes for different purposes
B) They receive different nutrients
C) They contain different sets of enzymes ✓
D) They have the same enzymes in different quantities

5. **What is the site of enzyme synthesis inside the cell?**
A) Nucleus B) Mitochondria
C) Ribosomes ✓ D) Lysosomes

6. **Which of the following enzymes are found dissolved in cytoplasm?**
A) Enzymes of Calvin cycle
B) Enzymes of protein synthesis
C) Enzymes of glycolysis ✓
D) Enzymes of Krebs cycle

7. **Where are the enzymes of the Calvin and Krebs cycles located?**
A) Dissolved in cytoplasm
B) Floating freely in blood
C) Tightly bound to membranes of organelles ✓
D) Stored in the nucleus

SQ

1. **What are enzymes and how do they function in chemical reactions?**

**Ans.** The specific globular proteins that speed up specific chemical reactions by lowering the required activation energy without themselves being used up are called enzymes. Enzymes are also known as biocatalysts. Rates of enzyme-catalysed reactions may be $10^3$ to $10^8$ times greater than the rates of corresponding uncatalyzed reactions.

2. **Do all cells have the same set of enzymes? Why or why not?**

**Ans:** All cells do not have the same set of enzymes. The chemical reactions going on in red blood cells are very different from those going on within a nerve cell because red blood cells and nerve cells contain different sets of enzymes. So, the difference in enzyme-sets makes the basé of division of labour among cells.

3. **How and where are enzymes synthesized?**

**Ans:** All enzymes are synthesized inside cells by the protein synthesizing machinery of ribosomes, mRNAs and tRNAs. So, we can say that ribosomes are the factories of enzymes (proteins) synthesis. After their synthesis, either they stay and work inside the cell or they are secreted out for functioning at other sites.

4. **Where in the cytoplasm are enzymes found and what is an example?**

**Ans:** Many enzymes are dissolved in cytoplasm. For example, the enzymes of glycolysis (the process in which breakdown of glucose takes place).

5. **Where else are enzymes located in the cell besides the cytoplasm?**

**Ans:** Many enzymes are tightly bound to membranes of certain organelles. For example, the enzyme of Calvin cycle and Krebs cycle (both processes are involved in the production of energy in the form of ATP). Some enzymes are integral part of ribosomes (factories of protein synthesis). For example, the enzymes involved in the process of protein synthesis.

Q 2. **Describe the structural regions of an enzyme in detail?**

**Ans.** **Enzymes** are three-dimensional globular proteins. They are made up of polypeptide chains that are coiled upon themselves.

**Active Site**

The location at which catalysis occurs is called **active site**.

- Active site is a small cleft or depressionon the surface of globular enzyme molecule.
- Active site consists of only a few amino acids.

**Specificity of Active Site**

The active site of each enzyme is shaped very specifically so that only a certain substrate molecule can fit into it. It is three-dimensional and bears a specific charge.

**Regions of Active Site**

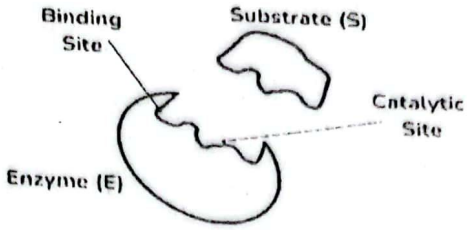
Active site has two distinct regions

**A: Binding Site**

The site at which substrate molecule fits & held by weak chemical forces, such as hydrogen bonds, is called the **binding site.**

**B: Catalytic Site**

**Catalytic site** catalyses the reaction after the binding of substrate to binding site and hence substrate is transformedinto products.




## MCQs

1. **What are enzymes made up of?**
   A) DNA chains B) Polysaccharide units
   C) Polypeptide chains that are coiled upon themselves ✓
   D) Nucleotide bases
2. **What is the active site of an enzyme?**
   A) The region where energy is stored
   B) The location at which catalysis occurs ✓
   C) The place where enzymes are destroyed
   D) The outer surface of the substrate
3. **How is the active site positioned on the enzyme?**
   A) Hidden inside the enzyme's core
   B) Located on the tail of the enzyme
   C) A large open cavity
   D) A small cleft or depression on the surface of globular enzyme molecule ✓
4. **What is the composition of the active site in terms of amino acids?**
   A) All amino acids in the enzyme
   B) Only hydrophobic amino acids
   C) Only a few amino acids ✓
   D) All polar amino acids
5. **Why can only a specific substrate bind to an enzyme's active site?**
   A) The substrate must have energy
   B) The active site is three-dimensional and bears a specific charge ✓
   C) All substrates can fit any active site
   D) Enzymes have no selectivity
6. **What is the function of the binding site in an enzyme?**
   A) Breaking down the product
   B) Destroying the enzyme
   C) Holding the substrate by weak chemical forces ✓
   D) Deactivating the enzyme
7. **What happens at the catalytic site of an enzyme?**
   A) Substrate binds reversibly
   B) Enzyme gets decomposed
   C) Reaction is catalysed, and substrate is transformed into products ✓
   D) Active site closes permanently

**SQ 1. What are enzymes?**

**Ans.** Enzymes are three-dimensional globular proteins. They are made up of polypeptide chains that are coiled upon themselves.

**2. What is the active site of an enzyme?**

**Ans.** The location at which catalysis occurs is called active site.

**3. How is the active site described in terms of its structure and position?**

**Ans.** Active site is a small cleft or depression on the surface of globular enzyme molecule.

**4. What is the specificity of the active site based on?**

**Ans.** The active site of each enzyme is shaped very specifically so that only a certain substrate molecule can fit into it. It is three-dimensional and bears a specific charge.

**5. What are the two distinct regions of the active site, and what are their functions?**

**Ans.** Active site has two distinct regions:

**A: Binding Site** – The site at which substrate molecule fits & held by weak chemical forces, such as hydrogen bonds, is called the binding site.

**B: Catalytic Site** – Catalytic site catalyses the reaction after the binding of substrate to binding site and hence substrate is transformed into products.

## 5.2 COFACTORS AND COENZYMES

**Q 3. Write a complete note on the cofactors & coenzymes?**

**Ans.** Many enzymes use additional chemical components to aid in catalysis. These additional non-protein components are called **cofactors.**

**Types of Cofactors**

There are three kinds of cofactors (metal ions, prosthetic group & coenzymes)

**A: Metal Ions**

Many enzymes use **metal ions** as their cofactors.

**For Example** - $Ca^{+2}$, $Mg^{+2}$, $Mn^{+2}$, $Cu^{+2}$, and $Zn^{+2}$ are used as cofactors.

**How Metal Ions Work**

Metal ions change non-functional active sites of enzymes into functional active sites. In these enzymes, the attachment of a metal ion as cofactor, changes the shape of active site of enzyme and allows it to combine with substrate.

**B: Prosthetic Group**

The nonpeptide inorganic or organic cofactor, tightly attached with an enzyme by the formation of covalent bond is known as **prosthetic group**.

**For Example** - Hematin is an organic compound that is an excellentexample of prosthetic group.

**C: Coenzyme**

When the cofactor is a non-protein organic molecule and is loosely attached with enzyme, it is called a **coenzyme**.

**For Example**: Many vitamins (e.g., niacin and riboflavin) function as coenzymes.

**How Coenzyme Works**

Coenzyme participates in enzyme-catalysed reactions, often by transportingelectrons (hydrogen atoms), from one enzyme to another.

**The most important coenzyme in cell is the hydrogen acceptor nicotinamide adenine dinucleotide ($NAD^+$).** When $NAD^+$ acquires a hydrogen atom from an enzyme, it reduces to NADH. The electron of hydrogen atom contains energy that NADH molecule carries. **For example**, when food is oxidized in cell, enzymes draw electrons from food molecules and transfer them to $NAD^+$, which reduces to NADH.

## MCQs

1. **What are cofactors in enzyme activity?**
   A) Enzyme inhibitors
   B) Non-protein components that assist in catalysis ✓
   C) Only metal ions
   D) Denatured proteins

2. **How do metal ions assist enzymes?**
   A) By denaturing them
   B) By providing nutrients
   C) By changing non-functional active sites into functional ones ✓
   D) By blocking substrate binding

3. **Which of the following metal ions can act as enzyme cofactors?**
   A) $Na^+$, $Cl^-$
   B) $Ca^{+2}$, $Mg^{+2}$, $Mn^{+2}$, $Cu^{+2}$, $Zn^{+2}$ ✓
   C) $K^+$, $Fe^{3+}$ only
   D) $OH^-$, $CO_3^{2-}$

4. **What is a prosthetic group in relation to an enzyme?**
   A) A loosely bound organic molecule
   B) A permanently bound nonpeptide cofactor ✓
   C) A temporary metal ion
   D) A non-functional enzyme part

5. **Which compound is an example of a prosthetic group?**
   A) $NAD^+$
   B) Niacin
   C) Hematin ✓
   D) Riboflavin

6. **What is the difference between a coenzyme and a prosthetic group?**
   A) Coenzymes are metal ions; prosthetic groups are vitamins
   B) Coenzymes are loosely attached; prosthetic groups are tightly bound ✓
   C) Coenzymes are proteins; prosthetic groups are non-proteins
   D) Coenzymes cannot transport electrons

7. **What happens when $NAD^+$ acquires a hydrogen atom?**
   A) It becomes inactive
   B) It oxidizes into NADH
   C) It reduces to NADH and carries energy ✓
   D) It breaks down

## SQ

**1. What are cofactors and how do they assist enzymes in catalysis?**

**Ans.** Many enzymes use additional chemical components to aid in catalysis. These additional non-pro components are called cofactors. There are three kinds of cofactors: metal ions, prosthetic groups, coenzymes.

**2. How do metal ions function as enzyme cofactors?**

**Ans.** Many enzymes use metal ions as their cofactors. For example, $Ca^{+2}$, $Mg^{+2}$, $Mn^{+2}$, $Cu^{+2}$, and $Zn^{+2}$ are used as cofactors. Metal ions change non-functional active sites of enzymes into functional active sites. In these

enzymes, the attachment of a metal ion as cofactor changes the shape of active site of enzyme and allows it to combine with substrate.

**3. What is a prosthetic group and how is it associated with an enzyme?**

**Ans.** The nonpeptide inorganic or organic cofactor, tightly attached with an enzyme by the formation of covalent bond is known as prosthetic group.

For example – Hematin is an organic compound that is an excellent example of prosthetic group.

**4. What is a coenzyme and how is it different from a prosthetic group?**

**Ans.** When the cofactor is a non-protein organic molecule and is loosely attached with enzyme, it is called a coenzyme.

For example – Many vitamins (e.g., niacin and riboflavin) function as coenzymes.

**5. How does the coenzyme $NAD^+$ function in enzyme-catalysed reactions?**

**Ans.** Coenzyme participates in enzyme-catalysed reactions, often by transporting electrons (hydrogen atoms), from one enzyme to another. The most important coenzyme in cell is the hydrogen acceptor nicotinamide adenine dinucleotide ($NAD^+$). When $NAD^+$ acquires a hydrogen atom from an enzyme, it reduces to NADH. The electron of hydrogen atom contains energy that NADH molecule carries. For example, when food is oxidized in cell, enzymes draw electrons from food molecules and transfer them to $NAD^+$, which reduces to NADH.

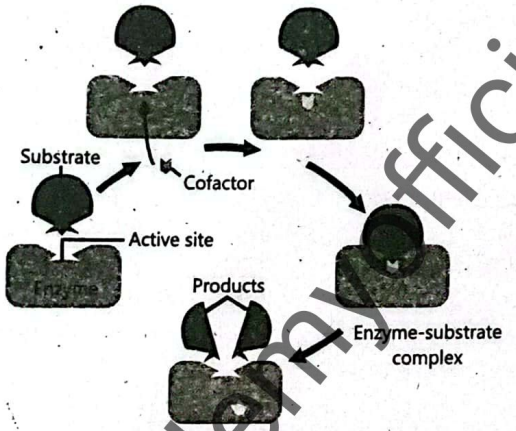



***Fig. 5.1: Cofactor, changing the shape of active sit e***

**Point to Ponder**

Many trace elements such as molybdenum and manganese, which are necessary for our health, are used by enzymes as cofactors.

**Point to Ponder**

The protein part of enzyme is called apoenzyme and complete enzyme including co-factor is called holoenzyme.

## 5.3 MECHANISM OF ENZYME ACTION

**4. What is meant by activation energy & how enzymes?**

**Ans.** The speed of a chemical reaction depends on the amount of activation energy required to initiate it.

**Activation Energy**

**Activation energy** is the energy which works to destabilizethe existing chemical bonds **or** the minimum amount of energy required to start a chemical reaction is called **activation energy**.

**How Enzymes Lower the Activation Energy?**

Enzymes bring reactants together in correct orientation**or** stress particular chemical bonds of reactants. Thus, they lower the activation energy required for new bonds to form and speed upthe rate of reactions. Reactions proceed much faster than their normal speed.

**Note**

The presence of enzymes does not affect the natureor properties of end products.

**For example**, sucrose (substrate) will always be hydrolysed into glucose and fructose (products) whether sucrase (enzyme) is present or not.

Binding site of every enzyme is very specificdue to its specificity; an enzyme recognizes a specific substrate.

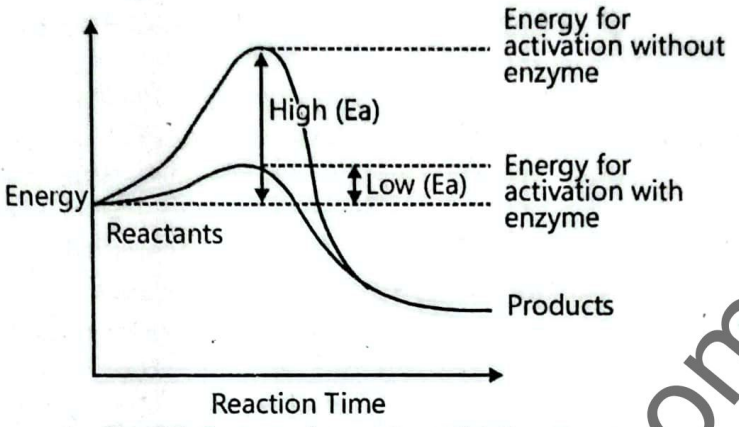



***Fig. 5.2: Enzymes lower the activation energy***

## MCQs

1. **What are enzymes primarily composed of?**
   A) DNA chains B) Polysaccharide units
   C) Polypeptide chains that are coiled upon themselves ✓
   D) Nucleotide bases
2. **What role do enzymes play in chemical reactions?**
   A) They increase the activation energy required
   B) They act as substrates for reactions
   C) They speed up reactions by lowering activation energy ✓
   D) They are permanently consumed in reactions
3. **Why do different types of cells have different sets of enzymes?**
   A) Because they all perform the same chemical reactions
   B) Because red blood cells and nerve cells have different chemical reactions ✓
   C) Because enzymes are not important in cells
   D) Because all cells have identical functions
4. **What is activation energy?**
   A) The energy released by a reaction
   B) The energy required to initiate a chemical reaction ✓
   C) The energy stored in substrates
   D) The energy enzymes produce
5. **How do enzymes lower activation energy?**
   A) By breaking the bonds of substrates directly
   B) By bringing reactants together in the correct orientation or stressing bonds ✓
   C) By increasing temperature of the reaction
   D) By changing the final products
6. **Does the presence of enzymes change the nature of the end products?**
   A) Yes, enzymes create new products
   B) No, enzymes do not affect the nature of products ✓
   C) Yes, enzymes modify substrates permanently
   D) No, but enzymes destroy the products
7. **What determines the specificity of an enzyme?**
   A) The size of the enzyme
   B) The shape of the enzyme's binding site ✓
   C) The temperature of the environment
   D) The color of the enzyme

## SQ

**1. What are enzymes and how do they function in chemical reactions?**

**Ans.** The specific globular proteins that speed up specific chemical reactions by lowering the required activation energy without themselves being used up are called enzymes. Enzymes are also known as biocatalysts. Rates of enzyme-catalysed reactions may be $10^3$ to $10^8$ times greater than the rates of corresponding uncatalyzed reactions.

**2. Do all cells have the same set of enzymes? Why or why not?**

**Ans.** All cells do not have the same set of enzymes. The chemical reactions going on in red blood cells are very different from those going on within a nerve cell because red blood cells and nerve cells contain different sets of enzymes. So, the difference in enzyme-sets makes the base of division of labour among cells.

**3. What is activation energy and how does it influence the speed of a chemical reaction?**

**Ans.** The speed of a chemical reaction depends on the amount of activation energy required to initiate it.

**Activation Energy**

Activation energy is the energy which works to destabilize the existing chemical bonds or the minimum amount of energy required to start a chemical reaction is called activation energy.

**4. How do enzymes lower the activation energy required for a reaction to proceed?**

**Ans.** Enzymes bring reactants together in correct orientation or stress particular chemical bonds of reactants. Thus, they lower the activation energy required for new bonds to form and speed up the rate of reactions. Reactions proceed much faster than their normal speed.

**5. Do enzymes affect the end products of a reaction? What determines their specificity?**

**Ans.** The presence of enzymes does not affect the nature or properties of end products.

For example, sucrose (substrate) will always be hydrolysed into glucose and fructose (products) whether sucrase (enzyme) is present or not.

Binding site of every enzyme is very specific due to its specificity; an enzyme recognizes a specific substrate.

## Q 5?. Explain the mechanism of enzyme action by the formation of ES Complex?

**Ans. Formation of ES Complex**

- The substrate binds with the binding site of an enzyme. In this way, an enzyme-substrate complex (**ES complex**) is formed and catalytic site is activated.
- The atoms of catalytic site stress and destabilizeparticular bonds of substrate. So, activation energy is lowered.
- This action initiates the reaction and substrate is transformed into products.
- After it, enzyme detaches itself from the products, in an unaltered state. The mechanism of enzyme action can be summarised as follows.

$$E + S \longrightarrow ES \longrightarrow E + P$$

Enzyme Substrate — Enzyme-substrate complex — Enzyme Product

- In complex metabolic pathways e.g., respiration, photosynthesis, protein synthesis etc., many enzymes act in a sequence and regulate the steps of pathway. The successive enzymes controlling these steps are present together along with their cofactors. The products from one enzyme's catalysis serve as substrate for the enzyme of next step and are transformed into next products. The series goes on and finally ends products are formed that inhibit (through feedback) the first enzyme.

## MCQs

**1. What happens when a substrate binds to an enzyme?**
A) The enzyme is permanently altered
B) The enzyme-substrate (ES) complex is formed and catalytic site is activated ✓
C) The substrate is destroyed immediately
D) The enzyme loses its specificity

**2. How do enzymes lower the activation energy during a reaction**
A) By breaking all bonds in substrate
B) By stressing and destabilizing particular bonds of substrate ✓
C) By increasing the temperature of the reaction
D) By changing the substrate into an inhibitor

**3. What happens to the enzyme after the substrate is transformed into products?**
A) It is permanently attached to the product
B) It detaches from the products unchanged ✓
C) It becomes inactive
D) It is consumed in the reaction

**4. In complex metabolic pathways, how do enzymes act?**
A) Independently without interaction
B) In sequence, regulating each step ✓
C) By competing with each other
D) Randomly with no order

**5. What serves as substrate for the enzyme of the next step in metabolic pathways?**
A) The original substrate only
B) The products from the previous enzyme's catalysis ✓
C) The enzyme itself
D) Cofactors only

**6. What regulates the first enzyme in a metabolic pathway?**
A) Temperature changes
B) The final end products through feedback inhibition ✓
C) Enzyme concentration only
D) Random mutations

**7. Which of the following is true about enzymes in metabolic pathways?**
A) They work in isolation
B) They require cofactors and act sequentially ✓
C) They do not interact with substrates
D) They are consumed after one reaction

**SQ** **1. What happens during the formation of the enzyme-substrate (ES) complex?**

**Ans.** The substrate binds to the enzyme's binding site forming an enzyme-substrate (ES) complex which activates the catalytic site. This site stresses and destabilizes certain bonds in the substrate, lowering activation energy and starting the reaction. The substrate then changes into products, and the enzyme detaches unchanged.

**2. How can the mechanism of enzyme action be summarized?**

**Ans.** The enzyme binds substrate forming the ES complex, lowers activation energy by stressing bonds, converts substrate into products, and then releases the products while remaining unchanged.

**3. How do enzymes work in complex metabolic pathways like respiration or photosynthesis?**

**Ans.** Many enzymes act in sequence to regulate pathway steps. The product of one enzyme becomes the substrate for the next, allowing stepwise transformations until final products form.

**4. What role do products play in sequential enzyme reactions in metabolic pathways?**

**Ans.** Products from one enzyme act as substrates for the next enzyme, continuing the chain of reactions until the end products are produced.

**5. How is the first enzyme regulated in a metabolic pathway?**

**Ans.** The final end products inhibit the first enzyme through feedback, controlling the pathway by preventing excess product formation.

## MODELS FOR MECHANISM OF ACTION OF ENZYMES

**Q 6.** **Explain the models for mechanism of enzyme action?**

**Ans. A: Lock-and-Key Model**

In **1894** a German chemist **Emil Fischer** proposed lock-and-key model.

**Definition**

**According to this model,** "as a specific key can open only a specific lock, in the same manner a specific enzyme can transform only one specific substrate into products".

**Postulates**

Active site is a rigid structure

There is no modification or flexibility in the active site before, during or after the enzyme action.

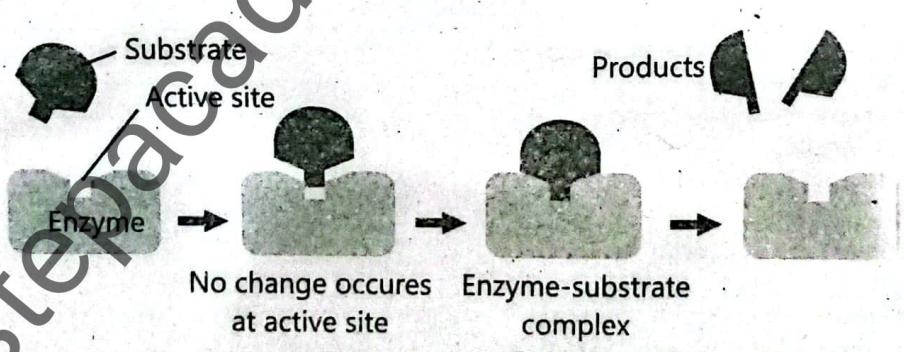



***Fig. 5.3: Lock-and-key model of enzyme action***

**B: Induced Fit Model**

Later studies did not support lock-and-key model in all reactions. On the basis of new evidences, an American biochemist **Daniel Koshland** presented induced fit model in **1958**.

**Definition**

**According to this model**, "when a substrate combines with the binding site of an enzyme, it induces changes in enzyme structure. These changes enable the enzyme to perform its catalytic activity more effectively."

**Postulates**

Active site is not a rigid structure

Active site is capable of going under modification and flexibility, before the enzyme action (catalysis) starts.

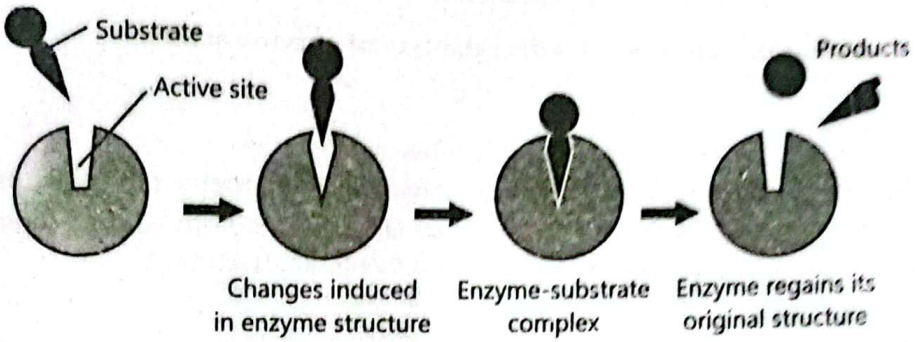



***Fig. 5.4: Induced-fit model of enzyme action***

## MCQs

1. **Who proposed the Lock-and-Key model of enzyme action?**
   A) Daniel Koshland B) Emil Fischer✓
   C) Louis Pasteur D) James Watson
2. **According to the Lock-and-Key model, what is true about the active site of an enzyme?**
   A) It changes shape when substrate binds
   B) It is a flexible structure
   C) It is a rigid structure with no modification before, during, or after enzyme action✓
   D) It is formed after substrate binds
3. **What analogy is used in the Lock-and-Key model to explain enzyme specificity?**
   A) A puzzle piece fitting into a puzzle
   B) A specific key opening a specific lock✓
   C) A magnet attracting metal
   D) A lock changing to fit multiple keys
4. **Who proposed the Induced Fit model?**
   A) Emil Fischer B) Daniel Koshland✓
   C) Alexander Fleming D) Robert Hooke
5. **What does the Induced Fit model say happens when a substrate binds to an enzyme?**
   A) The substrate remains unchanged
   B) The enzyme's active site changes shape to better fit the substrate✓
   C) The enzyme breaks down immediately
   D) The substrate detaches instantly
6. **How is the active site described in the Induced Fit model?**
   A) Rigid and unchanging
   B) Flexible and capable of modification before catalysis starts✓
   C) Non-specific to substrates
   D) Destroyed after reaction
7. **Which model explains that the active site does NOT change its shape during enzyme action?**
   A) Induced Fit model B) Lock-and-Key model✓
   C) Feedback inhibition model
   D) Allosteric model

## SQ

1. **What is the Lock-and-Key model proposed by Emil Fischer in 1894?**

**Ans.** According to the lock-and-key model, "as a specific key can open only a specific lock, in the same manner a specific enzyme can transform only one specific substrate into products." The postulates of this model state that the active site is a rigid structure and there is no modification or flexibility in the active site before, during, or after enzyme action.

2. **What are the key postulates of the Lock-and-Key model?**

**Ans.** The key postulates are that the active site of the enzyme is rigid and does not undergo any modification or flexibility before, during, or after the enzyme catalyzes a reaction.

3. **Why was the Induced Fit model proposed and by whom?**

**Ans.** Later studies did not support the lock-and-key model for all reactions. On the basis of new evidence, an American biochemist Daniel Koshland presented the induced fit model in 1958.

4. **What does the Induced Fit model state about enzyme structure when a substrate binds?**

**Ans.** According to the induced fit model, "when a substrate combines with the binding si of an enzyme, it induces changes in enzyme structure. These changes enable the enzyme to perform its catalytic activity more effectively."

5. **What are the postulates of the Induced Fit model regarding the active site?**

**Ans.** The active site is not a rigid structure. It is capable of undergoing modification and flexibility before the enzyme action (catalysis) starts, allowing better interaction with the substrate.

## 5.4 FACTORS AFFECTING THE RATE OF ENZYME ACTION

**Q 7. Discuss in detail the factors which affect the rate of enzyme action?**

**Ans.**

Enzymes are very sensitive to the environment in which they work.

The functional specificity of every enzyme depends upon its specific chemistry and configuration.

The activity of an enzyme is affected by any change that alters its chemistry and its three-dimensional shape. Some of the factors that can affect the rate of enzyme action are being discussed next.

**1. Temperature**

**Optimum Temperature**

Every enzyme works at its maximum rate at a specific temperature called its **optimum temperature**

**For Example,**

The optimum temperature for human enzymes is **37 °C.**

**Shape of Protein**

The shape of a protein is determined by the hydrogen bonds and hydrophobic interactions that hold its polypeptide chains in particular position. Both the hydrogen bonds and hydrophobic interactions are easily disrupted by slight changes in temperature.

**Effect of Temperature on the Shape of Protein**

**When Temperature Fails**

When temperature falls below optimum temperature, the bonds that determine the shape of enzyme become less flexible. They do not permitthe induced change in active sites that is necessary for enzyme action and so reaction rate is slow.

**When Temperature Rises**

When temperature is raised up to a certain limit, the heat adds in activation energy and so reactions are accelerated. Heat also provides kinetic energy to substrate and enzyme molecules. It causes them to move rapidly. Thus, they collide more frequently and reaction rate is increased.

**Denaturation**

When temperature is raised well above optimum temperature, the heat energy increases the vibrations of atoms of enzyme molecules. When vibrations become too violent, bonds cannot hold polypeptide chains in the proper position and globular structure of enzyme is lost. This phenomenon is known as **denaturation** of enzyme. It results in a rapid decrease in the rate of enzyme action and it may be blocked completely.

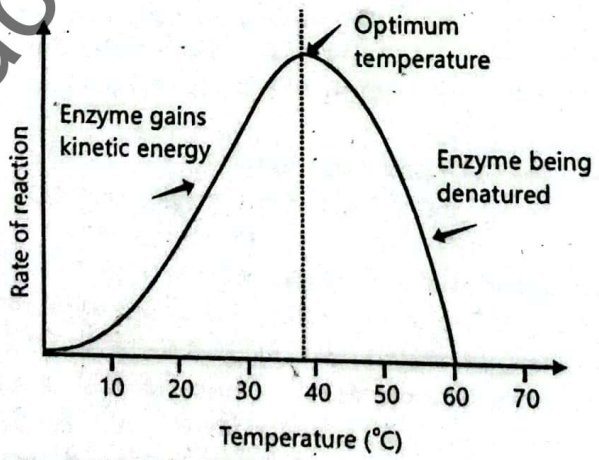



***Fig. 5.5: Effect of temperature on enzyme activity***

**2. pH**

**Optimum pH**

Every enzyme works its best at a specific pH, called its **optimum pH.**

**For example,**

Pepsin is active in acidic medium (low pH) while trypsin shows its optimum activity in alkaline medium (high pH).

**Effect of pH on the Activity of Enzymes**

All enzymes work at their maximum rate at a narrow range of pH. A slight change (increase or decrease) in this pH causes retardation in enzyme activity or blocks it completely.

In the globular structure of an enzyme, polypeptide chains are held by bonds between oppositely charged amino acids, such as glutamic acid (-) and lysine (+).

These bonds are sensitive to hydrogen ion concentration. Any change in pH can change the ionization of amino acids at active site. Moreover, it may affect the ionization of substrate. Extreme change in pH can break the bonds in enzymes, resulting in enzyme denaturation.

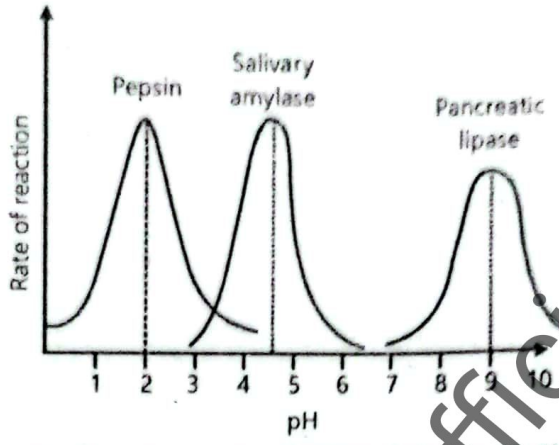



***Fig. 5.6: Optimum pH of some enzyme and effect of change of pH on enzyme activity***

| Enzyme | Optimum pH |
|---|---|
| Pepsin | 1.5–1.6 |
| Salivary amylase | 4.6–5.2 |
| Sucrase | 6.2 |
| Pancreatic amylase | 6.7–7.0 |
| Catalase | 7.0 |
| Urease | 7.0 |
| Trypsin | 7.8–8.7 |
| Pancreatic lipase | 8.0 |
| Arginase | 10.0 |

**3. Enzyme Concentration**

Enzymes are very efficient and a small number of enzyme molecules can catalyse reactions of large amount of substrate. The overall rate of enzyme-controlled reactions depends directly on the amount of enzyme present at a specific time (if substrate concentration is unlimited).

**Effect of Increasing Enzyme Concentration**

When enzyme concentration increases, there are more enzyme molecules and more active sites. So, more substrate molecules bind with new active sites and are transformed into products.

**Rate of Reaction at Constant Substrate Concentration**

If enzyme concentration goes on increasing but substrate concentration remains the same, no more substrate molecules will attach with enzymes. So, the rate of reaction stays constant and does not increase further.

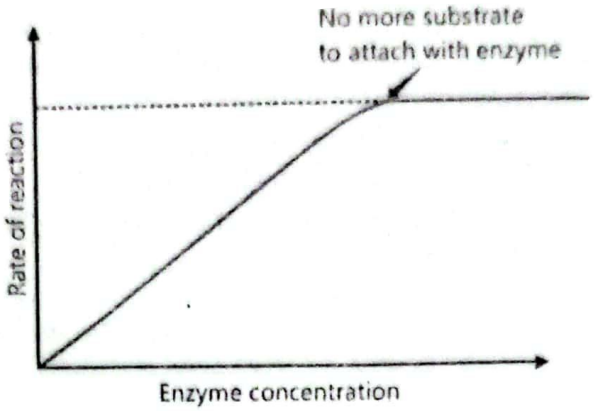



*Fig. 5.7: Effect of enzyme concentration on enzyme activity*

**4. Substrate Concentration**

If there are enzyme molecules with vacant active sites, an increase in substrate concentration will increase the rate of reaction.

**Rate of Reaction at Constant Enzyme Concentration**

If enzyme concentration is kept constant and the amount of substrate is increased, a point is reached where any further increase in substrate does not increase the rate of reaction any more.

**Saturation of Active Sites**

Saturation of active sites means that all active sites of the available enzymes are bounded to substrates & now there are no free active sites. This situation is called **saturation of active sites**& occurs at high levels of substrate concentration while keeping the enzyme concentration constant.

**Availability of Active Sites**

When enzyme molecules are free (at low substrate concentration) new substrate molecules bind with the available active sites and so more products are formed in the given time i.e. rate of enzyme action is increased.

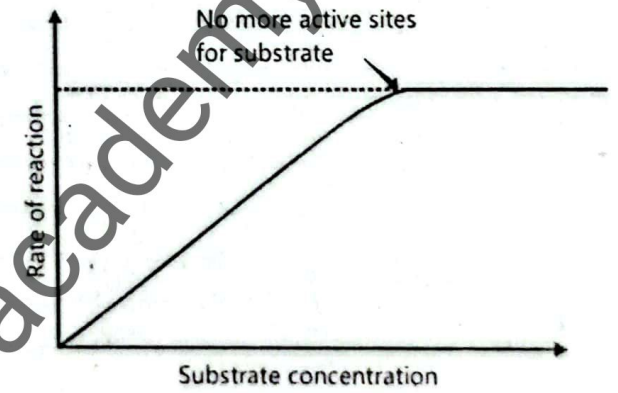



*Fig. 5.8: Effect of substrate concentration on enzyme activity*

## MCQs

**1. What is meant by the optimum temperature of an enzyme?**
A) The highest temperature an enzyme can withstand
B) The temperature at which the enzyme denatures
C) The temperature at which an enzyme works at maximum rate ✓
D) The average temperature of all enzymes

**2. What happens to enzyme activity when the temperature falls below the optimum?**
A) Enzyme gets denatured
B) Bonds become more flexible
C) Bonds become less flexible and slow the reaction ✓
D) Substrate concentration increases

**3. What is denaturation of an enzyme?**
A) A reversible change in enzyme shape
B) Permanent loss of enzyme activity due to temperature or pH ✓
C) Reaction with substrate
D) Temporary inhibition of active site

**4. What causes denaturation of enzymes at high temperatures?**
A) Weak hydrogen bonds
B) Substrate depletion
C) Violent vibrations breaking bonds in enzyme ✓
D) Loss of optimum pH

5. **At which pH does pepsin show optimum activity?**
A) 7.0 B) 8.0
C) 4.5 D) 1.5–1.6 ✓

6. **What happens when the pH level is changed significantly from an enzyme's optimum pH?**
A) Enzyme becomes more active
B) Ionization increases the reaction rate
C) Enzyme activity decreases or stops ✓
D) Enzyme gains more active sites

7. **What is the effect of increasing enzyme concentration when substrate is unlimited?**
A) Reaction rate decreases
B) Enzyme gets denatured
C) More active sites become available and reaction rate increases ✓
D) Substrate concentration increases

8. **What happens when enzyme concentration increases but substrate concentration remains the same?**
A) All active sites stay vacant
B) Reaction rate continues to increase
C) Reaction rate becomes constant ✓
D) Substrate binds with itself

9. **What is meant by saturation of active sites?**
A) Enzymes are fully denatured
B) All enzyme active sites are bound with substrates ✓
C) No substrate is available
D) Optimum temperature is reached

10. **How does pH affect bonds in the enzyme structure?**
A) pH strengthens hydrogen bonds
B) pH affects ionization of water only
C) pH changes ionization of amino acids at active site and breaks bonds ✓
D) pH increases bond flexibility

SQ

1. **How does the environment affect enzyme activity?**

**Ans.** Enzymes are very sensitive to the environment in which they work. The functional specificity of every enzyme depends upon its specific chemistry and configuration. The activity of an enzyme is affected by any change that alters its chemistry and its three-dimensional shape. Factors like temperature, pH, and enzyme concentration can affect the rate of enzyme action.

2. **What is meant by the optimum temperature for enzymes?**

**Ans.** Every enzyme works at its maximum rate at a specific temperature called its optimum temperature. For example, the optimum temperature for human enzymes is 37 °C. At this temperature, the enzyme's structure and activity are ideal for catalysis.

3. **How does temperature affect the shape of an enzyme protein?**

**Ans.** The shape of a protein is determined by hydrogen bonds and hydrophobic interactions holding its polypeptide chains in position. Both these bonds are easily disrupted by slight changes in temperature. When temperature falls below optimum, the bonds become less flexible, slowing enzyme action. When temperature rises, heat adds activation energy, speeding reactions, but very high temperature causes denaturation where the enzyme loses its shape and activity.

4. **What happens when the temperature rises well above the optimum temperature?**

**Ans.** When temperature rises well above the optimum, heat energy increases vibrations of enzyme atoms. Violent vibrations break the bonds holding the polypeptide chains in place, causing the globular structure of the enzyme to be lost. This process is called denaturation and results in a rapid decrease or complete loss of enzyme activity.

5. **What is optimum pH and how does pH affect enzyme activity?**

**Ans.** Every enzyme works best at a specific pH called its optimum pH. For example, pepsin is active in acidic medium (low pH), while trypsin works best in alkaline medium (high pH). Enzymes work at their maximum rate within a narrow pH range; slight changes in pH can reduce or block enzyme activity by affecting bonds between charged amino acids and altering the ionization of the enzyme's active site or substrate.

6. **How does extreme pH change cause enzyme denaturation?**

**Ans.** In the globular structure of an enzyme, polypeptide chains are held by bonds between oppositely charged amino acids like glutamic acid (-) and lysine (+). These bonds are sensitive to hydrogen ion concentration. Extreme changes in pH can break these bonds, causing the enzyme to lose its three-dimensional structure, a process called denaturation, which stops enzyme activity.

7. **How does enzyme concentration affect the rate of enzyme-controlled reactions?**

**Ans.** The rate of enzyme-controlled reactions depends directly on the amount of enzyme present when substrate concentration is unlimited. Increasing enzyme concentration increases the number of active sites, allowing more substrate molecules to bind and transform into products, thereby increasing the reaction rate.

**8. What happens to the reaction rate when enzyme concentration increases but substrate concentration remains constant?**

**Ans.** If enzyme concentration increases while substrate concentration remains the same, no more substrate molecules can bind as all are already occupied. Therefore, the rate of reaction reaches a maximum and stays constant, no longer increasing with more enzyme.

## 5.5 ENZYME INHIBITION

**8. Explain the inhibition of enzymes with reference to various types of inhibitors?**

**Ans. Inhibitor**

A chemical that interferes and blocks an enzyme's activity is called an **inhibitor**.

**Enzyme Inhibition**

Inhibitors attach with enzymes but are not transformed into products and thus block active sites temporarily or permanently. This phenomenon is known as enzyme **inhibition. The final products of complex enzymatic reactions also act as the inhibitors of the enzyme of the first step.**

**Types of Inhibitors**

**Classes of Inhibitors**

**A: Competitive Inhibitors**

A **competitive inhibitor** resemblesthe enzyme's substrate. It competes with substrate for the same binding site on enzyme. When competitive inhibitor is selected by binding site, it blocks active site and does not permit substrate from attaching. Thus, it prevents enzyme from acting.

**For Example,**

The enzyme succinic dehydrogenase catalyses the oxidation of **succinic acid** to **fumaric acid**. Malonic acid has structural similarity with substrate (succinic acid). So, both of them compete for active site of enzyme. Malonic acid is selected by active site and thus blocks it.

**B: Non-competitive inhibitors**

A **non-competitive inhibitor** has no real structural similarity to substrate. So, it does not enter active site. Instead, it binds enzyme at other places. Its binding alters the shape of enzyme so that active site does not fit substrate and so enzyme is inhibited.

**For example,**

Two substrates i.e., **succinic acid** and **CoA** react to form **succinyl-CoA**. This reaction is catalysed by enzyme succinyl-CoA synthetase. After its formation, the product i.e., succinyl CoA acts as a non-competitive inhibitor and binds with enzyme. Thus, enzyme is inhibited and no more succinyl-CoA is produced.

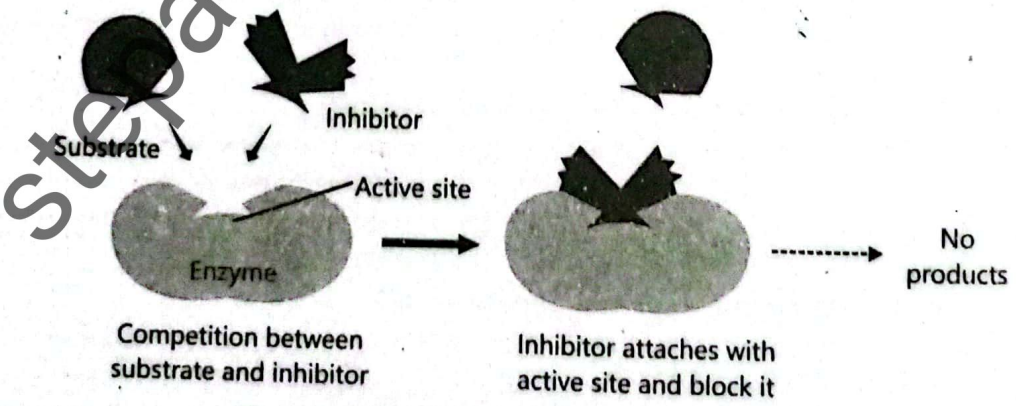



***Fig. 5.9: Competitive inhibition of an enzyme***

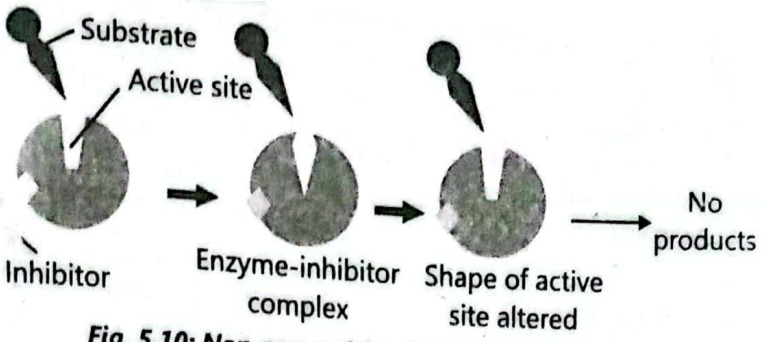



*Fig. 5.10: Non-competitive inhibition of an enzyme*

**Types of Inhibitors on the Base of Bond Formation**

The action of any inhibitor can be irreversible or reversible, depending upon the kind of bond formed between inhibitor and enzyme.

**A: Reversible Inhibitors**

**Reversible inhibitors** make weak bonds (e.g., hydrogen bonds) with enzyme. Such inhibitors can be released and the inhibition caused by them can be neutralized by increasing the concentration of substrate for example, malonate is a reversible inhibitor. It temporarily slows down the reaction by blocking the enzyme succinate dehydrogenase, which is involved in cellular respiration. This inhibition can be reversed when malonate is removed.

**B: Irreversible Inhibitors**

**Irreversible inhibitors** make covalent bonds with enzyme. Such inhibitors cannot be released by dilution or dialysis or by increasing the concentration of substrate. **for example,** penicillin permanently disables the enzyme responsible for building bacterial cell walls.

Inhibitors are often used as drugs, but they can also act as poisons. An example of an enzyme inhibitor being used as a drug is aspirin. It inhibits the enzymes that produce prostaglandin (that causes inflammation). Thus, aspirin suppresses pain and inflammation. The poison cyanide is an irreversible enzyme inhibitor that combines with copper and iron in the active site of enzyme cytochrome oxidase and blocks cellular respiration.

Competitive inhibitors are used as antibiotics to kill bacteria. These inhibitor molecules are similar in structure to bacterial enzymes which are necessary for their life. The inhibitors bind and inhibit the enzymes of bacteria.



## MCQs

1. **What is an inhibitor in the context of enzymes?**
   A) A substance that enhances enzyme action
   B) A chemical that blocks an enzyme's activity ✓
   C) A coenzyme that binds to the enzyme
   D) A product of an enzymatic reaction
2. **What happens during enzyme inhibition?**
   A) Enzymes speed up reactions
   B) Products are transformed into enzymes
   C) Inhibitors attach to enzymes and block active sites ✓
   D) Enzymes are permanently destroyed
3. **What is a competitive inhibitor?**
   A) An inhibitor that binds at a different site on the enzyme
   B) A product of the enzymatic reaction
   C) A substance that resembles the substrate and competes for active site ✓
   D) An enzyme that helps other enzymes
4. **Which of the following is an example of a competitive inhibitor?**
   A) Succinyl-CoA B) CoA
   C) Malonic acid ✓ D) Penicillin
5. **How does a non-competitive inhibitor work?**
   A) It enters the active site and blocks it
   B) It changes the shape of the enzyme by binding elsewhere ✓
   C) It resembles the enzyme's substrate
   D) It enhances the enzyme's activity
6. **What is the effect of succinyl-CoA on succinyl-CoA synthetase?**
   A) It enhances the enzyme's activity
   B) It acts as a competitive inhibitor
   C) It permanently destroys the enzyme
   D) It acts as a non-competitive inhibitor ✓
7. **What determines whether an inhibitor is reversible or irreversible?**
   A) The presence of substrate
   B) The enzyme's temperature tolerance
   C) The type of bond formed with the enzyme ✓
   D) The number of products formed
8. **What characterizes a reversible inhibitor?**
   A) Forms strong covalent bonds
   B) Cannot be removed

C) Makes weak bonds and can be neutralized ✓
D) Destroys the enzyme structure

9. **What is true about irreversible inhibitors?**
A) They can be removed by dilution
B) They make covalent bonds and cannot be removed ✓
C) They temporarily slow down reactions
D) They bind only to coenzymes

10. **How does penicillin act as an inhibitor?**
A) Enhances bacterial cell wall formation
B) Acts as a coenzyme for bacterial enzymes
C) Permanently disables an enzyme for bacterial cell wall synthesis ✓
D) Competes with substrate for active site

SQ

**1. What is an inhibitor and how does it affect enzyme activity?**

**Ans.** A chemical that interferes and blocks an enzyme's activity is called an inhibitor. Inhibitors attach with enzymes but are not transformed into products and thus block active sites temporarily or permanently. This phenomenon is known as enzyme inhibition. The final products of complex enzymatic reactions also act as the inhibitors of the enzyme of the first step.

**2. What are competitive inhibitors and how do they function?**

**Ans.** A competitive inhibitor resembles the enzyme's substrate. It competes with substrate for the same binding site on enzyme. When competitive inhibitor is selected by binding site, it blocks active site and does not permit substrate from attaching. Thus, it prevents enzyme from acting.

**For example,** The enzyme succinic dehydrogenase catalyses the oxidation of succinic acid to fumaric acid. Malonic acid has structural similarity with substrate (succinic acid). So, both of them compete for active site of enzyme. Malonic acid is selected by active site and thus blocks it.

**3. What are non-competitive inhibitors and how do they function?**

**Ans.** A non-competitive inhibitor has no real structural similarity to substrate. So, it does not enter active site. Instead, it binds enzyme at other places. Its binding alters the shape of enzyme so that active site does not fit substrate and so enzyme is inhibited.

**For example**, two substrates i.e., succinic acid and CoA react to form succinyl-CoA. This reaction is catalysed by enzyme succinyl-CoA synthetase. After its formation, the product i.e., succinyl CoA acts as a non-competitive inhibitor and binds with enzyme. Thus, enzyme is inhibited and no more succinyl-CoA is produced.

**4. How are inhibitors classified based on the type of bond formation with enzymes?**

**Ans.** The action of any inhibitor can be irreversible or reversible, depending upon the kind of bond formed between inhibitor and enzyme.

**5. What are reversible inhibitors and how do they act?**

**Ans.** Reversible inhibitors make weak bonds (e.g., hydrogen bonds) with enzyme. Such inhibitors can be released and the inhibition caused by them can be neutralized by increasing the concentration of substrate.

**For example,** Malonate is a reversible inhibitor. It temporarily slows down the reaction by blocking the enzyme succinate dehydrogenase, which is involved in cellular respiration. This inhibition can be reversed when malonate is removed.

**6. What are irreversible inhibitors and how do they act?**

**Ans.** Irreversible inhibitors make covalent bonds with enzyme. Such inhibitors cannot be released by dilution or dialysis or by increasing the concentration of substrate.

**For example,** Penicillin permanently disables the enzyme responsible for building bacterial cell walls.

**7. How does the product of an enzymatic reaction act as an inhibitor?**

**Ans.** The final products of complex enzymatic reactions also act as the inhibitors of the enzyme of the first step. This is part of enzyme inhibition, where the product binds the enzyme either competitively or non-competitively to prevent further reaction, thus regulating the process.

## Q 9. Define the feedback inhibition of enzymes & explain its mechanism?

**Ans. Feedback Inhibition**

**Feedback inhibition** is a cellular control mechanism in which an enzyme's activity is inhibited by the enzyme's end product.

***Importance***

This mechanism allows cells to regulate how much of an enzyme's end product is produced.

**Mechanism**

- We know that in enzymatic / metabolic pathways, the product of one reaction becomes the substrate for next reaction.
- The final product of pathway acts as inhibitor.
- It reacts with some initial enzyme and changes its conformation.
- That enzyme can no longer bind to its substrate. So, enzymatic / metabolic pathway closes and no more product is prepared.

**For Example,**

When a cell has a greater number of ATP than its requirement, ATP itself acts as a non-competitive inhibitor and blocks the enzyme that catalyses ATP synthesis.

**Feedback inhibition** is the phenomenon where the product of a process controls the process itself, oftentimes limiting the production of more products.

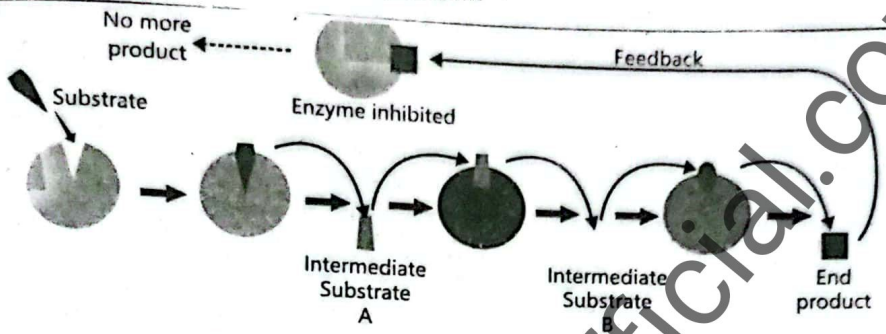



***Fig. 5.11: Feedback inhibition of enzyme action***

## MCQ's

1. **What is feedback inhibition in cells?**
   A) A process that accelerates all metabolic reactions
   B) A mechanism that allows enzymes to function continuously
   C) A control mechanism in which enzyme activity is inhibited by its end product ✓
   D) A method for DNA replication in cells
2. **What is the main importance of feedback inhibition?**
   A) It promotes enzyme overproduction
   B) It initiates new metabolic pathways
   C) It helps cells regulate how much of an enzyme's end product is produced ✓
   D) It allows all enzymes to bind permanently to substrates
3. **In a metabolic pathway, what does the final product usually do?**
   A) Stimulates the first enzyme to work faster
   B) Acts as a coenzyme to enhance the pathway
   C) Becomes a permanent part of the enzyme
   D) Acts as an inhibitor that changes the conformation of an initial enzyme ✓
4. **Whathappens to an enzyme when its conformation is changed during feedback inhibition?**
   A) It becomes more reactive
   B) It binds permanently to its substrate
   C) It can no longer bind to its substrate ✓
   D) It breaks down into amino acids
5. **How does ATP participate in feedback inhibition?**
   A) It is used up by all enzymes
   B) It becomes a catalyst for new reactions
   C) It acts as a non-competitive inhibitor and blocks the ATP-synthesizing enzyme ✓
   D) It triggers the start of protein synthesis

**SQ**

**1. What is feedback inhibition and what is its importance in cells?**

**Ans.** Feedback inhibition is a cellular control mechanism in which an enzyme's activity is inhibited by the enzyme's end product.

**Importance**

This mechanism allows cells to regulate how much of an enzyme's end product is produced.

**2. What is the mechanism of feedback inhibition?**

**Ans. Mechanism**

We know that in enzymatic / metabolic pathways, the product of one reaction becomes the substrate for next reaction.

The final product of pathway acts as inhibitor.

It reacts with some initial enzyme and changes its conformation.

That enzyme can no longer bind to its substrate. So, enzymatic / metabolic pathway closes and no more product is prepared.

**3. Can you give an example of feedback inhibition?**

**Ans. For Example,** when a cell has a greater number of ATP than its requirement, ATP itself acts as a non-competitive inhibitor and blocks the enzyme that catalyses ATP synthesis.

## Q 10. Write a note on the significance of enzyme inhibition?

**Ans. Enzyme inhibition is crucial in various biological processes.**

1. Enzyme inhibition plays a vital role in regulating metabolic pathways. By inhibiting specific enzymes, the rate of a metabolic reaction can be controlled.
2. Many drugs work as inhibitors. For example, antibiotics inhibit the enzymes of bacteria, while cancer drugs may inhibit enzymes involved in cell division.
3. Enzyme inhibitors are used to manage various medical conditions. For example, some inhibitors of enzymes involved in blood clotting are used as anticoagulants.
4. Some toxins and poisons inhibit important enzymes in the body. Understanding how these inhibitors affect enzymes can be critical in treating cases of poisoning.
5. Enzyme inhibitors serve as valuable tools in pharmaceutical research. They are used to study the function of specific enzymes, and potential drugs. Enzyme inhibition is an important part of studying enzyme kinetics. It helps to understand the factors that influence enzyme activity.

## MCQ's

**1. What role does enzyme inhibition play in metabolism?**
A) It enhances energy production
B) It lowers enzyme concentration
C) It regulates metabolic pathways by controlling reaction rates ✓
D) It increases the size of enzymes

**2. What do antibiotics typically inhibit?**
A) Human enzymes
B) Plant metabolism
C) Enzymes of bacteria ✓
D) Blood clotting enzymes

**3. How do cancer drugs generally work?**
A) By destroying DNA
B) By promoting blood clotting
C) By inhibiting enzymes involved in cell division ✓
D) By enhancing nerve conduction

**4. How are enzyme inhibitors useful in treating blood clotting disorders?**
A) They speed up clotting
B) They eliminate blood cells
C) They enhance nerve responses
D) They inhibit enzymes involved in clotting to act as anticoagulants ✓

**5. Why is understanding enzyme inhibition important in toxicology?**
A) It helps prevent genetic mutations
B) It helps treat cases of poisoning ✓
C) It enhances immune response
D) It increases blood sugar

## SQ

**1. What role does enzyme inhibition play in regulating metabolic pathways?**

**Ans.** Enzyme inhibition plays a vital role in regulating metabolic pathways. By inhibiting specific enzymes, the rate of a metabolic reaction can be controlled.

**2. How do many drugs exert their effects in the body?**

**Ans.** Many drugs work as inhibitors. For example, antibiotics inhibit the enzymes of bacteria, while cancer drugs may inhibit enzymes involved in cell division.

**3. How are enzyme inhibitors used to manage various medical conditions?**

**Ans.** Enzyme inhibitors are used to manage various medical conditions. For example, some inhibitors of enzymes involved in blood clotting are used as anticoagulants.

**4. What is the effect of toxins and poisons on enzymes in the body?**

**Ans.** Some toxins and poisons inhibit important enzymes in the body. Understanding how these inhibitors affect enzymes can be critical in treating cases of poisoning.

**5. Why are enzyme inhibitors valuable tools in pharmaceutical research?**

**Ans.** Enzyme inhibitors serve as valuable tools in pharmaceutical research. They are used to study the function of specific enzymes, and potential drugs. Enzyme inhibition is an important part of studying enzyme kinetics. It helps to understand the factors that influence enzyme activity.

## 5.6 CLASSIFICATION OF ENZYMES

Enzymes are classified on the basis of reactions they catalyse and also on the basis of substrates they use.

**Q 11. Write a detailed note on the classification on enzymes on the base of reactions as well as substrates?**

**Ans. Classification on the Basis of Reactions**

According to the general type of reaction, enzymes are classified into six classes.

**1: Oxidoreductases**

These enzymes catalyse the oxidation / reduction of their substrates. They add or remove $H^+$ ions or electrons from substrates.

**For Example,**

**Cytochromeoxidase** catalyses the oxidation of cytochrome.

**2: Transferases**

The enzymes of this class catalyse the transfer of a specific functional group (e.g., methyl, acyl, amino, or phosphate) from one substrate to another.

**For example,**

**Hexokinasetransfers** phosphate group from ATP to glucose.

**3: Hydrolases**

These enzymes catalyse hydrolysis reactions. They break their substrates into monomers by adding water.

**For Example,**

**Lipase, amylase, peptidase,** and other digestive enzymes catalyse the hydrolysis of food molecules.

**4: Lyases**

These enzymes catalyse non-hydrolytic addition or removal of groups (e.g., $CO_2$, $NH_2$ etc.) from substrates.

**For Example,**

**Pyruvatedecarboxylase** removes $CO_2$ from pyruvic acid.

**5: Isomerases**

These enzymes catalyse the intra-molecular rearrangement i.e.; one isomer is converted into another.

**For Example,**

**Hexoseisomerase** converts glucose to fructose.

**6: Ligases**

These enzymes catalyse the reactions in which two molecules join by forming new C-C, C-N, C-O, or C-S bonds, using energy from ATP.

**For Example,**

**Polymerase** enzymes join monomers by using ATP.

**Classification on the basis of substrates**

Enzymes are also classified into following groups on the basis of their substrates.

**1: Proteases**

This group included the enzymes which catalyse the breakdown of proteins.

**For Example,**

**Pepsin** and **trypsin** enzymes catalyse the breakdown of large polypeptides into smaller polypeptides.

**Amino peptidases** further breakdown small polypeptides into dipeptides.

**Erypsin**breaks dipeptides into amino acids.

**2: Lipases**

These enzymes act upon lipids and catalyse their breakdown.

**For Example,**

Pancreatic **lipase** hydrolyses lipids into fatty acids and glycerol.

**3: Carbohydrases**

These enzymes act upon bigger carbohydrates and break them into smaller units.

**For Example,**

**Amylase** acts upon starch or glycogen and breaks them into maltose.

**Cellulase** breaks cellulose into cellobiose (a disaccharide) or glucose.

**Maltase** breaks down maltose into glucose.

**Sucrase** breaks sucrose into glucose and fructose.

**Lactase** breaks lactose into glucose and galactose.

**4: Nucleases**

These enzymes act upon nucleic acids and catalyse their breakdown.

**For Example,**

**RNAase, DNAase, ATPase** are responsible for the breakdown of RNA, DNA and ATP respectively.

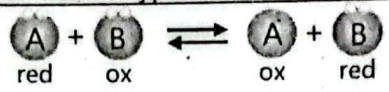
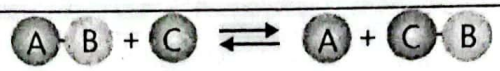
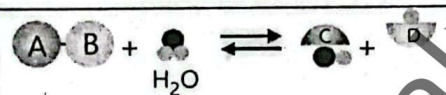
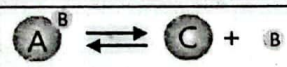
| Class | Reaction Type | Important Subclasses |
|---|---|---|
| Oxidoreductases |   | Dehydrogenases<br>Oxidases<br>Reductases |
| transferases |   | Phosphotransferases<br>Amino transferases<br>Acyl transferases |
| hydrases |   | Peptidases<br>Ligases<br>Glycosidases |
| Lyases |   | Decarboxylases<br>Aldolases<br>Synthases |
| Isomerases |   | Epimerases<br>Mutases<br>Cis trans isomerases |
| ligases |   | C-C ligases<br>C-O Ligases<br>C-N Ligases |

***Fig. 5.12 - Enzyme classification on the basis of reactions***

## mCQs

1. **What are enzymes made up of?**
   A) DNA chains
   B) Polysaccharide units
   C) Polypeptide chains that are coiled upon themselves ✓
   D) Nucleotide bases
2. **How do enzymes speed up chemical reactions?**
   A) By increasing activation energy
   B) By lowering activation energy ✓
   C) By changing substrate structure
   D) By being consumed during the reaction
3. **What is the main reason cells have different sets of enzymes?**
   A) To produce energy differently
   B) Different chemical reactions occur in different cell types ✓
   C) To make enzymes faster
   D) To store more proteins
4. **Which class of enzymes catalyses oxidation and reduction reactions?**
   A) Transferases
   B) Hydrolases
   C) Oxidoreductases ✓
   D) Ligases
5. **What is the function of transferase enzymes?**
   A) Transfer functional groups from one substrate to another ✓
   B) Break down large molecules by adding water
   C) Remove $CO_2$ from substrates
   D) Rearrange molecular structure within the same molecule
6. **Which enzyme transfers a phosphate group from ATP to glucose?**
   A) Lipase
   B) Hexokinase ✓
   C) Pepsin
   D) Polymerase
7. **Hydrolase enzymes catalyse which type of reaction?**
   A) Oxidation
   B) Hydrolysis ✓
   C) Rearrangement
   D) Addition of groups
8. **Which enzyme is an example of a lyase?**
   A) Pyruvate decarboxylase ✓
   B) Amylase
   C) Hexose isomerase
   D) Pepsin
9. **What reaction do isomerases catalyse?**
   A) Oxidation
   B) Transfer of phosph
   C) Intra-molecular rearrangement ✓
   D) Hydrolysis
10. **Ligases catalyse which type of reaction?**
    A) Hydrolysis
    B) Joining two molecules with new bonds using ATP energy ✓

C) Oxidation groups
D) Transfer of functional

11. **What type of enzyme is pepsin?**
A) Lipase
B) Protease ✓
C) Carbohydrase
D) Nuclease

12. **Which enzyme breaks down lipids into fatty acids and glycerol?**
A) Amylase
B) Trypsin
C) Pancreatic lipase ✓
D) Maltase

13. **Which enzyme breaks starch into maltose?**
A) Sucrase
B) Amylase ✓
C) Lactase
D) Cellulase

14. **What do nucleases act upon?**
A) Proteins
B) Lipids
C) Nucleic acids ✓
D) Carbohydrates

15. **Which of the following enzymes breaks down maltose into glucose?**
A) Maltase ✓
B) Lactase
C) Sucrase
D) Amylase

SQ

1. **What are enzymes and how do they function in chemical reactions?**

**Ans.** The specific globular proteins that speed up specific chemical reactions by lowering the required activation energy without themselves being used up are called enzymes. Enzymes are also known as biocatalysts. Rates of enzyme-catalysed reactions may be $10^3$ to $10^8$ times greater than the rates of corresponding uncatalyzed reactions.

2. **Do all cells have the same set of enzymes? Why or why not?**

**Ans.** All cells do not have the same set of enzymes. The chemical reactions going on in red blood cells are very different from those going on within a nerve cell because red blood cells and nerve cells contain different sets of enzymes. So, the difference in enzyme-sets makes the base of division of labor among cells.

3. **What are oxidoreductases and give an example?**

**Ans.** Oxidoreductases are enzymes that catalyse the oxidation or reduction of their substrates by adding or removing $H^+$ ions or electrons. An example is Cytochrome oxidase which catalyses the oxidation of cytochrome.

4. **What role do transferases play in enzyme-catalyzed reactions?**

**Ans.** Transferases catalyse the transfer of specific functional groups such as methyl, acyl, amino, or phosphate from one substrate molecule to another. For example, Hexokinase transfers a phosphate group from ATP to glucose.

5. **What are hydrolases and which enzymes are included in this class?**

**Ans.** Hydrolases catalyse hydrolysis reactions by breaking down their substrates into monomers through the addition of water. Examples include digestive enzymes such as Lipase, amylase, and peptidase, which catalyse the hydrolysis of food molecules.

6. **What are proteases and how do they function?**

**Ans.** Proteases are enzymes that catalyse the breakdown of proteins. For example, Pepsin and trypsin break down large polypeptides into smaller polypeptides, amino peptidases further break small polypeptides into dipeptides, and erypsin breaks dipeptides into amino acids.

7. **How do lipases function and what is an example?**

**Ans.** Lipases act upon lipids and catalyse their breakdown. For example, Pancreatic lipase hydrolyses lipids into fatty acids and glycerol.

8. **What are Carbohydrases and what substrates do they act upon?**

**Ans.** Carbohydrases act upon large carbohydrates and catalyse their breakdown into smaller units. Examples include amylase, which breaks starch or glycogen into maltose; cellulase, which breaks cellulose into cellobiose or glucose; maltase, which breaks maltose into glucose; sucrase, which breaks sucrose into glucose and fructose; and lactase, which breaks lactose into glucose and galactose.

9. **What are nucleases and what is their function?**

**Ans.** Nucleases act upon nucleic acids and catalyse their breakdown. Examples include RNAase, DNAase, and ATPase, which are responsible for breaking down RNA, DNA, and ATP respectively.

10. **How are enzymes classified on the basis of their substrates?**

**Ans.** Enzymes are also classified into groups based on the substrates they act upon. These include proteases, which break down proteins; lipases, which break down lipids; Carbohydrases, which break down carbohydrates; and nucleases, which break down nucleic acids. Each group includes specific enzymes that target particular molecules for breakdown.

# SOLVED EXERCISE

## MULTIPLE CHOICE QUESTIONS

**Tick (✓) the correct answer.**

1. **What role does nicotinamide adenine dinucleotide ($NAD^+$) play in oxidative pathways?**
   (a) Enzyme (b) Coenzyme ✓
   (c) Prosthetic group (d) Inhibitor
2. **The enzymes that catalyse the reactions in which two molecules are joined together by synthesis of new bonds, using energy from ATP, are placed in which group?**
   (a) Hydrolase (b) Ligase ✓
   (c) Lyase (d) Transferase
3. **Which of the following is an example of hydrolases?**
   (a) Lipase ✓ (b) Glycogen phosphorylase
   (c) Pyruvate decarboxylase (d) Cytochrome oxidase
4. **Which of the following statements about enzymes is correct?**
   (a) They increase the activation energy of a reaction.
   (b) They are consumed during the reaction.
   (c) They are specific in terms of the reactions they catalyse. ✓
   (d) They always work optimally at high temperatures.
5. **Enzyme B requires $Zn^{2+}$ to catalyse the conversion of substrate X. The zinc is best identified as a(n)?**
   (a) Coenzyme (b) Activator ✓
   (c) Substrate (d) Product
6. **If an enzyme solution is saturated with substrate, the most effective way to obtain an even faster yield of products would be?**
   (a) Add more of the enzymes ✓ (b) Add more substrate
   (c) Add an allosteric inhibitor (d) Add a non-competitive inhibitor
7. **How does a non-competitive inhibitor decrease the rate of an enzyme-catalysed reaction?**
   (a) By binding the active site of the enzyme
   (b) By changing the shape of the enzyme ✓
   (c) By changing the free energy change of the reaction
   (d) By acting as a coenzyme for the reaction
8. **Which enzyme class is responsible for catalysing the addition of water to a substrate molecule?**
   (a) Ligase (b) Lyase
   (c) Hydrolase ✓ (d) Isomerase

## SHORT ANSWER QUESTIONS

1. **Define enzyme and co-factor?**
   - **Enzyme:** A biological catalyst, usually a protein, that speeds up chemical reactions without being consumed.
   - **Co-factor:** A non-protein component (metal ion or organic molecule) required for enzyme activity.
2. **Differentiate between co-enzyme and prosthetic group?**
   - **Co-enzyme:** An organic co-factor that binds temporarily with the enzyme (e.g., $NAD^+$).
   - **Prosthetic group:** A tightly or permanently bound non-protein component (e.g., heme group in cytochromes).
3. **What do you mean by hydrolases? Give two examples?**
   - **Hydrolases:** Enzymes that catalyse hydrolysis reactions (breaking bonds using water).
   - **Examples:** Amylase, Lipase.
4. **What is meant by activation energy?**
   - **Activation energy:** The minimum amount of energy required to start a chemical reaction.
5. **Define feedback inhibition?**
   - **Feedback inhibition:** A regulatory mechanism where the end product of a metabolic pathway inhibits an earlier enzyme to control the pathway's activity.

6. **Give examples of competitive and non-competitive inhibitors?**
   - **Competitive inhibitor:** Malonate (inhibits succinate dehydrogenase).
   - **Non-competitive inhibitor:** Cyanide (inhibits cytochrome oxidase).
7. **What is optimum pH? Give optimum pH of three human enzymes?**
   - **Optimum pH:** The specific pH at which an enzyme shows maximum activity.
   - **Examples:**
     - Pepsin: pH 2
     - Amylase: pH 7
     - Trypsin: pH 8

## LONG QUESTIONS

**Q1. Describe the structure of enzyme, explaining the role and component parts of the active site of an enzyme?**

Ans. See Q2

**Q2. Differentiate among the three types of co-factors, by giving examples?**

Ans. See Q3

**Q3. Explain the mechanism of enzyme action through Induced Fit Model, comparing it with Lock and Key Model?**

Ans. See Q6

**Q4. Define activation energy and explain through graph how an enzyme speeds up a reaction by lowering activation energy?**

Ans. See Q4

**Q5. Describe the effect of temperature on the rate of enzyme action?**

Ans. See Q5

**Q6. Compare the optimum temperatures of enzymes of human and thermophilic bacteria?**

Ans. See Q5

**Q7. Describe how the concentration of enzyme affects the rate of enzyme action?**

Ans. See Q5

**Q8. Explain the effect of substrate concentration on the rate of enzyme action?**

Ans. See Q5

**Q9. Describe enzymatic inhibition, its types and its significance?**

Ans. See Q6 & Q8

**Q10. Categorize inhibitors into competitive and non-competitive inhibitors?**

Ans. See Q6

**Q11. Explain feedback inhibition?**

Ans. See Q7

**Q12. Classify enzymes on the basis of the reactions catalysed?**

Ans. See Q9

**Q13. Give examples of enzymes' naming according to substrates?**

Ans. See Q9

## INQUISTIVE QUESTIONS

1. **Does physical exercise involve anabolic processes, catabolic processes, or both? Give evidence for your answer.**

Ans. Physical exercise involves both anabolic and catabolic processes.

- **Catabolic** processes break down molecules (e.g., glucose, fatty acids) to release energy for muscle contraction.
- **Anabolic** processes occur during recovery, where the body synthesizes proteins to repair and build muscle tissue.

# Self-Assessment Unit 5

Max. Marks: 28 Time allowed 60 Mins

**Q1. Each of the following question has four options. Select the correct answer. (10x1=10)**

1. **What function does nicotinamide adenine dinucleotide ($NAD^+$) serve in cellular oxidation processes?**
(a) Enzyme (b) Coenzyme (c) Prosthetic group (d) Inhibitor
2. **Enzymes that facilitate the bonding of two molecules using ATP energy are grouped under which class?**
(a) Hydrolase (b) Ligase (c) Lyase (d) Transferase
3. **Which of the following enzymes is classified as a hydrolase?**
(a) Lipase (b) Glycogen phosphorylase (c) Pyruvate decarboxylase (d) Cytochrome oxidase
4. **Which of the following statements accurately describes enzyme behavior?**
(a) They raise the activation energy of a reaction
(b) They are used up in the reaction
(c) They show specificity for the reactions they catalyze
(d) They always function best at elevated temperatures
5. **Enzyme B needs $Zn^{2+}$ to convert substrate X. What is the best term for $Zn^{2+}$ in this context?**
(a) Coenzyme (b) Activator (c) Substrate (d) Product
6. **If the enzyme solution is fully saturated with substrate, what is the best method to increase the product formation rate?**
(a) Add more enzyme (b) Increase substrate concentration
(c) Introduce an allosteric inhibitor (d) Use a non-competitive inhibitor
7. **How does a non-competitive inhibitor interfere with an enzyme-catalyzed reaction?**
(a) It occupies the enzyme's active site (b) It alters the enzyme's structure
(c) It changes the overall energy of the reaction (d) It acts as a coenzyme
8. **Which class of enzymes is responsible for breaking bonds by adding water to the substrate?**
(a) Ligase (b) Lyase (c) Hydrolase (d) Isomerase
9. **Which feature allows enzymes to lower the activation energy of a reaction?**
(a) Their irreversible binding to substrates
(b) Their ability to bind cofactors permanently
(c) Their specific interaction with substrates at the active site
(d) Their denaturation at low pH
10. **What happens to enzyme activity when the temperature significantly exceeds the optimal range?**
(a) It increases continuously (b) It decreases due to denaturation
(c) It becomes more stable (d) It remains unchanged

**Q2. Write short answers to the following questions. (5x2=10)**

1. Differentiate between co-enzyme and prosthetic group.
2. What do you mean by hydrolases? Give two examples.
3. What is meant by activation energy?
4. Define feedback inhibition.
   Give examples of competitive and non-competitive inhibitors.

**Q3. Write detailed answer to the following question. (4+4=8)**

1. Describe enzymatic inhibition, its types and its significance.
2. Explain the mechanism of enzyme action through Induced Fit Model, comparing it with Lock and Key Model.