Enzymes

Definition of Enzymes

- Enzymes are biological macromolecules that primarily consist of proteins, although some are RNA-based and are known as ribozymes.
- They act as biocatalysts, meaning they speed up biochemical reactions by lowering the activation energy required.
- During the reaction, enzymes do not undergo any permanent structural change and are not consumed, allowing them to function repeatedly.
- Enzymes are highly specific—each enzyme typically acts on a particular substrate and catalyzes a specific type of chemical reaction.
- Unlike non-biological or chemical catalysts, enzymes operate under mild physiological conditions, such as:
    - Normal body temperature (~37°C)
    - Near-neutral pH (~7.4)
- These properties make enzymes indispensable for metabolic and life-sustaining processes in living organisms.

Key Features of Enzymes

- **Biocatalysts**: Enzymes increase the rate of biochemical reactions without being consumed, much like chemical catalysts.
- **Specificity**: Each enzyme typically acts on a specific substrate and catalyzes a particular type of chemical reaction.
- **Reusability**: Enzymes remain unchanged after the reaction and can be used repeatedly.
- **Regulation**: Enzymatic activity can be modulated, activated or inhibited—by various physiological factors, allowing fine control of metabolic pathways.
- **Mild Operating Conditions**: Enzymes function efficiently under normal body temperature, pH, and pressure, unlike non-biological catalysts which may require extreme conditions.

Example

- **Amylase**: An enzyme that catalyzes the hydrolysis of starch into simpler sugars like maltose and glucose.

Properties of Enzymes

1. Specificity

- Enzymes exhibit high specificity toward their substrates. This is explained by models such as the **Lock and Key** and **Induced Fit** models.

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2. Catalytic Power

- Enzymes can accelerate the rate of biochemical reactions by **10^6 to 10^{14} times**, making them extremely efficient catalysts.

3. Reversibility

- Enzymes can catalyze reactions in both forward and reverse directions, depending on **concentration gradients** of substrates and products.

4. Regulation

- Enzyme activity is **highly regulated** through mechanisms such as:
  - Feedback inhibition
  - Allosteric modulation
  - Covalent modification (e.g., phosphorylation)

5. Temperature and pH Sensitivity

- Enzymes operate best within **specific temperature and pH ranges**, and their activity declines sharply outside these optimal conditions.

6. No Change in Equilibrium

- Enzymes **lower the activation energy** of a reaction but do **not alter the equilibrium position** of the reaction.

7. Reusability

- Since enzymes are **not consumed** during the reaction, they can be used **repeatedly** for multiple reaction cycles.

Enzyme Classification (IUB and MB Classification)

- The International Union of Biochemistry and Molecular Biology (IUBMB) classifies enzymes into 6 major classes, based on the type of reaction catalyzed.
- Each enzyme is given an EC number (Enzyme Commission number), consisting of four digits.

A. IUB (International Union of Biochemistry) Classification

- Enzymes are divided into **6 major classes** based on the type of reaction they catalyze:

Class	Name	Reaction Catalyzed	Examples
EC 1	**Oxidoreductases**	Oxidation-reduction reactions	Dehydrogenase, Oxidase
EC 2	**Transferases**	Transfer of functional groups	Transaminase, Kinase

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EC 3	**Hydrolases**	Hydrolysis of bonds (using water)	Amylase, Protease
EC 4	**Lyases**	Addition/removal of groups without hydrolysis	Decarboxylase
EC 5	**Isomerases**	Rearrangement of atoms within a molecule	Isomerase, Mutase
EC 6	**Ligases** (Synthetases)	Joining two molecules using ATP	DNA ligase, Synthetase

Note: Each enzyme is assigned an EC number (e.g., EC 3.1.1.1 for esterase).

B. MB (Medical Biochemistry) Based Classification

- Based on the clinical function or site of action:
  - Digestive enzymes (amylase, lipase)
  - Blood coagulation enzymes (thrombin)
  - Metabolic enzymes (G6PD)
  - Diagnostic enzymes (ALT, AST, CK-MB)

Factors Affecting Enzyme Activity

Several factors can alter the activity of enzymes. These include:

1. Temperature

Effect:

- **Increases reaction rate (up to a point):** As temperature increases, the kinetic energy of molecules also increases, leading to more frequent collisions between enzymes and substrates.
- **Denaturation at high temperatures:** If the temperature gets too high (above the enzyme’s optimum temperature), the enzyme’s three-dimensional structure can be disrupted (denatured), resulting in loss of function.

Optimal Temperature:

- Each enzyme has an optimum temperature at which it functions most efficiently. For human enzymes, it's typically around **37°C** (body temperature).

2. pH (Acidity/Alkalinity)

Effect:

- Enzymes have an optimal pH at which their activity is highest.

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- **Too acidic or too basic** conditions can alter the enzyme's active site shape by affecting ionic and hydrogen bonds, leading to **denaturation** or reduced binding with the substrate.

Examples:

- **Pepsin**, a stomach enzyme, works best at **pH 2** (acidic).
- **Amylase**, found in saliva, functions best at around **pH 7** (neutral).

3. Substrate Concentration

Effect:

- **Increasing substrate concentration** increases the rate of reaction—up to a point.
- Once all enzyme active sites are occupied (saturation point), adding more substrate **won’t increase the rate** further.

Michaelis-Menten Kinetics:

- The relationship between substrate concentration and enzyme activity follows a hyperbolic curve.
- **Vmax**: Maximum rate achieved by the system.
- **Km**: Substrate concentration at which the reaction rate is half of Vmax.

4. Enzyme Concentration

Effect:

- Increasing enzyme concentration increases the reaction rate, provided substrate is not limiting.
- If substrate is in excess, more enzymes mean more active sites are available, leading to faster reactions.

5. Presence of Inhibitors

Types of Inhibitors:

1. Competitive Inhibitors:

- Compete with the substrate for the active site.
- Can be overcome by increasing substrate concentration.
- Example: Methotrexate inhibits the enzyme dihydrofolate reductase.

2. Non-competitive Inhibitors:

- Bind to a site other than the active site (allosteric site).
- Change the enzyme's shape, reducing activity.

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- Cannot be overcome by adding more substrate.

3. Uncompetitive Inhibitors:

- Bind only to the enzyme-substrate complex, locking the substrate in place.

6. Cofactors and Coenzymes

Effect:

- Many enzymes require **non-protein helpers** for activity:
  - **Cofactors:** Inorganic ions (e.g., Mg^{2+}, Fe^{2+}, Zn^{2+}).
  - **Coenzymes:** Organic molecules (often derived from vitamins), like NAD^{+} or FAD.

Role:

- Help in stabilizing the enzyme-substrate complex or participate in the reaction.

7. Enzyme Activators

Effect:

- Some molecules can increase enzyme activity.
- They may bind allosterically or help form the correct active conformation of the enzyme.

8. Time

Effect:

- Over time, enzymes may become **inactivated** or denatured, especially if exposed to suboptimal conditions.
- Reaction rate may decrease as enzyme degrades or product accumulates and causes feedback inhibition.

Mechanism of Action of Enzymes

- Enzymes are biological catalysts that accelerate chemical reactions by **lowering the activation energy** required for the reaction to occur.
- They are not consumed in reaction and can be reused multiple times.

Steps in Enzyme Action



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