

Enzyme

Enzyme: Enzymes are protein molecules that act as biological catalysts (biocatalysts) and accelerate rate of chemical reactions by lowering activation energy. Activation energy is the minimum amount of energy required for the reactant to be converted to products. All enzymes are proteins made up of chains of amino acids linked together by peptide bonds.

Enzymes act upon molecules (substrates), convert them into products of different molecules, and remain unchanged

A. The physical properties of enzymes

1. **Denaturation:** -is the process of breaking the intra and inter-molecular non-covalent bonds that distort the shape and active site of the enzymes. Enzymes are denatured by high heat (above 40°C), alternation in the pH (too low or too high), heavy metals and high salt concentrations, solvents and other reagents.

2. **Solubility** is the property of enzymes that allow them to be dissolved in water, salt (NaCl), diluted glycerol and alcohol causing denaturation.

3. **The colloidal nature of enzyme** is the tendency of having little or no dialysis cross the semipermeable membrane due to the large size or high molecular weight

“In chemistry and biology, **dialysis** is a process where small molecules (like salt or sugar) pass through a parchment-like material called a **semipermeable membrane**, while larger molecules are trapped behind.”

Because of their **colloidal nature** and high molecular weight, enzymes are the "big players" that stay stuck on one side.

4. **The biocatalyst property** is the activity of enzymes in which very small quantities or a small amount of enzyme is enough to convert a large quantity of substrate and remain unchanged after the reaction.

5. **Enzyme precipitation** is the separation of enzymes for analysis using different aqueous or ethanol solvents.

In the context of enzymes and chemistry, precipitation happens when a substance that was dissolved in a liquid suddenly becomes insoluble and turns into a solid.

6. **Molecular weights of enzymes** are large protein biomolecules that hold polypeptide chains of various amino acid sequences in enzymes having a high molecular weight.

- Enzymes show the highest activity at optimum temperature and pH that a low concentration of enzymes and substrates slows down the enzymatic reaction.

B. Chemical properties of enzymes

1. Heat and PH Sensitivity is an enzymatic reaction to heat (temperatures) and pH (acidity and basicity) activated at optimum levels.

2. Regulation is the process of controlling the activity of enzymes by activator and inhibitor molecules.

3. Catalysis is the process of the acceleration of a chemical reaction by a catalyst. Enzymes are biological catalysts that possess high catalytic efficiency. They can transform about 100-10,000 substrates per second. The reactions catalyzed by the enzymes show a 10^3 - 10^8 times faster reaction rate in comparison to the non-catalyzed reactions.

4. If there is too much Substrate: The enzyme pushes the reaction forward to make Product.

If there is too much Product: The enzyme pushes the reaction backward to recreate Substrate. These shows the reversibility of Enzymes

5. Enzyme specificity is a property of the enzyme that describes how restrictive the enzyme is in its choice of substrate.

● Functions of Enzyme

- Enzymes help speed up chemical reactions in the human body.*
- The turn over number of molecules is the number of substrates converted by one enzyme molecule per second at saturated (fully occupied) active sites.*
- Enzymes are markers of the states of various diseases like myocardial infraction, jaundice, pancreatitis, cancer and neurodegenerative disorders etc.*
- Each enzyme has an active site with a unique shape that speeds up metabolism or chemical reactions in our bodies and builds substances in all living things.*
- Enzymes perform their function by lowering a reaction's activation energy. Activation energy is the energy required to start a reaction. The lower the activation energy, the faster a reaction happens*

● Protein structure

- Proteins have different structures. Protein structure is a polymer of amino acids joined by peptide bonds with three-dimensional arrangements of atoms in amino acid chain molecules.*
- The protein complex macromolecules have four structural levels:*

1.Primary structure:It is the sequence of amino acids linked together to form a polypeptide chain through peptide bonds created during the protein biosynthesis process.

*It is simply the **linear sequence of amino acids** in a polypeptide chain.*

- ❖ Proteins with fewer than 50 sequences are peptides, and proteins with longer than 50 sequences of amino acids are polypeptides.*
- ❖ Humans require 20 amino acids out of which 10 amino acids are synthesized in the human body, and the rest 10 amino acids are obtained from diets.*
- ❖ Peptide bonds form through a dehydration reaction between the carboxyl group of one amino acid and the amino group of the next.*

2.Secondary structure of protein:The secondary structure of a protein is a folded structure formed within a polypeptide due to interactions between atoms of the backbone based on hydrogen bonding and containing α -helix and β -sheet types of strands.

- ❖ **Alpha helix:**This looks like a delicate spiral or a telephone cord. The backbone twists into a right-handed screw shape.*

Bonding: A hydrogen bond forms between every fourth amino acid.

*Purpose: This shape is very strong yet flexible. You find many of these in **keratin** (the protein in your hair).*

- ❖ **The Beta Pleated Sheet***

This looks like a folded paper fan or a series of ridges and valleys. Two or more segments of the polypeptide chain align side-by-side.

Bonding: Hydrogen bonds form between the parallel "strands."

Purpose: These sheets provide structural rigidity. They are the main component of silk (produced by spiders and silkworms).

3.Tertiary structure of protein:The tertiary protein structure is the three dimensional shape of protein molecules that bend and twist to achieve the maximum stability or the lowest energy state.

4.Quaternary structure of protein: It is the association of several protein chains or subunits into closely packed arrangements with their own primary,

secondary, or tertiary structures and held together by the hydrogen bonds.(Hemoglobin)

All polypeptide chains are held together by a specific spatial arrangement and interactions.(Quaternary)

Enzyme substrate model

1.The Lock and Key Model

Proposed by Emil Fischer in 1894, this is the classic explanation.

- *The Concept: The enzyme's **active site** (the lock) and the **substrate** (the key) have complementary shapes that fit together perfectly from the very start.*
- *Key Takeaway: It emphasizes **specificity**. If the "key" doesn't have the exact right shape, it won't enter the "lock," and no reaction occurs.*

2. The Induced Fit Model

Proposed by Daniel Koshland in 1958, this is the more modern and accurate view. It suggests that enzymes are flexible, not rigid.

- *The Concept: As the substrate approaches the enzyme, the enzyme **changes its shape slightly** to wrap more tightly around the substrate.*
- *The "Handshake" Analogy: Think of a glove. A glove has a general hand shape, but as you put your hand in, the glove stretches and molds to fit your fingers perfectly.*

★ Enzyme regulation

1. Allosteric enzymes Allosteric enzymes are enzymes that have additional binding sites for effector molecules other than the active site that cause conformational changes, leading to changes of catalytic properties. Allosteric enzymes contain two binding sites called active site/catalytic site and allosteric site/regulatory site for binding effectors and substrates respectively.

- *Effectors are small molecules (inhibitor or activator) modulating the enzyme activity and function through reversible non-covalent binding of a regulatory metabolite in the allosteric site or non-active site*

Effectors lead to conformational changes in a concrete part of the enzyme that affect the overall conformation of the active site, causing modifications in the activity of the reaction.

2. Genetic and covalent modification The genetic and covalent modification modifies the protein surface and facilitates intracellular delivery. Genetic modification of enzymes is to improve the properties of enzymes and gain active and inactive forms. Covalent modulated enzymes are active and inactive forms of the enzymes altered due to covalent modification of structures catalyzed by other enzymes. Covalent modifications are enzyme-catalyzed alterations of synthesized proteins by the addition or removal of chemical groups.

- *Phosphorylation is the addition of phosphate groups to proteins. It is the most frequent regulatory modification mechanism in our cells*

3. Enzyme inhibition: Enzyme inhibition is a decrease in enzyme activity by enzyme inhibitors. Enzyme inhibitors are molecule that binds to an enzyme and blocks its activity.

Irreversible inhibitor: is a substance that permanently blocks the action of an enzyme.

Reversible inhibitor: inactivates an enzyme through noncovalent easily reversed interactions. Reversible inhibitors can be competitive and uncompetitive.

*1. A **noncompetitive inhibitor** doesn't care if the substrate is there or not. It has its own special parking spot (called an **allosteric site**) away from the main active site.*

- *How it works: It can bind to the **Enzyme alone** OR the **Enzyme-Substrate Complex**.*

2. Uncompetitive Inhibitor: "The Door-Locker"

*This one is more "shy." It **cannot** bind to the enzyme if the enzyme is empty. It has to wait for the substrate to get in there first.*

- *How it works: Once the substrate enters the enzyme (forming the **Enzyme-Substrate Complex**), a new "pocket"*

opens up. The uncompetitive inhibitor jumps into that pocket and "locks" the substrate inside.

1. Simple Proteins

These enzymes consist **only** of amino acids. They don't need any extra help to do their job.

- **Status:** Active on their own.

2. Conjugated Proteins (Holoenzymes)

These are "complex" enzymes. A **Holoenzyme** is the complete, functional unit made of a protein part and a non-protein part.

The Breakdown of a Holoenzyme:

- **Apoenzyme:** This is the protein part. By itself, it is **inactive**. Think of it like a flashlight with no batteries.
- **Cofactor:** This is the non-protein "helper" part. Without it, the apoenzyme can't catch the substrate.
 - Finally, the non-protein part (cofactor) separates into the firmly attached metal ion (prosthetic group) and the loosely attached vitamin B complex (coenzyme) groups
- Lyases are enzymes that cleave bonds by other means rather than hydrolysis or oxidation in which two or more substrates are involved in one reaction.
- ❖ enzymes require a maximum limit of substrate concentration to bind.
- ❖ The drug Tipranivir used to treat HIV blocks the activity of a viral genome enzyme to make more copies as a reversible inhibitor.

Table 3.3 the applications and functions of enzymes

Cellulases	Biofuel industry	Breakdown cellulose into sugars and ferment to produce cellulosic ethanol
Ligninase	Biofuel industry	Pre-treatment of biomass for biofuel production
Protease, Amylase, Lipase	Biological detergent	Protease removes protein, amylase removes starch, and lipase removes fat or oil stains from laundry and dishware
Mannanase	Biological detergent	Remove food stains from the common food additive guar gum
Betaglucanase	Brewing industry	Improve beer filtration
Papain	Culinary uses	Tenderize meat for cooking
Rennin	Dairy industry	It hydrolyses protein in the manufacture of cheese
Trypsin	Food processing	Manufacture hypo-allergenic baby foods
Cellulases, Pectinase	Food processing	Clarify fruit juices.
Nuclease, DNA Ligase, Polymerase	Molecular biology	Uses restriction digestion and polymerase chain reaction to create recombinant DNA