ENZYMES: STRUCTURE AND CHARACTERISTICS

(Introduction to Enzyme Structure & Functions)

What are Enzymes?

There are thousands of chemical reactions in a living system. The chemical reactions in the cell are catalyzed by the biological catalysts called enzymes. Almost all enzymes are highly specialized proteins. (Exception: Ribozymes – Ribozymes are RNA with catalytic activity). The current post we will discuss the Characteristics of Enzymes. We will also discuss the features of a Catalyst and the concept of Activation Energy of a reaction.

What are catalysts?

- The catalyst is substances that accelerate the rate of a chemical reaction.
- The catalyst is not consumed or transformed by the reaction.
- It will not change the equilibrium constant of the reaction.
- Catalysts only change the rate to approach equilibrium constant.
- Catalysts are not required in stoichiometric quantities.
- Examples: Platinum, Palladium etc.

Brief History about Enzymes

- The history of biochemistry is the history of enzyme research.
- Louis Pasteur reported fermentation of sugar into alcohol by yeast is catalyzed by “ferments”.
- Frederick W. Kuhne coined the term ENZYME for the ‘ferments’.

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The first enzyme discovered was **Diastase** from malt by Anselme Payen in 1833.

The first crystallized enzyme is **Urease** by James **Sumner**.

**Characteristics of Enzymes**

- The enzymes have extraordinary catalytic power.
- Enzymes accelerate reactions up to **10^14 to 10^20 times**.
- Enzymes have a high degree of **specificity** for their substrates and reactions.
- They function in an aqueous solution.
- Enzymes work under a mild condition of **temperature** and **pH**.

*Image source: Wikipedia*
- Enzymes make macromolecules from simple precursors.
- The enzymes act in an organized sequence.
- They catalyze the hundreds of stepwise reaction.
- Enzymes can regulate metabolic pathways and these enzymes are regulatory enzymes.
- In some genetic disorders, there may be a deficiency one or several enzymes (Eg. albinism).
- Enzyme reduces the activation energy of the reaction.

**Activation Energy**

- The term activation energy was introduced by Svante Arrhenius (1889).
- **Definition:** “The minimum energy that must be input to a chemical system, containing potential reactants, in order for a chemical reaction to occur”.
- In simple, the minimum energy required to start a chemical reaction.
- For a chemical reaction to proceed at a reasonable rate, there should exist an appreciable number of molecules with energy equal to or greater than the activation energy.
The activation energy of a reaction is denoted as $E_a$.

The $E_a$ is given in units of kilojoules per mole.

**Enzymes Structure**

- All enzymes are **proteins** except Ribozymes. Ribozymes are specialized RNA molecules with catalytic activity.

![Ribozymes](https://www.easybiologyclass.com/image)

- The catalytic activity of an enzyme depends on the integrity of the enzyme’s **native** conformation.

- **The primary, secondary, tertiary & quaternary** structures of protein are essential for its catalytic properties.

- **The denatured** enzyme will not have catalytic activity.

- Most of the enzymes consist of **multi-subunits (more than one polypeptide chains)**.

- Some enzymes require no chemical groups for activity other than their amino acid residues.

- Others enzymes require additional chemical components (one or more) for their activity.

- Enzymes are much larger than their substrates.

- The smallest enzyme **4-oxalocrotonate tautomerase** consists of 62 amino acid residues.

- The largest enzyme **Fatty acid synthase** consists of ~ 2000 amino acid residues.
Even though most of the enzymes contain thousands of amino acids only 2–4 amino acids are directly involved in the catalysis.

- Binding Sites in the enzyme:
  - **Substrate binding site**: the areas of an enzyme where the substrate binding occurs.
  - **Catalytic site**: one or many sites, located near to the binding site. They perform the catalysis.
  - **Active site**: Binding site and catalytic site together called active site.

- **Cofactor site**: Additional sites for the binding of cofactors.
- **Allosteric site**: Additional sites for the binding of allosteric modulators. Allosteric modulators are involved in the regulation of enzymatic activity.

**Apoenzyme and Holoenzyme**

- **Apoenzyme (apoprotein)**: The protein part of an enzyme is called apoenzyme.
- **Prosthetic group**: The non-protein part of an enzyme is called the prosthetic group.
- **Holoenzyme**: The fully functional apoenzyme and the required prosthetic group together are called holoenzyme.
- **Holoenzyme = Apoenzyme + Prosthetic Group**
Cofactors and Coenzymes

- The prosthetic groups of an enzyme are of different types and they are broadly categorized into two groups.
  - Cofactors
  - Coenzymes

Cofactors

- **Cofactors**: A non-protein chemical compound in an enzyme that is bound to an enzyme is called the cofactor.

- **They are tightly** bound to the enzyme.

- **Cofactors may be organic** groups or **inorganic** groups.

- Inorganic cofactors include **metal ions such as** Fe2+, Mg2+, Mn2+, Zn2+ and iron-sulfur clusters.

- Organic cofactor includes **Flavin** and **Haem**.

- Cofactors are required for the proper functioning of enzymes.

- Some enzymes require **several** cofactors.

- Example: The pyruvate dehydrogenase of the link reaction of respiration requires **five** cofactors. They are:
  1. Metal ion
  2. Loosely bound thiamine pyrophosphate (TPP)
  3. Covalently bound lipoamide
  4. Flavin adenine dinucleotide (FAD)
  5. Co-substrates (NAD, Coenzyme A and Mg2+)
Coenzymes

- **Co-enzyme:** Additional chemical component in the enzyme (prosthetic group) which is complex organic or metallo-organic molecules.

- The main difference from cofactor is that coenzymes are NOT tightly bound to the enzyme.

![Coenzymes](source: Wikipedia)

- Coenzymes act as the carriers of specific functional groups.

- They **transport** chemical groups from one enzyme to another.

- Most of the coenzymes are derived from vitamins.

- Co-enzyme is **released** from the enzyme’s active site during the reaction.

- Usually, coenzymes are chemically modified after the catalytic reaction.

- Thus, the coenzymes are considered as the second substrate.

- Examples for co-enzymes: NADHH+, NADPH+, ATP

- One coenzyme is common to many different enzymes.

- Example: The NADHH+ is a coenzyme for about 700 different enzymes in human.
Coenzymes are continuously generated in the cell.

Their concentration is maintained at a steady level in the cell.