

## Lecture 8 “Biochemical catalysis and enzyme functions in living systems”

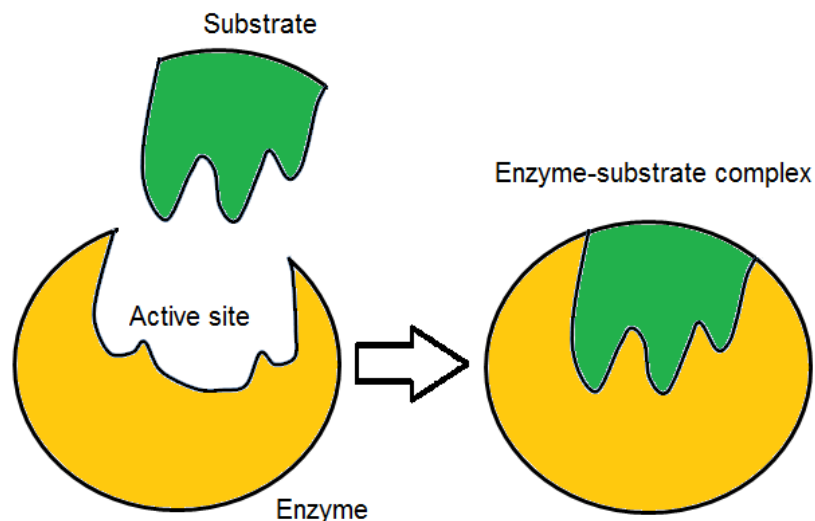
**Goal of the lecture:** To study the nature and function of enzymes as biological catalysts, understand their structure and mechanisms of action, explore the factors influencing enzyme activity, and recognize their essential roles in living systems and applied sciences.

**Brief lecture notes: Biochemical catalysis** is the process by which chemical reactions in living organisms are accelerated by special biological molecules known as **enzymes**. Enzymes are primarily **proteins** (and sometimes RNA molecules) that act as highly efficient catalysts, increasing reaction rates by lowering the **activation energy** required for a reaction to occur. They make biological reactions possible under mild conditions of temperature, pressure, and pH, which are typical of living organisms.

Each enzyme acts on specific reactant molecules called **substrates**, binding to them at a special region known as the **active site**. The enzyme and substrate form an **enzyme–substrate complex**, which undergoes transformation to produce the desired product, while the enzyme itself remains unchanged and ready to catalyze another reaction. This process can be expressed as:



where *E* is the enzyme, *S* the substrate, and *P* the product.



**Figure – 1. Enzyme Substrate complex**

Two main models describe enzyme activity. The **lock-and-key model** suggests that the active site is exactly shaped to fit the substrate, like a key fitting into a lock. The **induced-fit model**, however, proposes that the enzyme slightly changes shape when the substrate binds, allowing a more precise interaction and better catalysis.

The activity of enzymes is influenced by several factors. **Temperature** affects reaction rate — as temperature increases, so does enzyme activity, until it reaches an optimal level (around 37°C for most human enzymes). Beyond this temperature, enzymes lose their structure and become inactive, a process known as **denaturation**. **pH** also has a significant effect; each

enzyme functions best at a specific pH (for example, pepsin at pH 2 and trypsin at pH 8). **Substrate concentration** affects reaction speed up to a maximum point where all enzyme molecules are fully engaged, leading to the **maximum velocity (V<sub>max</sub>)** of the reaction.

The relationship between substrate concentration and reaction rate is mathematically described by the **Michaelis–Menten equation**:

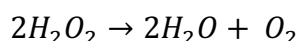
$$v = \frac{V_{max}[S]}{K_m + [S]}$$

where  $V_{max}$  is the maximum velocity and  $K_m$  (Michaelis constant) represents the substrate concentration at which the reaction rate is half of  $V_{max}$ .

Many enzymes require non-protein components called **cofactors** to be active. These cofactors can be **metal ions** (e.g.,  $Zn^{2+}$ ,  $Fe^{2+}$ ,  $Mg^{2+}$ ) or organic molecules called **coenzymes**, often derived from vitamins such as  $NAD^+$  (from niacin) and FAD (from riboflavin). The complete, active enzyme including its cofactor is known as a **holoenzyme**, while the protein part alone is the **apoenzyme**.

Examples of enzyme-catalyzed reactions include:

- **Catalase:** Breaks down hydrogen peroxide into water and oxygen –



- **Amylase:** Hydrolyzes starch into maltose during digestion.
- **Lipase:** Decomposes fats into fatty acids and glycerol.
- **Carbonic anhydrase:** Regulates blood pH by converting  $CO_2$  and  $H_2O$  into carbonic acid.

Enzyme activity in cells is carefully controlled. In **feedback inhibition**, the final product of a metabolic pathway inhibits the first enzyme in the sequence, preventing overproduction and conserving energy. Enzymes can also be regulated by **allosteric effects**, where binding of a molecule at a regulatory site changes the enzyme's activity. Enzymes are essential to all forms of life, driving processes such as metabolism, DNA replication, energy conversion, and respiration. They also have numerous **industrial and medical applications** — for example, in drug design, diagnostics (like glucose oxidase in blood sugar tests), food processing, and biotechnology.

### Questions for self-control

1. What is biochemical catalysis, and how do enzymes differ from inorganic catalysts?
2. Describe the structure and function of the enzyme active site.
3. Explain the difference between the lock-and-key model and the induced-fit model of enzyme action.
4. How do temperature, pH, and substrate concentration affect enzyme activity?
5. What are cofactors and coenzymes, and why are they important for enzyme function?

**Literature:**

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