Enzymes

Introduction to Enzymes

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- **Enzymes** are biological molecules, mostly proteins (and some RNA), that act as **catalysts**.
- They speed up chemical reactions in living organisms without being consumed in the process.
- They play essential roles in many processes such as:
    - Digestion
    - Metabolism
    - DNA replication and repair

Characteristics of Enzymes

1. **Specificity**
    - Each enzyme is highly specific to a particular reaction or substrate.
    - This specificity comes from the **active site**—a unique region where the substrate binds.
2. **Efficiency**
    - Enzymes accelerate reaction rates by **millions of times**.
    - They do this by **lowering the activation energy** required for the reaction.
3. **Regulation**
    - Enzyme activity can be controlled by factors such as:
        - Temperature
        - pH
        - Inhibitors or activators
    - This ensures that reactions occur at the right time and rate.
4. **Reusability**
    - Enzymes are **not used up** during reactions.
    - After the reaction, they can interact with new substrate molecules.

Types of Enzymes

Enzymes are classified into six major categories based on the type of reaction they catalyze:

1. **Oxidoreductases**: Catalyze oxidation-reduction reactions.
2. **Transferases**: Transfer functional groups from one molecule to another.
3. **Hydrolases**: Catalyze the hydrolysis of various bonds.

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4. **Lyases**: Add atoms or groups to double bonds or form double bonds by removing atoms or groups.
5. **Isomerases**: Catalyze the rearrangement of atoms within a molecule.
6. **Ligases**: Catalyze the joining of two molecules with the input of energy (usually from ATP).

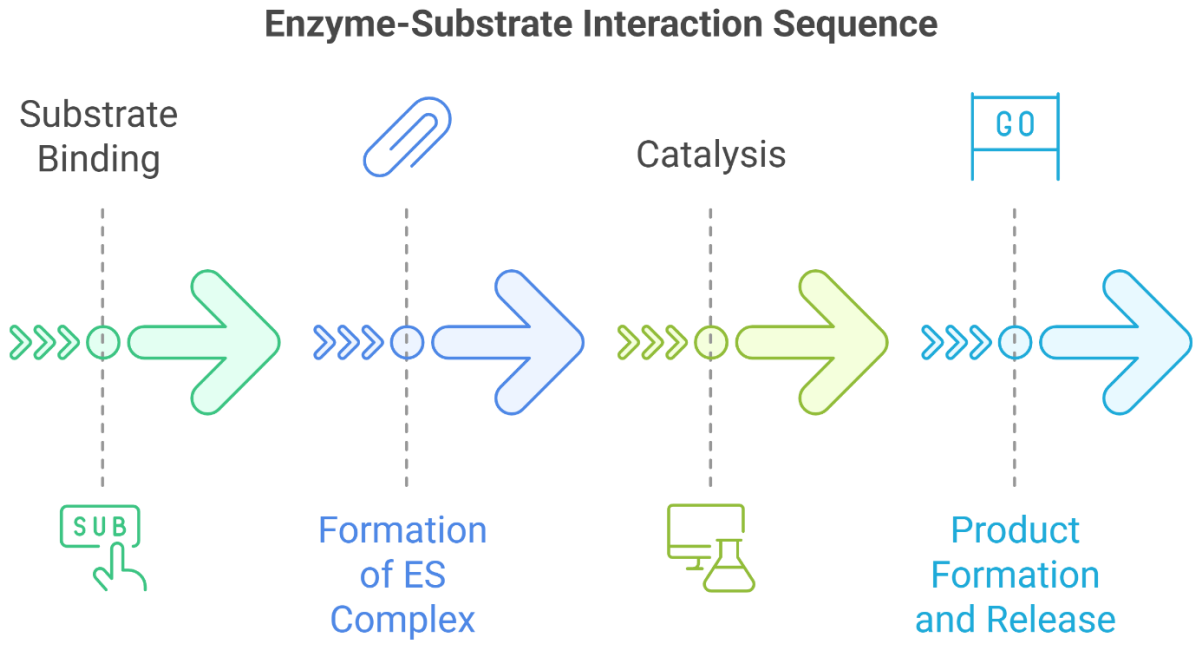
Importance of Enzymes

- Enzymes are **essential for life** because they control the speed of reactions that keep cells alive.
- Without enzymes, these reactions would be **too slow** to support life.
- Enzymes are also used in **industries and medicine**, for example:
  - Making medicines
  - Processing food
  - Diagnosing diseases

Enzyme Action (Mechanism of Enzyme Activity)

- The process by which enzymes catalyze reactions involves a series of steps.
- The most commonly accepted model is the **induced fit model** (modified from the lock-and-key model).

Basic Steps:



1. Substrate Binding:

- The substrate binds to the **active site** of the enzyme.
- The **active site** is a specific region with complementary shape and charge to the substrate.

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- According to the **induced fit model**, the enzyme **changes shape slightly** to accommodate the substrate better.

2. **Formation of Enzyme-Substrate Complex (ES Complex):**
   - Temporary and reversible binding.
   - This complex reduces the **activation energy** required for the reaction.
3. **Catalysis (Transition State Formation):**
   - The enzyme stabilizes the high-energy **transition state**.
   - Bonds are **broken and/or formed** to convert the substrate into the **product**.
4. **Product Formation and Release:**
   - The product has **lower affinity** for the active site.
   - The product is **released**, and the enzyme returns to its original state.

Energy Consideration: Activation Energy

- Enzymes **lower the activation energy** (Ea), allowing reactions to occur faster.
- They do **not** change the overall free energy (**ΔG**) of the reaction.

Factors Affecting Enzyme Activity

Enzyme activity can be influenced by various **internal and external factors**. Each enzyme works best under specific conditions (called **optimum conditions**).

1. **Temperature**
   - Enzymes have an **optimum temperature** (usually ~37°C for human enzymes).
   - Below optimum: enzyme activity is **reduced** due to decreased molecular motion.
   - Above optimum: enzymes may become **denatured** — their structure changes, and they lose activity.
2. **pH**
   - Enzymes have an **optimum pH** (e.g., pepsin: ~pH 2; trypsin: ~pH 8).
   - Changes in pH affect the **ionization of amino acid residues**, especially at the active site.
   - Extreme pH can **denature** the enzyme.
3. **Substrate Concentration**
   - Increasing substrate concentration increases enzyme activity **up to a point**.
   - Beyond that, all enzyme active sites become saturated, and the rate **plateaus** (this is called **Vmax**).

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4. Enzyme Concentration

- Higher enzyme concentration (if substrate is unlimited) increases the reaction rate proportionally.

5. Presence of Inhibitors

- **Competitive inhibitors**: Resemble the substrate and compete for binding at the **active site**.
- **Non-competitive inhibitors**: Bind elsewhere and alter the enzyme's shape.
- **Uncompetitive inhibitors**: Bind only to the enzyme-substrate complex.

6. Presence of Activators or Cofactors

- Some enzymes require **non-protein helpers**:
  - **Cofactors** (metal ions like Mg^{2+}, Zn^{2+})
  - **Coenzymes** (organic molecules, e.g., NAD^{+}, FAD)
  - **Prosthetic groups**: Tightly bound coenzymes (e.g., heme group in cytochromes)

Properties of Enzymes

1. Catalytic Efficiency:

- Enzymes accelerate chemical reactions by millions-fold, making vital biochemical processes occur rapidly.

2. Specificity:

- They exhibit high specificity, recognizing and interacting precisely with specific substrates due to the unique structure of their active sites.

3. Saturation Kinetics:

- Reaction rates increase with substrate concentration until enzymes are saturated, reaching a maximum velocity (Vmax) beyond which the rate plateaus.

4. Environmental Sensitivity:

- Enzyme activity is influenced by factors like pH, temperature, and the presence of inhibitors or activators, each enzyme having optimal conditions for maximal activity.

5. Reversibility:

- Many enzyme-catalyzed reactions are reversible, with the direction dependent on substrate and product concentrations.

6. Regulation:

- Enzyme activity can be modified through mechanisms such as allosteric regulation, covalent modification, or changes in enzyme synthesis to meet metabolic demands.

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7. Cofactor Dependence:

- Many enzymes require non-protein cofactors—metal ions (e.g., Mg^{2+}, Zn^{2+}) or organic molecules (coenzymes)—to be active.

Nomenclature and IUBMB Classification of Enzymes

Enzyme Nomenclature

Systematic and Descriptive Names

- Enzymes are named based on the **type of reaction** they catalyze.
- Most enzyme names end with **"-ase"**.
- The name is usually formed from the **substrate** name or the **type of reaction**.

Examples:

- **Sucrase** → breaks down sucrose
- **DNA Polymerase** → helps build DNA strands

Common Names

- Some enzymes have traditional or common names that don't follow the naming rules.
- These names are widely used, even if they are not systematic.

IUBMB Classification

What is IUBMB?

- **IUBMB** stands for the **International Union of Biochemistry and Molecular Biology**.
- It created a global system to name and classify enzymes based on the reactions they catalyze.

Enzyme Commission (EC) Numbers

- Each enzyme is given a unique **EC number** for identification.
- EC numbers have **four parts**:
  - Example: **EC 1.1.1.1**

EC Number Part	Meaning
1st digit	Main class (type of reaction)
2nd digit	Subclass (type of substrate or group)
3rd digit	Sub-subclass (specific reaction details)
4th digit	Serial number of the enzyme

The Six Major Classes of Enzymes

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