Chapter 5: Enzymes

1. What are Enzymes?

- [cite_start]Enzymes are proteins that function as biological catalysts[cite: 19]. [cite_start]They are created in all living cells[cite: 20].
- [cite_start]A catalyst is a substance that increases the rate of a chemical reaction without being changed by the reaction itself[cite: 18].
- [cite_start]Like other catalysts, enzymes can be used repeatedly because they are not consumed during the reaction, and only small amounts are needed to speed up a reaction[cite: 21, 22].
- [cite_start]Enzymes are crucial for controlling all metabolic reactions in a cell, ensuring they happen fast enough for the cell to function properly[cite: 19, 23, 24].

2. How Enzymes Work: The Lock and Key Model

- [cite_start]An enzyme-controlled reaction involves a **substrate** and an **enzyme** to produce a **product**[cite: 41].
- [cite_start]The substance an enzyme acts upon is called the substrate, and the molecules that are created are called the products[cite: 46]. [cite_start]For example, the enzyme sucrase works on the substrate sucrose to produce the products glucose and fructose[cite: 47].
- [cite_start]The **active site** is the specific part of an enzyme molecule that combines with a substrate[cite: 48].
- [cite_start]The active site and the substrate molecules have **complementary shapes**, fitting together like pieces of a jigsaw puzzle[cite: 51]. [cite_start]This is why an enzyme is specific to only one reaction—other molecules with the wrong shape will not fit into the active site[cite: 52].
- [cite_start]When the substrate and enzyme join, a temporary **enzyme-substrate complex** is formed[cite: 189]. [cite_start]After the reaction is complete, the product is released, and the enzyme is free to catalyze another reaction[cite: 54].
- Enzymes significantly increase the reaction rate. [cite_start]For example, a reaction that might take hours or days to occur without an enzyme can be completed in just a few seconds with one[cite: 55, 58]. [cite_start]The enzyme catalase, for instance, can break down 40,000 molecules of hydrogen peroxide every second[cite: 57].

3. Factors Affecting Enzyme Activity

- **Temperature:**
    - [cite_start]An increase in temperature generally increases the rate of a chemical reaction[cite: 90]. [cite_start]This is because the enzyme and substrate molecules gain more kinetic energy, move faster, and are more likely to collide[cite: 214].

    - [cite_start]The **optimum temperature** is the temperature at which an enzyme works best[cite: 147]. [cite_start]For many enzymes in the human body, this is around $37^{\circ}C$[cite: 211].
    - [cite_start]Above approximately $50^{\circ}C$, most enzymes are **denatured**[cite: 91]. [cite_start]Denaturation is a permanent change in the shape of the enzyme molecule[cite: 221].
    - [cite_start]When denatured, the active site becomes deformed and can no longer combine with the substrate, causing the reaction to stop[cite: 94, 219]. [cite_start]This is why high temperatures can be lethal to organisms, as their enzymes stop working[cite: 95, 96].
    - [cite_start]Boiling an enzyme to test its properties is a common technique; if it can still perform its function after boiling, it is not an enzyme because its catalytic properties were not changed[cite: 104, 105, 257].
    - [cite_start]Some bacteria living in extremely hot environments, like hot springs, have enzymes with stable proteins whose active sites are not deformed by high temperatures[cite: 109, 111].
- **pH:**
    - [cite_start]Enzymes are also affected by the acidity or alkalinity of their environment[cite: 143]. [cite_start]Most enzymes have an **optimum pH** at which they function best[cite: 144, 147].
    - [cite_start]For example, the protein-digesting enzyme in your stomach, pepsin, works best at a pH of 2, while most enzymes inside cells work best at a neutral pH of 7[cite: 145, 146]. [cite_start]Pancreatic lipase, which works in the slightly alkaline conditions of the duodenum, has an optimum pH of 8[cite: 148].
    - [cite_start]Extreme pH levels can denature some enzymes by changing the shape of the active site, preventing the enzyme and substrate from fitting together[cite: 227, 228].
    - However, the effects of pH changes on enzyme activity are often reversible. [cite_start]An enzyme that is disabled by a low pH can resume normal activity if the optimum pH is restored[cite: 149].

4. Types of Enzymes

- [cite_start]**Intracellular enzymes:** Most enzymes remain inside the cell where they are made to speed up reactions in the cytoplasm and nucleus[cite: 165, 166].
- [cite_start]**Extracellular enzymes:** Some enzymes are released from the cell to work outside of it[cite: 167]. [cite_start]For example, fungi and bacteria release extracellular enzymes to digest food, and animals release them into their stomachs and intestines for digestion[cite: 167, 170].

5. Enzyme Naming Convention

- [cite_start]The names of enzymes typically end with the suffix "-ase"[cite: 199].
- [cite_start]They are often named based on the substrate they act upon or the reaction they catalyze[cite: 199]. [cite_start]For instance, an enzyme that works on proteins is called a protease, and one that removes hydrogen is a dehydrogenase[cite: 201].