

Chapter 8 Introduction to Enzymes and Metabolism

Notes:

Catabolism: Breaking down large biological molecule (proteins, polysaccharides, fats etc.), and liberating energy by breaking chemical bonds. Sometimes the monomers (monosaccharides, amino acids etc.) are re-cycled to build new macromolecules.

Anabolism: Assembling large biological molecules. Anabolism requires input of energy to form chemical bonds (ie-peptide bonds in proteins, glycosidic bonds in polysaccharides).

Metabolism: Collective term referring to catabolism and anabolism combined.

Enzymes: Protein catalysts that facilitate reactions **by lowering the activation energy** (E_A) required for the reaction to take place. Enzymes also facilitate reactions by keeping reagents close to one another. (Enzymes do not 'cause' chemical reactions to occur, they merely make it easier for the reactions to start.)

ATP and ADP: **Exergonic reactions** occur spontaneously, and **liberate** energy (ie-catabolism). Enzymes help to let these reactions occur more readily. **Endergonic reactions** require input of energy (ie-anabolism). Different enzymes also facilitate these reactions. **Adenosine Triphosphate** acts as a fungible intermediate, allowing the energy freed from exergonic reactions to be used for endergonic reactions. The conversion of Adenosine Triphosphate (ATP) into Adenosine Diphosphate (ADP) and free inorganic phosphate (P_i) liberates energy. Conversely, conversion of $ADP + P_i$ into ATP consumes energy. Thus, in the cell catabolic reactions that liberate energy are used to make ATP from ADP, and the energy liberated from the conversion of ATP back to ADP is then used for anabolic reactions. ADP and P_i are converted to ATP through a 'dehydration reaction' (water is liberated), and ATP is 'hydrolyzed' to ADP and P_i through the addition of water.

One of the most important catabolic reactions in the cell is the breakdown of glucose by a process called **aerobic respiration**, leading to the **creation of approximately 34 molecules** of ATP (discussed in Chapter 9). ATP is used to power several other types of processes in the cell. In addition to building biological molecules (anabolism), ATP is also used to pump ions across membranes against their concentration gradients (a process called active transport), and do mechanical operations, like moving things around inside the cell by manipulation of the cytoskeleton. The most dramatic example of the latter process is muscle contraction.

Common Names for Enzymes: The reagents that an enzyme works on are called its **substrate**. Although there is a complicated nomenclature (technical naming system) for enzymes, most can be referred to by their common names. Enzyme common names are derived by taking the name of the substrate that the enzyme works on, and **adding ‘-ase’** to the end. Examples:

- a. **Cellulases:** Enzymes that break down cellulose.
- b. **Amylases:** Enzymes that break down starch.
- c. **Lipases:** Enzymes that break down lipids (usually fats and oils).
- d. **Phosphatases:** Enzymes that remove phosphate groups from their substrate.
- e. **Kinases:** Enzymes that put phosphate groups onto their substrates (usually proteins). Note that many proteins are activated when kinases link phosphate groups to serines, threonines or tyrosines; and de-activated by removing these phosphate groups. Thus, protein kinases and protein phosphatases are very important enzymes.
- f. **Polymerases:** Enzymes that put together monomers to form polymers.
- g. **Proteases:** Enzymes that break down proteins.

Specific enzyme names can then be made by adding terms to the function name. Examples:

- a. **DNA Polymerase:** an enzyme that joins DNA nucleotides together to form DNA chains.
- b. **RNA Polymerase:** an enzyme that joins RNA nucleotides together to form mRNA using a DNA ‘template.’

Active Site: Most enzymes are large, consisting of hundreds or thousands of amino acids. The place on the enzyme where the chemical reactions actually take place, however, is called the enzyme’s **active site**. Most if the other amino acids comprising an enzyme can be mutated or changed (through DNA mutations) without effecting the enzyme’s biological activity (what it does). The few amino acids that comprise the active site, however, are critical to the enzyme’s biological activity, and can’t be mutated without destroying the enzyme’s ability to do its job. Some enzymes have only one active site, while others have more than one.

Enzyme Cofactors: You learned in Chapter 5 that many proteins incorporate ‘prosthetic groups’ (non-protein components of a protein). This is also true of enzymes. Many enzymes require non-protein components to do their jobs. These components include **metal ions** and **vitamins**. (This is why it’s essential for humans to have adequate vitamins and minerals in their diets. Many vitamins and minerals are used as prosthetic groups by metabolic enzymes.) Non-protein molecules that assist enzymes to do their jobs are called **enzyme cofactors**.

Regulation of Enzymatic Activity: As mentioned above, many enzymes can be turned on or off by adding or removing phosphate groups (mediated by kinases and phosphatases). In addition, other cofactors can bind to proteins at spots other than their active sites, and cause an **allosteric change (a change of shape)**, that either activates or de-activates an enzyme. Thus, many enzymes are regulated by cofactors that cause an allosteric change to the enzyme.

Optimum Conditions for Enzyme Activity: Most enzymes have optimum (best) conditions, where they can catalyze their reactions at the fastest possible rate. These conditions include:

- a. **Optimum Temperature:** the temperature at which an enzyme can catalyze reactions fastest. Most biological enzymes show optimum activity at around 37-degrees (normal human body temperature) or slightly above.
- b. **Optimum pH:** the pH at which enzymes show optimum activity. Most biological enzymes show optimum activity at around pH 7.4 (biological pH), but some, such as those that work in the acidic environment of the stomach, work best at lower pH.
- c. **Optimum Substrate Concentration:** An enzyme can 'turn over' or convert a certain number of substrate molecules into products per minute. If you give the enzyme a less than optimal concentration of substrate, it will convert them to products, but it is capable of working faster. On the other hand, if you give the enzyme more substrate than it is capable of converting each minute, adding more substrate cannot increase the reaction rate. This is called the substrate **saturation point**. The point at which the enzyme is working at its fastest is its optimum substrate concentration. Adding more substrate will not increase the reaction rate.

Competitive vs. Non-competitive Inhibition of Enzymes: Enzymes can be inhibited (prevented from doing their jobs) by adding something to the reaction mixture that will stop them from doing their job. Things that can stop an enzyme from doing its job are called enzyme inhibitors. There are two types:

- a. **Competitive Inhibitors:** are usually molecules that mimic the actual substrate, but are not the actual substrate. Thus, the enzyme wastes its time dealing with molecules that are not the real substrate. They are called competitive inhibitors because they compete with the real substrate for a place in the enzyme's active site.
- b. **Non-competitive Inhibitors:** Are molecules that do not compete with the real substrate for a place in the enzymes active site, but instead inhibit enzyme activity in other ways. Usually by binding to other spots on the enzyme and causing an **allosteric** change. (An allosteric change is a change in shape of the enzyme.)

Reversible vs. Non-reversible Inhibition of Enzyme Activity: A reversible enzyme inhibitor will stop an enzyme from doing its job, but can be 'washed away,' or 'wear off,' so that the enzyme can resume its activity later. Non-reversible inhibitors will permanently de-activate an enzyme, usually by binding permanently to its active site, or to another part of the enzyme causing an irreversible allosteric change. Many poisons and toxins are irreversible enzyme inhibitors that permanently de-activate enzymes.

PRACTICE QUESTIONS:

Short Answer Questions:

1. What is the collective term referring to both catabolism and anabolism?
2. What term is used to describe the process of breaking down large biological molecules in order to release and utilize the energy from their chemical bonds?
3. What term is used to describe the cellular process of utilizing energy to put large biological molecules together?
4. What is an enzyme? (2 points)
5. Name two common types of enzyme cofactors. (2 points)
6. Why is it important for humans to have sufficient vitamins and minerals in their diets? What are these needed for? (2 points)
7. Name one way in which enzymes facilitate biochemical reactions?
8. **List three physical conditions (ie-optimum conditions) that can affect the reaction rate of an enzyme. (3 points)**
9. At what temperature do most enzymes in the human body work best?
10. At what pH do most enzymes in the human body work best? (Excluding those that work in the low pH of the stomach.)
11. What do you call a change of shape of an enzyme that leads to a change in its biological activity?
12. What is the main 'large currency' biological molecule used by the cell?
13. What is the main 'small currency' biological molecule used by the cell?
14. Does the conversion of ATP to ADP and Pi (inorganic phosphate) consume or liberate energy?
15. Does the conversion of ADP and Pi (inorganic phosphate) to ATP liberate or consume energy?
16. Which type of reaction requires input of energy, endergonic or exergonic?
17. What term is used to describe pumping ions across membranes, against their concentration gradient?
18. What do you call an enzyme that breaks down cellulose?
19. What do you call an enzyme that breaks down starch?
20. What do you call an enzyme that removes phosphate groups from biological molecules?
21. What do you call an enzyme that adds phosphate groups to biological molecules?
22. What do you call an enzyme that breaks down lipids?
23. What do you call an enzyme that breaks down proteins?

Essay Type Questions:

1. What is the difference in the mechanism of inhibition between a competitive and a non-competitive enzyme inhibitor? (10 points)
2. Explain what is meant by the optimum substrate concentration for an enzyme. (10 points)
3. Explain the difference between reversible and irreversible enzyme inhibition. (10 points)

Extended Matching Questions:

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|---------------------------|-------------------|
| A. Activation Energy | M. Fungible |
| B. Active Site | N. Glucose |
| C. Active Transport | O. Kinase |
| D. Adenosine Triphosphate | P. Lipase |
| E. Allosteric | Q. Metabolism |
| F. Amylase | R. Nomenclature |
| G. Anabolism | S. Phosphatase |
| H. Catabolism | T. Polymerase |
| I. Cellulase | U. Protease |
| J. DNA Polymerase | V. RNA Polymerase |
| K. Endergonic | W. Substrate |
| L. Exergonic | |

1. Easily convertible (the way money can be converted to goods and labor, and vice versa).
2. An enzyme that breaks down proteins.
3. A 'barrier' of repulsion energy that must be overcome to allow reagents to react.
4. Name for an enzyme that puts together DNA nucleotides from a DNA template.
5. A term referring to the technical way of naming and organizing biological things.
6. Term for the molecule or molecules that an enzyme works on.
7. Name for an enzyme that puts together RNA nucleotides from a DNA template.
8. An enzyme that removes phosphate groups from biological molecules.
9. Refers to a change in shape of an enzyme or protein.
10. General term for an enzyme that assembles monomers into long chains (puts together large macromolecules from individual subunits).
11. An enzyme that breaks down cellulose.
12. An enzyme that breaks down lipids (fats and oils).
13. Refers to a reaction that liberates energy.
14. An enzyme that adds phosphate groups to biological molecules (usually proteins).
15. An enzyme that breaks down starch.
16. Refers to putting together large biological molecules, and consuming energy in the process.
17. The part of an enzyme where biochemical reactions take place.
18. Refers to a reaction that consumes (or requires) energy.
19. The main 'large currency' energy molecule catabolized by cells.
20. The process of pumping ions across semi-permeable membranes, against their concentration gradient.
21. Refers to breaking down large biological molecules, and liberating energy which can then be used for other cellular processes.
22. The main 'small currency' energy molecule used in the cell.

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