

BIO100_CH 5

Enzymes

Formation of the Complex

Environmental Effects

Control Processes

ATP

Terms:

Activation energy, binding site, coenzyme, inhibition, denature, enzymatic competition, enzyme, substrate, enzyme-substrate complex, gene-regulator proteins, inhibitor, negative-feedback inhibition, autotroph, photosynthesis, heterotroph, cellular respiration, ATP

Questions:

Describe the sequence of events in an enzyme-controlled reaction.

How does changing temperature affect the rate of an enzyme-controlled reaction?

Why would you not expect a fat and a sugar molecule to be acted on by the same enzyme?

What factors in the cell can speed up or slow down enzyme reactions?

What is the relationship between vitamins and coenzymes?

What is enzyme competition, and why is it important to all cells?

What effect might a change in pH have on enzyme activity?

Biochemical reactions must take place at very rapid rates to be useful.

Activation energy: an initial input of energy required for a chemical reaction to take place.

Catalyst: a chemical that speeds up a reaction but is not consumed in the process.

Enzyme: a protein that acts as a catalyst.

Formation of the Enzyme-Substrate Complex

Each enzyme has a specific **three-dimensional shape**. That 3-D shape is specific to the reactant that it can combine with. There is a **physical fit** between the enzyme and the **substrate** (that is, the reactants).

Enzyme-substrate complex: the temporary molecule that is formed when an enzyme and substrate combine.

An **enzyme is specific** because it has a specific shape that can combine with substrates that have a specific shape.

The enzyme must attach to the substrate. The **binding site** is where the substrate can be attached to the enzyme.

Enzymes work rapidly and they are not used up. For this reason, only a very small quantity of it is needed.

Wrench analogy: Compare using a wrench vs. by hand to an enzyme vs. the chemical reaction occurring without the enzyme.

In the same way that a wrench comes together to form a **complex** with the nut—at a specific site, the enzyme comes together to form a complex with the substrate at a specific site.

In the same way that the wrench reduces the amount of time it takes to remove a nut compared to doing it by hand, enzymes **reduce the amount of time** it takes for a reaction to occur compared to having the reaction occur through basic chemical reactions.

In the same way that the wrench is not used up in removing the nut, the enzyme **is not used** up in the reaction.

In the same way that a wrench can be modified to fit the nut tightly (one part of the substrate!), the enzyme shape is induced to fit the substrate (**induced fit hypothesis**).

Coenzymes: molecules that help an enzyme function rapidly, usually by **removing an end product** from the enzyme, or by **binding to part of the substrate**. Often **vitamins or minerals** or nucleotides. (for example, NAD— nicotinamide adenine dinucleotide—from niacin; carries away the hydrogen)

Remember, enzymes are very specific. **Naming of enzymes:**

Usually three parts

1. The molecule to which the enzyme attaches
2. The type of reaction that occurs
3. -ase; denotes that it is an enzyme

Examples: DNA polymerase
glycogen synthetase
amylose (starch) hydrolase = amylase

This last is the common name. Some are much different because they were given names before enzymes were well understood: **pepsin, trypsin**.

Environmental Effects: Enzymes can speed up a reaction greatly, from a thousand to more than a million times faster, however, **the environment that the enzyme is in can have a dramatic effect on how well it works**.

Environmental conditions of importance:

Optimum Temperature: the temperature at which the product forms most rapidly.

Chemical reactions take place more rapidly at higher temperatures because there is more energy available, but organisms die at temperatures that are too high. (consider fevers) Why? **Because enzymes become denatured.**

At low temps: motion of molecules slows down; there is **little energy available** to activate the reaction. Refrigerator—preserves food.

At high temps: remember that enzymes are proteins with very complex shape. Shape is maintained bonds (hydrogen, sulfur, etc), which are broken with increased temperatures, so **the enzyme does not fit the substrate** as well—causing the reaction rate to decrease. At extreme temperatures, the enzyme shape is permanently altered—**denatured**, and it no longer functions as an enzyme.

pH: enzyme tertiary and quaternary structure depends upon how the side chains bind to each other. In addition the **enzyme-substrate complex binding site** also depend on those side chains. If the right pH exists, the side chains have the appropriate charges and the complex fit occurs more easily and rapidly. But if the pH is too high or too low, the charges that would have attracted the enzyme and substrate together are no longer present, or less exact.

Appropriate pH depends on where the normal environment of the enzyme is:

Amylase: found in saliva. pH =7. used to hydrolyze starch to glucose

Pepsin: found in stomach. pH = 2 to 3. used to hydrolyze proteins.

Trypsin: found in small intestine. pH =8. used to hydrolyze proteins.

Control Processes: mechanisms that ensure that the organism will carry out the metabolic activities in the proper sequence and at the proper rate. (coordination and regulation).



Malic acid → oxaloacetic acid → citric acid → isocitric acid
(small part of Kreb's cycle—part of getting energy from sugar—ATP).

Enzyme concentration: when there is a huge amount of substrate available, the amount of enzyme can be the limiting factor in the reaction. As enzyme concentration increases, production increases. **The rate is not faster.**

Substrate concentration: when the substrate is in short supply, it is the limiting factor in the reaction. One way to regulate production is to limit the amount of substrate available to enzymes.

Substrate limitation: yield a final product may require several reactions, where the product in one enzymatic reaction is the substrate for the next reaction. Until the first product is generated, the second reaction does not take place.

Product concentration: If the product(s) is in large supply, it may bind with the enzyme, decreasing the rate at which the substrate binds with the enzyme. (more below.)

Enzymatic Inhibition (negative-feedback inhibition): the end product binds with the enzyme, thereby interfering with the enzymes ability to bind with the substrate. **Because the end product is no longer produced at a rapid rate, it gets used and its concentration decreases, so it binds less with the enzyme.** (Kreb's cycle—malonic acid inhibits enzyme).

Inhibitors: molecules that interfere with the ability of an enzyme to bind with the substrate. They resemble the normal substrate

Arsenic: attaches to insect enzymes and prevents normal growth

Organophosphates: inhibit insect enzymes that are part of nervous system

Sulfa drugs: bind with bacterial enzymes, kills bacteria

Gene regulator proteins: proteins that increase or decrease the production of enzymes by the genes coding for the enzymes.

Gene-repressor proteins—decrease the production of enzymes

Gene-activator proteins—increase the production of enzymes

Enzymatic Competition: when several enzymes are present and can use the same substrate. One of the pathways may not occur at a high rate because the substrate is being used up rapidly by the other pathways.

ATP:

Chemical bonds are what living organism's use to do metabolic processes. Carbon bonds is where energy is stored and preserved for cell metabolism. Carbon-carbon bonds are not an immediately accessible form of energy. By undergoing respiration, some of the energy in those carbon-carbon bonds can be transferred to other bonds that are high in energy and whose energy can be accessed by chemical reactions in cells. Those high energy bond occur between phosphate groups that are attached to each other. The molecule which carries the phosphate groups is called **ATP (adenosine triphosphate)**. When one phosphate bond is broken, it is then **ADP**. When a second is broken, it is called **AMP**.

Realize that AMP is the same as an adenine with a ribose sugar on it plus one phosphate group. So this energy molecule is closely related to one nucleotide for DNA/RNA.

Dehydration synthesis reactions require an input of energy to form the chemical bonds, whereas hydrolysis reaction provide a net production of energy by breaking chemical bonds. The energy molecule that is initially generated through hydrolysis or used in dehydration synthesis is **ATP (adenosine triphosphate)**.