Enzymes II – How Enzymes Work

Slide 2 In the previous lesson, we saw that enzymes act as catalysts by lowering the activation energy associated with chemical reactions. In this lesson, we will take a closer look at how enzymes work, including how enzymes affect substrate molecules, what factors affect how well enzymes work, and what other types of molecules may be required for an enzyme to function.

Slide 3 Enzymes work in several ways to catalyze chemical reactions. First, enzymes may hold substrate molecules in a position such that the reactive sites of the substrate molecules are exposed to each other. As an example, consider the formation of a peptide bond between two amino acids. When two amino acids are free in solution, the chances of them colliding such that the carboxyl group of one amino acid comes into contact with the amino group of the other amino acid is very slim. If the proper enzyme is present, however, the amino acids may bind to the active site of the enzyme such that their amino and carboxyl groups are held close to each other and may react to form a peptide bond.

Some enzymes affect substrate molecules by adding charges to the substrate. Such cases often involve acidic or basic R-groups of the enzyme’s amino acids, or metal ions, such as iron or manganese, that are bound to the enzyme. Charge transfer reactions are important in the oxidation-reduction reactions that make up the electron transport chains of aerobic respiration and photosynthesis.

Lastly, some enzymes put physical strain on substrate molecules when they are bound. The physical strain changes the shape of the substrate molecules, making them more reactive.

Slide 4 A number of factors affect the activity of enzymes. These include pH, temperature, substrate and enzyme concentration, the presence of inhibitors, allosteric interactions, and the presence of required molecular groups that interact with the enzyme. First, let’s consider the effects of pH on enzyme activity.

Slide 5 pH, a measure of the hydrogen ion concentration of a solution, affects enzyme activity in two basic ways. First, varying pH can change the charge of R-groups within the active site or other parts of an enzyme. Second the charge of substrate molecules may also be affected by pH. In either case, changing the charge of enzyme active sites or substrate molecules can alter the interaction of substrate and enzyme.

Most enzymes function best at a certain pH, called the pH optimum. If enzymes are exposed to a pH too far away from their pH optimum, their activity will decrease. In extreme cases, drastic changes in pH will completely disrupt the structure of the enzyme, resulting in denaturation of the enzyme and a complete loss of activity.
It is interesting to note that the optimal pH of many enzymes corresponds to the environment in which they are found. For example, the enzyme salivary amylase is found inside your mouth, which typically maintains a neutral pH. As you can see from the graph on this slide, salivary amylase is most active around pH 7, a neutral pH. Similarly, the enzyme pepsin, found in your normally acidic stomach, functions best at a very acidic pH of around 2.

**Slide 6**  As with pH, most enzymes also have a particular temperature at which they function best, called the optimal temperature. As a general rule, enzyme activity increases with increasing temperature. However, if temperatures become too high, the molecular interactions that hold the enzyme together may be disrupted, resulting in denaturation and loss of enzyme activity.

**Slide 7**  Substrate concentration also may affect how fast an enzyme is able to work. Simply stated, if there isn’t much substrate around, the chance of an enzyme colliding with and binding a substrate molecule is slimmer than if there were a lot of substrate around. At some point, however, the concentration of substrate may become so high that the enzymes present are essentially working as fast as they can. At this point, the enzyme active sites are said to be saturated, and further increases in substrate concentration will have a minimal effect on enzyme activity.

**Slide 8**  Substrate concentration plays a crucial role in the activity of allosteric enzymes. Allosteric enzymes are enzymes with multiple binding sites. Often, these binding sites are found on different subunits of the enzyme. In other words, many allosteric enzymes have quaternary structure. Some of the binding sites on an allosteric enzyme are active, or catalytic, sites and bind substrate molecules. Other sites are called allosteric sites, and bind regulatory molecules. When an allosteric enzyme binds a molecule of substrate at an active site, the enzyme’s shape is changed slightly so that it is easier to bind a second molecule of substrate at another active site. Because of this, the activity of allosteric enzymes is very sensitive to changes in substrate concentration. At a certain point, a very slight increase in substrate concentration can result in a great increase in enzyme activity.

When an allosteric enzyme binds a regulatory molecule, on the other hand, the enzyme changes shape so that it is more difficult to bind a substrate molecule, and may be easier to bind another regulatory molecule.

**Slide 9**  Due to their sensitive nature, allosteric enzymes often play important roles in metabolic pathways. Often, it is crucial for cells to regulate metabolic pathways very stringently, so that the product of a pathway is not produced in excess of what is needed by the cell. In many cases, allosteric enzymes catalyze early steps in a metabolic pathway. In addition, the end product of the pathway acts as a regulatory molecule for the enzyme. When too much product builds up, the product itself binds to regulatory sites on the enzyme, resulting in a decrease in enzyme activity. This, in turn, results in the formation of less product.
As we have just seen with the regulatory molecules of allosteric enzymes, certain molecules can inhibit the activity of enzymes. Some inhibitors bind so strongly to the enzyme that they cause permanent loss of enzyme activity. This type of inhibition is called irreversible inhibition. Other inhibitors do not bind so tightly, and so may unbind due to various factors. This type of inhibition is called reversible inhibition.

Reversible inhibitors may be of two types: competitive and non-competitive. Competitive inhibitors are molecules that closely resemble the normal substrate molecules of the enzyme. Because of their structural similarities to substrate molecules, competitive inhibitors may bind the enzyme’s active site, thereby ‘competing’ with the substrate. Non-competitive inhibitors, on the other hand, bind to sites on the enzyme other than the active site. This binding results in a conformational change in the enzyme, making it difficult or impossible for the enzyme to bind molecules of substrate. The regulatory molecules of allosteric enzymes are examples of non-competitive inhibitors.

Finally, many enzymes require the presence of other molecular groups in order to function. Without these molecular groups, some enzymes are not able to function. These types of molecules fall into three general categories: cofactors, coenzymes, and prosthetic groups.

Cofactors are inorganic ions, such as iron, copper, or zinc that bind temporarily to enzyme active sites. Due to the positive nature of these ions, they usually serve to draw electrons away from substrate molecules. As an example, you might think of the hemoglobin in your blood. Each molecule of hemoglobin also carries iron as a cofactor, which is used to bind oxygen for transport from your lungs to your muscles.

Coenzymes are relatively small carbon molecules. Coenzymes are not permanently bound to an enzyme. Rather, they react with an enzyme by binding to the active site and facilitating the catalytic activity of the enzyme. Some coenzymes, such as nicotinamide adenine dinucleotide (NAD) play important roles in the reactions of respiration and photosynthesis.

Prosthetic groups are relatively small molecules that are permanently bound to an enzyme. Prosthetic groups can play a variety of roles for enzymes. The heme of hemoglobin, for example, is a prosthetic group that functions in oxygen binding. In your eyes, the pigment retinal is a prosthetic group of the enzyme rhodopsin, and functions in absorbing light.