6.4A: Enzyme Active Site and Substrate Specificity

Enzymes catalyze chemical reactions by lowering activation energy barriers and converting substrate molecules to products.

Learning Objectives

• Describe models of substrate binding to an enzyme’s active site.

Key Points

• The enzyme’s active site binds to the substrate.
• Increasing the temperature generally increases the rate of a reaction, but dramatic changes in temperature and pH can denature an enzyme, thereby abolishing its action as a catalyst.
• The induced fit model states an substrate binds to an active site and both change shape slightly, creating an ideal fit for catalysis.
• When an enzyme binds its substrate it forms an enzyme-substrate complex.
• Enzymes promote chemical reactions by bringing substrates together in an optimal orientation, thus creating an ideal chemical environment for the reaction to occur.
• The enzyme will always return to its original state at the completion of the reaction.

Key Terms

• **substrate**: A reactant in a chemical reaction is called a substrate when acted upon by an enzyme.
Enzyme Active Site and Substrate Specificity

Enzymes bind with chemical reactants called substrates. There may be one or more substrates for each type of enzyme, depending on the particular chemical reaction. In some reactions, a single-reactant substrate is broken down into multiple products. In others, two substrates may come together to create one larger molecule. Two reactants might also enter a reaction, both become modified, and leave the reaction as two products.

The enzyme’s active site binds to the substrate. Since enzymes are proteins, this site is composed of a unique combination of amino acid residues (side chains or R groups). Each amino acid residue can be large or small; weakly acidic or basic; hydrophilic or hydrophobic; and positively-charged, negatively-charged, or neutral. The positions, sequences, structures, and properties of these residues create a very specific chemical environment within the active site. A specific chemical substrate matches this site like a jigsaw puzzle piece and makes the enzyme specific to its substrate.

Active Sites and Environmental Conditions

Environmental conditions can affect an enzyme’s active site and, therefore, the rate at which a chemical reaction can proceed. Increasing the environmental temperature generally increases reaction rates because the molecules are moving more quickly and are more likely to come into contact with each other.

However, increasing or decreasing the temperature outside of an optimal range can affect chemical bonds within the enzyme and change its shape. If the enzyme changes shape, the active site may no longer bind to the appropriate substrate and the rate of reaction will decrease. Dramatic changes to the temperature and pH will eventually cause enzymes to denature.

Induced Fit and Enzyme Function

For many years, scientists thought that enzyme-substrate binding took place in a simple “lock-and-key” fashion. This model asserted that the enzyme and substrate fit together perfectly in one instantaneous step. However, current research supports a more refined view called induced fit. As the enzyme and substrate come together, their interaction causes a mild shift in the enzyme’s structure that confirms an ideal binding arrangement between the enzyme and the substrate. This dynamic binding maximizes the enzyme’s ability to catalyze its reaction.
Figure 1: Induced Fit: According to the induced fit model, both enzyme and substrate undergo dynamic conformational changes upon binding. The enzyme contorts the substrate into its transition state, thereby increasing the rate of the reaction.

Enzyme-Substrate Complex

When an enzyme binds its substrate, it forms an enzyme-substrate complex. This complex lowers the activation energy of the reaction and promotes its rapid progression by providing certain ions or chemical groups that actually form covalent bonds with molecules as a necessary step of the reaction process. Enzymes also promote chemical reactions by bringing substrates together in an optimal orientation, lining up the atoms and bonds of one molecule with the atoms and bonds of the other molecule. This can contort the substrate molecules and facilitate bond-breaking. The active site of an enzyme also creates an ideal environment, such as a slightly acidic or non-polar environment, for the reaction to occur. The enzyme will always return to its original state at the completion of the reaction. One of the important properties of enzymes is that they remain ultimately unchanged by the reactions they catalyze. After an enzyme is done catalyzing a reaction, it releases its products (substrates).