Chapter 6-2 - Enzymes

Enzymes speed up metabolic reactions by lowering energy barriers

- A **catalyst** is a chemical agent that changes the rate of a reaction (speeds it up) without being consumed by the reaction.
  - An **enzyme** is a catalytic protein.
- Enzymes regulate the movement of molecules through metabolic pathways.
- Chemical reactions between molecules involve both bond breaking and bond forming
- Even in an exergonic reaction, the reactants must absorb energy from their surroundings, the **free energy of activation** or **activation energy** (E_A), to break the bonds.
  - This energy makes the reactants unstable, increases the speed of the reactant molecules, and creates more powerful collisions.
- Activation energy is the amount of energy necessary to push the reactants over an energy barrier.
- For some processes, the barrier is not high and the thermal energy provided by room temperature is sufficient to reach the transition state.
- ***<u>In most cases</u>***, E_A is higher and a significant input of energy is required.
  - However, typical cell temperatures **<u>do not provide</u>** enough energy for most molecules to make it over the hump of activation energy.
  - But a cell ***<u>must be</u>*** metabolically active!!!
  - Heat would speed reactions, but it would also denature proteins and kill cells.
- Enzymes speed reactions by lowering E_A.
  - Transition state can then be reached even at moderate temperatures.
- Enzymes do not change delta G.
  - They speed up reactions that would occur eventually
  - Because enzymes are so selective, they determine which chemical processes will occur at any time

Enzymes are substrate specific

- A **substrate** is a reactant which binds to an enzyme
- One type of enzyme will typically only react with one specific substrate (enzyme-substrate specificity)
- When a substrate binds to an enzyme, the enzyme catalyzes (speeds up) the conversion of the substrate to the product.
- The **active site** of an enzyme is typically a three-dimensional pocket or groove on the surface of the enzyme into which the substrate fits.
- The specificity of an enzyme is due to the fit between the active site and that of the substrate.
- As the substrate binds, the enzyme changes shape leading to a tighter **induced fit**, bringing chemical groups in position to catalyze the reaction.

The active site is an enzyme's catalytic center

- Substrates attach to the active site by weak interactions, such as hydrogen bonds and ionic bonds.
- A single enzyme molecule can catalyze thousands or more reactions a second.
- Enzymes are unaffected by the reaction and are reusable.
- Most metabolic enzymes can catalyze a reaction in both the forward and reverse direction.
  - The actual direction depends on the relative concentrations of products and reactants.
  - Enzymes catalyze reactions in the direction of equilibrium.
- Enzymes use a variety of mechanisms to lower activation energy and speed a reaction.
  - The active site orients substrates in the correct orientation for the reaction.
  - As the active site binds the substrate, it may put stress on bonds that must be broken, making it easier to reach the transition state.

The rate of enzyme-substrate reactions can be affected by concentration

- The rate that a specific number of enzymes converts substrates to products depends in part on substrate concentrations.
- At low substrate concentrations, an increase in substrate speeds binding to available active sites.
- However, there is a limit to how fast a reaction can occur.
- At some substrate concentrations, the active sites on all enzymes are engaged, called enzyme saturation.
  - The only way to increase productivity at this point is to add more enzyme molecules.
- Temperature and pH have a major impact on reaction rate.
  - Each enzyme has optimal temperature and pH ranges in which it works best
  - Reaction rates can slow and/or an enzyme can become denatured outside of this range
    - Weak bonds are disrupted, ***changing 3D shape***
- Many enzymes require non protein helpers, **cofactors**, for catalytic activity.
  - They bind permanently or reversibly to the enzyme
  - Some *inorganic* cofactors include zinc, iron, and copper.
- Organic cofactors, **coenzymes**, include vitamins or molecules derived from vitamins.
- The manners by which cofactors assist catalysis are diverse.
- Binding by some molecules, inhibitors, prevent enzymes from catalyzing reactions.
  - If binding involves covalent bonds, then inhibition is often irreversible.
  - If binding is weak, inhibition may be reversible.
- If the inhibitor binds to the active site of the enzyme, then it blocks substrate binding via ***competitive inhibition***.