CONCEPT: ENZYMES

Enzyme Basics

● **Enzymes** are protein or RNA molecules (*ribozymes)* that reduce the energy necessary for a reaction to occur

□ Enzymes act on a **substrate** in a highly _____ manner

- Enzymes **catalyze** (increase the rate of) chemical reactions of the substrate

- Make reactions 10^8–10^{13} times faster which = taking 1 second to complete a 3 - 300,000-year reaction

□ Enzymes catalyze the forward and reverse reactions

□ Enzymes must meet three main conditions

- They cannot be consumed by the reaction

- They cannot be changed by the reaction

- They only effect the rate of the reaction – and do not effect the free energy of the reaction

EXAMPLE: Enzyme substrate complex

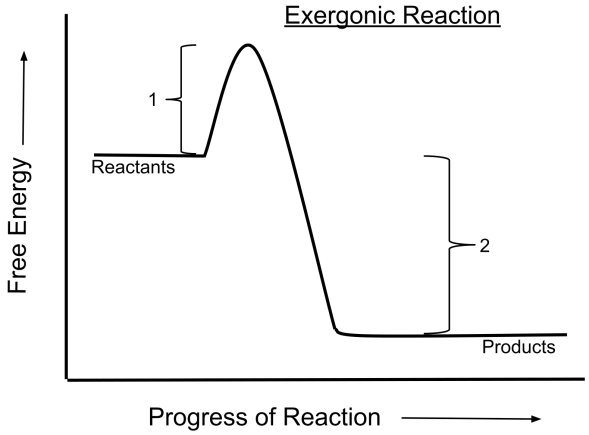
Enzymes Speed Up Reactions

● Enzymes overcome **activation energy (E_a) =** minimum amount of energy reactants must have before becoming products

□ Thermodynamically favorable reactions ($\Delta G<0$) don't always occur in cells - they need an energy _____

- **Metastable state** molecules are thermodynamically unstable, but cannot react (Too high E_a)

EXAMPLE: Activation energy (1) shown on an energy diagram



□ Two potential ways of _____ activation energy

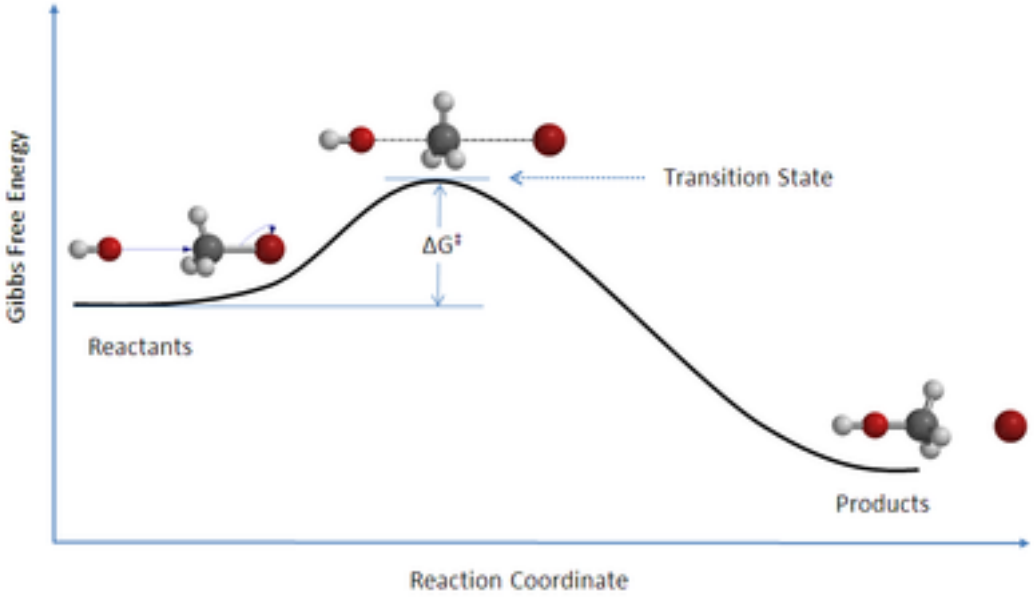
- **Bad:** Increase in heat will increase kinetic (and therefore activation) energy – but we will all overheat

- **Good:** Use of an enzyme that lowers activation energy

□ Enzymes bind to the **transition state** form of the reactant, which has the highest free energy

- This binding stabilizes the transition state, and allows the reaction to overcome the E_a and occur

EXAMPLE: A Gibbs free energy graph demonstrating the transition state form



Reaction: $HO^- + CH_3Br \rightarrow [HO{-}{-}{-}CH_3{-}{-}{-}Br]^‡ \rightarrow CH_3OH + Br^-$

Specific Enzyme-Substrate Interactions

● Enzyme and substrate _____ regulate the reaction

□ **Diffusion** is the passive movement of substrates throughout the cytoplasm

- An average molecules take 1/15th of a second to travel 10μm distance (average cell diameter =15μm)

- Enzymes get hit by about 500,000 random collisions each second

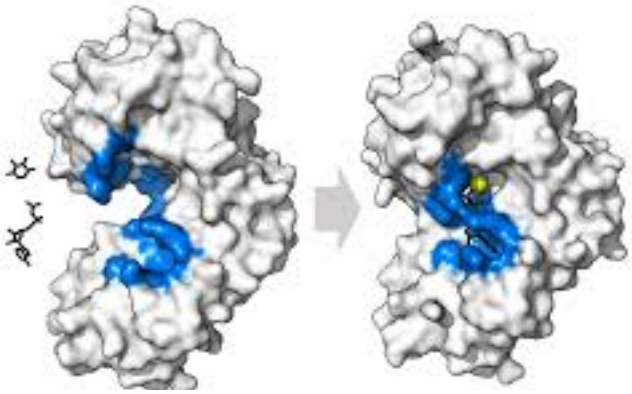
- Enzymes can catalyze 1000s of substrate reactions each second

□ An **active site** is groove in which the substrate binds to the enzyme and the reaction takes place

- Usually has complementarity to the substrate's shape and charge and interacts by noncovalent bonds

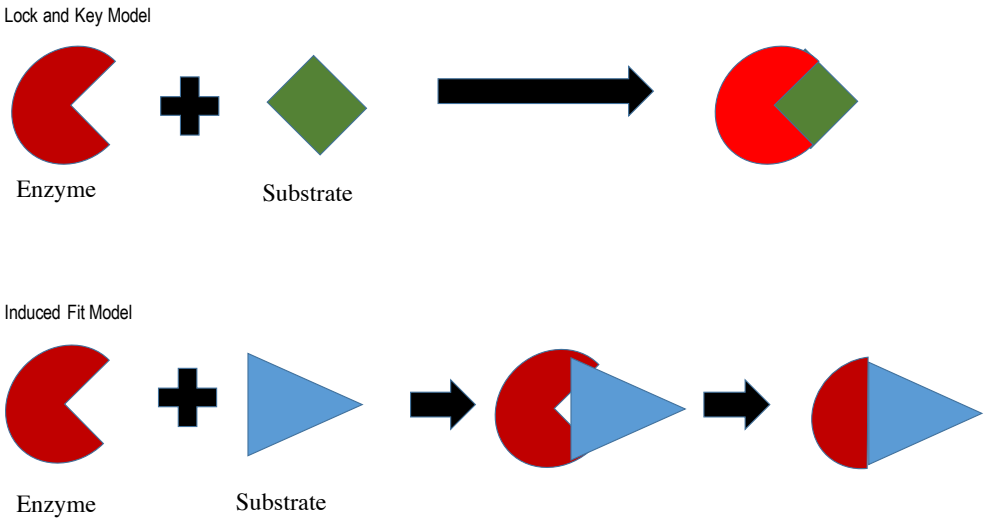
- Buried in the enzyme to separate from aqueous environment

EXAMPLE: Substrates bind to the enzymes active site (blue)



- Can bind directly **(lock and key model)** or by inducing a change in the substrate **(induced fit model)**

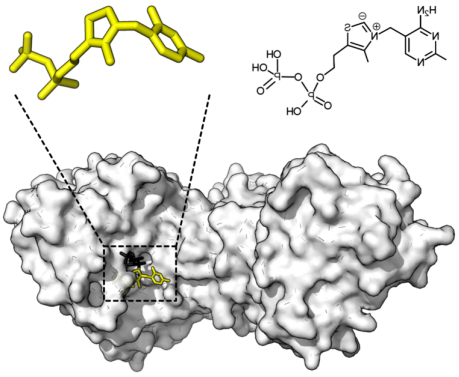
EXAMPLE: Comparison of two models of enzyme-substrate interactions



□ Enzymes also contain molecules like **cofactors** (inorganic) or **coenzymes** (organic) to facilitate the reaction

- Also called **prosthetic groups**

EXAMPLE: A cofactor (yellow) aids in an enzyme facilitated reaction



Enzyme Regulation

● Enzyme catalysis is highly _____

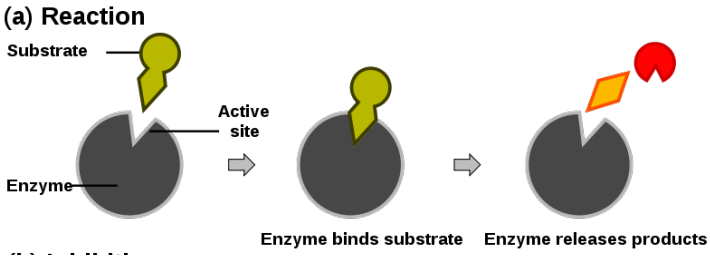
□ **Feedback inhibition** is when a product of one metabolic pathway inhibits enzyme involved in its synthesis

□ **Allosteric** regulation occurs when a small molecule binds to a regulatory site on the enzyme

- Can change the shape or structure of the enzyme and/or active site

□ **Phosphorylation** (addition of phosphate group) can inhibit or activate enzymatic activity

EXAMPLE: Inhibitors compete with substrate for active site binding



Practice

1. Which of the following is not one of the three major conditions of enzymes?
    a. Enzymes cannot be consumed by a reaction
    b. Enzymes cannot be changed by a reaction
    c. Enzymes do not effect the rate of the reaction, only the free energy
    d. Enzymes do not effect the free energy of the reaction, only the reaction rate