Student Handout

Introduction

Enzymes are specialized proteins that **catalyze** or speed up chemical reactions within cells. The substance upon which an enzyme acts is called a **substrate**. Substrates are small molecules.

Enzymes:

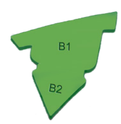
- Accomplish catalysis without being consumed in the reaction.
- Catalyzes a specific chemical reaction.

The Enzyme in Action Kit© allows you to explore how enzymatic reactions occur.

Catabolism

Model pieces needed

gray A foam piece without stickers



green B_1 and B_2 foam pieces

orange C_1 and C_2 foam pieces

1. The gray foam piece is a model of an **enzyme**. Place it with the **A** label facing up. Assemble the two green pieces (B_1 and B_2) into a single unit to model the **substrate** in this reaction.

2. Draw and label the **enzyme** and **substrate** before the enzymatic action.

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Enzyme Action Continues

3. In this first metabolic action, the enzyme will act on the substrate to break it apart. Experiment with the pieces to model how the enzyme and substrate might interact.

4. The substance an enzyme acts upon is referred to as the ______________________________.

5. Place an "**X**" on the drawing of the enzyme and substrate you created on page 1 to show where the substrate binds to the enzyme.

The part of the enzyme that binds the substrate to be acted on is referred to as the **active site**.

Once the substrate is locked into the enzyme, the two green substrate pieces may be easily pulled apart. This type of metabolic process is called **catabolism** (the breaking down of complex molecules into simpler molecules).

6. Draw and label the **enzyme**, **products** and **active site** after enzymatic action.

7. Although the substrate model changed in this reaction, what changes did you observe in the model of the enzyme during this reaction?

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8. Why do you think it is an advantage for the enzyme to remain unchanged while catalyzing a chemical reaction?

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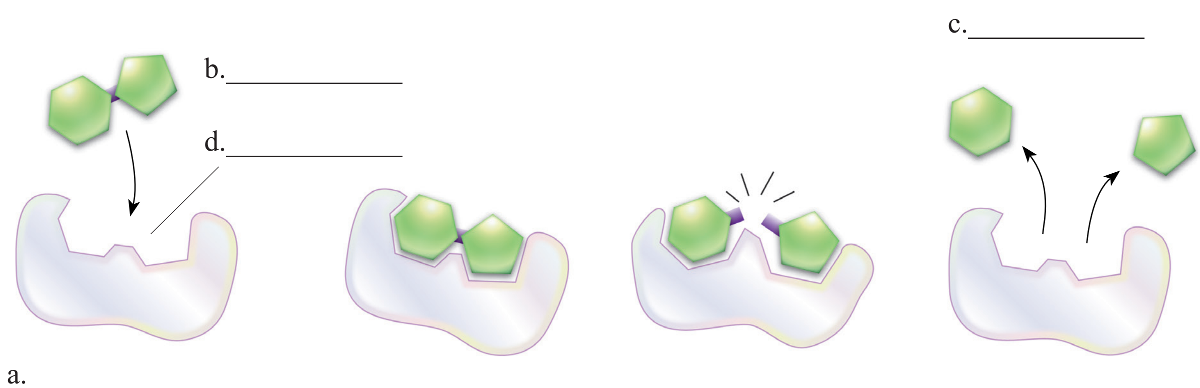
Enzyme Action Continues

Note: A real life example of catabolism occurs when the enzyme **sucrase** breaks down the substrate sucrose into glucose and fructose (monosaccharides).

9. Given what you now know about catabolism, identify the following components in the model illustrated below: enzyme, substrate, products and active site.



Induced Fit Model of Enzyme Action

In 1958 scientist Daniel Koshland, Jr., PhD., proposed the **induced fit model** to describe enzyme-substrate interaction. This model suggests that enzymes are flexible structures in which the binding of the substrate results in small changes to the shape of the active site, maximizing its interaction with the substrate.

10. Describe how the foam catabolism model illustrates the induced fit model of enzyme-substrate interaction.

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11. Explain the difference between **catalysis** and **catabolism**.

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Enzyme Action Continues

Anabolism

Enzymes may also bring substrates together to form a final product. This metabolic process is called **anabolism** (the building of complex molecules from simpler molecules).

12. Use the gray foam piece and the orange foam pieces (C_1 and C_2) to simulate an anabolic process. The orange pieces should not be assembled prior to the anabolism action.

13. Sketch and label the **enzyme** and **substrate** prior to enzyme action in the space below.

14. Place the small pointed orange piece (C_2) into the enzyme. Join the larger orange piece (C_1) to C_2. Note that the two pieces lock together to form a final product.

15. In the space below, sketch and label the **enzyme** and **products** after the enzyme has acted on the substrate.

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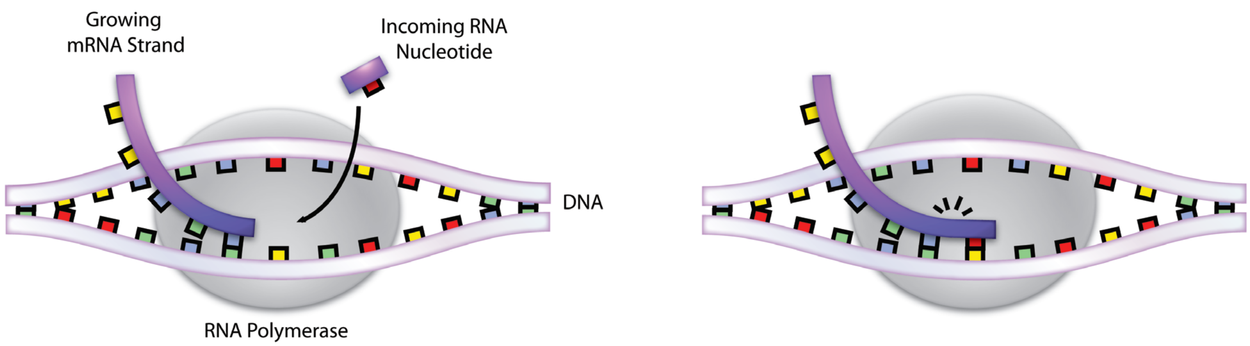
Enzyme Action Continues

Note: A real life example of anabolism occurs when **RNA polymerase** links RNA nucleotides together by catalyzing the formation of a bond between the backbone sugar of one nucleotide to the backbone phosphate of another nucleotide during transcription.



16. Given what you now know about anabolism, identify the substrate in the above diagram.

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17. Explain why the above process is an example of anabolism.

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Lock and Key Model of Enzyme Action

In 1894 scientist Emil Fisher wrote, “To use a picture, I would like to say that enzyme and glucoside have to fit to each other like a lock and key in order to exert a chemical effect on each other.” Fisher created a mental model of how an enzyme acts and referred to it as the ***Lock and Key Model of Enzyme Action***.

This model suggests that the enzyme and the substrate possess specific complementary geometric shapes that fit exactly into one another like a key into a lock.

18. Describe how the anabolic process you previously modeled illustrates the lock and key model of enzyme-substrate interaction.

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Enzyme Action Continues

Note: Most enzymes catalyze either **catabolic** OR **anabolic** processes. There are a few enzymes that do both. ATP synthase and ATPase are the same protein but have different names because they function as enzymes in both catabolic and anabolic reactions.

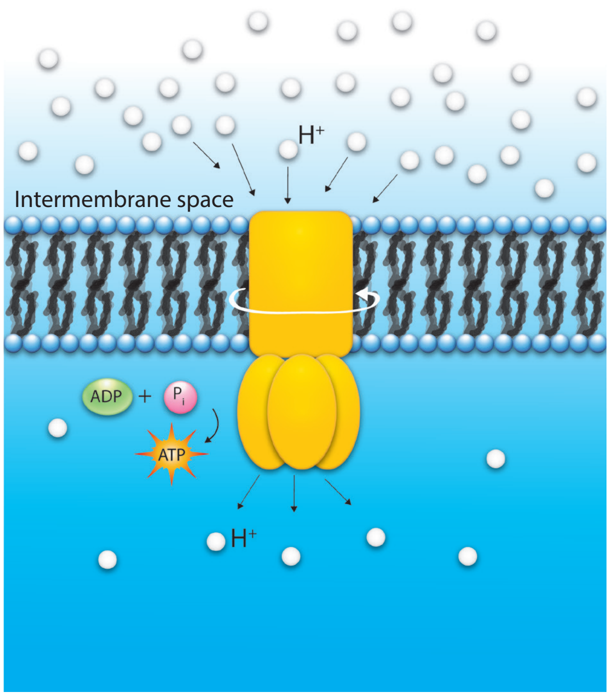

Diagram A — ATP Synthase

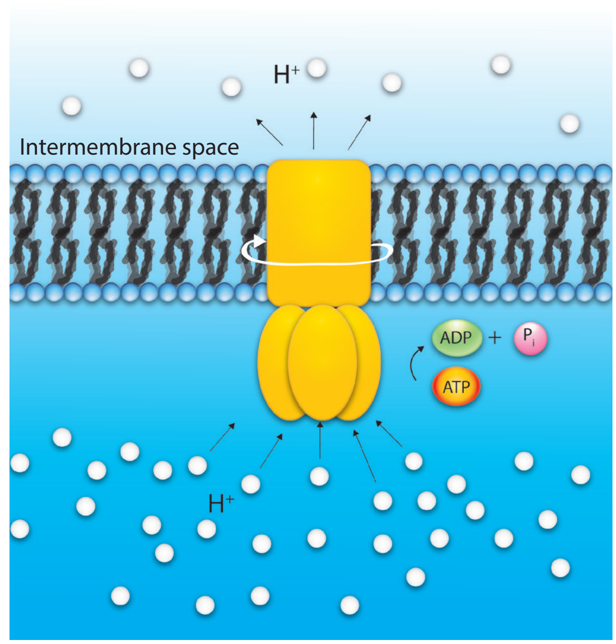

Diagram B — ATPase

19. Describe the action of the enzyme in diagram A. In your description, identify the substrate and enzyme.

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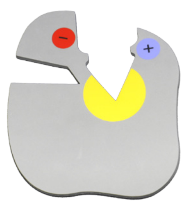
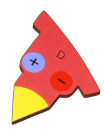
Enzyme Specificity

The reaction catalyzed by an enzyme is very specific. Most enzymes are proteins with unique three-dimensional configurations based on their amino acid sequence. The specificity of an enzyme can be attributed to the compatibility between the shape of the enzyme's active site and the shape of the substrate.

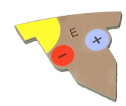
Model pieces needed



gray foam piece with stickers



red D foam piece with stickers



tan E foam piece with stickers

1. Place the enzyme model with the sticker side facing up. Write your observation about the active site of the enzyme below.

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2. What might these specialized areas in the enzyme represent?

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3. What do the red D and tan E foam pieces represent?

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4. How do the specialized areas of the red D piece interact with the specialized areas of the enzyme?

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5. In order for enzymes to bind to the correct substrate, enzymes have specific active site configurations that allow for interaction with the substrate. Explain why the tan E substrate would not interact with the enzyme.

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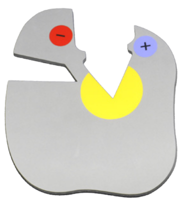
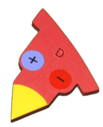
Enzyme Inhibition

Model pieces needed



gray foam piece with stickers



red D foam piece with stickers

purple (F) foam piece

blue (G) foam piece

Competitive Inhibition

1. Place the gray A, red D, purple F and blue G foam pieces on your work surface. Which two pieces may fit into the active site?

_________________________________ and ____

2. Can the red D substrate bind to the active site if the purple F piece is bound to the enzyme? _______

A substance which binds in the active site and prohibits normal substrate interaction is called a **competitive inhibitor**.

3. Create a sketch using the foam models to illustrate **competitive inhibition**.

4. Predict what might happen in a cell if the concentration of competitive inhibitor exceeded that of the substrate.

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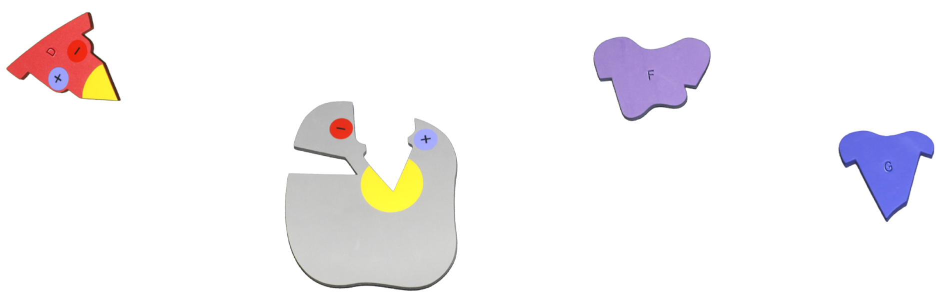
Enzyme Inhibition

Noncompetitive Inhibition

A **noncompetitive inhibitor** impedes enzymatic action by binding to another part of the enzyme. This second site, known as the ***allosteric site***, is the place on an enzyme where a molecule that is not a substrate may bind, thus changing the shape of the enzyme and influencing its ability to be active.

5. In the diagram below, draw an "**X**" where the **blue G** piece may noncompetitively bind to the enzyme.



6. Sketch what happens to the shape of the enzyme when the blue piece is bound to the allosteric site.

7. How does this affect the binding of the substrate?

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Activation Energy

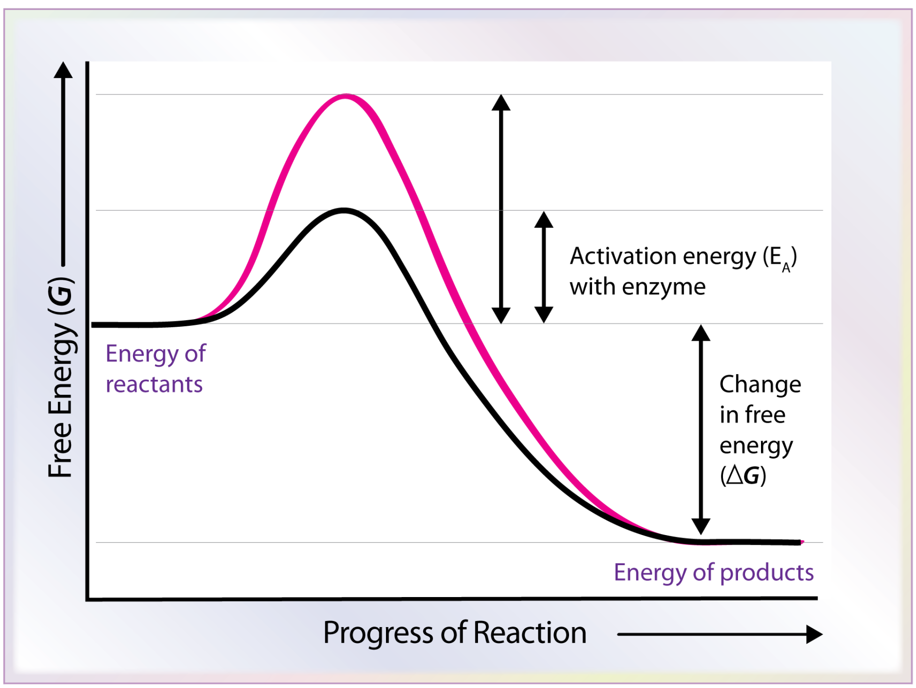
Activation energy may be defined as the minimum amount of energy required to get the reactants in a chemical reaction to the transition state, in which bonds are broken and new bonds are formed. The activation energy of a reaction is usually denoted by E_A. By now you know that enzymes are proteins that catalyze chemical reactions. Enzymes lower the activation energy needed to start a reaction.

You may use the foam pieces to simulate the activation energy needed in a reaction with and without an enzyme. Begin by connecting the green foam pieces. To illustrate the activation energy without the enzyme interaction, pull the apart the two green pieces with your hands.

Reconnect the green pieces. This time lock them into the active site on the gray A enzyme (without stickers) foam piece. With the help of the enzyme it takes less energy to pull the pieces apart. The activation energy has been lowered!

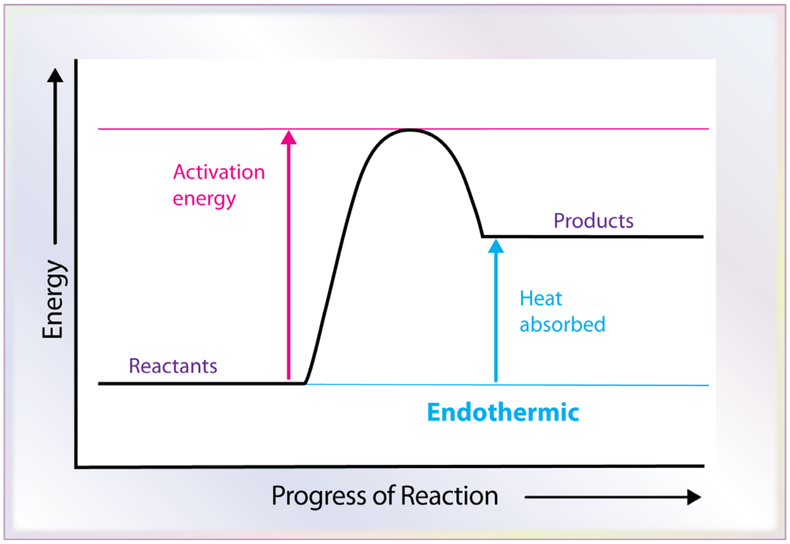
Notice in the graph below that the resulting products have less free energy than the reactants. In such a reaction, energy has been released and the reaction is said to be **exothermic**. A specific example of an exothermic reaction is the breakdown of hydrogen peroxide into water and oxygen. The enzyme used to facilitate this reaction is known as **catalase**.

$$2H_2O_2 \rightarrow 2H_2O + O_2$$



Activation Energy Continues

Conversely, in the graph below, the products have more free energy than the reactants. Reactions that absorb heat from the environment are known as **endothermic** reactions. A common example is a chemical ice pack which typically contains water and a packet of ammonium chloride. To activate the ice pack, the barrier separating the two substances must be physically broken so the two substances may react. Enzymes may also facilitate endothermic reactions.



1. Examine the graph below. Is the reaction depicted exothermic or endothermic? Explain your answer.

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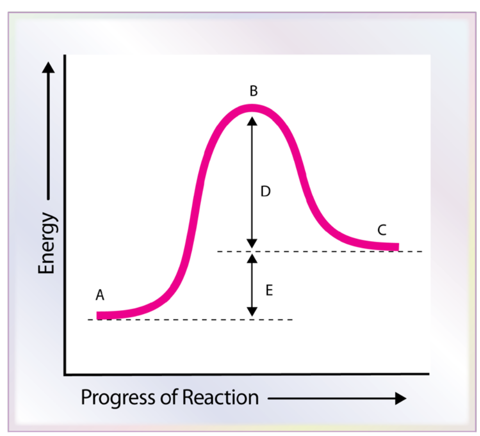
The activation energy curve show below represents a non-enzyme catalyzed reaction.



2. Draw a line on the graph indicating the activation energy in the presences of an enzyme.

3. Which letter depicts the activation energy without the enzyme present?

______________________________________.

4. What does the letter 'E' represent?

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Activation Energy Continues

Post Lab Questions

1. Predict what might happen if enzyme activity were not regulated within a cell's metabolic pathways.

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2. Contrast the action of a competitive inhibitor with that of a noncompetitive inhibitor.

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Activation Energy Continues

Ethanol is metabolized in the body into acetaldehyde. Normally, acetaldehyde does not accumulate in the body because aldehyde dehydrogenase rapidly oxidizes the acetaldehyde into acetic acid. The drug disulfiram inhibits aldehyde dehydrogenase, which causes an accumulation of acetaldehyde in the body with the subsequent unpleasant side effects of nausea and vomiting. Disulfiram is sometimes used to treat patients with a drinking habit.

3. Create a sketch to illustrate the action of the competitive inhibitor disulfiram. Be sure to label your diagram with the following terms, **aldehyde dehydrogenase**, **disulfiram**, **acetaldehyde**, **enzyme**, **competitive inhibitor**, **substrate** and **product**.

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Activation Energy Continues

4. How is Koshland's theory of induced fit supported by noncompetitive inhibition of enzymes?

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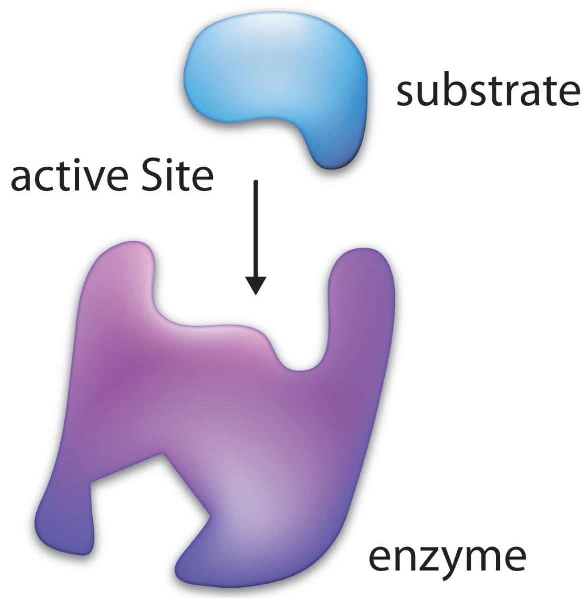
5. Examine the model of the enzyme shown below. Design a competitive and noncompetitive inhibitor for this enzyme.



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