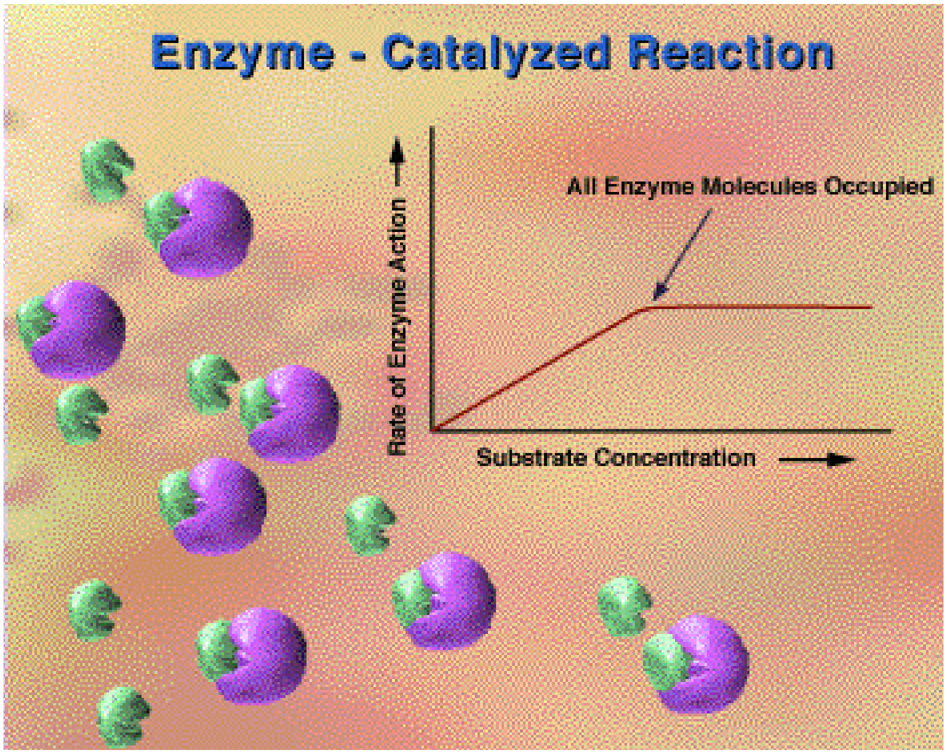
Interactive Biology Multimedia Courseware

Enzymes
Program Supplement



Enzymes
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Enzymes
TEACHING OBJECTIVES

The following subject areas are illustrated throughout the Interactive Biology Multimedia program, *Enzymes*. Ideally, these areas would be augmented with additional course work outside of this program.

- Introduction to reactions**: Including enzyme-catalyzed reactions, reactants, and energy of activation.**
- Enzyme-substrate complexes and the lock-and-key as well as induced fit models of substrate binding.
- Factors affecting the functioning of enzymes**: Including temperature, concentration of substrate, pH, and cofactors.**
- Enzyme regulation through allosteric inhibitors and activators, cooperativity, and feedback inhibition.

Study Guide #1
INTRODUCTION TO ENZYMES

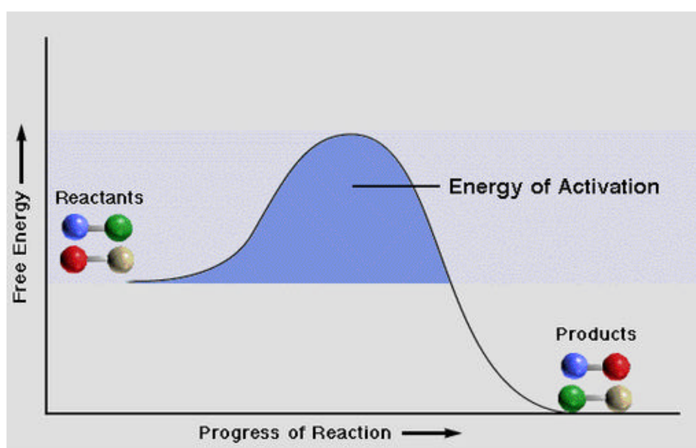
Inside of your body, and the bodies of other living organisms, chemical reactions are occurring that fuel all of life's processes. Most of these reactions would occur on their own if the chemicals involved were simply placed inside of beakers and left alone.

Although these reactions could proceed on their own, the rates at which they take place would be far too slow to sustain life. Many reactions, such as the splitting of glucose molecules during the process of glycolysis, must take place thousands of times each second for life to continue in complex organisms such as humans.

ENZYMES are very large protein molecules that speed up biochemical reactions. Anything that speeds up reaction rates is known as a CATALYST. Some enzymes are active inside of cells whereas other enzymes are produced to be active in the spaces or fluid found outside of cells.

A chemical reaction occurs when molecules react with one another to form different molecules. For instance, hydrogen and oxygen may react with each other to form water, or an electric current may be passed though water to produce hydrogen and oxygen. In either scenario, new products are formed. The molecules that react with each other are referred to as REACTANTS.

A chemical reaction involving an enzyme is said to be an ENZYME-CATALYZED REACTION. The molecules on which an enzyme acts make up the SUBSTRATE. For instance, HEXOKINASE ENZYMES bind to glucose molecules. Therefore, glucose is the substrate of hexokinase.



In a chemical reaction, the reactants must absorb a certain amount of energy from the environment before a reaction can take place. The specific amount of energy required for the reaction to proceed is called the ENERGY OF ACTIVATION.

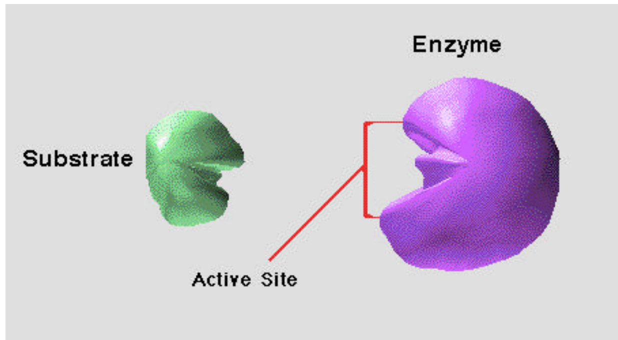
In reactions occurring outside of living organisms, simply adding heat can provide activation energy. Inside of living organisms, however, another method must be used. Heat is very harmful to the cells and proteins of plants and animals.

To overcome the activation energy required for certain reactions to take place, living organisms employ enzymes. Enzymes function by being able to LOWER the activation energy needed in specific reactions. With a lower energy requirement, more molecules will be able to react with each other and the reaction can swiftly occur at temperatures able to support life.

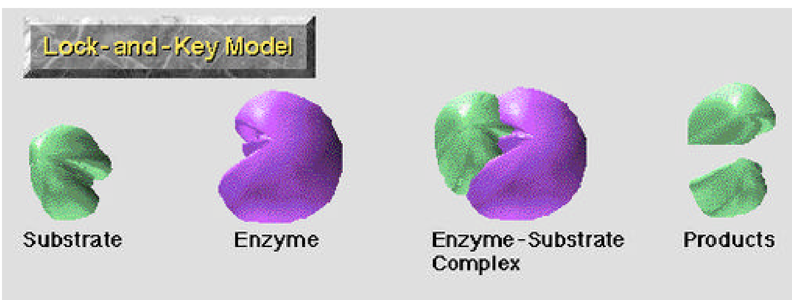
Study Guide #2
ENZYME NAMES AND SUBSTRATE BINDING

The names of most enzymes end in the suffix -ase. The rest of the name is derived from the substrate acted upon. For instance, the enzyme that breaks down protein is known as PROTEASE and the enzyme responsible for forming, or polymerizing, DNA is known as DNA POLYMERASE.

On the surface of enzymes is a pocket called an ACTIVE SITE. Each active site is specifically shaped so that only certain, very specific substrate molecules can fit into it. The active site on hexokinase, for instance, is shaped so that glucose molecules fit nearly perfectly inside.

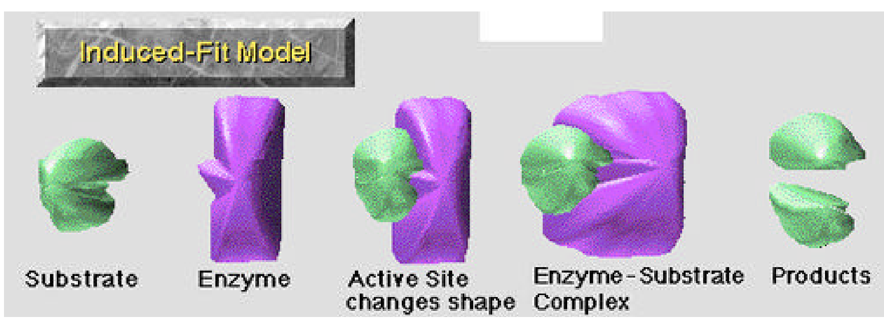


Two methods of describing the mechanism by which substrate binds to its active site are the LOCK-AND-KEY MODEL and the INDUCED FIT MODEL.



In the lock-and-key method, the substrate fits into an enzyme's active site and forms an ENZYME-SUBSTRATE COMPLEX much like a key fitting into its complimentary keyhole. In this case, the key would be the substrate and the keyhole would be the active site. Although somewhat accurate, biologists have steered away from the lock-and-key description in favor of the induced fit model.

In the induced fit model, the shape of the enzyme changes after binding with the substrate to form an enzyme-substrate complex. Similar to closing your hand around a quarter, the shape change brings about a



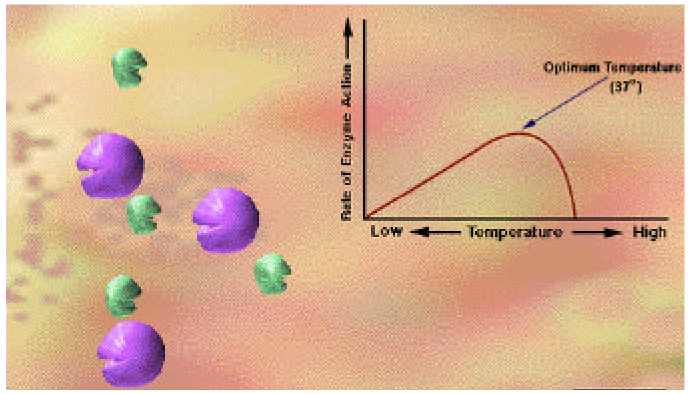
closer fit between enzyme and substrate.

This sudden change in shape can lead to the breaking of bonds within a single substrate molecule, forming two new molecules. Conversely, it can also bring two-substrate molecules close enough together for them to bond with each other, forming one new molecule.

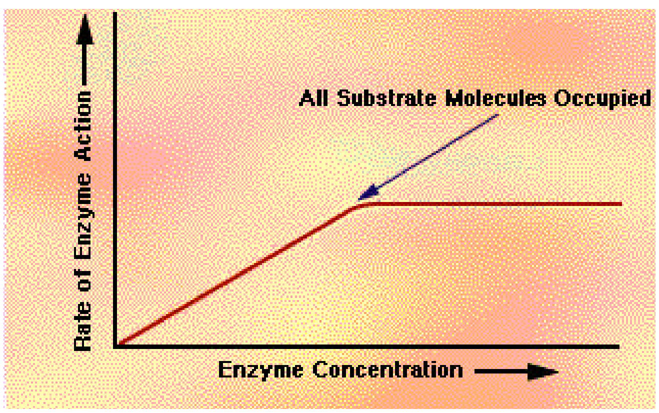
An important quality of enzymes is that they are NOT CHANGED in the reactions they catalyze. After a new product is formed, the enzyme releases it, goes back to its original shape, and is able to bind new substrate molecules and start the reaction once again. A single enzyme is able to catalyze thousands of reactions every second if conditions are right.

Study Guide #3
FACTORS AFFECTING THE FUNCTIONING OF ENZYMES

MANY factors affect the rates at which enzymes are able to catalyze reactions. Enzymes are only able to function efficiently under a certain range of conditions, and, if conditions slip outside of this range, enzymes may not function at all.



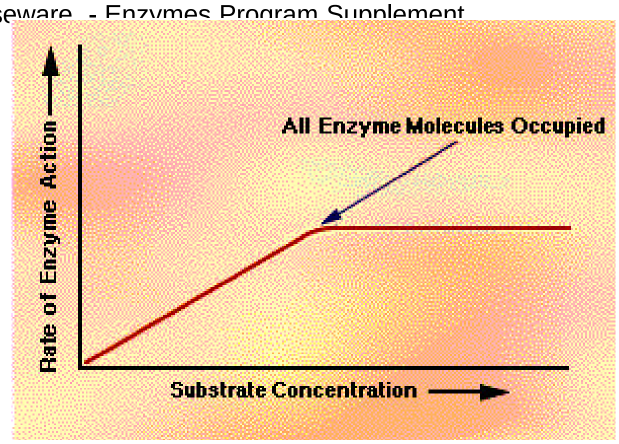
One of the factors affecting enzymes is TEMPERATURE. As the temperature rises, substrate molecules begin to move around at an increased rate. This brings more substrate molecules into contact with the active sites on enzymes, and subsequently allows more substrate to bind. For this reason, the rate of enzyme activity (measured in the amount of product made) increases steadily with an increase in temperature.



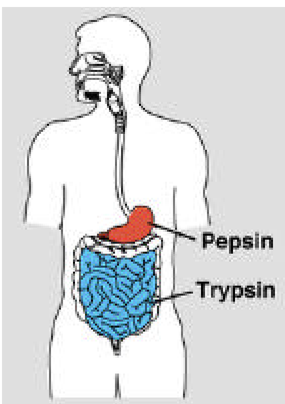
This increased activity with temperature is only true up to a point. Remember that enzymes are proteins. Many of these proteins are large molecules and can withstand a moderate rise in temperature, but at some point temperature will DENATURE proteins. This means that the enzyme will begin to "unravel" and no longer be able to function. For instance, enzymes in humans function best at about 36 degrees Celsius. After the temperature rises above about 40 degrees Celsius, the enzymes begin to denature and reaction rates begin to decline sharply.

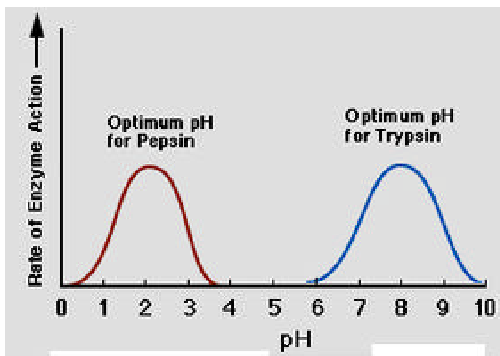
Another factor affecting reaction rates is CONCENTRATION. This can be either concentration of substrate of the concentration of enzyme. If there is very little substrate or very few enzyme molecules, it stands to reason that they will come into contact with one another only rarely. As you increase the amount of substrate or the number of enzymes, you also increase the number of times they come into contact with each other. This means the reaction rate will increase accordingly.

The reaction rate can only increase to a certain degree. Each enzyme has a saturation point. Once this point has been reached, the enzyme is binding substrate and releasing product as quickly as it is able to. Adding more substrate will not make the enzyme bind and release any faster.



Another factor affecting enzyme activity is pH, which is a measure of how much acid is present. A pH below 7 indicates acidic conditions whereas a pH above 7 indicates basic conditions. Some enzymes, such as the PEPSIN found inside of your stomach where there is a great deal of acid, must have a high tolerance for the amount of acid present. Other enzymes, such as TRYPSIN, which is found in your small intestine where the conditions are more basic, must be able to perform in an environment with much different pH. Just as all enzymes have a temperature range in which they perform best, they also have a pH range in which they perform best.

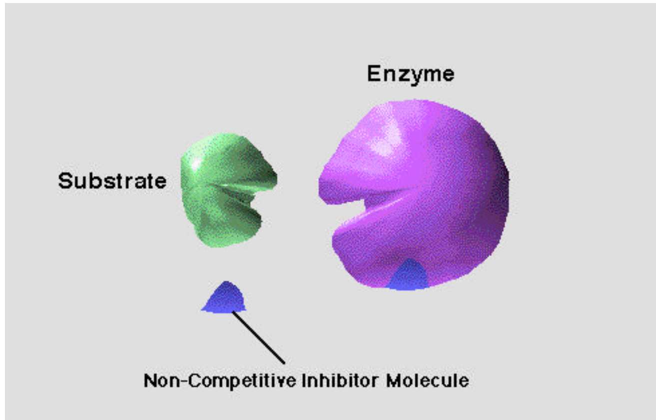




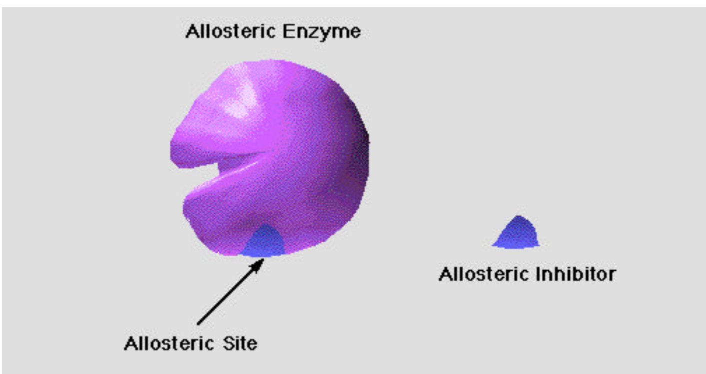
Many enzymes require one or more nonprotein additions, called COFACTORS, to be active. Cofactors may be derived from vitamins or from minerals such as iron and magnesium. If the cofactor is an organic molecule such as a vitamin, it is called a COENZYME. These cofactors and coenzymes must be present for the enzyme to function properly, and explains in part why vitamins and minerals are so important to our diet.

Study Guide #4
ENZYME REGULATION

Allosteric Enzymes

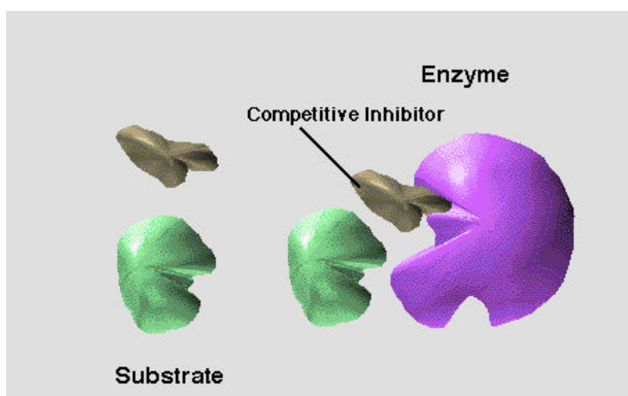


The activity of some enzymes can be regulated by the presence of certain INHIBITOR MOLECULES. A NONCOMPETITIVE INHIBITOR MOLECULE blocks enzyme activity, in other words it stops the enzyme from catalyzing reactions, by binding to the enzyme and slightly changing the shape of the active site. Substrate is no longer able to bind under these conditions. These molecules are called noncompetitive inhibitors because they do not "compete" with the substrate for the active site. These molecules bind elsewhere on the protein.

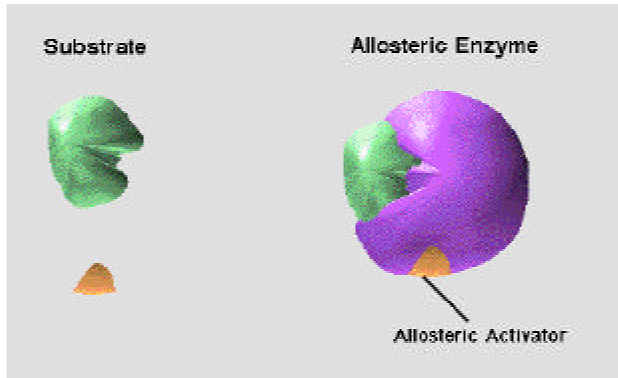


The receptor site for the noncompetitive inhibitor molecule is called the ALLOSTERIC SITE and these molecules are often called ALLOSTERIC INHIBITORS. Enzymes that can be regulated by allosteric molecules are known as ALLOSTERIC ENZYMES.

While allosteric inhibitors do not compete with substrate for binding at the active site, some molecules do regulate enzyme activity by binding here. These molecules are called COMPETITIVE INHIBITORS. The antibiotic penicillin is an example of a competitive inhibitor. It binds to bacterial enzymes, and prevents bacteria cells from producing functional cell walls.



Not all allosteric sites on enzymes are used to inhibit enzyme activity. Certain enzymes must have a molecule bound to one of their allosteric sites before they can become activated. In these cases, regulating molecules are not inhibitors, but are rather ALLOSTERIC ACTIVATORS.

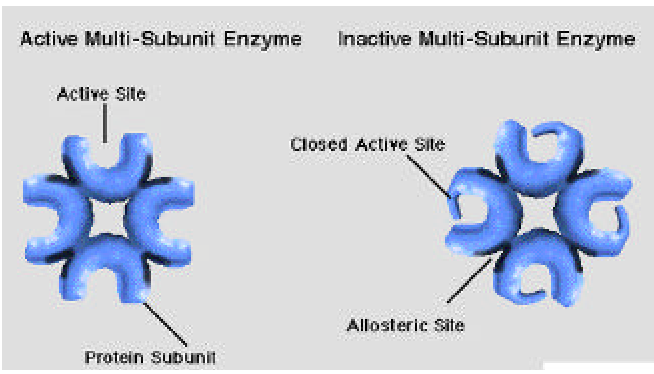


When an allosteric activator binds to an enzyme, it slightly changes the shape or conformation of that enzyme. The enzyme thus changes into one with an active site that can bind substrate. The allosteric activator STABILIZES the active form of the enzyme. When the allosteric activator releases from the enzyme, the enzyme once again becomes inactive. Conversely, when an allosteric inhibitor binds to an enzyme, it STABILIZES the inactive form.

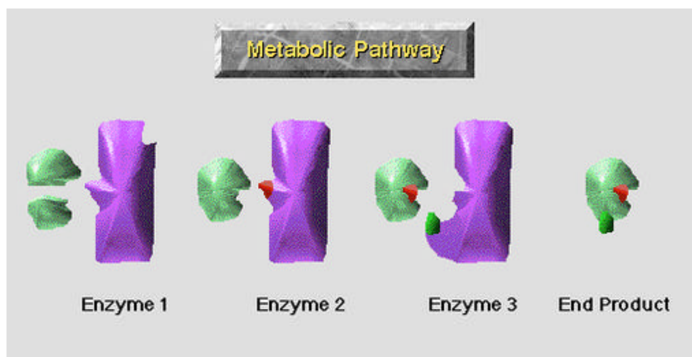
Study Guide #5
ENZYME REGULATION

Cooperativity and Feedback

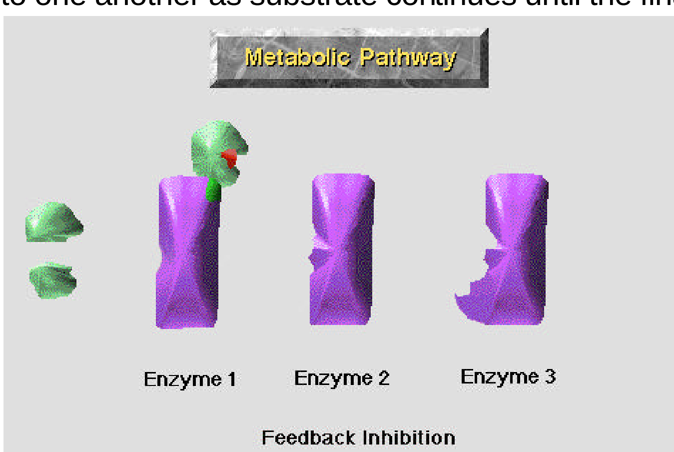
Often, substrate molecules are themselves involved in regulating enzyme activity. Most of the enzymes you learned about on the previous study guide, allosteric enzymes, are composed of two or more SUBUNITS. Each subunit has its own active site.



Enzymes that are regulated by substrate are also composed of two or more subunits. When one substrate molecule binds to an active site, this stabilized the active form of the enzyme. Substrate can now more easily bind to the remaining open active sites on the other subunits. This method of stabilization by substrate binding is called COOPERATIVITY.



Most of the enzyme-catalyzed reactions inside your body are part of a specific METABOLIC PATHWAY. These pathways allow very complex molecules to be either built up or broken down. Along these pathways, the product from one enzyme will be the substrate for another enzyme. This process of enzymes passing their products off to one another as substrate continues until the final product is reached.



By controlling enzymes along the path, metabolic pathways may be switched on or off. One of the most common means of regulating these pathways is through FEEDBACK INHIBITION.

In feedback inhibition, some of the final product made binds to allosteric sites on enzymes near the start of the path. These enzymes become inactivated and the pathway is shut down. In this way, cells don't continue to manufacture molecules that they have a sufficient supply of. When the number of these molecules begins to decline, the allosteric sites corresponding to them become open more frequently. This allows the enzymes to once again become activated, and the pathway starts.

Enzymes
QUIZ PACK

The following quizzes are meant to test student understanding of specific topic areas covered in the Interactive Biology Multimedia program, *Enzymes*. Many, but not all, of these questions have been addressed directly in the study guides designed to strengthen student understanding of these topics.

QUIZ #1	Introduction To Enzymes
QUIZ #2	Binding Of Enzymes
QUIZ #3	Factors Affecting Enzymes
QUIZ #4	Enzyme Regulation
QUIZ #5	Enzyme Regulation
EXAM	Comprehensive Exam

Quiz #1
INTRODUCTION TO ENZYMES

1. Chemical reactions fuel the life processes in living things.

   A. True
   B. False

2. _________ speed up chemical reactions.

   A. Enzymes
   B. Catalysts
   C. Both A and B
   D. Neither A nor B

3. Enzymes are composed of ________.

   A. carbohydrate
   B. lipid
   C. nucleic acid
   D. protein

4. Molecules that react with one another to form a new product are called ________.

   A. reactants
   B. active molecules
   C. inactive molecules
   D. products

5. The enzyme hexokinase binds to ________.

   A. water
   B. oxygen
   C. glucose
   D. maltose

6. The amount of energy needed for a specific chemical reaction to take place is known as ________.

   A. reaction energy
   B. chemical energy
   C. energy of absorption
   D. energy of activation

Quiz #2
BINDING OF ENZYMES

1. Very few enzymes are named after the molecules they bind to.

   A. True
   B. False

2. The one major drawback to enzyme-catalyzed reactions is that enzymes are constantly being destroyed in these reactions.

   A. True
   B. False

3. The molecule an enzyme binds to is known as its ________.

   A. template
   B. reactant
   C. sub-unit
   D. substrate

4. The region on an enzyme that binds this molecule is know as the ________.

   A. active site
   B. active region
   C. binding site
   D. binding region

5. The ________ method attempts to describe how an enzyme binds.

   A. lock-and-key
   B. induced fit
   C. Both A and B
   D. Neither A nor B

6. In the ________ method, the enzyme shape changes slightly after it has bound to its specific molecule.

   A. lock-and-key
   B. induced fit
   C. Both A and B
   D. Neither A nor B

Quiz #3
FACTORS AFFECTING ENZYMES

1. Enzymes are able to function efficiently under a very wide range of conditions.

   A. True
   B. False

2. While a slight increase in temperature can speed up reaction rates, a large increase in temperature can ________.

   A. greatly speed up reaction rates
   B. unravel enzymes
   C. Both A and B
   D. Neither A nor B

3. An unraveled enzymes is called ________.

   A. an ionized enzyme
   B. a heat shock protein
   C. a denatured enzyme
   D. All of the above

4. In our bodies, enzymes work best at about ________.

   A. 26 degrees Celsius
   B. 36 degrees Celsius
   C. 46 degrees Celsius
   D. 56 degrees Celsius

5. As the concentration of substrate increases, the reaction rate ________.

   A. decreases to a point, then levels off
   B. increases to a point, then levels off
   C. continuously decreases as substrate is added
   D. continuously increases as substrate is added

6. pH is a measure of ________.

A. how much enzyme is present
B. how much substrate is present
C. how much acid is present
D. how much heat is present

7. Non-protein substances needed by some enzymes before they can become active are called ________.

A. coproducts
B. cofactors
C. coreactants
D. codependents

Quiz #4
ENZYME REGULATION

1. Some molecules regulate enzyme activity by binding to the enzyme and changing the shape of the substrate molecules.

   A. True
   B. False

2. Inhibitor molecules that bind at the active site are _______.

   A. competitive inhibitors
   B. noncompetitive inhibitors
   C. active inhibitors
   D. passive inhibitors

3. Inhibitor molecules that bind at a location other than the active site are ________.

   A. competitive inhibitors
   B. noncompetitive inhibitors
   C. active inhibitors
   D. passive inhibitors

4. The receptor site for inhibitor molecules that bind at a location other than the active site is called ________.

   A. the passive site
   B. the regulatory site
   C. the allosteric site
   D. All of the above (depending upon the enzyme involved).

5. A molecule that binds to the receptor site in question #4 and inhibits enzyme activity is called ________.

   A. a passive inhibitor
   B. a regulatory inhibitor
   C. an allosteric inhibitor
   D. All of the above (depending upon the enzyme involved).

6. A molecule that binds to the receptor site in question #4 and increases enzyme activity is called ________.

A. a passive activator
B. a regulatory activator
C. an allosteric activator
D. All of the above (depending upon the enzyme involved).

Quiz #5
ENZYME REGULATION

1. On some allosteric enzymes, substrate molecules are involved in regulating enzyme activity.

   A. True
   B. False

2. Most allosteric enzymes are composed of two or more ________.

   A. branches
   B. units
   C. subunits
   D. None of the above

3. Stabilization by substrate binding is called ________.

   A. cooperation
   B. cooperativity
   C. substrate-induced stability
   D. substrate-dependent stability

4. ________ allow very complex molecules to be either built up or broken down by several different enzymes working closely with each other.

   A. Metabolic pathways
   B. Product pathways
   C. Synthetic pathways

5. If the pathway in question #5 is regulated by the final product looping back and acting as an allosteric inhibitor, thus preventing the cell from producing too much of this product, it is known as ________.

   A. loop inhibition
   B. enzymatic inhibition
   C. feedback inhibition

Enzymes
COMPREHENSIVE EXAM

The following exam is based on the Interactive Biology Multimedia Courseware program, *Enzymes.* Most, but not all, of these questions have been addressed directly in the study guides. All of the questions on this exam, however, are based on information put forth in the program.

Please determine if the following statements are true or false.

1. A chemical reaction is a process by which one or more substances react to form a different substance.

   A. True
   B. False

2. Many enzymes end in the suffix -ase.

   A. True
   B. False

3. Very few enzymes are named after the molecules they bind to.

   A. True
   B. False

4. One enzyme can bind to many different kinds of substrate molecules.

   A. True
   B. False

5. Enzymes speed up the rates of biochemical reactions.

   A. True
   B. False

6. The one major drawback to enzyme-catalyzed reactions is that enzymes are destroyed after each reaction.

   A. True
   B. False

7. Enzymes are able to function efficiently under a very wide range of conditions.

   A. True
   B. False

8. Some molecules regulate enzyme activity by binding to the enzyme and changing its shape slightly.

   A. True
   B. False

9. No known enzyme is composed of more than a single subunit.

   A. True
   B. False

In the following portion of the exam, please choose the letter beside the word, words, or phrase that best completes each sentence.

10. Enzymes are composed of ________.

   A. carbohydrate
   B. fat
   C. protein
   D. All of the above

11. ________ speed up chemical reactions.

   A. Enzymes
   B. Catalysts
   C. Both A and B

12. Enzymes are produced inside of cells and are found ________.

A. only inside of cells
B. only outside of cells
C. both inside and outside of cells

13. ________ molecules bind to an enzyme at the ________.

A. Substrate, primary subunit
B. Many kinds of, active site
C. Substrate, active site
D. Many kinds of, primary subunit

14. The ________ method attempts to describe how an enzyme binds.

A. lock-and-key
B. induced fit
C. Both A and B
D. Neither A nor B

15. While a slight increase in temperature can speed up reaction rates, a large increase in temperature can ________.

A. greatly speed up reaction rates
B. unravel enzymes
C. Both A and B
D. Neither A nor B

16. In our bodies, enzymes function best at about ________.

A. 26 degrees Celsius
B. 36 degrees Celsius
C. 46 degrees Celsius
D. 56 degrees Celsius

17. As the concentration of substrate increases, the reaction rate ________.

A. decreases to a point, then levels off
B. increases to a point, then levels off
C. continuously decreases as substrate is added
D. continuously increases as substrate is added

18. pH is a measure of ________.

A. how much enzyme is present
B. how much substrate is present
C. how much acid is present
D. how much heat is present

19. The enzyme ________ is found inside the human stomach.

A. trypsin
B. pepsin
C. hexokinase

20. An organic cofactor, such as a vitamin or mineral, is called ________.

A. an organic-factor
B. an organic enzyme
C. a coenzyme
D. a supplement

21. Inhibitor molecules that bind at the active site are _______.

A. competitive inhibitors
B. noncompetitive inhibitors
C. active inhibitors
D. passive inhibitors

22. Inhibitor molecules that bind at a location other than the active site are ________.

A. competitive inhibitors
B. noncompetitive inhibitors
C. active inhibitors
D. passive inhibitors

23. The inhibitor molecules in question #22 bind at ________.

A. the passive site
B. the allosteric site
C. the regulatory site
D. All of the above (depending upon the enzyme involved)

24. A molecule that binds to the receptor site in question #23 and inhibits enzyme activity is called ________.

A. a passive inhibitor
B. a regulatory inhibitor
C. an allosteric inhibitor
D. All of the above (depending upon the enzyme involved)

25. A molecule that binds to the receptor site in question #23 and increases enzyme activity is called ________.

A. a passive activator
B. a regulatory activator
C. an allosteric activator
D. All of the above (depending upon the enzyme involved)

26. ________ allow very complex molecules to be either built up or broken down in a series of steps.

A. Metabolic pathways
B. Product pathways
C. Synthetic pathways

27. If the pathway in question #26 is regulated by the final product looping back and blocking enzyme activity, it is known as ________.

A. loop inhibition
B. enzymatic inhibition
C. feedback inhibition

In the following portion of the exam, please fill in the word or phrase that best completes each sentence.

28. The amount of energy needed for a specific chemical reaction to take place is known as ___________________________________.

29. In the _____________________________________ method, enzyme shape changes slightly after it has bound its substrate.

30. An enzyme that has been unraveled by environmental conditions is said to have been _____________________________________.

31. Stabilization of an enzyme due to substrate binding, making it easier for more substrate to bind, is known as _________________________________.

Enzymes
ANSWER GUIDE

QUIZ PACK

QUIZ #1	QUIZ #2	QUIZ #3	QUIZ #4	QUIZ #5
1. A	1. B	1. B	1. B	1. A
2. C	2. B	2. B	2. A	2. C
3. D	3. D	3. C	3. B	3. B
4. A	4. A	4. B	4. C	4. A
5. C	5. C	5. B	5. C	5. C
6. D	6. B	6. C	6. C	
		7. B		

COMPREHENSIVE EXAM

1. A	9. B	17. B	25. C
2. A	10. C	18. C	26. A
3. B	11. C	19. B	27. C
4. B	12. C	20. C	28. activation enery
5. A	13. C	21. A	29. induced fit
6. B	14. C	22. B	30. denatured
7. B	15. B	23. B	31. cooperativity
8. A	16. B	24. C	

Enzymes
GLOSSARY

ACTIVE SITE: A pocket-like structure on the surface of an enzyme where substrate molecules attach, thus enabling a reaction to proceed.

ALLOSTERIC ACTIVATOR: A molecule that binds to an enzyme at the allosteric site and renders the enzyme active.

ALLOSTERIC ENZYME: An enzyme that can be regulated by the attachment of a molecule at a location different from the active site.

ALLOSTERIC INHIBITOR: A molecule that binds to an enzyme at the allosteric site and inhibits the enzyme's activity.

ALLOSTERIC SITE: A receptor site on an enzyme that is separate from the active site. Certain molecules bind to the allosteric site that either inhibit or activate an enzyme.

AMINO ACIDS: The structural molecules that make up proteins. These have an amino group (NH2), a carboxy group (COOH), and a side chain of atoms.

CATALYST: A substance that speeds up the rate at which chemical reactions occur without themselves being altered.

CHEMICAL REACTION: The process by which molecules react with one another to produce different molecules.

COENZYME: An organic molecule that functions as a cofactor.

COFACTOR: A non-protein addition, derived from either a mineral or vitamin, that is required for an enzyme's activity.

COMPETITIVE INHIBITOR: A substance that blocks enzyme activity by occupying the active site of an enzyme, thus preventing the binding of substrate.

COOPERATIVITY: The interaction of the subunits of an enzyme that causes a conformational change in one subunit to be transmitted to all others.

DENATURATION: A change in the shape of a molecule due to physical factors, such as temperatures or pH, which renders the molecule inactive.

ENERGY OF ACTIVATION: The input of energy that is required for a chemical reaction to occur.

ENZYME: A large protein molecule that allows chemical reactions to occur within living systems at rates necessary for life.

ENZYME-CATALYZED REACTION: A reaction that has been sped up by an enzyme.

ENZYME-SUBSTRATE COMPLEX: The structure formed when an enzyme and substrate unite.

FEEDBACK INHIBITION: The process in which the end-product of a metabolic pathway binds to an enzyme - typically the initial enzyme in the pathway - thus changing the shape of the active site and preventing the enzyme from accepting more substrate.

INDUCED FIT MODEL: A theory that describes the mechanism by which the substrate fits into the active site of an enzyme. In this model, once the active site forms a union with its substrate, the enzyme changes its shape for a better fit, unlike the rigid Lock and Key model.

LOCK AND KEY MODEL: A theory that describes the mechanism by which the substrate fits into the active site of an enzyme. In this model, the substrate fits into an enzyme active site much the same way a key fits into its complimentary keyhole.

METABOLIC PATHWAY: A series of reactions that enables certain compounds to be built up or broken down. A specific enzyme is used in each reaction in the pathway.

NONCOMPETITIVE INHIBITOR: A substance that blocks enzyme activity by binding to an area of the enzyme separate from the active site.

PEPSIN: A digestive enzyme in the stomach.

pH: A measure of how basic or acidic a solution is on a scale of 0-14. A pH above 7 is a basic solution, while a pH below 7 is an acidic one.

PROTEASE: An enzyme that is involved in the break-down of proteins.

PROTEIN: A molecule that is made up of amino acids.

SUBSTRATE: The compound or pair of reacting compounds on which a given enzyme can react.

TRYPSIN: A digestive enzyme in the intestine.