AP Biology Student Interactive Learning Guide

North Salem University

MISSION: *Engage students to continuously learn, question, define and solve problems through critical and creative thinking.*

Fall 2024

The living cell is a miniature chemical factory. Sugars are converted into energy and small molecules are synthesized into larger ones, which may be hydrolyzed later as the needs of the cell changes. Cells utilize the energy stored in ***organic*** *compounds (mainly sugars) to perform various types of work, such as the synthesis of the macromolecules studied in the last chapter. The concept of metabolism studied in this chapter will help you to further understand the connections between chemistry and biology. Although much of the material presented in this chapter is considered "prior knowledge" by the College Board, we will be spending some time in class going over the more "complex" topics as well as doing a few labs on enzymes.*

If you have any problems – feel free to drop me an email.

Chapter 6: *An Introduction to Metabolism*

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OBJECTIVES:

Metabolism, Energy, and Life

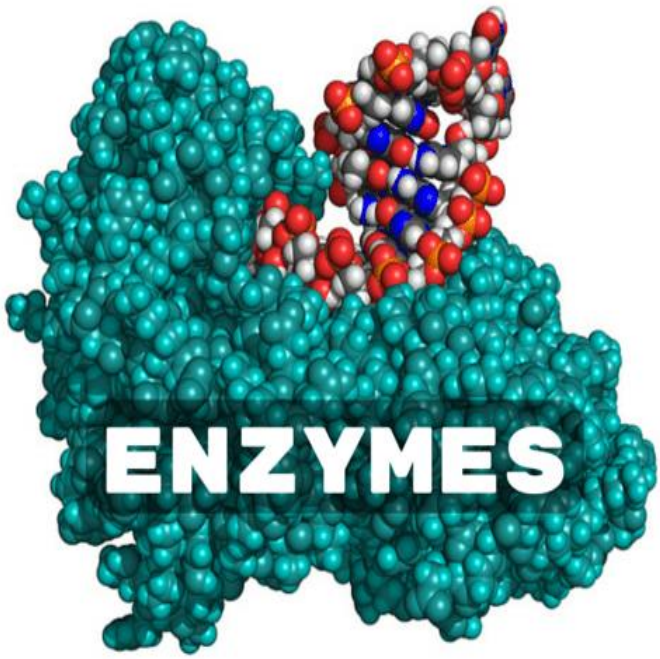
___1. Explain the role of catabolic and anabolic pathways in the energy exchanges of cellular metabolism.
___2. Distinguish between kinetic and potential energy.
___3. Explain, in your own words, the first and second laws of thermodynamics.
___4. Write and define each component of the equation for free-energy change.
___5. Distinguish between exergonic and endergonic reactions.
___6. Describe the structure and function of ATP in a cell.

Enzymes

___7. Describe the function of enzymes in biological systems.
___8. Explain the relationship between enzyme structure and enzyme specificity.
___9. Explain the induced-fit model of enzyme function and describe the catalytic cycle of an enzyme.
___10. Explain how substrate concentration, enzyme concentration, temperature and pH affects the rate of an enzyme-controlled reaction.
___11. Explain how enzyme activity can be regulated or controlled by environmental factors, co-factors, and enzyme inhibitors.

The Control of Metabolism

___12. Explain how metabolic pathways are regulated.
___13. Explain how the location of enzymes in a cell influences metabolism.



(ALL enzymes are proteins and most enzymes are tertiary in structure.)

KEY TERMS:

activation energy
active site
allosteric site
anabolic pathway
ATP (adenosine triphosphate)
bioenergetics
catabolic pathway
catalyst
chemical energy
competitive inhibitor
cooperativity
endergonic reaction
energy coupling
energy
entropy
exergonic reaction
feedback inhibition
first law of thermodynamics
free energy of activation
free energy
induced fit model
kinetic energy
metabolism
noncompetitive inhibitor
phosphorylated
potential energy
second law of thermodynamics
substrate
thermodynamics

- -

WORD ROOTS:

allo- = different (*allosteric site*: a specific receptor site on some part of an enzyme molecule remote from the active site)
ana- = up (*anabolic pathway*: a metabolic pathway that consumes energy to build complex molecules from simpler ones)
bio- = life (*bioenergetics*: the study of how organisms manage their energy resources)
cata- = down (*catabolic pathway*: a metabolic pathway that releases energy by breaking down complex molecules into simpler ones)
endo- = within (*endergonic reaction*: a reaction that absorbs free energy from its surroundings)
ex- = out (*exergonic reaction*: a reaction that proceeds with a net release of free energy)
kinet- = movement (*kinetic energy*: the energy of motion)
therm- = heat (*thermodynamics*: the study of the energy transformations that occur in a collection of matter)

Guided Reading: Chapter 6

1. Define **metabolism**.

2. There are two types of reactions in metabolic pathways: **anabolic** and **catabolic**.

a. Which reactions release energy? _____

b. Which reactions consume energy? _____

c. Which reactions build up larger molecules? _____

d. Which reactions break down molecules? _____

e. What type of reaction is photosynthesis? _____

f. What type of reaction is cellular respiration? _____

3. Define the following terms:

Energy -

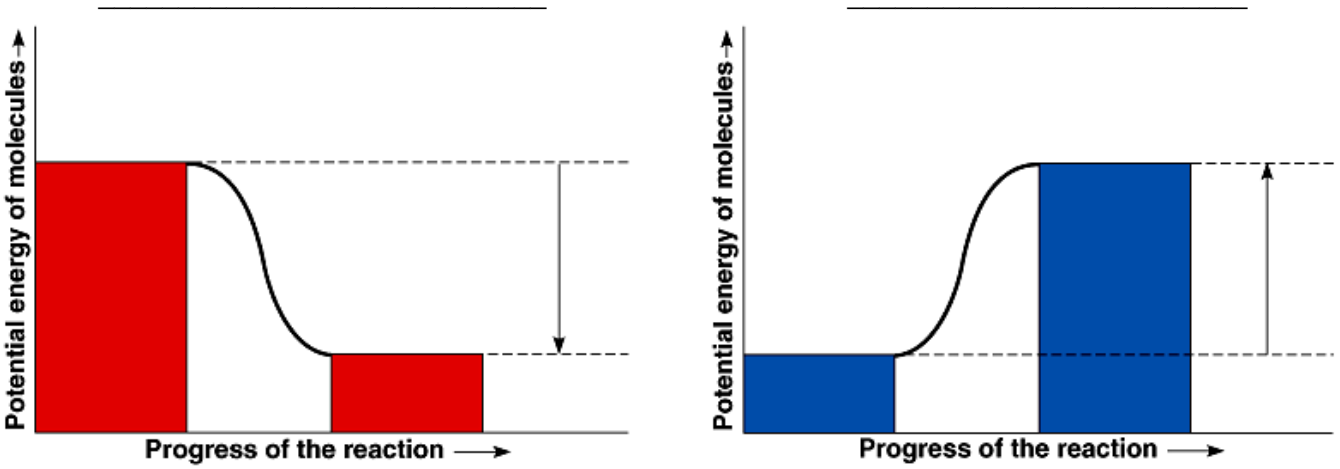
Kinetic Energy -

Potential Energy -

Thermodynamics -

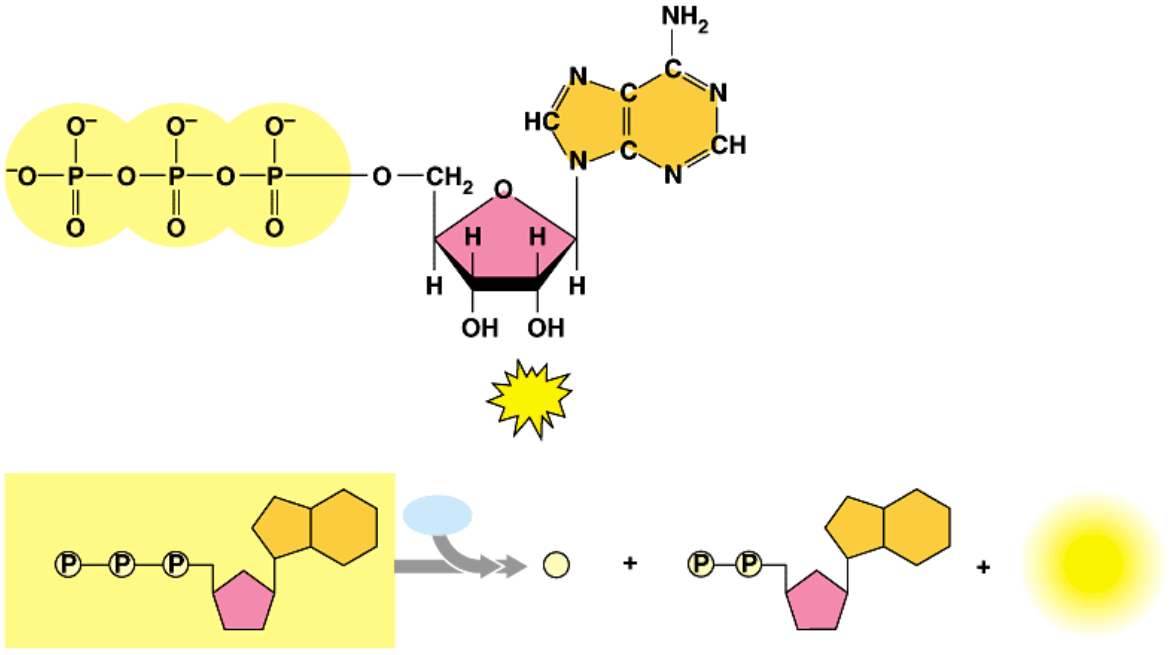
First Law of Thermodynamics -

4. Label the diagram below and use it to contrast **exergonic** and **endergonic** reactions in terms of free energy (G).



5. How do you know if a reaction is **spontaneous**?

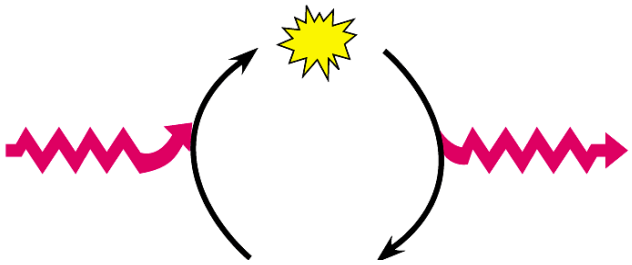
6. Label the structure of ATP below and indicate how cellular work is done by ATP.



7. In your own words, explain the concept of **coupled reactions** and ATP doing work.

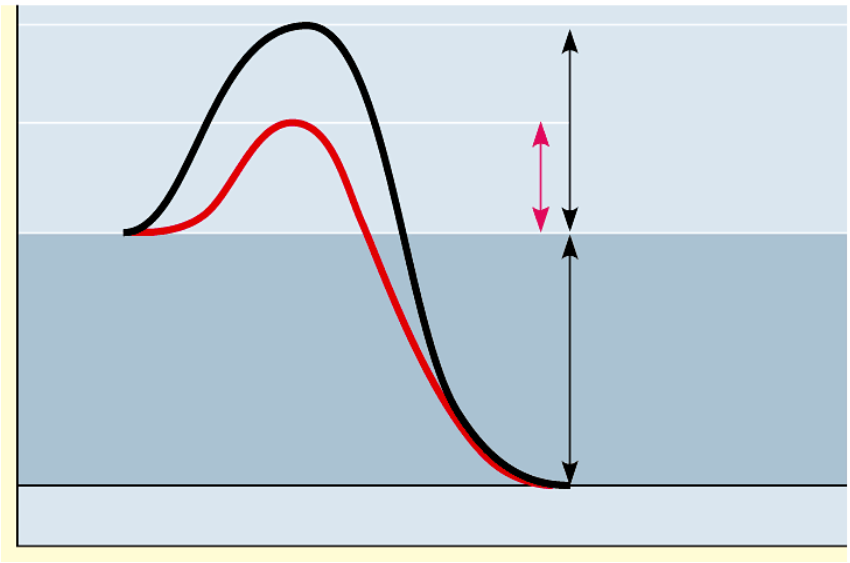
8. Define **phosphorylated**.

9. Label the diagram below and use it to describe the regeneration of ATP?



10. What is **activation energy**?

11. Label the diagram below and use it to explain how enzymes affect the **activation energy** of a chemical reaction.



12. Define the following terms:

Catalyst -

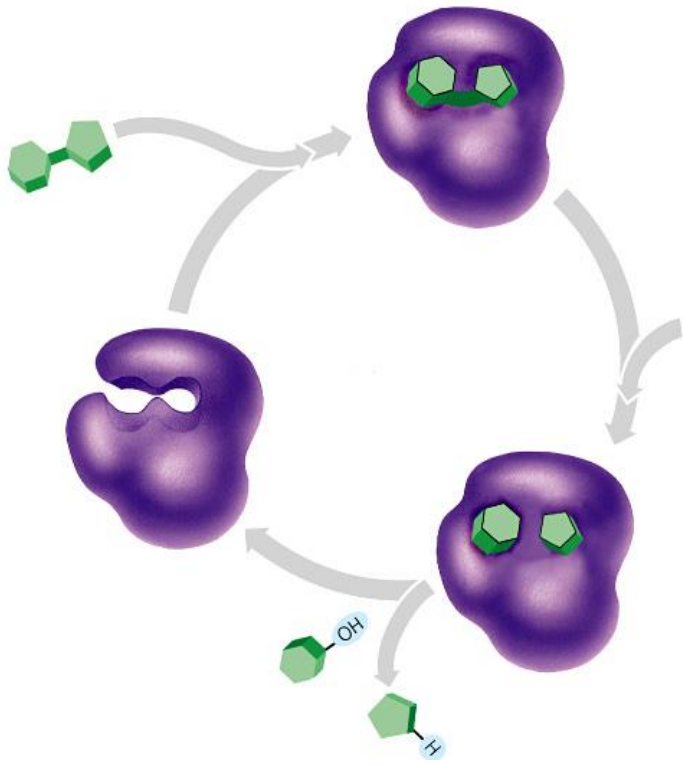
Substrate -

Enzyme Substrate Complex -

Active Site -

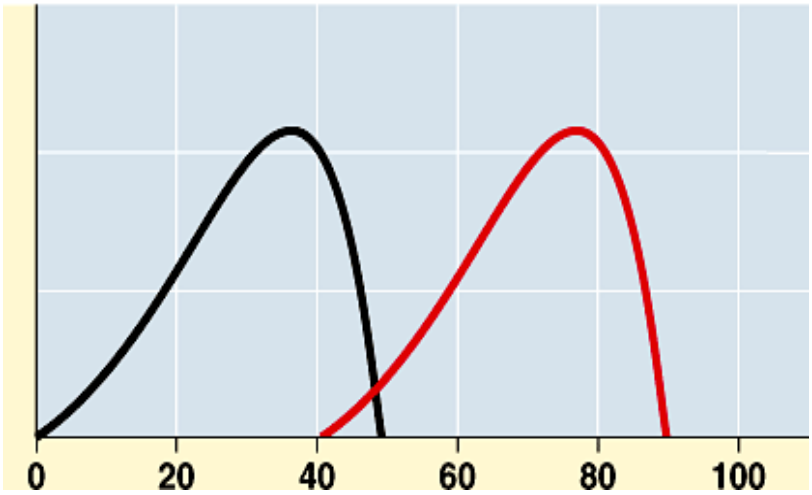
Induced Fit -

13. Label the following diagram and use it to describe the catalytic cycle of an enzyme.



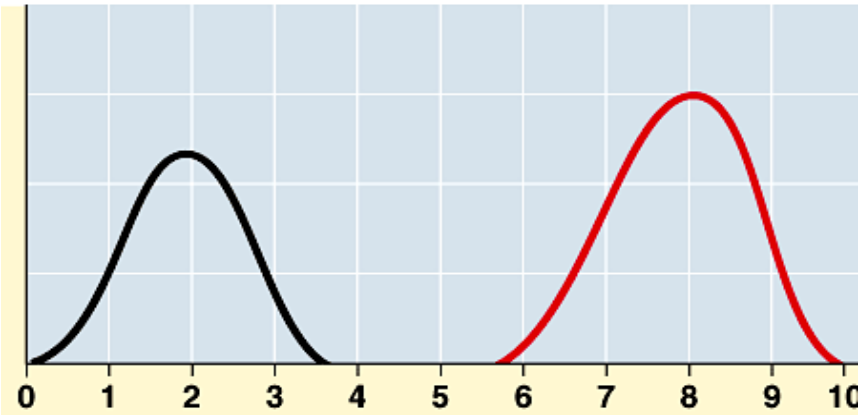
14. Label the graph below and use it to describe how SPECIFICALLY temperate affects enzyme activity?

Graph Title: _____



15. Label the graph below and use it to describe how pH SPECIFICALLY affects enzyme activity?

Graph Title: _____



16. Define the following terms:

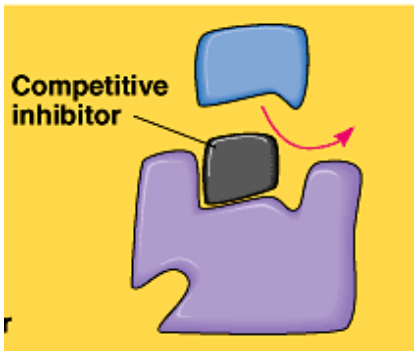
Cofactors –

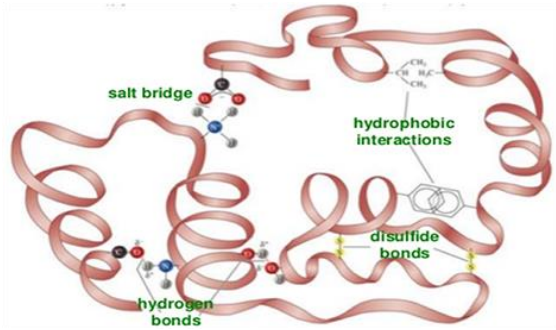
Coenzymes –

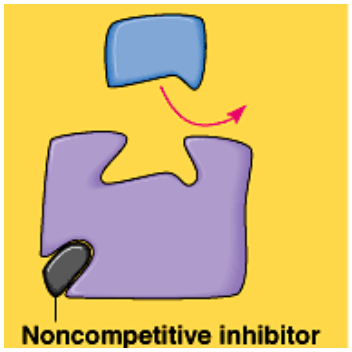
Allosteric Site -

17. Use the diagrams below to help you compare and contrast **competitive** and **noncompetitive inhibitors**.

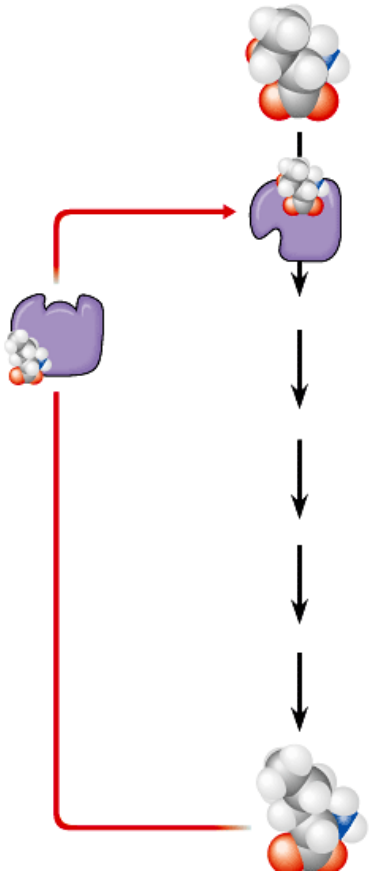
(Most enzymes are *TERTIARY* in structure)







18. Label the diagram to the right and use it to explain how **feedback inhibition** works?



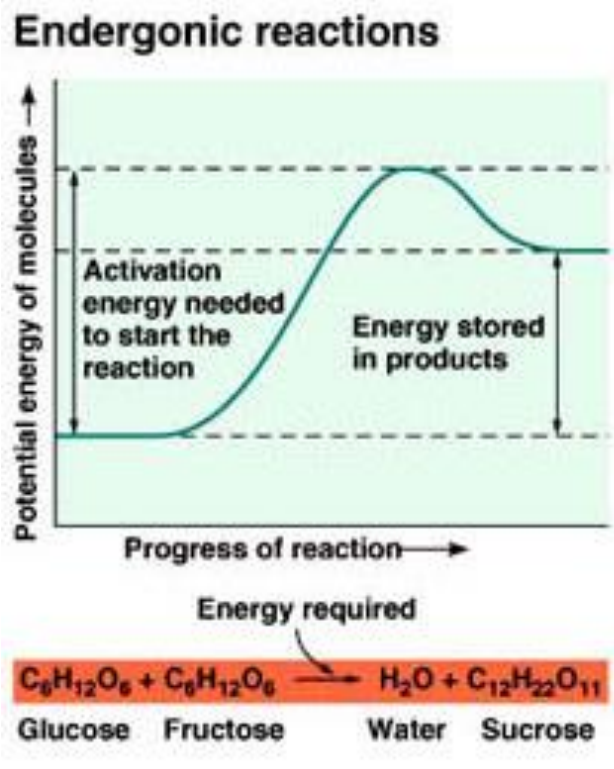
Chapter 6 – Summary of Key Concepts

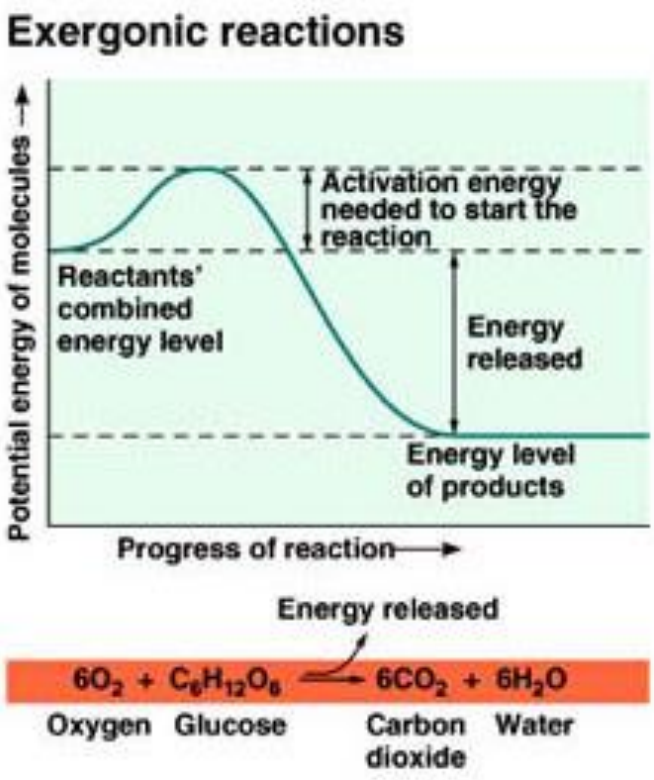
METABOLISM, ENERGY, AND LIFE

- The chemistry of life is organized into metabolic pathways (pp. 87-88) Metabolism is the collection of chemical reactions that occur in an organism. Aided by enzymes, it follows intersecting pathways, which may be catabolic (breaking down molecules, releasing energy) or anabolic (building molecules, consuming energy).
- Organisms transform energy (pp. 88-89) Energy is the capacity to do work by moving matter. A moving object has kinetic energy. Potential energy is stored in the location or structure of matter and includes chemical energy stored in molecular structure. Energy can change form, governed by the laws of thermodynamics.

Energy Transformations

- The energy transformations of life are subject to two laws of thermodynamics (pp. 89-90, FIGURE 6.3and 6.4) The first, conservation of energy, states that energy cannot be created or destroyed. The second states that when energy changes form, entropy (S), or the disorder of the universe, increases. Matter can become more ordered only if the surroundings become more disordered.
- Organisms live at the expense of free energy (pp. 91-94, FIGURE 6.5-6.7) A living system's free energy is energy that can do work under cellular conditions. Free energy (G) is related directly to total energy (H) and to entropy (S). Spontaneous changes involve a decrease in free energy ($-\Delta G$). In an exergonic (*spontaneous*) chemical reaction, the products have less free energy than the reactants ($-\Delta G$). Endergonic (*nonspontaneous*) reactions require an input of energy ($+\Delta G$). In cellular metabolism, exergonic reactions power endergonic reactions (*energy coupling*). The addition of starting materials and the removal of end products prevent metabolism from reaching equilibrium.





- ATP powers cellular work by coupling exergonic reactions to endergonic reactions (pp. 94-96, FIGURES 6.8-6.10) ATP is the cell's energy shuttle. Release of its terminal phosphate group produces ADP, inorganic phosphate, and free energy. ATP drives endergonic reactions by transfer of the phosphate to specific reactants, making them more reactive. In this way, cells can carry out work, such as movement and anabolism. Catabolic pathways drive the regeneration of ATP from ADP and phosphate.

ENZYMES

- Enzymes speed up metabolic reactions by lowering energy barriers (pp. 96-97, FIGURES 6.12 and 6.13) Enzymes, which are proteins, are biological catalysts. They speed up reactions by lowering activation energy (E_A), allowing bonds to break at moderate temperatures.
- Enzymes are substrate specific (pp. 97-98, FIGURE 6.14) Each type of enzyme has a unique active site that combines specifically with its substrate, the reactant molecule on which it acts. The enzyme changes shape slightly when it binds the substrate (induced fit).
- The active site is an enzyme's catalytic center (pp. 98-99, FIGURE 6.15) The active site can lower activation energy by orienting substrates correctly, straining their bonds, and providing a microenvironment that favors the reaction.
- A cell's physical and chemical environment affects enzyme activity (pp. 99-101, FIGURES 6.16and 6.17) As proteins, enzymes are sensitive to conditions that influence their three-dimensional structure. Each has an optimal temperature and pH. Cofactors are metal ions or molecules required for some enzymes to function. Coenzymes are organic cofactors. Inhibitors reduce enzyme function. A competitive inhibitor binds to the active site, while a noncompetitive inhibitor binds to a different site on the enzyme.

THE CONTROL OF METABOLISM

- Metabolic control often depends on allosteric regulation (pp. 101-102, FIGURES 6.18-6.20) Many enzymes change shape when regulatory molecules, either activators or inhibitors, bind to specific allosteric sites. In feedback inhibition, the end product of a metabolic pathway allosterically inhibits the enzyme for an earlier step in the pathway. In cooperativity, a substrate molecule binding to one active site of a multi-subunit enzyme activates the other subunits.
- The localization of enzymes within a cell helps order metabolism (pp. 102-103, FIGURE 6.21) Some enzymes are grouped into complexes, some are incorporated into membranes, and others are contained inside organelles.
- The theme of emergent properties is manifest in the chemistry of life: a review (p. 103). Higher levels of organization result in the emergence of new properties. Organization is the key to the chemistry of life.

Chapter 6 - Review Questions

___1. An atom gains energy when -
A) an electron is lost from it.
B) it undergoes reduction.
C) it undergoes oxidation.
D) it undergoes an oxidation-reduction reaction.

___2. Which of the following is concerned with the amount of energy in the universe?
A) the First Law of Thermodynamics
B) the Second Law of Thermodynamics.
C) thermodynamics
D) entropy

___3. In a chemical reaction, if ΔG is negative, it means that -
A) the products contain more free energy than the reactants.
B) an input of energy is required to break the bonds.
C) the reaction will proceed spontaneously.
D) the reaction is endergonic.

___4. A catalyst -
A) allows an endergonic reaction to proceed more quickly.
B) increases the activation energy so a reaction can proceed more quickly.
C) lowers the amount of energy needed for a reaction to proceed.
D) is require for an exergonic reaction to occur.

___5. Which of the following statements about enzymes is false?
A) Enzymes are catalysts within cells.
B) All the cells of an organism contain the same enzymes.
C) Enzymes brings substances together so they undergo a reaction.
D) Enzymes lower the activation energy of spontaneous reactions in the cell.

___6. Which of the following has no effect on the rate of enzyme-catalyzed reactions?
A) temperature B) pH C) concentration of substrate D) none of these

___7. How is ATP used in the cell to produce cellular energy?
A) ATP provides energy to drive exergonic reactions.
B) ATP hydrolysis is coupled to endergonic reactions.
C) A liberated phosphate group attaches to another molecule, which generates energy.
D) ATP generates energy by the repulsion of the negatively-charged phosphates.

___8. Anabolic reactions are reactions that -
A) break chemical bonds.
B) make chemical bonds.
C) harvest energy.
D) occur in a sequence.

___9. How is a biochemical pathway regulated?
A) The product of one reaction becomes the substrate for the next.
B) The end product replaces the initial substrate in the pathway.
C) The end product inhibits the first enzyme in the pathway by binding to an allosteric site.
D) All of these are correct.

___10. Coenzymes differ from enzymes in that coenzymes are -
A) only active outside the cell.
B) polymers of amino acids.
C) smaller, non-protein molecules, such as vitamins.
D) specific for one reaction.

___11. Which statement about thermodynamics is true?
A) Free energy is used up in an exergonic reaction.
B) Free energy can be kinetic but not potential energy.
C) Free energy cannot be used to do work.
D) The total amount of energy remains the same.

___12. Which statement about enzymes is not true?
A) They usually consist of proteins.
B) They change the rate of the catalyzed reaction.
C) They change the G of the reaction.
D) They are sensitive to heat and pH.

___13. The active site of an enzyme -
A) never changes shape.
B) forms no chemical bonds with substrates.
C) determines, by its structure, the specificity of the enzyme.
D) looks like a lump projecting from the surface of the enzyme.

___14. The molecule ATP is -
A) a component of most proteins.
B) high in energy because of the presence of adenine.
C) required for many energy-producing biochemical reactions.
D) used in some endergonic reactions to provide energy.

___15. In an enzyme-catalyzed reaction, -
A) a substrate does not change.
B) the rate decreases as substrate concentration increases.
C) the enzyme temporarily changes shape to better fit the substrate.
D) the rate is not affected by substrate concentration.

___16. Which statement about temperature effects on enzyme activity is not true?
A) Raising the temperature may increase the activity of an enzyme.
B) Raising the temperature may denature an enzyme.
C) Some enzymes are stable at the boiling point of water.
D) All enzymes have the same optimal temperature.

___17. According to the first law of thermodynamics, -
A) matter can be neither created nor destroyed.
B) all processes increase the order of the universe.
C) energy is conserved in all processes.
D) systems rich in energy are intrinsically stable.

___18. If an enzyme solution is saturated with substrate, the most effective way to obtain an even faster yield of products is to -
A) cool the solution.
B) heat the solution.
C) add more enzyme.
D) add a noncompetitive inhibitor.

___19. An enzyme accelerates a metabolic reaction by -
A) altering the overall free-energy change for the reaction.
B) making an endergonic reaction occur spontaneously.
C) lowering the activation energy.
D) making the substrate molecule more stable.

___20. Some bacteria are metabolically active in hot springs because -
A) they are able to maintain an internal temperature much cooler than that of the surrounding water.
B) the high temperatures facilitate active metabolism without the need of catalysis.
C) their enzymes have high optimal temperatures.
D) their enzymes are insensitive to temperature.