Chapter 8: An Introduction to Metabolism

8.1 Identify the first two laws of thermodynamics and explain how they relate to biological systems.

8.2 Explain what is meant by change in free energy and relate it to the following: spontaneous reactions, capacity to do work, stability, and exergonic and endergonic reactions.

8.3 Use examples to illustrate the coupling of ATP hydrolysis to endergonic reactions.

8.4 Explain how enzymes speed up metabolic reactions.

8.5 Describe how regulation of enzyme activity helps control metabolism.

This chapter on energy transfer and enzyme function is fundamental to your understanding of numerous topics discussed later in the course. Your careful study of this chapter will help you understand biological pathways and the regulation of cellular processes.

Study Tip: As you read this chapter, consider which processes described release energy and which ones require an input of energy.

Concept 8.1 An organism's metabolism transforms matter and energy

LO 8.1: Identify the first two laws of thermodynamics and explain how they relate to biological systems.

The totality of an organism's chemical reactions is called *metabolism*. As a whole, metabolism manages the material and energy resources of the cell in intersecting pathways.

1. 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. Which reactions are considered "uphill"?

_____ f. Which type of reaction is photosynthesis?

_____ g. Which type of reaction is cellular respiration?

_____ h. In living systems which reactions require enzymes to catalyze them?

2. *Energy* is the capacity to cause change, do work, or move matter against opposing forces. It exists in various forms. Contrast *kinetic energy* with *potential energy*.

3. Which type of energy does water behind a dam have? A mole of glucose?

4. According to the first law of thermodynamics, what can and cannot happen to energy?

5. The second law of thermodynamics states that every energy transfer or transformation increases the entropy (molecular disorder) of the universe. Some call this the "you always lose rule". What always happens in each energy transfer that makes this an apt expression?

6. What is meant by a *spontaneous process*?

Concept 8.2 The free-energy change of a reaction tells us whether or not the reaction occurs spontaneously

LO 8.2: Explain what is meant by change in free energy and relate it to the following: spontaneous reactions, capacity to do work, stability, and exergonic and endergonic reactions.

7. What is *free energy*? What is its symbol?

8. Once we know the value of ΔG for a reaction we can use it to predict whether it will be spontaneous. For an exergonic reaction, is ΔG negative or positive?

9. Is cellular respiration an *endergonic* or an *exergonic* reaction? What is ΔG for this reaction?

10. Is photosynthesis endergonic or exergonic? What is the energy source that drives it?

11. To summarize, if energy is released, ΔG must be positive/negative. (Circle your choice.)

12. Study Figure 8.7 in your textbook. Explain why the light bulb goes off when the system is at equilibrium.

Concept 8.3 ATP powers cellular work by coupling exergonic reactions to endergonic reactions

LO 8.3: Use examples to illustrate the coupling of ATP hydrolysis to endergonic reactions.

13. List the three main kinds of work that a cell does. Give an example of each.

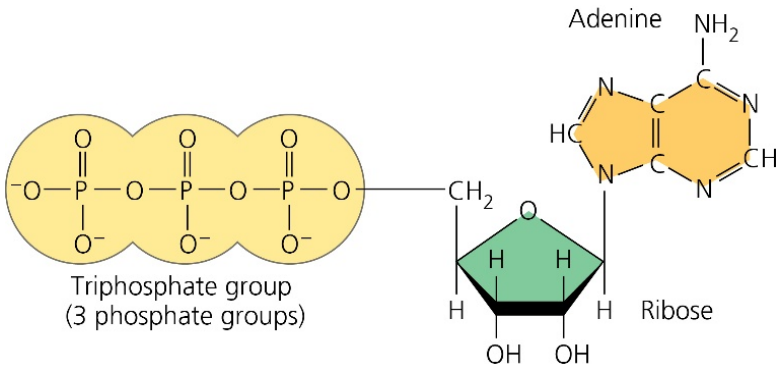
    a.

    b.

    c.

14. What is *energy coupling*?

15. Here is a molecule of ATP. Label it. Use an *arrow* to show which bond is likely to break.



a. By what process will that bond break?

b. Explain the name *ATP* by listing all the molecules that make it up.

16. When the terminal phosphate bond is broken, a molecule of inorganic phosphate P_i is formed, and energy is _____.

a. For this reaction: ATP → ADP + P_i, ΔG = _____

b. Is this reaction endergonic or exergonic? _____

17. In many cellular reactions, a phosphate group is transferred from ATP to some other molecule in order to make the second molecule less stable. What term is now used to describe the second molecule?

18. Look for this amazing bit of trivia on p. 151 in your text: If you could not regenerate ATP by phosphorylating ADP, how much ATP would you need to consume each day?

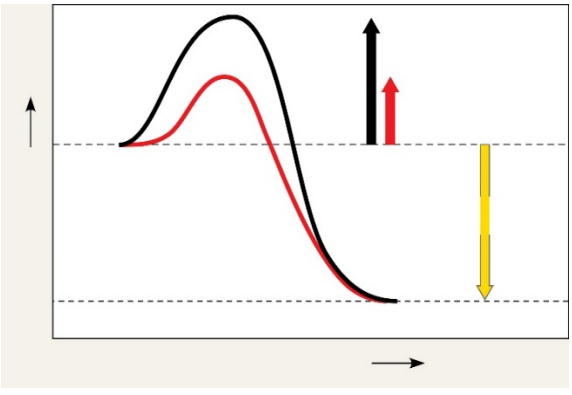
Concept 8.4 Enzymes speed up metabolic reactions by lowering energy barriers

LO 8.4: Explain how enzymes speed up metabolic reactions.

19. What is a *catalyst*?

20. What is *activation energy* (E_A)?

21. Label the *x*-axis of this graph "Progress of the Reaction" and the *y*-axis "Free Energy." Label E_A on this sketch, both with and without an enzyme.



a. What effect does an enzyme have on E_A?

b. Label ΔG. Is it positive or negative?

c. How is ΔG affected by the enzyme?

Use Figure 8.16, shown below, to answer questions 22 and 23.

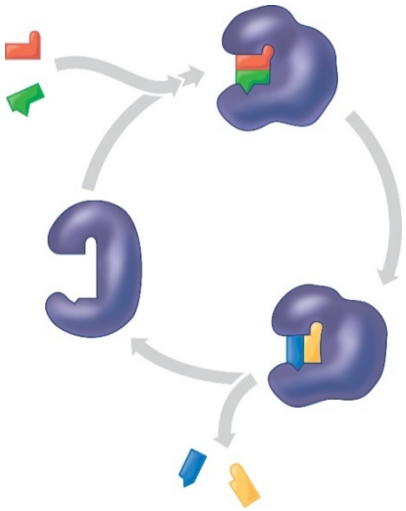
22. Define these terms and then use them to label the following figure.

enzyme

substrate

active site

products



23. Number and describe the six steps of enzyme action shown on the figure above.

24. What is meant by *induced fit*? How is it shown in the figure in question 22?

25. Explain how protein structure is involved in enzyme specificity.

26. Enzymes use a variety of mechanisms to lower activation energy. Describe four of these mechanisms.

27. Many factors can affect the rate of enzyme action. Explain the effects of each factor listed here.

    a. initial concentration of substrate

    b. pH

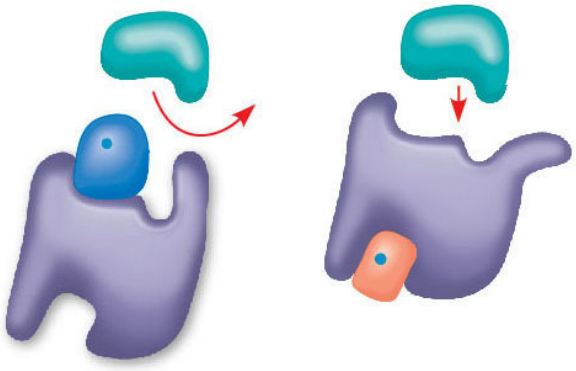
    c. temperature

28. Recall that enzymes are globular proteins. Why can extremes of pH or very high temperatures affect enzyme activity?

29. Name a human enzyme that functions well in pH 2. Where is it found?

30. Distinguish between *cofactors* and *coenzymes*. Give examples of each.

31. Compare and contrast *competitive inhibitors* and *noncompetitive inhibitors*. Label each type of inhibitor in this figure.



32. Many toxins and poisons cause irreversible enzyme inhibition. Select one example and explain why it is so deadly.

Concept 8.5 Regulation of enzyme activity helps control metabolism

LO 8.5: Describe how regulation of enzyme activity helps control metabolism.

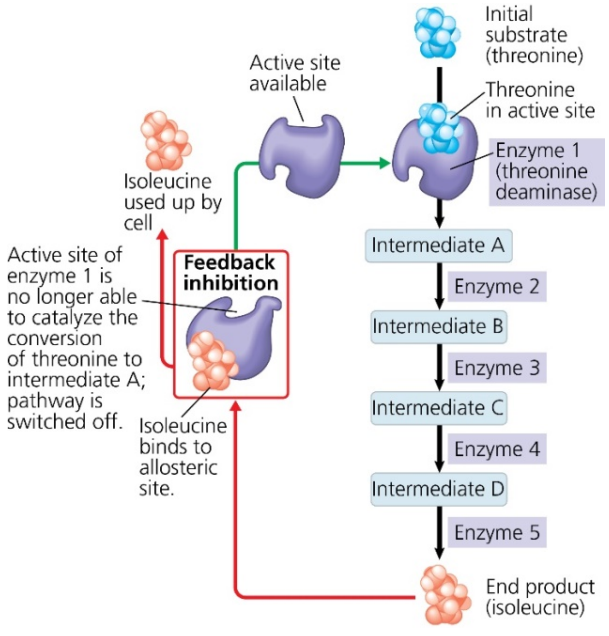
33. What is *allosteric regulation*?

34. How is allosteric regulation somewhat like noncompetitive inhibition? How might it be different?

35. Explain the difference between an allosteric activator and an allosteric inhibitor.

36. Although it is not an enzyme, hemoglobin shows *cooperativity* in binding O_2. Use O_2 binding in fish hemoglobin to explain cooperativity.

37. Study this figure from your book (Figure 8.21) and answer the questions that follow.



a. What is the substrate molecule that initiates this metabolic pathway? _____

b. What is the inhibitor molecule _____

c. What type of inhibitor is it? _____

d. When does it have the most significant regulatory effect? _____

e. What is this type of metabolic control called? _____

Test Your Understanding, p. 163

Now you should be ready to test your knowledge. Place your answers here:

1. _____ 2. _____ 3. _____ 4. _____ 5. _____ 6. _____