

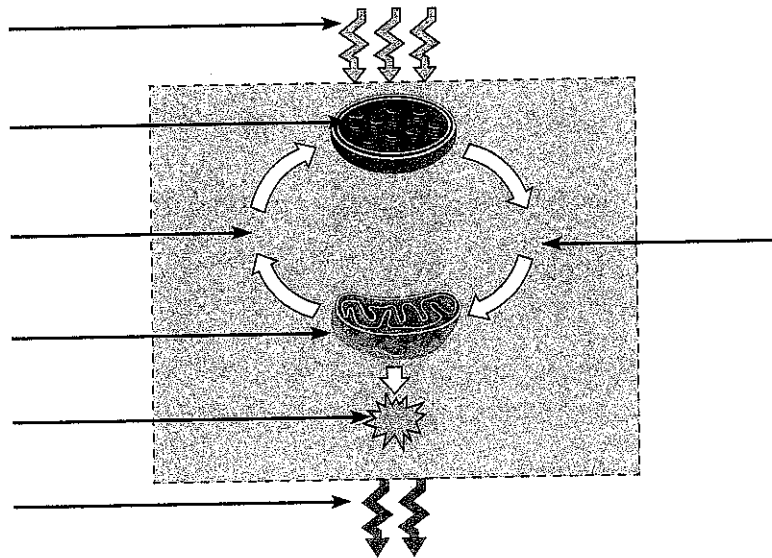
Name _____ Period _____

Chapter 9: Cellular Respiration and Fermentation

Although this is a challenging topic, it will give you the background necessary to understand much about energy transfer at the cellular level. Take your time as you work through the figures, and you will find you have mastered a very difficult area of biology when you finish. This chapter addresses much of EK 2.A.1.

Overview

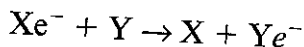
Before getting involved with the details of cellular respiration and photosynthesis, take a second to look at the big picture. Photosynthesis and cellular respiration are key ecological concepts involved with energy flow. Use Figure 9.2 from your text to label the missing parts in the following figure.



Concept 9.1 Catabolic pathways yield energy by oxidizing organic fuels

1. Explain the difference between *fermentation* and *aerobic respiration*.
2. Give the formula (with names) for the catabolic degradation of glucose by cellular respiration.
3. Both cellular respiration and photosynthesis are *redox reactions*. In redox reactions, pay attention to the flow of electrons. What is the difference between oxidation and reduction?

4. The following is a generalized formula for a redox reaction:



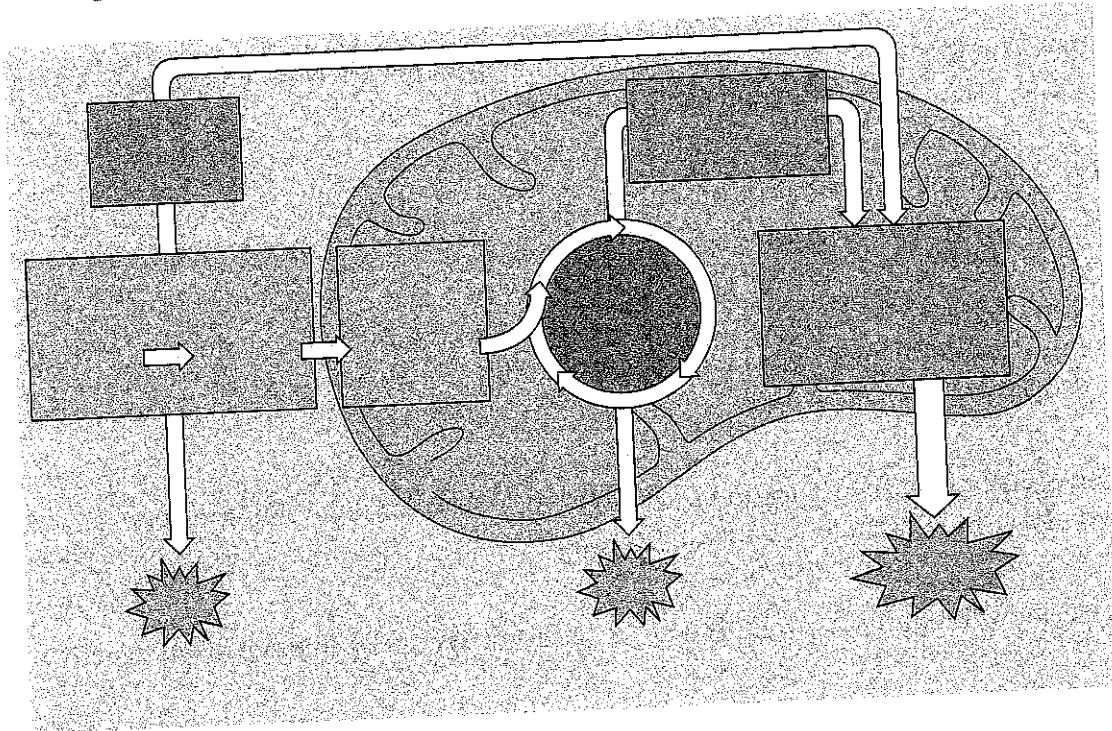
Draw an arrow showing which component (X or Y) is oxidized and which is reduced. _____ is the reducing agent in this reaction, and _____ is the oxidizing agent.

5. When compounds lose electrons, they _____ energy; when compounds gain electrons, they _____ energy.
6. In cellular respiration, electrons are not transferred directly from glucose to oxygen. Following the movement of hydrogens allows you to follow the flow of electrons. What *electron carrier* is hydrogen transferred to first?
7. The correct answer to question 6 is *NAD⁺*. It is a coenzyme. What are coenzymes? (If you have forgotten, look at page 156 in Chapter 8.)
8. Describe what happens when *NAD⁺* is reduced. What enzyme type is involved?
9. It is essential for you to understand the concept of oxidation/reduction and energy transfer. For the following pair, which molecule is the oxidized form, and which is reduced? Which molecule holds higher potential energy? Which is lower in potential energy?

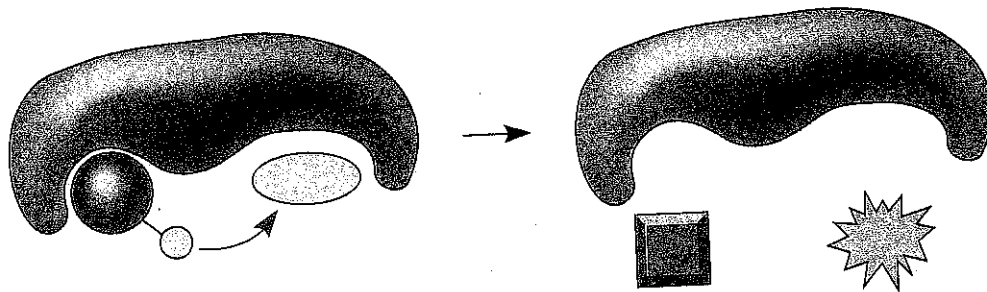
	Oxidized or Reduced?	Higher Energy/Lower Energy
NAD ⁺		
NADH		

10. What is the function of the *electron transport chain* in cellular respiration?
11. Electron transport involves a series of electron carriers.
Where are these found in eukaryotic cells? _____
Where are these found in respiring prokaryotic cells?? _____
12. What strongly electronegative atom, pulling electrons down the electron transport chain, is the final electron acceptor?

13. Understanding the overall map of how cellular respiration works will make the details easier to learn. Use Figure 9.6 from your text to label the missing information in the following figure.



14. Three types of *phosphorylation* (adding a phosphate) are covered in the text, and two of these occur in cellular respiration. Explain how the electron transport chain is utilized in *oxidative phosphorylation*.
15. The second form of phosphorylation is *substrate level*. Label the following figure to show the direct transfer of a phosphate from an organic substrate to ADP to form ATP.

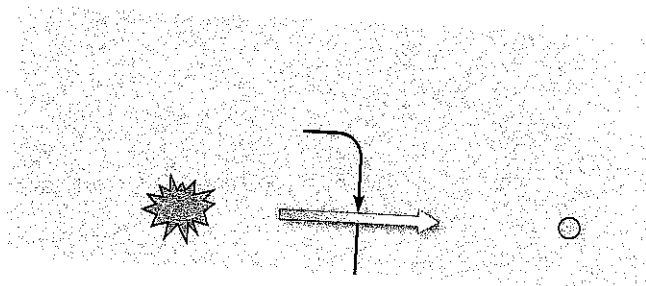


Concept 9.2 Glycolysis harvests chemical energy by oxidizing glucose to pyruvate

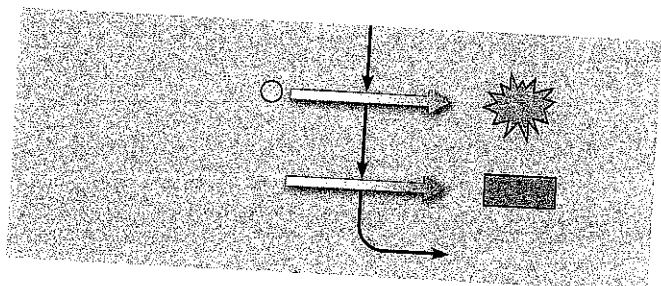
16. What is the meaning of *glycolysis*? What occurs in this step of cellular respiration?
17. The starting product of glycolysis is the six-carbon sugar _____, and the ending products are two _____-carbon molecules of _____.

The 10 individual steps of glycolysis can be divided into two stages: *energy investment* and *energy payoff*. These steps are shown in Figure 9.9 of the main text, which details the enzymes and reactions at each of the 10 steps. Although you are not expected to memorize these steps, structures, or enzymes, you *should* understand the figure. The next few questions will help you focus your study.

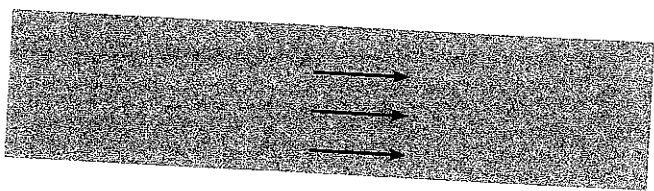
18. The following figures show a summary of glycolysis. Label the *energy investment phase* below and complete the figure. Then turn to Figure 9.9 on page 168 of your text to find the two specific steps where ATP is used.



19. The second phase in glycolysis is the *energy payoff phase*. Label this phase and complete the figure. Note that it provides both ATP and NADH. Look at Figure 9.9 from your text to locate the two steps where ATP is formed and the one step where NADH is formed.



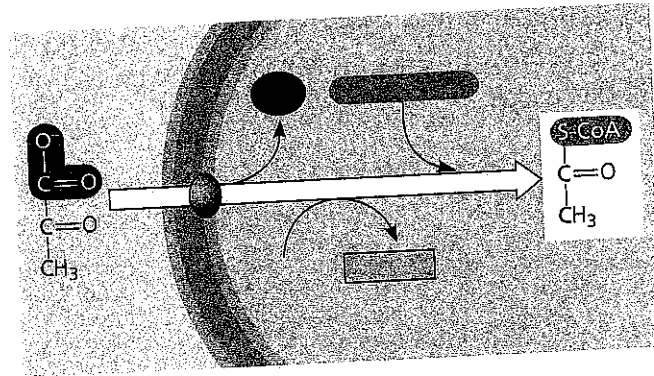
20. This final figure shows the net gain of energy for the cell after glycolysis. Most of the energy is still present in the two molecules of pyruvate. Complete the following figure to show the net energy gains.



21. Where does glycolysis occur in the cell? Is oxygen required?

Concept 9.3 After pyruvate is oxidized, the citric acid cycle completes the energy-yielding oxidation of organic molecules

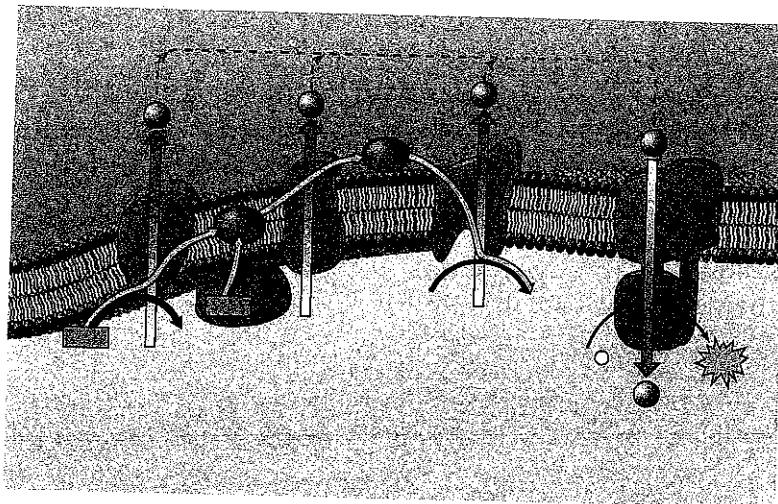
22. To enter the citric acid cycle, pyruvate must enter the mitochondria by active transport. Three things are necessary to convert pyruvate to acetyl CoA. Complete the missing parts of the following figure and then explain the three steps in the conversion process.



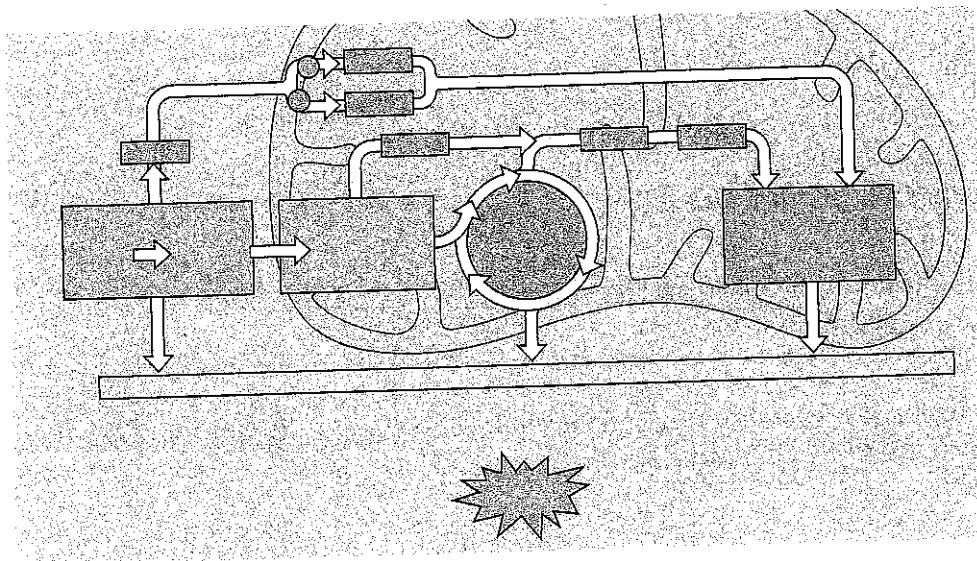
- a.
b.
c.
23. Use Figure 9.11 from your text to help you answer the following summary questions about the citric acid cycle:
- How many NADHs are formed?
 - How many total carbons are lost as pyruvate is oxidized?
 - The carbons are lost in which molecule?
 - How many FADH_2 are formed?
 - How many ATPs are formed?
 - How many times does the citric acid cycle occur for each molecule of glucose?
24. The step that converts pyruvate to acetyl CoA at the top of the diagram occurs twice per glucose. This oxidation of pyruvate accounts for two additional reduced _____ molecules and two molecules of CO_2 .
25. Explain what has happened to each of the six carbons found in the original glucose molecule.

Concept 9.4 During oxidative phosphorylation, chemiosmosis couples electron transport to ATP synthesis

26. Oxidative phosphorylation involves two components: the electron transport chain and ATP synthesis. Referring to Figure 9.13 in your text, notice that each member of the electron transport chain is lower in free _____ than the preceding member of the chain, but higher in _____. The molecule at zero free energy on this chart, which is _____, is the lowest of all the molecules in free energy and the highest in electronegativity.
27. Explain why oxygen is considered the ultimate electron acceptor.
28. Oxygen stabilizes the electrons by combining with two hydrogen ions to form what compound?
29. What are the two electron carrier molecules that feed electrons into the electron transport system?
30. Using Figure 9.14 in your text, explain the overall concept of how *ATP synthase* uses the flow of hydrogen ions to produce ATP.
31. What is the role of the electron transport chain in forming the H^+ gradient across the inner mitochondrial membrane?
32. Two key terms are *chemiosmosis* and *proton-motive force*. Relate both of these terms to the process of oxidative phosphorylation.
33. Figure 9.15 in your text will help you understand the production of ATP in the mitochondria. Label the figure to study this process. Then, use one color to trace the flow of electrons and another color to show the flow of protons.



34. At this point, you should be able to account for the total number of ATPs that could be formed from a glucose molecule. To accomplish this, we have to add the ATPs formed by substrate-level phosphorylation in glycolysis and the citric acid cycle to the ATPs formed by chemiosmosis. Each NADH can form a maximum of _____ ATP molecules. Each FADH₂, which donates electrons that activate only two proton pumps, makes _____ ATP molecules.
35. Label this figure to show the processes of cellular respiration. Then, show the production of NADH and FADH₂. Finally, show where ATP is formed, and indicate whether it is by substrate-level or oxidative phosphorylation. Use the text to be sure you understand how each subtotal on the bar below the figure is reached.

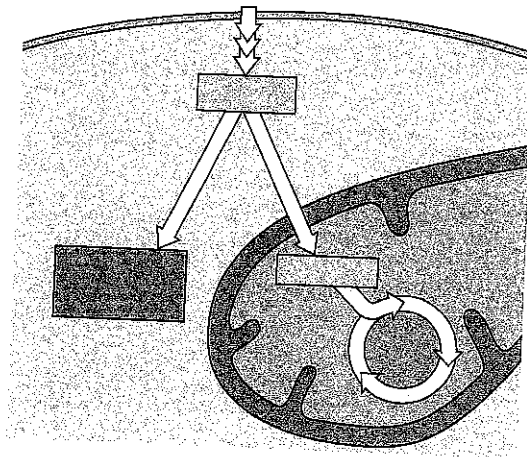


36. Why is the total count *about* 30 or 32 ATP molecules rather than a specific number?

Concept 9.5 Fermentation and anaerobic respiration enable cells to produce ATP without the use of oxygen

37. Fermentation allows for the production of ATP without using either _____ or any _____.
38. For aerobic respiration to continue, the cell must be supplied with oxygen—the ultimate electron acceptor. What is the electron acceptor in fermentation?

39. *Alcohol fermentation* starts with glucose and yields ethanol. Explain this process, and be sure to describe how NAD^+ is recycled.
40. *Lactic acid fermentation* starts with glucose and yields lactate. Explain this process, and be sure to describe how NAD^+ is recycled.
41. Label the following figure and then explain why pyruvate is a key juncture in metabolism.



42. Glycolysis is thought to have evolved very early in the evolution of life on Earth. Provide three pieces of evidence that justify this hypothesis.

Concept 9.6 Glycolysis and the citric acid cycle connect to many other metabolic pathways

43. What three organic macromolecules are often utilized to make ATP by cellular respiration?
44. Explain the difference in energy usage between the catabolic reactions of cellular respiration and the anabolic pathways of biosynthesis.

45. Study Figure 9.20 in your text. Explain how AMP stimulates cellular respiration, whereas citrate and ATP inhibit it.
46. *Phosphofructokinase* is an allosteric enzyme that catalyzes an important step in glycolysis. Explain how this step is a control point in cellular respiration.

Test Your Understanding Answers

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

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