Cellular Respiration

Section 9–1 Chemical Pathways (pages 221–225)
This section explains what cellular respiration is. It also describes what happens during a process called glycolysis and describes two types of a process called fermentation.

Chemical Energy and Food (page 221)
1. What is a calorie? **It is the amount of energy needed to raise the temperature of 1 gram of water 1 Celsius degree.**
2. How many calories make up 1 Calorie? **1000**
3. Cellular respiration begins with a pathway called **glycolysis**.
4. Is the following sentence true or false? Glycolysis releases a great amount of energy. **false**

Overview of Cellular Respiration (page 222)
5. What is cellular respiration? **It is the process that releases energy by breaking down food molecules in the presence of oxygen.**
6. What is the equation for cellular respiration, using chemical formulas? **6O_2 + C_6H_{12}O_6 → 6CO_2 + 6H_2O + Energy**
7. What would be the problem if cellular respiration took place in just one step? **All the energy from glucose would be released at once, and most of it would be lost in the form of light and heat.**
8. Label the three main stages of cellular respiration on the illustration of the complete process.
9. Where does glycolysis take place? **It takes place in the cytoplasm.**

10. Where do the Krebs cycle and electron transport take place? **They take place inside the mitochondria.**

**Glycolysis (page 223)**

11. What is glycolysis? **It is the process in which one molecule of glucose is broken in half, producing two molecules of pyruvic acid, a 3-carbon compound.**

12. How does the cell get glycolysis going? **It uses the energy of 2 molecules of ATP.**

13. If the cell uses 2 ATP molecules at the beginning of glycolysis, how does it end up with a net gain of 2 ATP molecules? **When glycolysis is complete, 4 ATP molecules have been produced.**

14. What is NAD⁺? **It is the electron carrier nicotinamide adenine dinucleotide.**

15. What is the function of NAD⁺ in glycolysis? **One of the reactions of glycolysis removes 4 high-energy electrons and passes them to NAD⁺, which becomes NADH and holds the electrons until they can be transferred to other molecules.**

16. Why can glycolysis supply energy to cells when oxygen is not available? **It does not require oxygen.**

17. What problem does a cell have when it generates large amounts of ATP from glycolysis? **In just a few seconds, all of the cell’s available NAD+ are filled with electrons.**

**Fermentation (pages 224–225)**

18. What is fermentation? **It is a process in which cells convert NADH to NAD⁺ by passing high-energy electrons back to pyruvic acid.**

19. How does fermentation allow glycolysis to continue? **Fermentation produces a steady supply of ATP.**

20. Because fermentation does not require oxygen, it is said to be **anaerobic.**

21. What are the two main types of fermentation?
   a. **Alcoholic fermentation**
   b. **Lactic acid fermentation**
22. What organisms use alcoholic fermentation? Yeasts and a few other microorganisms use it.

23. What is the equation for alcoholic fermentation after glycolysis?  
   \[ \text{Pyruvic acid} + \text{NADH} \rightarrow \text{alcohol} + \text{CO}_2 + \text{NAD}^+ \]

24. What happens to the small amount of alcohol produced in alcoholic fermentation during the baking of bread? It evaporates.

25. What does lactic acid fermentation convert into lactic acid? Glucose

26. What is the equation for lactic acid fermentation after glycolysis?  
   \[ \text{Pyruvic acid} + \text{NADH} \rightarrow \text{lactic acid} + \text{NAD}^+ \]

27. During rapid exercise, how do your muscle cells produce ATP? After they use up the ATP produced from cellular respiration, they produce it by lactic acid fermentation.

Reading Skill Practice

When you read about complex topics, writing an outline can help you organize and understand the material. Outline Section 9–1 by using the headings and subheadings as topics and subtopics and then writing the most important details under each topic. Do your work on a separate sheet of paper.

Students’ outlines should have four major topics, matching the four blue headings of the section. Details include highlighted vocabulary terms as well as the important concepts discussed under each heading.

Section 9–2 The Krebs Cycle and Electron Transport (pages 226–232)

This section describes what happens during the second stage of cellular respiration, called the Krebs cycle. It also explains how high-energy electrons are used during the third stage, called electron transport.

Introduction (page 226)

1. At the end of glycolysis, how much of the chemical energy in glucose is still unused? About 90 percent

2. Because the final stages of cellular respiration require oxygen, they are said to be aerobic.

The Krebs Cycle (pages 226–227)

3. In the presence of oxygen, how is the pyruvic acid produced in glycolysis used? It passes to the second stage of cellular respiration, the Krebs cycle.

4. What happens to pyruvic acid during the Krebs cycle? It is broken down into carbon dioxide in a series of energy-extracting reactions.
5. Why is the Krebs cycle also known as the citric acid cycle? **Citric acid is the first compound formed in this series of reactions.**

6. When does the Krebs cycle begin? **It begins when pyruvic acid produced by glycolysis enters the mitochondrion.**

7. What happens to each of the 3 carbon atoms in pyruvic acid when it is broken down? **One carbon atom becomes part of a molecule of carbon dioxide. Two of the carbon atoms are joined to a compound called coenzyme A to form acetyl-CoA.**

8. What happens to the carbon dioxide produced in breaking down pyruvic acid? **It is released into the air.**

9. How is citric acid produced? **Acetyl-CoA adds the 2-carbon acetyl group to a 4-carbon molecule, producing a 6-carbon molecule called acetic acid.**

10. During the energy extraction part of the Krebs cycle, how many molecules of CO₂ are released? **2**

11. What is the energy tally from 1 molecule of pyruvic acid during the Krebs cycle? **It is 4 NADH molecules, 1 FADH₂ molecule, and 1 molecule of ATP.**

12. When electrons join NAD⁺ and FAD during the Krebs cycle, what do they form? **They form NADH and FADH₂.**

13. Why is the 4-carbon compound generated in the breakdown of citric acid the only permanent compound in the Krebs cycle? **It is regenerated at the end of each complete turn of the cycle.**

**Electron Transport (pages 228–229)**

14. What is the electron transport chain? **It is a series of proteins in the inner membrane of mitochondria.**

15. What does the electron transport chain use the high-energy electrons from the Krebs cycle for? **The chain uses the electrons to convert ADP into ATP.**

16. How does the location of the electron transport chain differ in eukaryotes and prokaryotes? **In eukaryotes, the chain is composed of a series of proteins that is located in the inner membrane of the mitochondrion. In prokaryotes, the chain is in the cell membrane.**
Chapter 9, Cellular Respiration (continued)

17. Where does the electron transport chain get the high-energy electrons that are passed down the chain? It gets the electrons from NADH and FADH₂, which are produced in the Krebs cycle.

18. Is the following sentence true or false? Hydrogen serves as the final electron acceptor of the electron transport chain. ______________ false

19. What is the energy of the high-energy electrons used for every time 2 high-energy electrons move down the electron transport chain? Their energy is used to transport hydrogen ions across the membrane.

20. What causes the H⁺ ions in the intermembrane space to move through the channels in the membrane and out into the matrix? During electron transport, H⁺ ions build up in the intermembrane space, making it positively charged. The other side of the membrane, from which those H⁺ ions have been taken, is now negatively charged. The charge differences that build up cause the ions to move.

21. On average, how many ATP molecules are produced as each pair of high-energy electrons moves down the electron transport chain? 3 ATP molecules

22. Complete the flowchart about electron transport.

| High-energy electrons from NADH and FADH₂ are passed into and along the electron transport chain. |
| The energy from the electrons moving down the chain is used to move H⁺ ions across the inner membrane. |
| H⁺ ions build up in the intermembrane space, making it positively charged and making the matrix negatively charged. |
| H⁺ ions move through channels of ATP synthase in the inner membrane. |
| The ATP synthase uses the energy from the moving ions to combine ADP and phosphate, forming high-energy ATP. |
The Totals (page 229)

23. What is the total number of ATP molecules formed during cellular respiration? 36

24. Why can 18 times as much ATP be generated from glucose in the presence of oxygen than when oxygen is not available? When oxygen is not available, the Krebs cycle and electron transport cannot proceed, and glycolysis produces just 2 ATP molecules per glucose molecule. Under aerobic conditions, the Krebs cycle and electron transport enable the cell to produce 34 more ATP molecules per glucose molecule.

25. What happens to the 62 percent of the total energy of glucose that is not used to make ATP molecules? It is released as heat.

26. What are the final waste products of cellular respiration? Water and carbon dioxide

Energy and Exercise (pages 230–231)

27. What are the three sources of ATP a human body uses at the beginning of a race? The three sources are ATP already in the muscles and new ATP made by lactic acid fermentation and cellular respiration.

28. When a runner needs quick energy for a short race, what source can supply enough ATP for about 90 seconds? Lactic acid fermentation

29. Why does a sprinter have an oxygen debt to repay after the race is over? Lactic acid fermentation produces lactic acid as a byproduct. The only way to get rid of the lactic acid is in a chemical pathway that requires extra oxygen.

30. A runner needs more energy for a longer race. How does the body generate the necessary ATP? Cellular respiration is the only way to generate a continuing supply of ATP.

31. Why are aerobic forms of exercise so beneficial for weight control? Stores of glycogen used in cellular respiration usually last for 15 to 20 minutes. After that, the body begins to break down other stored molecules, including fats, for energy.

Comparing Photosynthesis and Cellular Respiration (page 232)

32. If photosynthesis is the process that “deposits” energy in a “savings account,” then what is cellular respiration? It is the process that “withdraws” energy.

33. How are photosynthesis and cellular respiration opposite in terms of carbon dioxide? Photosynthesis removes carbon dioxide from the atmosphere, and cellular respiration puts it back.
34. How are photosynthesis and cellular respiration opposite in terms of oxygen? Photosynthesis releases oxygen into the atmosphere, and cellular respiration uses the oxygen to release energy from food.

WordWise

Match each definition in the left column with the correct term in the right column. Then, write the number of each term in the box below on the line under the appropriate letter. When you have filled in all the boxes, add up the numbers in each column, row, and diagonal. All the sums should be the same.

<table>
<thead>
<tr>
<th>Definition</th>
<th>Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. The process in which cells convert NADH to NAD⁺ by passing high-energy electrons back to pyruvic acid</td>
<td>1. Krebs cycle</td>
</tr>
<tr>
<td>B. The second stage of cellular respiration</td>
<td>2. anaerobic</td>
</tr>
<tr>
<td>C. An electron carrier</td>
<td>3. calorie</td>
</tr>
<tr>
<td>D. The stage of cellular respiration in which a molecule of glucose is broken into two molecules of pyruvic acid</td>
<td>4. electron transport chain</td>
</tr>
<tr>
<td>E. The process that releases energy by breaking down food molecules in the presence of oxygen</td>
<td>5. cellular respiration</td>
</tr>
<tr>
<td>F. The amount of energy needed to raise the temperature of 1 gram of water 1 Celsius degree</td>
<td>6. fermentation</td>
</tr>
<tr>
<td>G. A process that does not require oxygen</td>
<td>7. glycolysis</td>
</tr>
<tr>
<td>H. A process that requires oxygen</td>
<td>8. NAD⁺</td>
</tr>
<tr>
<td>I. A series of carrier proteins in the inner membrane of mitochondria</td>
<td>9. aerobic</td>
</tr>
</tbody>
</table>

A = 6, B = 1, C = 8
D = 7, E = 5, F = 3
G = 2, H = 9, I = 4

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