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CHAPTER 7

The Working Cell: Energy from Food

Summary of Key Concepts

Concept 7.1 Sunlight powers life. (pp. 136–137)

Biologists classify organisms according to how they get food. An organism such as a plant that makes its own food is an *autotroph*. In the process of *photosynthesis*, plants use the sun's energy to convert water and carbon dioxide into sugars. Autotrophs are *producers* because they make the organic molecules that serve as food for other organisms. Organisms that cannot make their own food, such as animals, are *heterotrophs*. Heterotrophs, also called *consumers*, must get food by eating other organisms. Since most producers depend on sunlight to make food, life on Earth depends on the sun. Both producers and consumers release the energy in food through the process of *cellular respiration*. The released energy enables cells to produce the energy-storing molecule adenosine triphosphate (ATP).

1. How does an autotroph differ from a heterotroph? _____

_____

2. Describe how organisms release the energy in food. _____

_____

_____

Concept 7.2 Food stores chemical energy. (pp. 138–142)

Energy is the ability to do work. Work is done whenever an object is moved against an opposing force. *Kinetic energy* is the energy of motion, such as when you climb to the top of a water slide. *Potential energy* is energy that is stored due to an object's position or arrangement. You have potential energy when you stand at the top of the slide. *Thermal energy* is a type of kinetic energy that molecules have as they move randomly. As you slide down the slide, your potential energy is converted to kinetic energy. As you slide into the water, the kinetic energy of your body is converted into the thermal energy of the air and water.

The organic compounds that make up food have a form of potential energy called *chemical energy*. In cellular respiration, oxygen breaks the organic molecules into smaller molecules, releasing energy. The energy in food is usually measured in calories. A *calorie* is the amount of energy required to raise the temperature of 1 gram of water by 1 degree Celsius. One thousand calories equals one kilocalorie.

3. What is the difference between kinetic energy and potential energy?

_____

_____

4. How do cells release chemical energy from food? _____

_____

_____

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Concept 7.3 ATP provides energy for cellular work. (pp. 143–144)

ATP, adenosine triphosphate, is a molecule made of a nitrogen-containing compound (adenine), a five-carbon sugar (ribose), and a "tail" made of three phosphate groups. The triphosphate tail has potential energy because the negatively charged phosphate groups are crowded together. When a phosphate bond is broken, some potential energy is released. The released phosphate group can bond to another molecule and enable it to do work.

Cells perform three main types of work: chemical, mechanical, and transport. An example of chemical work is building large molecules such as proteins. The contraction of a muscle is mechanical work. Pumping ions across a cellular membrane is transport work. Once used, ATP can be recycled. The energy needed to recharge ATP comes from food.

5. How is energy released from ATP? _____

_____

6. What are the three main types of cellular work? _____

_____

Concept 7.4 Electrons "fall" from food to oxygen during cellular respiration. (pp. 145–147)

Cellular respiration is an *aerobic* process, meaning that it requires oxygen. Although cellular respiration is different from breathing (called respiration), the two processes are related. Breathing brings oxygen into the body where it is used for cellular respiration. Breathing also releases carbon dioxide, the waste product of cellular respiration.

The overall equation for cellular respiration is

$$\text{glucose} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water} + \text{energy}$$

In this process, up to 38 ATP molecules are produced from each molecule of glucose. Glucose is broken down in several steps. Molecules called electron carriers accept many of the high-energy electrons released from glucose. The electron carriers pass the electrons to other carriers in a series of transfers called the *electron transport chain*. At the end of the chain, oxygen pulls electrons from the final carrier molecule. These electrons join with hydrogen ions, forming water. As electrons undergo each transfer in the chain, they release a little energy, which is used to make ATP.

7. How is breathing related to cellular respiration? _____

_____

8. What are the products of cellular respiration? _____

_____

9. What happens to electrons in the electron transport chain? _____

_____

Concept 7.5 Cellular respiration converts energy in food to energy in ATP. (pp. 148–152)

Many enzymes involved in cellular respiration are built into the inner membranes of mitochondria. The complex folding of the inner membrane creates many sites where these reactions can occur. A specific enzyme speeds up each

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reaction. Cellular respiration is just one chemical process that takes place in cells. All of the chemical processes in a cell make up the cell's *metabolism*.

Cellular respiration has three main stages. *Glycolysis*, the first stage, occurs in the cytoplasm. In glycolysis, two ATP molecules help break down glucose into two molecules of pyruvic acid. Four new ATP molecules are also produced. Each of the two pyruvic acid molecules is then converted to acetyl CoA. In the *Krebs cycle*, each acetyl CoA molecule is broken down to two molecules of carbon dioxide, and one ATP molecule is made. The Krebs cycle occurs in the matrix of the inner membrane of a mitochondrion. The final stage of cellular respiration occurs in the inner membrane of the mitochondria. This stage has two parts: an electron transport chain and ATP production. The carrier molecule NADH transfers electrons to the electron transfer chain. Each transfer releases a small amount of energy. *ATP synthase* is an enzyme that uses the energy to produce up to 34 ATP molecules per glucose molecule. Cellular respiration can produce a total of up to 38 molecules of ATP from one glucose molecule.

10. How does the structure of a mitochondrion maximize its production of ATP?

_____

11. What occurs during glycolysis? _____

_____

_____

12. How many ATP molecules can be made from each glucose molecule in cellular respiration? _____

_____

Concept 7.6 Some cells can harvest energy without oxygen. (pp. 153–155)

At some times, such as when you sprint, your lungs and bloodstream can't supply oxygen fast enough to meet your muscles' need for ATP. In such situations, muscle cells rely on fermentation. *Fermentation* makes ATP entirely from glycolysis without using oxygen. Your body uses oxygen to convert lactic acid back to pyruvic acid.

Like your muscle cells, yeast cells are capable of both cellular respiration and fermentation. In an *anaerobic* environment, an environment without oxygen, yeast cells ferment sugar and other foods. Yeast fermentation produces alcohol instead of lactic acid, and also releases carbon dioxide. Yeast fermentation is used to make beer, wine, and bread. Some fungi and bacteria that produce lactic acid during fermentation are used to make cheese and yogurt, soy sauce, and sauerkraut.

13. How is ATP made during fermentation? _____

_____

14. List four food products made by fermentation. _____

_____

Reading Skills Practice

Creating a flowchart Make a flowchart that summarizes the steps in the process of cellular respiration as described in Concept 7.5 on pages 148–152.

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Vocabulary Review and Reinforcement

In 1–5, write the letter of the correct definition on the line next to each term.

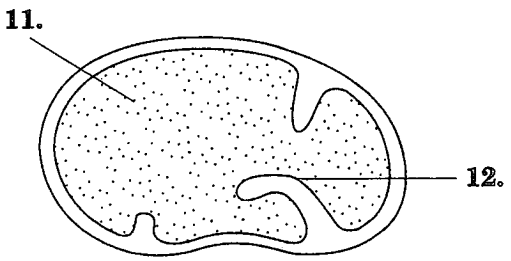
_____ 1. electron transport chain	a. term that describes an environment without oxygen
_____ 2. producer	b. process that uses oxygen to release the energy in glucose and produce ATP
_____ 3. anaerobic	c. potential energy due to the arrangement of atoms in molecules
_____ 4. chemical energy	d. series of electron transfers that release energy
_____ 5. cellular respiration	e. organism that produces food for itself and other organisms

In 6–9, fill in the blanks with the appropriate terms from the chapter.

6. In the second stage of cellular respiration, called the _____, carbon dioxide and ATP are produced.
7. The amount of energy required to raise the temperature of 1 gram of water by 1 degree Celsius is a(n) _____.
8. The process in which plants use the sun's energy to convert water and carbon dioxide into sugars is called _____.
9. The molecule _____ uses energy to convert ADP to ATP.

In 10–12, study the diagram. Then fill in the blanks to show where the three stages of cellular respiration occur in a mitochondrion.

10. _____
11. _____
12. _____



Mitochondrion

WordWise

Use the clues to unscramble the Key Terms. Then write the terms in the appropriate blanks.

mucosner metharl genrey ricobea mistamelob temnfatonier PTA

1. requiring oxygen _____
2. all of a cell's chemical processes _____
3. source of energy used by cells _____
4. the random energy of molecules _____
5. organism that obtains food by eating other organisms _____
6. process of making ATP without oxygen _____