8.1 Energy and Life

Key Questions

Why is ATP useful to cells?

What happens during the process of photosynthesis?

Vocabulary

adenosine triphosphate (ATP) • heterotroph • autotroph • photosynthesis

Taking Notes

Compare/Contrast Table As you read, create a table that compares autotrophs and heterotrophs. Think about how they obtain energy, and include a few examples of each.

BUILD Vocabulary

ACADEMIC WORDS The verb **obtain** means "to get" or "to gain." Organisms must obtain energy in order to carry out life functions.

THINK ABOUT IT Homeostasis is hard work. Just to stay alive, organisms and the cells within them have to grow and develop, move materials around, build new molecules, and respond to environmental changes. Plenty of energy is needed to accomplish all this work. What powers so much activity, and where does that power come from?

Chemical Energy and ATP

Why is ATP useful to cells?

Energy is the ability to do work. Nearly every activity in modern society depends upon energy. When a car runs out of fuel—more precisely, out of the chemical energy in gasoline—it comes to a sputtering halt. Without electrical energy, lights, appliances, and computers stop working. Living things depend on energy, too. Sometimes the need for energy is easy to see. It takes plenty of energy to play soccer or other sports. However, there are times when that need is less obvious. Even when you are sleeping, your cells are quietly busy using energy to build new molecules, contract muscles, and carry out active transport. Simply put, without the ability to obtain and use energy, life would cease to exist.

Energy comes in many forms, including light, heat, and electricity. Energy can be stored in chemical compounds, too. For example, when you light a candle, the wax melts, soaks into the wick, and is burned. As the candle burns, chemical bonds between carbon and hydrogen atoms in the wax are broken. New bonds then form between these atoms and oxygen, producing CO_2 and H_2O (carbon dioxide and water). These new bonds are at a lower energy state than the original chemical bonds in the wax. The energy lost is released as heat and light in the glow of the candle's flame.

Living things use chemical fuels as well. One of the most important compounds that cells use to store and release energy is **adenosine triphosphate** (uh DEN uh seen try FAHS fayt), abbreviated **ATP.** As shown in **Figure 8–1,** ATP consists of adenine, a 5-carbon sugar called ribose, and three phosphate groups. As you'll see, those phosphate groups are the key to ATP's ability to store and release energy.

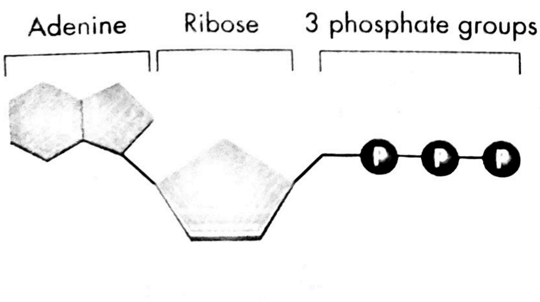


FIGURE 8–1 ATP ATP is the basic energy source used by all types of cells.

Storing Energy Adenosine diphosphate (ADP) is a compound that looks almost like ATP, except that it has two phosphate groups instead of three. This difference is the key to the way in which living things store energy. When a cell has energy available, it can store small amounts of it by adding phosphate groups to ADP molecules, producing ATP. As seen in **Figure 8–2**, ADP is like a rechargeable battery that powers the machinery of the cell.

Releasing Energy Cells can release the energy stored in ATP by the controlled breaking of the chemical bonds between the second and third phosphate groups. Because a cell can add or subtract these phosphate groups, it has an efficient way of storing and releasing energy as needed. **ATP can easily release and store energy by breaking and re-forming the bonds between its phosphate groups. This characteristic of ATP makes it exceptionally useful as a basic energy source for all cells.**

Using Biochemical Energy One way cells use the energy provided by ATP is to carry out active transport. Many cell membranes contain sodium-potassium pumps, membrane proteins that pump sodium ions (Na^+) out of the cell and potassium ions (K^+) into it. ATP provides the energy that keeps this pump working, maintaining a carefully regulated balance of ions on both sides of the cell membrane. In addition, ATP powers movement, providing the energy for motor proteins that contract muscle and power the wavelike movement of cilia and flagella.

Energy from ATP powers other important events in the cell, including the synthesis of proteins and responses to chemical signals at the cell surface. The energy from ATP can even be used to produce light. In fact, the blink of a firefly on a summer night comes from an enzyme that is powered by ATP!

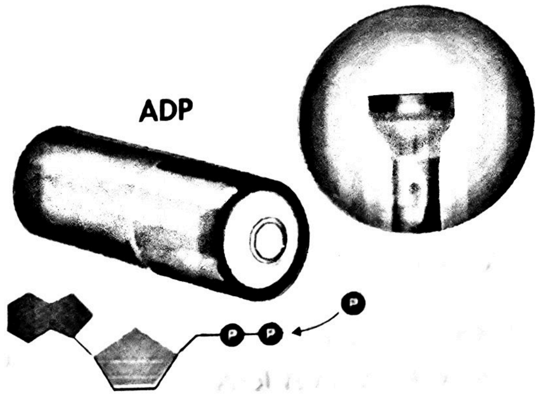
ATP is such a useful source of energy that you might think cells would be packed with ATP to get them through the day—but this is not the case. In fact, most cells have only a small amount of ATP—enough to last for a few seconds of activity. Why? Even though ATP is a great molecule for transferring energy, it is not a good one for storing large amounts of energy over the long term. A single molecule of the sugar glucose, for example, stores more than 90 times the energy required to add a phosphate group to ADP to produce ATP. Therefore, it is more efficient for cells to keep only a small supply of ATP on hand. Instead, cells can regenerate ATP from ADP as needed by using the energy in foods like glucose. As you will see, that's exactly what they do.

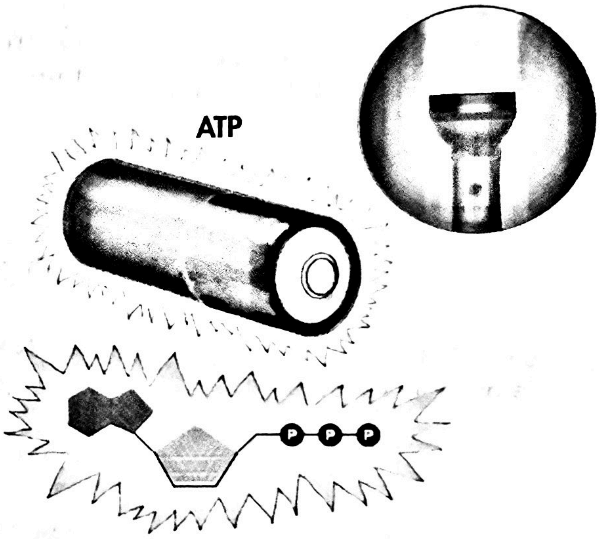
In Your Notebook *With respect to energy, how are ATP and glucose similar? How are they different?*

VISUAL ANALOGY

ATP AS A CHARGED BATTERY

FIGURE 8–2 When a phosphate group is added to an ADP molecule, ATP is produced. ADP contains some energy, but not as much as ATP. In this way, ADP is like a partially charged battery that can be fully charged by the addition of a phosphate group.
Use Analogies *Explain the difference between the beams of light produced by the flashlight "powered" by ADP and the flashlight "powered" by ATP.*





MYSTERY
CLUE

Like all plants, the willow tree van Helmont planted was an autotroph. What might its ability to harness the sun's energy and store it in food have to do with the tree's gain in mass?

Heterotrophs and Autotrophs

What happens during the process of photosynthesis?

Cells are not "born" with a supply of ATP—they must somehow produce it. So, where do living things get the energy they use to produce ATP? The simple answer is that it comes from the chemical compounds that we call food. Organisms that obtain food by consuming other living things are known as **heterotrophs.** Some heterotrophs get their food by eating plants such as grasses. Other heterotrophs, such as the cheetah in **Figure 8–3,** obtain food from plants indirectly by feeding on plant-eating animals. Still other heterotrophs—mushrooms, for example—obtain food by absorbing nutrients from decomposing organisms in the environment.

Originally, however, the energy in nearly all food molecules comes from the sun. Plants, algae, and some bacteria are able to use light energy from the sun to produce food. Organisms that make their own food are called **autotrophs.** Ultimately, nearly all life on Earth, including ourselves, depends on the ability of autotrophs to capture the energy of sunlight and store it in the molecules that make up food. The process by which autotrophs use the energy of sunlight to produce high-energy carbohydrates—sugars and starches—that can be used as food is known as **photosynthesis.** *Photosynthesis* comes from the Greek words *photo*, meaning "light," and *synthesis*, meaning "putting together." Therefore, photosynthesis means "using light to put something together." **In the process of photosynthesis, plants convert the energy of sunlight into chemical energy stored in the bonds of carbohydrates.** In the rest of this chapter, you will learn how this process works.

FIGURE 8–3 Autotrophs and Heterotrophs Grass, an autotroph, uses energy from the sun to produce food. Cheetahs, in turn, get their energy by eating other organisms that eat the grass.

8.1 Assessment

Review Key Concepts

1. **a. Review** What is ATP and what is its role in the cell?
   b. Explain How does the structure of ATP make it an ideal source of energy for the cell?
   c. Use Analogies Explain how ADP and ATP are each like a battery. Which one is "partially charged" and which one is "fully charged?" Why?
2. **a. Review** What is the ultimate source of energy for plants?
   b. Explain How do heterotrophs obtain energy? How is this different from how autotrophs obtain energy?
   c. Infer Why are decomposers, such as mushrooms, considered heterotrophs and not autotrophs?

Apply the Big idea

Interdependence in Nature

3. Recall that energy flows—and that nutrients cycle—through the biosphere. How does the process of photosynthesis impact both the flow of energy and the cycling of nutrients? You may wish to refer to Chapter 3 to help you answer this question.