4.1 Chemical Energy and ATP

KEY CONCEPT All cells need chemical energy.

MAIN IDEAS

- The chemical energy used for most cell processes is carried by ATP.
- Organisms break down carbon-based molecules to produce ATP.
- A few types of organisms do not need sunlight and photosynthesis as a source of energy.

VOCABULARY

ATP, p. 100
ADP, p. 101
chemosynthesis, p. 102

Review
carbohydrate, lipid, protein

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Connect The cells of all organisms—from algae to whales to people—need chemical energy for all of their processes. Some organisms, such as diatoms and plants, absorb energy from sunlight. Some of that energy is stored in sugars. Cells break down sugars to produce usable chemical energy for their functions. Without organisms that make sugars, living things on Earth could not survive.

MAIN IDEA

The chemical energy used for most cell processes is carried by ATP.

Sometimes you may feel that you need energy, so you eat food that contains sugar. Does food, which contains sugar and other carbon-based molecules, give you energy? The answer to this question is yes and no. All of the carbon-based molecules in food store chemical energy in their bonds. Carbohydrates and lipids are the most important energy sources in foods you eat. However, this energy is only usable after these molecules are broken down by a series of chemical reactions. Your energy does come from food, but not directly.

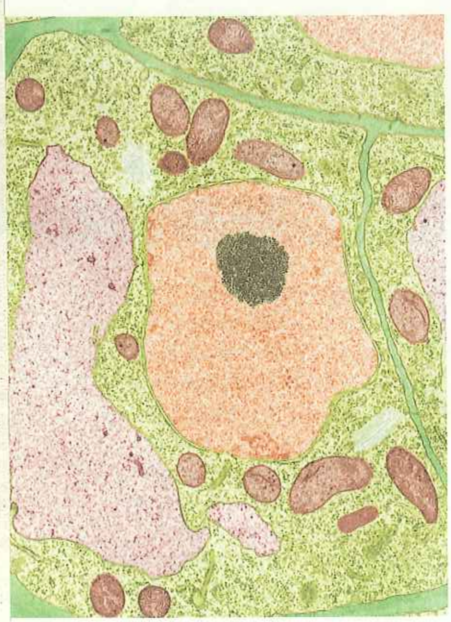
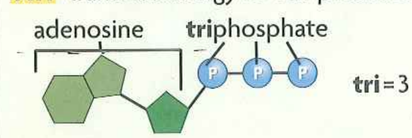


FIGURE 4.1 All cells, including plant cells, use ATP for energy. (colored TEM; magnification 9,000×)

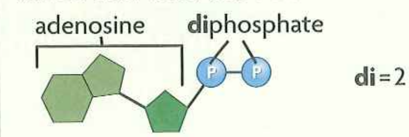
All cells, like that in **FIGURE 4.1**, use chemical energy carried by ATP—adenosine triphosphate. **ATP** is a molecule that transfers energy from the breakdown of food molecules to cell processes. You can think of ATP as a wallet filled with money. Just as a wallet carries money that you can spend, ATP carries chemical energy that cells can use. Cells use ATP for functions such as building molecules and moving materials by active transport.

VISUAL VOCAB

ATP transfers energy to cell processes.



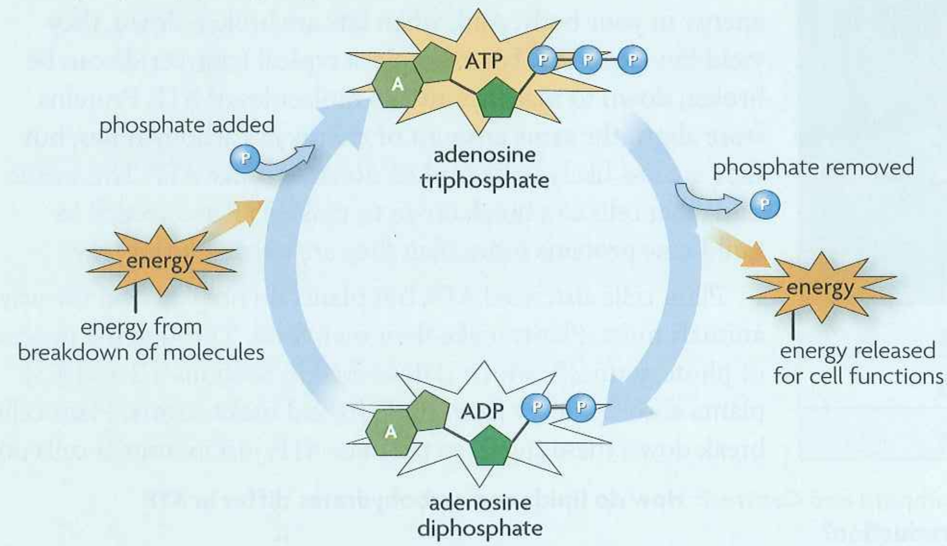
ADP is a lower-energy molecule that can be converted into ATP.



The energy carried by ATP is released when a phosphate group is removed from the molecule. ATP has three phosphate groups, but the bond holding the third phosphate group is unstable and is very easily broken. The removal of the third phosphate group usually involves a reaction that releases energy.

FIGURE 4.2 ATP and ADP

Adding a phosphate group to ADP forms ATP.



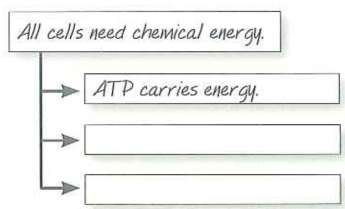
Infer **Where are molecules from food involved in the cycle?**

When the phosphate is removed, energy is released and ATP becomes ADP—adenosine diphosphate. **ADP** is a lower-energy molecule that can be converted into ATP by the addition of a phosphate group. If ATP is a wallet filled with money, ADP is a nearly empty wallet. The breakdown of ATP to ADP and the production of ATP from ADP can be represented by the cycle shown in **FIGURE 4.2**. However, adding a phosphate group to ADP to make ATP is not a simple process. A large, complex group of proteins is needed to do it. In fact, if just one of these proteins is faulty, ATP is not produced.

Synthesize **Describe the relationship between energy stored in food and ATP.**

TAKING NOTES

Use a supporting main ideas chart to organize concepts related to chemical energy.



MAIN IDEA

Organisms break down carbon-based molecules to produce ATP.

Foods that you eat do not contain ATP that your cells can use. First, the food must be digested. One function of digestion is to break down food into smaller molecules that can be used to make ATP. You probably know that different foods have different amounts of calories, which are measures of energy. Different foods also provide different amounts of ATP. The number of ATP molecules that are made from the breakdown of food is related to the number of calories in food, but not directly.

The number of ATP molecules produced depends on the type of molecule that is broken down—carbohydrate, lipid, or protein. Carbohydrates are not stored in large amounts in your body, but they are the molecules most commonly broken down to make ATP. The breakdown of the simple sugar glucose yields about 36 molecules of ATP.

Connecting CONCEPTS

Biochemistry As you learned in **Chapter 2**, carbon-based molecules in living things—carbohydrates, lipids, proteins, and nucleic acids—have different structures and functions.

FIGURE 4.3 FOOD AND ENERGY

MOLECULE	ENERGY
Carbohydrate	4 calories per mg
Lipid	9 calories per mg
Protein	4 calories per mg

You might be surprised to learn that carbohydrates do not provide the largest amount of ATP. Lipids store the most energy, as **FIGURE 4.3** shows. In fact, fats store about 80 percent of the energy in your body. And, when fats are broken down, they yield the most ATP. For example, a typical triglyceride can be broken down to make about 146 molecules of ATP. Proteins store about the same amount of energy as carbohydrates, but they are less likely to be broken down to make ATP. The amino acids that cells can break down to make ATP are needed to build new proteins more than they are needed for energy.

Plant cells also need ATP, but plants do not eat food the way animals must. Plants make their own food. Through the process of photosynthesis, which is described in Sections 4.2 and 4.3, plants absorb energy from sunlight and make sugars. Plant cells break down these sugars to produce ATP, just as animal cells do.

Compare and Contrast How do lipids and carbohydrates differ in ATP production?

MAIN IDEA

A few types of organisms do not need sunlight and photosynthesis as a source of energy.

Most organisms rely directly or indirectly on sunlight and photosynthesis as their source of chemical energy. But some organisms do not need sunlight. In places that never get sunlight, such as in the deep ocean, there are areas with living things. Some organisms live in very hot water near cracks in the ocean floor called hydrothermal vents. These vents release chemical compounds, such as sulfides, that can serve as an energy source. **Chemosynthesis** (KEE-mo-SIHN-thih-sihs) is a process by which some organisms use chemical energy instead of light energy to make energy-storing carbon-based molecules. However, these organisms still need ATP for energy. The processes that make their ATP are very similar to those in other organisms. Like plants, chemosynthetic organisms make their own food. It is the raw materials that differ.

Compare How are chemosynthetic organisms and plants similar as energy

4.1 ASSESSMENT

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REVIEWING MAIN IDEAS

1. How are ATP and ADP related?
2. What types of molecules are broken down to make ATP? Which are most often broken down to make ATP?
3. How are some organisms able to survive without sunlight and photosynthesis?

CRITICAL THINKING

4. **Apply** Describe how you do not get energy directly from the food that you eat.
5. **Compare and Contrast** How are the energy needs of plant cells similar to those of animal cells? How are they different?

Connecting CONCEPTS

6. **Chemical Reactions** A water molecule is added to an ATP molecule to break down ATP into ADP and a phosphate group. Write the chemical equation that represents this reaction.