Section 3

Photosynthesis

Reading Preview

Key Concepts

- How does the sun supply living things with the energy they need?
- What happens during the process of photosynthesis?

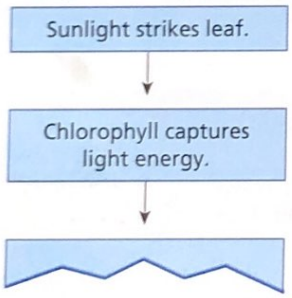
Key Terms

- photosynthesis
- autotroph
- heterotroph
- pigment
- chlorophyll
- stomata

Target Reading Skill

Sequencing A sequence is the order in which the steps in a process occur. As you read, create a flowchart that shows the steps in photosynthesis. Put each step in a separate box in the flowchart in the order in which it occurs.

Steps in Photosynthesis



Lab zone Discover Activity

Where Does the Energy Come From?

1. Obtain a solar-powered calculator that does not use batteries. Place the calculator in direct light.
2. Cover the solar cells with your finger. Note how your action affects the number display.
3. Uncover the solar cells. What happens to the number display?
4. Now cover all but one of the solar cells. How does that affect the number display?

Think It Over

Inferring From your observations, what can you infer about the energy that powers the calculator?

On a plain in Africa, dozens of zebras peacefully eat the grass. But watch out—the zebras' grazing will soon be harshly interrupted. A group of lions is about to attack the herd. The lions will kill one of the zebras and eat it.

Both the zebras and the lions use the food they eat to obtain energy. Every living thing needs energy. All cells need energy to carry out their functions, such as making proteins and transporting substances into and out of the cell. The zebra's meat supplies the lion's cells with the energy they need, just as the grass provides the zebra's cells with energy. But plants and certain other organisms, such as algae and some bacteria, obtain their energy in a different way. These organisms use the energy in sunlight to make their own food.

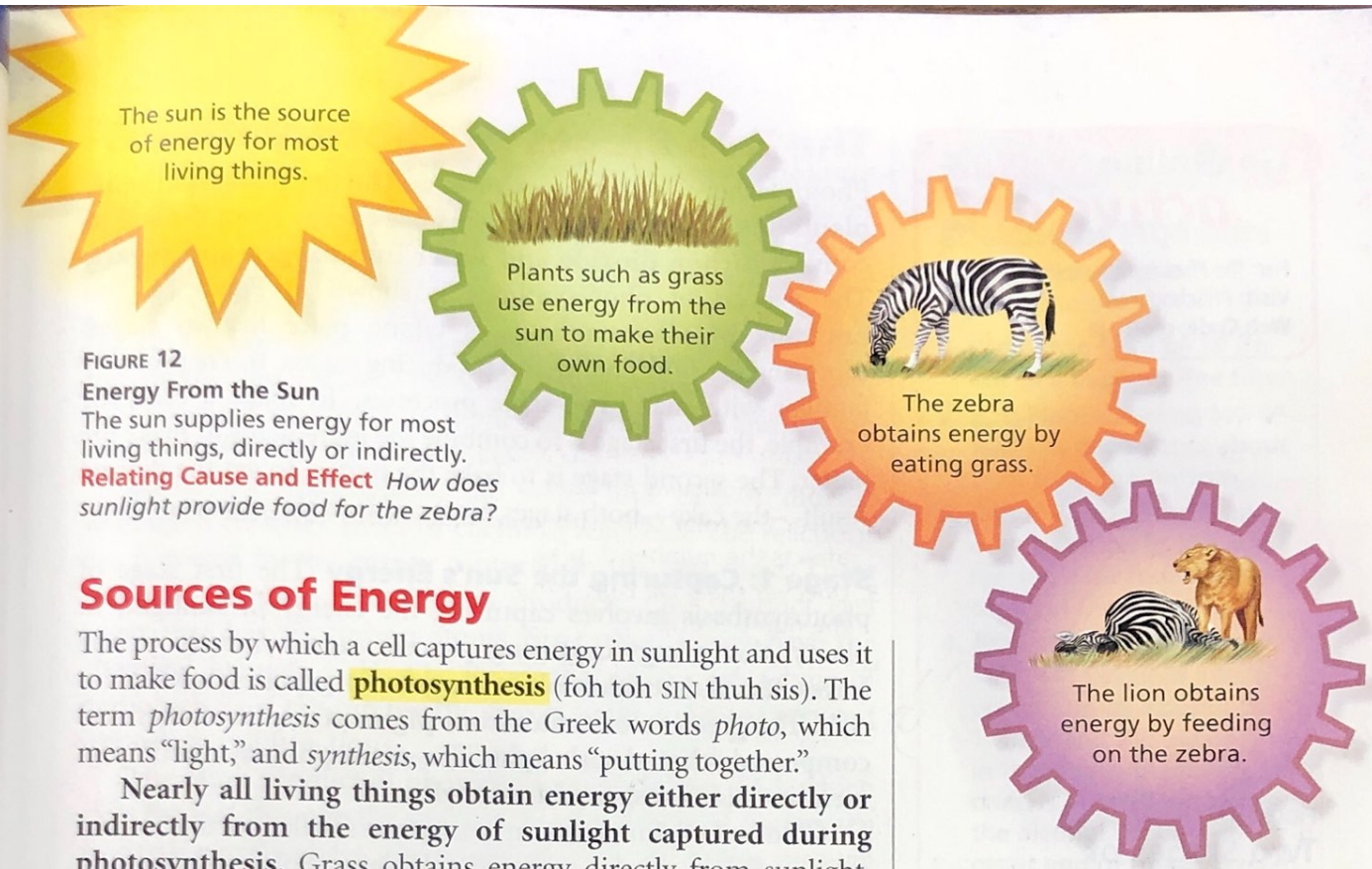


FIGURE 12
Energy From the Sun
The sun supplies energy for most living things, directly or indirectly.
Relating Cause and Effect *How does sunlight provide food for the zebra?*

Sources of Energy

The process by which a cell captures energy in sunlight and uses it to make food is called **photosynthesis** (foh toh SIN thuh sis). The term *photosynthesis* comes from the Greek words *photo*, which means "light," and *synthesis*, which means "putting together."

Nearly all living things obtain energy either directly or indirectly from the energy of sunlight captured during photosynthesis. Grass obtains energy directly from sunlight, because it makes its own food during photosynthesis. When the zebra eats the grass, it gets energy that has been stored in the grass. Similarly, the lion obtains energy stored in the zebra. The zebra and lion both obtain the sun's energy indirectly, from the energy that the grass obtained through photosynthesis.

Plants manufacture their own food through the process of photosynthesis. An organism that makes its own food is called an **autotroph** (AWT oh trahf). An organism that cannot make its own food, including animals such as the zebra and the lion, is called a **heterotroph** (HET ur oh trahf). Many heterotrophs obtain food by eating other organisms. Some heterotrophs, such as fungi, absorb their food from other organisms.

Reading Checkpoint What are autotrophs?

FIGURE 13
Autotrophs and Heterotrophs
Grass, which makes its own food during photosynthesis, is an autotroph. Zebras and lions are heterotrophs, because they cannot make their own food.

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For: The Photosynthesis Process
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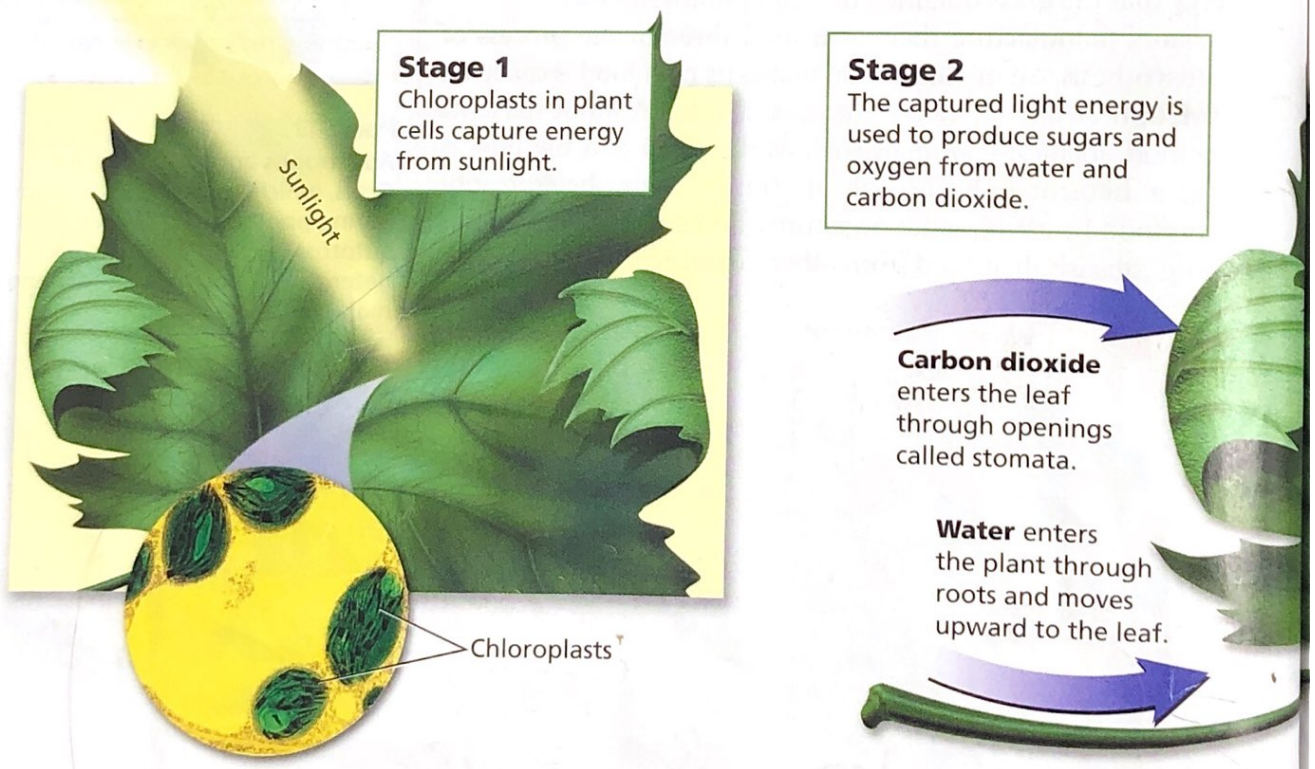
The Two Stages of Photosynthesis

Photosynthesis is a complex process. **During photosynthesis, plants and some other organisms use energy from the sun to convert carbon dioxide and water into oxygen and sugars.** The process of photosynthesis is shown in Figure 14. You can think of photosynthesis as taking place in two stages: capturing the sun's energy and producing sugars. You're probably familiar with many two-stage processes. To make a cake, for example, the first stage is to combine the ingredients to make the batter. The second stage is to bake the batter. To get the desired result—the cake—both stages must occur in the correct order.

Stage 1: Capturing the Sun's Energy The first stage of photosynthesis involves capturing the energy in sunlight. In plants, this energy-capturing process occurs mostly in the leaves. Recall that chloroplasts are green organelles inside plant cells. The green color comes from **pigments,** colored chemical compounds that absorb light. The main photosynthetic pigment in chloroplasts is **chlorophyll.**

Chlorophyll functions in a manner similar to that of the solar "cells" in a solar-powered calculator. Solar cells capture the energy in light and use it to power the calculator. Similarly, chlorophyll captures light energy and uses it to power the second stage of photosynthesis.

FIGURE 14
Two Stages of Photosynthesis
Photosynthesis has two stages, as shown in the diagram.
Interpreting Diagrams *Which stage requires light?*



Stage 2: Using Energy to Make Food In the next stage of photosynthesis, the cell uses the captured energy to produce sugars. The cell needs two raw materials for this stage: water (H_2O) and carbon dioxide (CO_2). In plants, the roots absorb water from the soil. The water then moves up through the plant's stem to the leaves. Carbon dioxide is one of the gases in the air. Carbon dioxide enters the plant through small openings on the undersides of the leaves called **stomata** (STOH muh tuh) (singular *stoma*). Once in the leaves, the water and carbon dioxide move into the chloroplasts.

Inside the chloroplasts, the water and carbon dioxide undergo a complex series of chemical reactions. The reactions are powered by the energy captured in the first stage. These reactions produce chemicals as products. One product is a sugar that has six carbon atoms. Six-carbon sugars have the chemical formula $C_6H_{12}O_6$. Recall that sugars are a type of carbohydrate. Cells can use the energy in the sugar to carry out important cell functions.

The other product of photosynthesis is oxygen (O_2), which exits the leaf through the stomata. In fact, almost all the oxygen in Earth's atmosphere was produced by living things through the process of photosynthesis.

Reading Checkpoint What makes plants green?

Lab zone Try This Activity

Looking at Pigments

You can observe the pigments in a leaf.

1. Cut a strip 5 cm by 20 cm out of a paper coffee filter.
2. Place a leaf on top of the paper strip, about 2 cm from the bottom.
3. Roll the edge of a dime over a section of the leaf, leaving a narrow band of color on the paper strip.
4. Pour rubbing alcohol into a plastic cup to a depth of 1 cm. Stand the paper strip in the cup so the color band is about 1 cm above the alcohol. Hook the other end of the strip over the top of the cup.
5. After 10 minutes, remove the paper strip and let it dry. Observe the strip.
6. Wash your hands.

Inferring What does the paper strip's appearance reveal about leaf pigments?

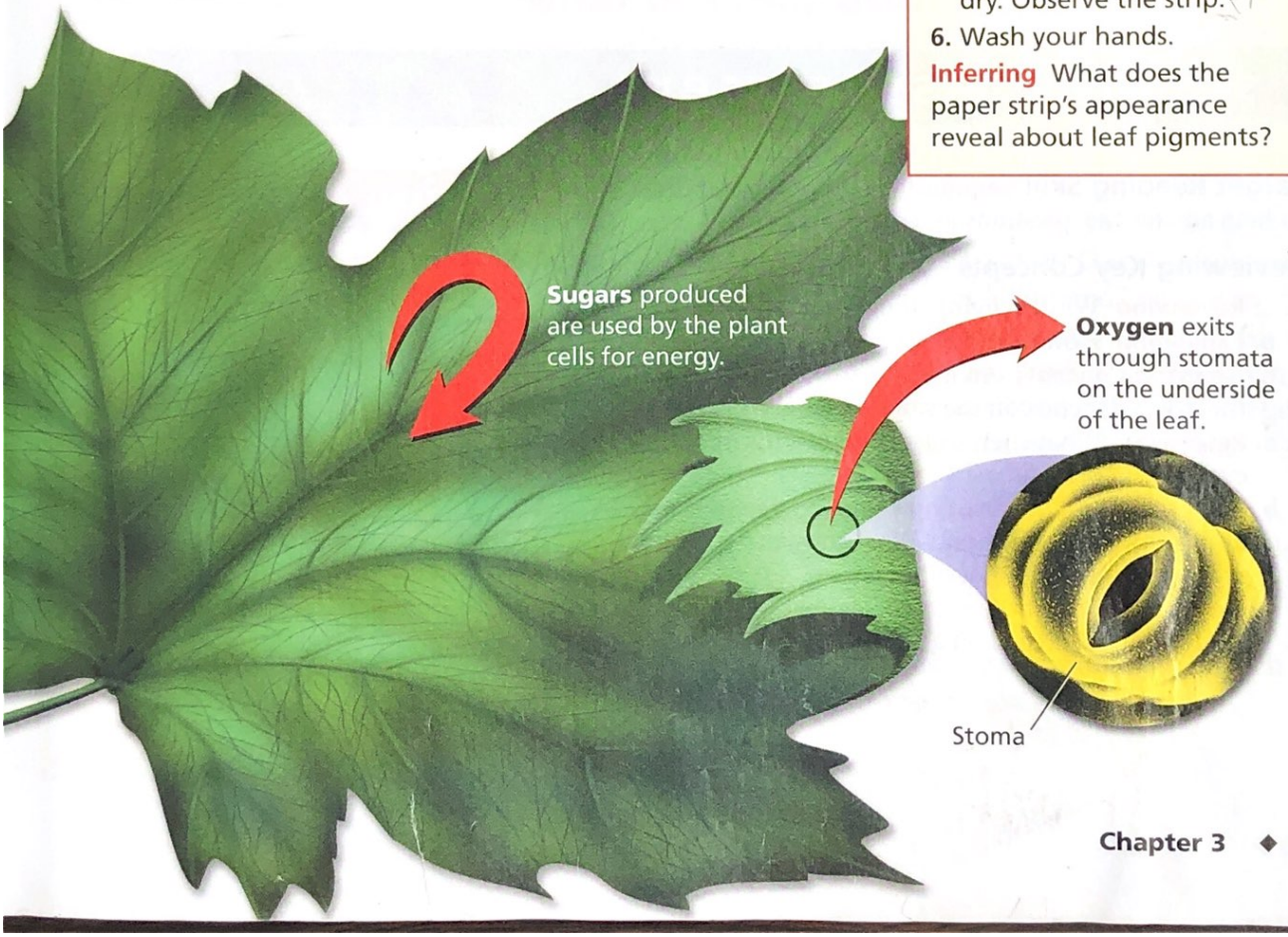


FIGURE 15 Stored Energy When you eat a carrot, you obtain energy stored during photosynthesis.

The Photosynthesis Equation The events of photosynthesis can be summed up by the following chemical equation:

$$6\,CO_2 + 6\,H_2O \xrightarrow{\text{light energy}} C_6H_{12}O_6 + 6\,O_2$$

carbon dioxide + water → a sugar + oxygen

Notice that the raw materials—six molecules of carbon dioxide and six molecules of water—are on the left side of the equation. The products—one molecule of a sugar and six molecules of oxygen—are on the right side of the equation. An arrow, which you can read as "yields," connects the raw materials to the products. Light energy, which is necessary for the chemical reaction to occur, is written above the arrow.

What happens to the sugar produced in photosynthesis? Plant cells use some of the sugar for food. The cells break down the sugar molecules to release the energy they contain. This energy can then be used to carry out the plant's functions. Some sugar molecules are converted into other compounds, such as cellulose. Other sugar molecules may be stored in the plant's cells for later use. When you eat food from plants, such as potatoes or carrots, you are eating the plant's stored energy.

Reading Checkpoint **In the photosynthesis equation, what does the arrow mean?**

Section 3 Assessment

Target Reading Skill **Sequencing** Use your definitions to help answer the questions.

Reviewing Key Concepts

1. a. **Reviewing** Why do living things need energy?
   b. **Explaining** How do plants obtain energy?
   c. **Applying Concepts** An insect eats a leaf. Explain how the insect depends on the sun for energy.
2. a. **Reviewing** What chemical equation sums up the events of photosynthesis?
   b. **Comparing and Contrasting** What are the substances needed for photosynthesis? What substances are produced during photosynthesis?
   c. **Making Generalizations** Would you expect a plant to produce more oxygen on a cloudy day or a sunny day? Explain.

Writing in Science

Job Qualifications When people apply for jobs, they often must complete a job application form in which they describe their qualifications for a job. Suppose that you are a leaf, and that you are applying for a job in a photosynthesis factory. Write a paragraph in which you summarize your qualifications for the job of photosynthesis. Your paragraph should include the following words: *chloroplasts, chlorophyll, light, energy, water, carbon dioxide,* and *stomata*.