chapter 8

Cellular Energy

section 2 Photosynthesis

MAIN Idea

Light energy is trapped and converted into chemical energy during photosynthesis.

What You'll Learn

- the two phases of photosynthesis
- how a chloroplast works during light reactions
- how electron transport works

Before You Read

Plants change energy from sunlight into energy that is used by other living things. Describe on the lines below what would happen to life on Earth if plants suddenly disappeared. Then read about how plants use the Sun's energy.

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Mark the Text

Identify Details As you read, highlight or underline the events of each stage of photosynthesis.

Read to Learn

Overview of Photosynthesis

Photosynthesis is the process in which light energy from the Sun is changed into chemical energy. Nearly all life on Earth depends on photosynthesis. The chemical equation for photosynthesis is shown below.

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

Photosynthesis occurs in two phases. In phase one—the light-dependent reactions—light energy is absorbed and changed into chemical energy in the form of ATP and NADPH.

In phase two—the light-independent reactions—the ATP and NADPH that were formed in phase one are used to make glucose. Glucose can then be joined with other simple sugars to form larger molecules such as complex sugars and carbohydrates. Sugar can also be changed into other molecules needed by the cell, such as proteins, lipids, and nucleic acids. ✔

✔ Reading Check

1. Identify one way cells can use glucose.

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Phase One: Light Reactions

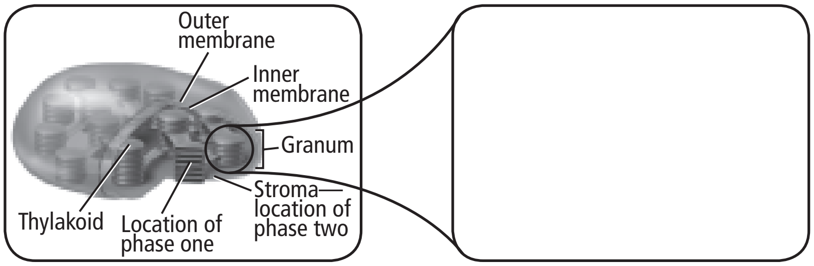
Plants have special organelles called chloroplasts to capture light energy. Photosynthesis begins when sunlight is captured. The captured energy is stored in two energy storage molecules—ATP and NADPH—that will be used in light-independent reactions.

What happens in chloroplasts?

Chloroplasts are large organelles that capture light energy from the Sun. They are found in plants and other photosynthetic organisms. The figure below shows a chloroplast.

A chloroplast is a disc-shaped organelle that contains two compartments. **Thylakoids** (THI la koyds) are flattened saclike membranes. The thylakoids are arranged in stacks called **grana**. The fluid-filled space outside the grana is the **stroma**. Phase one takes place in the thylakoids. Phase two takes place in the stroma.

Chloroplast



What is the role of pigments in photosynthesis?

Thylakoids contain light-absorbing colored molecules known as **pigments**. Different pigments absorb different wavelengths of light. Chlorophylls are the major light-absorbing pigments in plants. They absorb energy from violet-blue light and reflect green light, giving plants their green color.

Accessory pigments help plants absorb additional light. For instance, carotenoids (kuh ROH tuh noyds) absorb blue and green light and reflect yellow, orange, and red light. Carotenoids give carrots and sweet potatoes their orange color.

Accessory pigments are the reason leaves change colors in autumn. In green leaves, there is so much chlorophyll that it masks the other pigments. In autumn, as trees prepare to lose their leaves, the chlorophyll molecules break down, revealing the colors of other pigments. The colors red, yellow, and orange can be seen. ☑

Think it Over

2. Name Which organism has chloroplasts? (Circle your answer.)
- **a.** mushroom
- **b.** oak tree
- **c.** earthworm

Picture This

3. Illustrate In the box, draw an enlarged picture of a granum.

Reading Check

4. Explain Why do the leaves of some trees change colors in autumn?

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How does electron transport work?

Photosystem I and photosystem II are made of pigments that absorb light and proteins that are important in light reactions. They are in the thylakoid membrane. Follow along in the figure below as you read about their role in photosynthesis. ✔

Photosynthesis begins when light energy causes electrons in photosystem II to go into a high energy state. The light energy also causes a water molecule to split, releasing an electron into the electron transport system, a hydrogen ion into the thylakoid space, and oxygen as a waste product. The excited electrons move from photosystem II and move along a series of electron-carriers to photosystem I. Photosystem I absorbs more light, and the excited electrons move along electron-carriers again. Finally, the electrons are moved to **NADP$^+$**, forming the energy-storage molecule NADPH.

✔ Reading Check

5. Describe Of what are photosystem I and photosystem II made?

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How is ATP made during photosynthesis?

ATP is made when light energy causes the water molecule to split into oxygen and two hydrogen ions (H^+), or protons. Protons build up inside the thylakoid. Protons diffuse through ion channels into the stroma where the concentration is lower. These channels are enzymes called ATP synthases. As protons move into the stroma, ATP is formed.

Picture This

6. Identify On the figure, highlight the path that electrons follow. What molecule is the electron's final destination?

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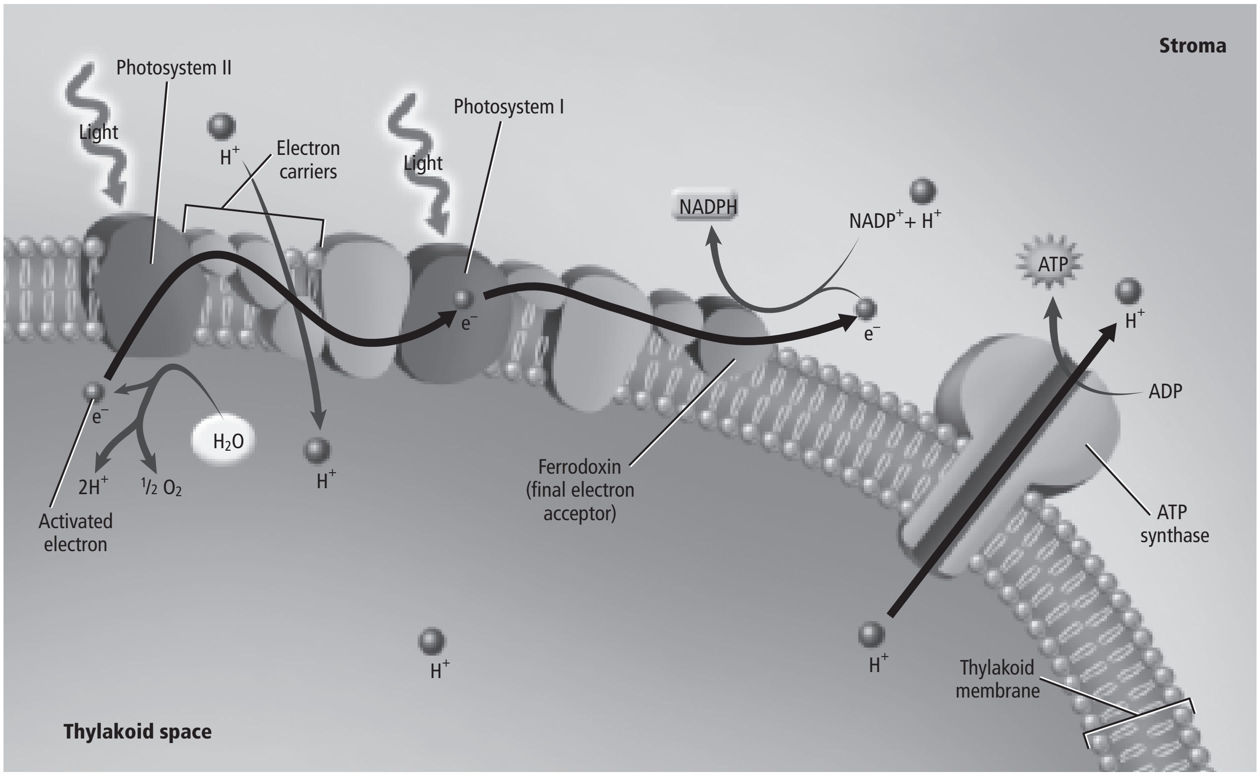

Phase Two: The Calvin Cycle

NADPH and ATP are temporary storage molecules. During phase two, also known as the **Calvin cycle**, the energy in these molecules is stored in organic molecules, such as glucose.

What happens in the Calvin cycle?

The Calvin cycle builds sugars out of carbon dioxide and water using the energy stored in ATP and NADPH. The Calvin cycle's reactions do not require sunlight, which is why they are also referred to as light-independent reactions.

In the Calvin cycle, carbon dioxide molecules combine with six 5-carbon compounds to make twelve 3-carbon molecules. The chemical energy stored in ATP and NADPH is passed to the 3-carbon molecules. Two 3-carbon molecules leave the cycle to be used to make glucose and other organic compounds. The enzyme **rubisco** changes ten 3-carbon molecules into six 5-carbon molecules to continue the cycle. Because rubisco changes carbon dioxide molecules into organic molecules that can be used by the cell, it is considered one of the most important enzymes. Sugar formed in the Calvin cycle can be used as energy and as building blocks for complex carbohydrates, such as starch.

Think it Over

7. **Name** the main energy-storing products of each phase of photosynthesis.

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Alternative Pathways

Photosynthesis might be difficult for plants that grow in hot, dry environments. Many plants in extreme climates have evolved other photosynthesis pathways.

Tropical plants such as sugar cane and corn use the C_4 pathway. Instead of the 3-carbon molecules of the Calvin cycle, C_4 plants fix carbon dioxide into 4-carbon molecules. Less water is lost in the C_4 pathway. These plants keep their stomata closed during hot days to minimize water loss.

What are CAM plants?

Another alternative pathway is called the CAM pathway. CAM plants live in deserts, salt marshes, and other environments where access to water is limited. Cacti and orchids are CAM plants. Carbon dioxide enters the leaves of CAM plants only at night, when the atmosphere is cooler and more humid. The plants also fix carbon dioxide into organic compounds at night. During the day, carbon dioxide is released from organic compounds in the plants. The carbon dioxide enters the Calvin cycle at that point. The CAM pathway minimizes water loss, while allowing for adequate carbon uptake. ✔

Reading Check

8. **Name** two places where CAM plants live.

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