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Summary

8–1 Energy and Life

Plants and some other types of organisms are able to use light energy from the sun to produce food. Organisms that make their own food are called autotrophs. Other organisms cannot use the sun's energy directly. These organisms, called heterotrophs, obtain energy from the foods they consume.

One of the principal chemical compounds that cells use to store and release energy is adenosine triphosphate, or ATP. ATP consists of adenine, a 5-carbon sugar called ribose, and three phosphate groups. Adenosine diphosphate (ADP) is a similar compound that has only two phosphate groups instead of three. When a cell has energy available, it can store small amounts of energy by adding a third phosphate group to ADP, producing ATP. The energy stored in ATP can be released by breaking the bond between the second and third phosphate groups. Because a cell can subtract this third phosphate group, it can release energy as needed. The characteristics of ATP make it exceptionally useful as the basic energy source of all cells. Cells use energy from ATP to carry out many important activities, including active transport, synthesis of proteins and nucleic acids, and responses to chemical signals at the cell surface. Cells store a small amount of ATP because ATP is easy to regenerate from ADP. When ATP is needed, cells use the energy in foods such as glucose to produce ATP.

8–2 Photosynthesis: An Overview

Research into photosynthesis began centuries ago. In 1643, Jan van Helmont concluded that trees gain most of their mass from water. In 1771, Joseph Priestley determined that plants release oxygen, which can keep a candle burning.

In 1779, Jan Ingenhousz concluded that plants need sunlight to produce oxygen. The experiments performed by van Helmont, Priestley, and Ingenhousz led to work by other scientists who finally discovered that in the presence of light, plants transform carbon dioxide and water into carbohydrates and plants also release oxygen.

The overall equation for photosynthesis can be shown as follows:

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

carbon dioxide + water $\xrightarrow{\text{light}}$ sugars + oxygen

Photosynthesis uses the energy of sunlight to convert water and carbon dioxide into high-energy sugars and oxygen. Plants use the sugars to produce complex carbohydrates such as starches. Plants obtain the carbon dioxide they need for photosynthesis from the air or from the water in which they grow.

In addition to water and carbon dioxide, photosynthesis requires light and chlorophyll. Plants gather the sun's energy with light-absorbing molecules called pigments. The plants' principal pigment is chlorophyll. There are two main types of chlorophyll: chlorophyll *a* and chlorophyll *b*.

The wavelengths of sunlight you can see make up the visible spectrum, which contains all the colors. Chlorophyll absorbs light in the blue-violet and red regions very well. But it does not absorb light in the green region well. Green light is reflected by leaves, which is why plants look green.

Any compound that absorbs light absorbs the energy in light. When chlorophyll absorbs sunlight, much of the energy of the light is transferred directly to the electrons in the chlorophyll molecule, raising the energy level of the electrons.

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8–3 The Reactions of Photosynthesis

In plants and other photosynthetic prokaryotes, photosynthesis takes place inside the chloroplasts. Chloroplasts contain saclike photosynthetic membranes called thylakoids. Thylakoids are arranged in stacks called grana. Proteins in the thylakoid membrane organize chlorophyll and other pigments into clusters known as photosystems. These photosystems are the light-collecting units of chlorophyll. The reactions of photosynthesis occur in two parts: (1) the light-dependent reactions and (2) the light-independent reactions, also known as the Calvin cycle. The light-dependent reactions take place within the thylakoid membranes. The Calvin cycle takes place in the stroma—the region outside of the thylakoid membranes.

When sunlight excites electrons in chlorophyll, the electrons gain a great deal of energy. A carrier molecule is a compound that can accept a pair of high-energy electrons and transfer them along with most of their energy to another molecule. One of these carrier molecules is $NADP^+$. In the process of photosynthesis, $NADP^+$ accepts and holds 2 high-energy electrons along with a hydrogen ion (H^+). This converts the $NADP^+$ into NADPH.

The light-dependent reactions require light. These reactions use energy from light to produce oxygen gas and convert ADP and $NADP^+$ into the energy carriers ATP and NADPH. Photosynthesis begins when pigments in photosystem II absorb light. A series of reactions follows. The reactants are water, ADP, and $NADP^+$. The products are oxygen gas, ATP, and NADPH. The oxygen gas produced by photosynthesis is the source of nearly all the oxygen in Earth's atmosphere.

The Calvin cycle does not require light. During the Calvin cycle, plants use the energy of ATP and NADPH—products of the light-dependent reactions—to produce high-energy sugars. The Calvin cycle uses carbon dioxide in its series of reactions. As photosynthesis proceeds, the Calvin cycle works steadily, removing carbon dioxide from the atmosphere and turning out energy-rich sugars. Six carbon dioxide molecules are needed to produce a single 6-carbon sugar.

Many factors affect the rate of photosynthesis. Such factors include availability of water, temperature, and intensity of light.

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Section 8–1 Energy and Life (pages 201–203)

Key Concepts

- Where do plants get the energy they need to produce food?
- What is the role of ATP in cellular activities?

Autotrophs and Heterotrophs (page 201)

1. Where does the energy of food originally come from? _____

_____

2. Complete the table describing the types of organisms.

TYPES OF ORGANISMS

Type	Description	Examples
	Organisms that make their own food	
	Organisms that obtain energy from the food they eat	

Chemical Energy and ATP (page 202)

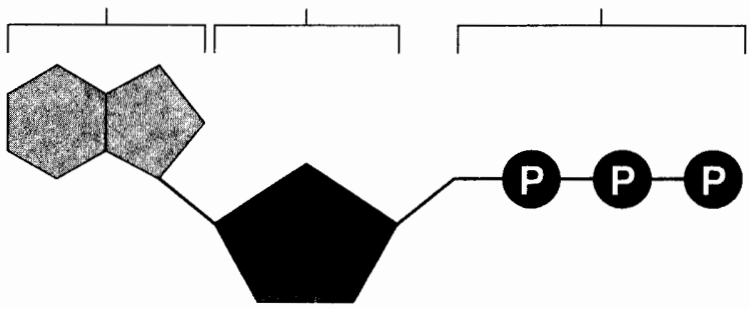
3. What is one of the principal chemical compounds that cells use to store energy?

_____

4. How is ATP different from ADP? _____

_____

5. Label each part of the ATP molecule illustrated below.



6. When a cell has energy available, how can it store small amounts of that energy?

_____

_____

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7. When is the energy stored in ATP released? _____

_____

_____

8. For what purpose do the characteristics of ATP make it exceptionally useful to all types of cells? _____

_____

9. What are two ways in which cells use the energy provided by ATP?

   a. _____

   b. _____

Using Biochemical Energy (pages 202–203)

10. Why is it efficient for cells to keep only a small supply of ATP on hand?

_____

_____

_____

11. Circle the letter of where cells get the energy to regenerate ATP.

   a. ADP

   b. phosphates

   c. foods like glucose

   d. organelles

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Section 8–2 Photosynthesis: An Overview (pages 204–207)

Key Concepts

- What did the experiments of van Helmont, Priestley, and Ingenhousz reveal about how plants grow?
- What is the overall equation for photosynthesis?
- What is the role of light and chlorophyll in photosynthesis?

Introduction (page 204)

1. What occurs in the process of photosynthesis? _____

_____

_____

Investigating Photosynthesis (pages 204–206)

2. What did Jan van Helmont conclude from his experiment? _____

_____

_____

3. Circle the letter of the substance produced by the mint plant in Joseph Priestley's experiment.
   - **a.** carbon dioxide
   - **b.** water
   - **c.** air
   - **d.** oxygen
4. What did Jan Ingenhousz show? _____

_____

_____

The Photosynthesis Equation (page 206)

5. Write the overall equation for photosynthesis using words.

_____

6. Photosynthesis uses the energy of sunlight to convert water and carbon dioxide into oxygen and high-energy _____.

Light and Pigments (page 207)

7. What does photosynthesis require in addition to water and carbon dioxide?

_____

_____

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8. Plants gather the sun's energy with light-absorbing molecules called _____.
9. What is the principal pigment of plants? _____
10. Circle the letters of the regions of the visible spectrum in which chlorophyll absorbs light very well.
    a. blue-violet region
    b. green region
    c. red region
    d. yellow region

Reading Skill Practice

By looking at illustrations in textbooks, you can help yourself remember better what you have read. Look carefully at Figure 8–4 on page 206. What important ideas does this illustration communicate? Do your work on a separate sheet of paper.

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Section 8–3 The Reactions of Photosynthesis

(pages 208–214)

Key Concepts

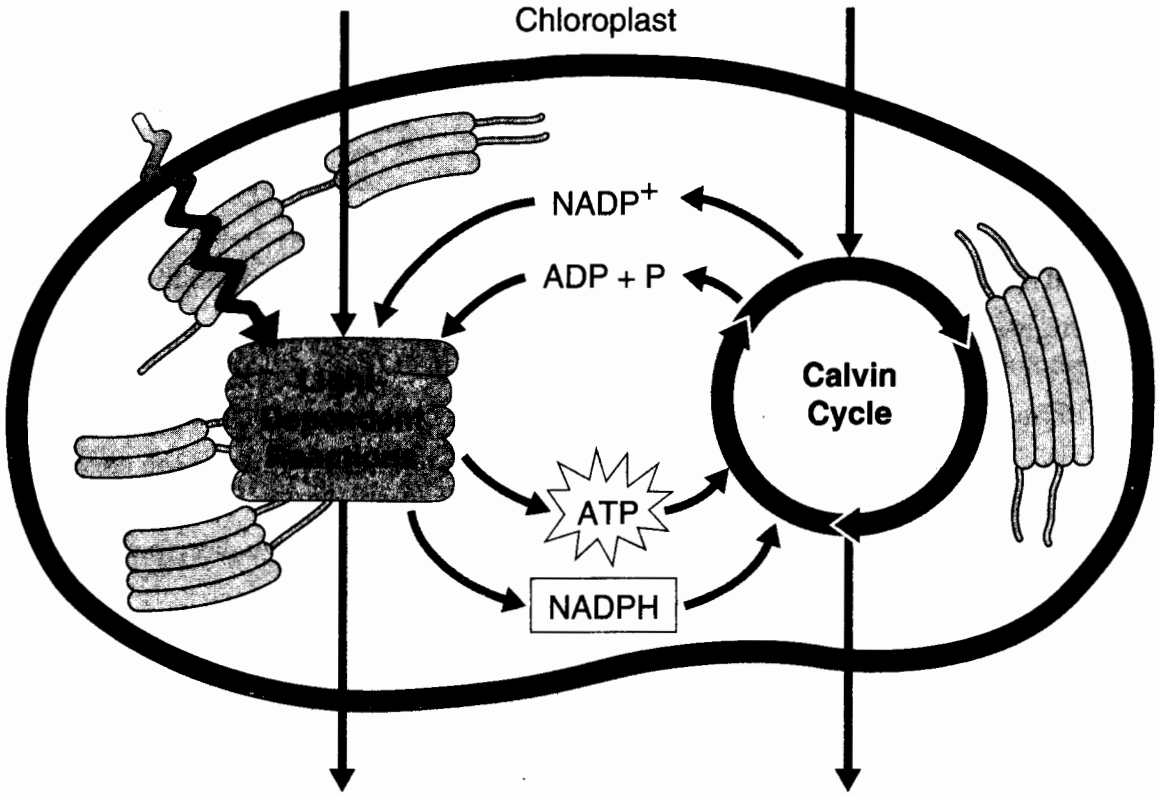
- What happens in the light-dependent reactions?
- What is the Calvin cycle?

Inside a Chloroplast (page 208)

1. Chloroplasts contain saclike photosynthetic membranes called _____.
2. What is a granum? _____

_____

3. The region outside the thylakoid membranes in the chloroplasts is called the _____.
4. What are the two stages of photosynthesis called?
   a. _____
   b. _____
5. Complete the illustration of the overview of photosynthesis by writing the products and the reactants of the process, as well as the energy source that excites the electrons.



Name_____ Class_____ Date _____

Electron Carriers (page 209)

6. When sunlight excites electrons in chlorophyll, how do the electrons change?

_____

_____

7. What is a carrier molecule? _____

_____

_____

_____

8. Circle the letter of the carrier molecule involved in photosynthesis.

   a. H_2O c. CO_2

   b. $NADP^+$ d. O_2

9. How does $NADP^+$ become NADPH? _____

_____

_____

Light-Dependent Reactions (pages 210–211)

10. Circle the letter of each sentence that is true about the light-dependent reactions.

    a. They convert ADP into ATP.

    b. They produce oxygen gas.

    c. They convert oxygen into carbon dioxide.

    d. They convert $NADP^+$ into NADPH.

11. Where do the light-dependent reactions take place? _____

_____

12. Circle the letter of each sentence that is true about the light-dependent reactions.

    a. High-energy electrons move through the electron transport chain from photosystem II to photosystem I.

    b. Photosynthesis begins when pigments in photosystem I absorb light.

    c. The difference in charges across the thylakoid membrane provides the energy to make ATP.

    d. Pigments in photosystem I use energy from light to reenergize electrons.

13. How does ATP synthase produce ATP? _____

_____

_____

_____

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The Calvin Cycle (pages 212–214)

14. What does the Calvin cycle use to produce high-energy sugars?

_____

_____

15. Why are the reactions of the Calvin cycle also called the light-independent reactions?

_____

16. Circle the letter of each statement that is true about the Calvin cycle.

    a. The main products of the Calvin cycle are six carbon dioxide molecules.

    b. Carbon dioxide molecules enter the Calvin cycle from the atmosphere.

    c. Energy from ATP and high-energy electrons from NADPH are used to convert 3-carbon molecules into higher-energy forms.

    d. The Calvin cycle uses six molecules of carbon dioxide to produce a single 6-carbon sugar molecule.

Factors Affecting Photosynthesis (page 214)

17. What are three factors that affect the rate at which photosynthesis occurs?

    a. _____

    b. _____

    c. _____

18. Is the following sentence true or false? Increasing the intensity of light decreases the rate of photosynthesis. _____

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Vocabulary Review

Matching *In the space provided, write the letter of the definition that best matches each term.*

_____ **1.** photosynthesis
_____ **2.** chlorophyll
_____ **3.** pigment
_____ **4.** adenosine triphosphate
_____ **5.** thylakoid
_____ **6.** photosystems
_____ **7.** stroma
_____ **8.** $NADP^+$
_____ **9.** Calvin cycle
_____ **10.** light-dependent reactions

a. clusters in the thylakoid membrane of chlorophyll and other pigments
b. the region of the chloroplast outside the thylakoid membranes
c. electron carrier
d. process in which plants use the energy of sunlight to make high-energy carbohydrates
e. reactions that use ATP and NADPH to produce high-energy sugars
f. light-absorbing molecules
g. the basic energy source of all cells
h. reactions that produce oxygen gas and convert ADP and $NADP^+$ into the energy carriers ATP and NADPH
i. saclike photosynthetic membranes in chloroplasts
j. principal pigment of plants

Answering Questions *In the space provided, write an answer to each question.*

11. What is an organism that obtains energy from the food it consumes? _____

_____

12. What is an organism that is able to make its own food? _____

_____

13. What is released when the chemical bond is broken between the second and third phosphates of an ATP molecule? _____

_____

14. What are the reactants of the equation for photosynthesis? _____

_____

15. What are the products of the equation for photosynthesis? _____

_____