Chapter 9 Organizer

Energy in a Cell

Refer to pages 4T-5T of the Teacher Guide for an explanation of the National Science Education Standards correlations.

Section	Objectives	Activities/Features
Section 9.1 **ATP in a Molecule** National Science Education Standards UCP.2, UCP.3; A.1, A.2; B.3, B.6; C.1, C.5 (1 session, $^1/_2$ block)	1. **Explain** why organisms need a supply of energy. 2. **Describe** how energy is stored and released by ATP.	**Problem-Solving Lab 9-1,** p. 228
Section 9.2 **Photosynthesis: Trapping the Sun's Energy** National Science Education Standards UCP.2, UCP.3; A.1, A.2; B.3, B.6; C.1, C.5; G.1 (2 sessions, 1 block)	3. **Relate** the structure of chloroplasts to the events in photosynthesis. 4. **Describe** light-dependent reactions. 5. **Explain** the reactions and products of the light-independent Calvin cycle.	**Problem-Solving Lab 9-2,** p. 232 **MiniLab 9-1:** Use Isotopes to Understand Photosynthesis, p. 234 **Inside Story:** The Calvin Cycle, p. 235 **Careers in Biology:** Biochemist, p. 236 **Internet BioLab:** What factors influence photosynthesis? p. 244 **Chemistry Connection:** Plant Pigments, p. 246
Section 9.3 **Getting Energy to Make ATP** National Science Education Standards UCP.1-3; A.1, A.2; B.3, B.6; C.1, C.5; F.6 (3 sessions, $^1/_2$ block)	6. **Compare and contrast** cellular respiration and fermentation. 7. **Explain** how cells obtain energy from cellular respiration.	**Inside Story:** The Citric Acid Cycle, p. 239 **Problem-Solving Lab 9-3,** p. 241 **MiniLab 9-2:** Determine if Apple Juice Ferments, p. 242

Need Materials? Contact Carolina Biological Supply Company at 1-800-334-5551 or at **http://www.carolina.com**

MATERIALS LIST

BioLab

p. 244 1000 mL beaker, *Elodea* plants (3), string, washers, colored cellophane, 150-watt light with reflector, 0.25% baking soda solution, watch with second hand

MiniLabs

p. 234 clay (various colors)
p. 242 small beaker, plastic pipette, large test tube, water, metal washers, baker's yeast, apple juice

Alternative Lab

p. 240 black paper, labels, iodine solution, paper clips, hot plate, beaker, 95% ethanol, small bowl, *Coleus* plants

Quick Demos

p. 229 potato, water, beaker, Bunsen burner
p. 233 prism
p. 238 sugar (sucrose), water, flask, baker's yeast
p. 251 potato, meat, vegetable oil, molecular model of lipid

Key to Teaching Strategies

- L1 Level 1 activities should be appropriate for students with learning difficulties.
- L2 Level 2 activities should be within the ability range of all students.
- L3 Level 3 activities are designed for above-average students.
- ELL ELL activities should be within the ability range of English Language Learners.
- COOP LEARN Cooperative Learning activities are designed for small group work.
- P These strategies represent student products that can be placed into a best-work portfolio.
- These strategies are useful in a block scheduling format.

Teacher Classroom Resources

Section	Reproducible Masters	Transparencies
Section 9.1 **ATP in a Molecule**	Reinforcement and Study Guide, p. 37 L2 Tech Prep Applications, pp. 15-16 L2 Content Mastery, pp. 41-42, 44 L1	Section Focus Transparency 21 L1 ELL Basic Concepts Transparency 11 L2 ELL
Section 9.2 **Photosynthesis: Trapping the Sun's Energy**	Reinforcement and Study Guide, p. 38-39 L2 Concept Mapping, p. 9 L3 ELL Critical Thinking/Problem Solving, p. 9 L3 BioLab and MiniLab Worksheets, p. 39 L2 Content Mastery, pp. 41, 43-44 L1	Section Focus Transparency 22 L1 ELL Basic Concepts Transparency 12 L2 ELL
Section 9.3 **Getting Energy to Make ATP**	Reinforcement and Study Guide, p. 40 L2 BioLab and MiniLab Worksheets, pp. 40-42 L2 Laboratory Manual, pp. 61-68 L2 Content Mastery, pp. 41, 43-44 L1	Section Focus Transparency 23 L1 ELL Basic Concepts Transparency 13 L2 ELL Reteaching Skills Transparency 14 L1 ELL Reteaching Skills Transparency 15 L1 ELL

Assessment Resources

Chapter Assessment, pp. 49-54
MindJogger Videoquizzes
Performance Assessment in the Biology Classroom
Alternate Assessment in the Science Classroom
Computer Test Bank
BDOL Interactive CD-ROM, Chapter 9 quiz

Additional Resources

Spanish Resources ELL
English/Spanish Audiocassettes ELL
Cooperative Learning in the Science Classroom COOP LEARN
Lesson Plans/Block Scheduling

NATIONAL GEOGRAPHIC Teacher's Corner

Products Available From Glencoe

To order the following products, call Glencoe at 1-800-334-7344:

CD-ROMs
NGS PictureShow: The Cell
NGS PictureShow: Plants: What It Means to Be Green

Curriculum Kit
GeoKit: Cells and Microorganisms

Transparency Sets
NGS PicturePack: The Cell
NGS PicturePack: Plants: What It Means to Be Green

Products Available From National Geographic Society

To order the following products, call National Geographic Society at 1-800-368-2728:

Video
Discovering the Cell
Photosynthesis: Life Energy

Index to National Geographic Magazine

The following articles may be used for research relating to this chapter:

"How the Sun Gives Life to the Sea," by Paul A. Zahl, February 1961.

GLENCOE TECHNOLOGY

The following multimedia resources are available from Glencoe.

Biology: The Dynamics of Life

CD-ROM ELL
Animation: *The Light Reactions*
Exploration: *Parts of the Cell*
Exploration: *Phases of Mitosis*
BioQuest: *Cellular Pursuit*

Videodisc Program
The Light Reactions

The Infinite Voyage
Unseen World
The Champion Within

The Secret of Life Series
ATP Structure
ATP Function
ATP Serves as an Energy Carrier

Getting Started Demo

Bring out play money in several size bills—$1, $10, $50, and $100. Have students point out expensive and inexpensive objects. Relate the cost of goods to the energy needs required by an ant to lift and move a crumb. Point out that sometimes a lot of energy must be broken down into smaller amounts, just as a $100 bill must be broken down to make change for a smaller purchase.

Theme Development

The main theme of this chapter is **energy**. ATP is presented as the energy storage molecule and the most prevalent source of energy for cells. Both the synthesis and breakdown of ATP are covered. An underlying theme is that there is cellular **unity within diversity.** All cells carry out respiration and many cells also carry out photosynthesis.

0:00 Out of Time?

If time does not permit teaching the entire chapter, use the BioDigest at the end of the unit as an overview.

Resource Manager

Section Focus Transparency 21 and Master L1 ELL
Basic Concepts Transparency 11 and Master L2 ELL

Chapter 9 Energy in a Cell

What You'll Learn

- You will learn what ATP is.
- You will explain how ATP provides energy for the cell.
- You will describe how chloroplasts trap the sun's energy to make ATP and complex carbohydrates.
- You will compare ATP production in mitochondria and chloroplasts.

Why It's Important

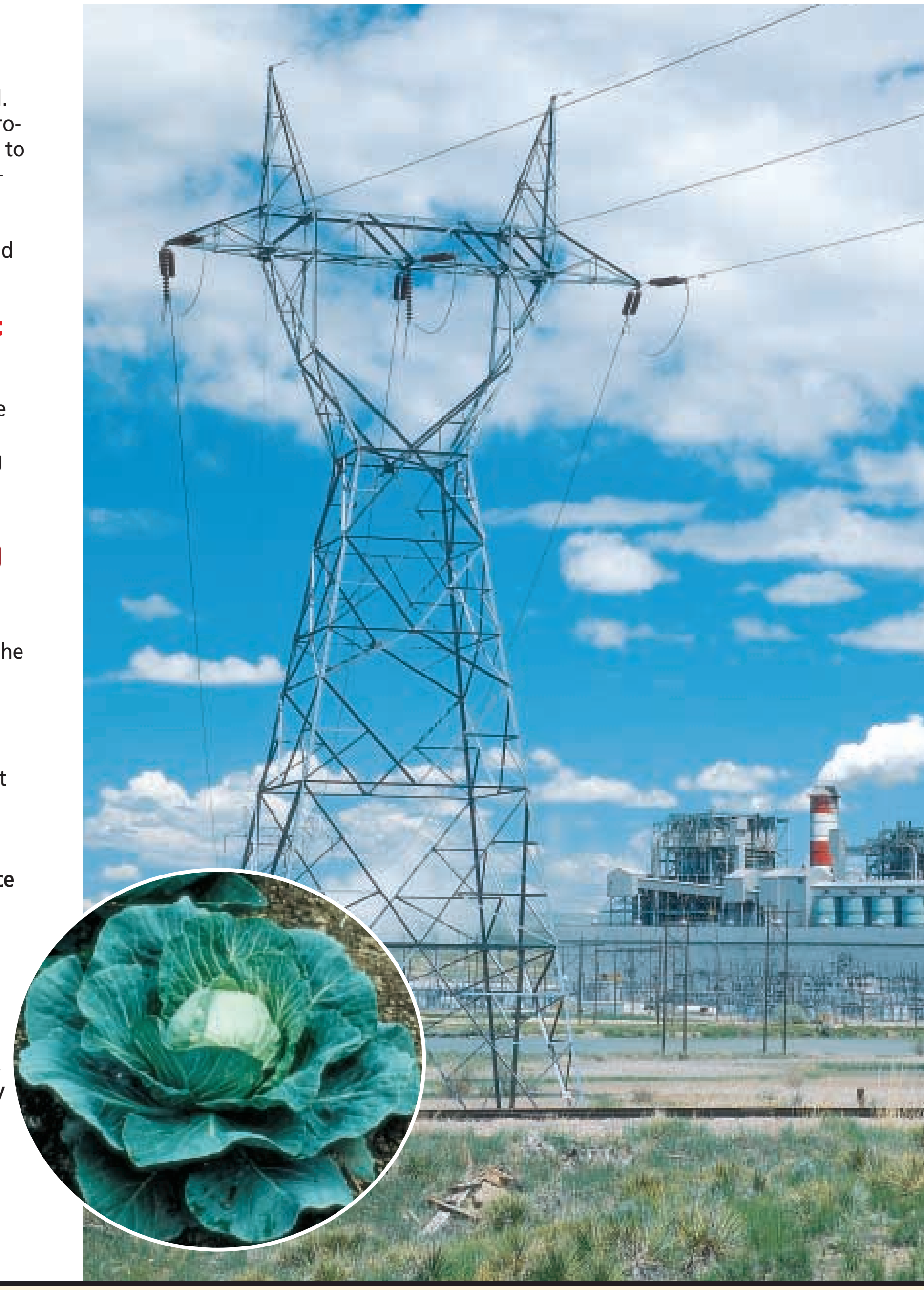
Every cell in your body needs energy in order to function. The energy your cells produce and store is the fuel for basic body functions such as eating and breathing.

Getting Started

The Source of Energy

Watch your teacher's movements as he or she conducts the class. *Where does the energy for this activity come from?*

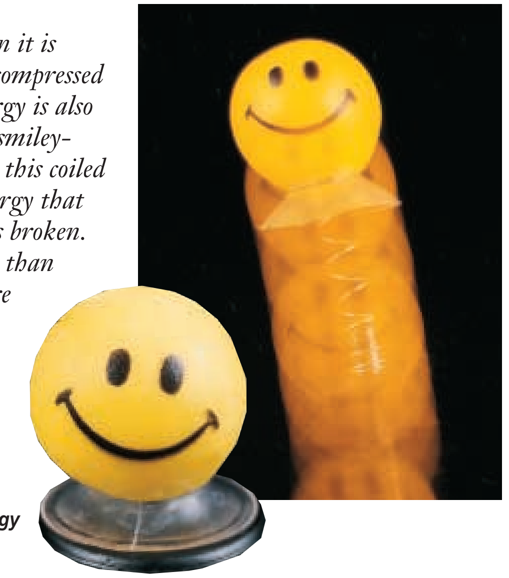
interNET CONNECTION To find out more about how cells use and produce energy, visit the Glencoe Science Web Site.
www.glencoe.com/sec/science



Energy can be captured through photosynthesis in these cabbage leaves, or burned into electricity at this power plant.

Section 9.1 ATP in a Molecule

A spring stores energy when it is compressed. When the compressed spring is released, energy is also released, energy that sends this smiley-face toy flying into the air. Like this coiled spring, chemical bonds store energy that can be released when the bond is broken. Just as some springs are tighter than others, some chemical bonds store more energy than others.



Stored energy

Section Preview

Objectives

Explain why organisms need a supply of energy.

Describe how energy is stored and released by ATP.

Vocabulary

ATP (adenosine triphosphate)
ADP (adenosine diphosphate)

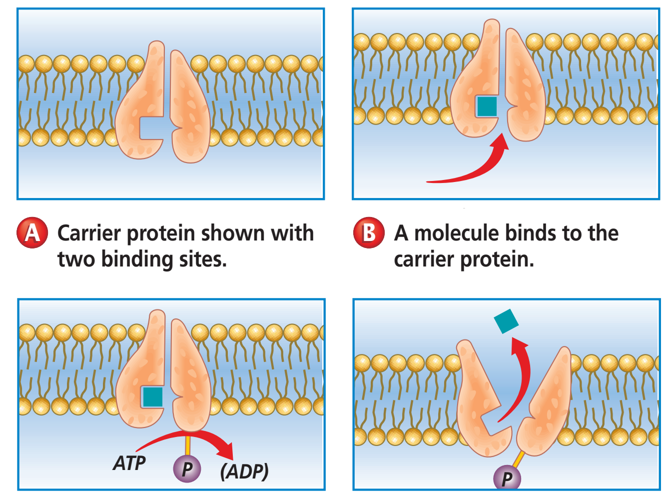
Figure 9.1
Active transport requires energy to bind and pump this molecule across the plasma membrane.

Cell Energy

Energy is essential to life. All living organisms must be able to produce energy from the environment in which they live, store energy for future use, and use energy in a controlled manner.

Work and the need for energy

You've learned about several cell processes that require energy. Active transport, cell division, movement of flagella or cilia, and the production and storage of proteins are some examples. The transport of proteins is shown in ***Figure 9.1***. You can probably come up with other examples of biological work, such as muscles contracting during exercise, your heart pumping, and your brain



A Carrier protein shown with two binding sites.
B A molecule binds to the carrier protein.
C Energy released as a phosphate group from ATP is transferred to the protein.
D The phosphate group and energy trigger the protein to pump the molecule through the membrane.

Prepare

Key Concepts

Students will examine the source of cellular energy—the ATP molecule. They will also learn about the processes in which cells use the energy stored in ATP.

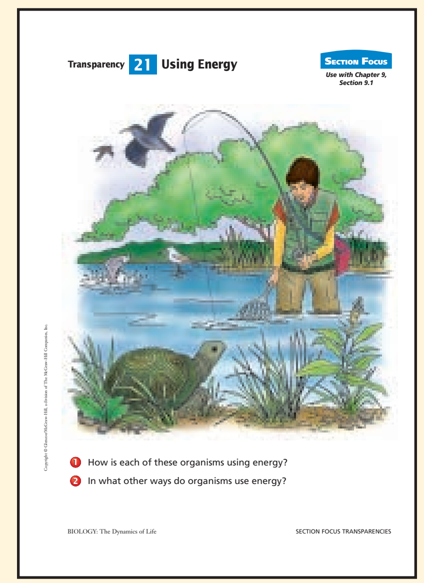
Planning

- Obtain a potato, peanuts, a dissection needle, a cork, and a Bunsen burner for the Quick Demo and closing Demonstration.
- Gather toothpicks, gumdrops, and construction paper for the modeling activities.

1 Focus

Bellringer

Before presenting the lesson, display **Section Focus Transparency 21** on the overhead projector and have students answer the accompanying questions. L1 ELL



Multiple Learning Styles

Look for the following logos for strategies that emphasize different learning modalities.

Kinesthetic Portfolio, p. 228; Reteach, p. 230; Project, p. 233
Visual-Spatial Portfolio, p. 239; Check for Understanding, p. 243
Interpersonal Portfolio, p. 232;
Intrapersonal Meeting Individual Needs, pp. 229, 238; Extension, p. 236
Linguistic Biology Journal, pp. 229, 234; Extension, p. 230; Meeting Individual Needs, p. 231

Assessment Planner

Portfolio Assessment
Assessment, TWE, p. 243
BioLab, TWE, pp. 244-245

Performance Assessment
Problem-Solving Lab, TWE, pp. 228, 232
MiniLab, TWE, p. 242
Assessment, TWE, p. 236
Alternative Lab, TWE, pp. 240-241
MiniLab, SE, pp. 234, 242
BioLab, SE, pp. 244-245

Knowledge Assessment
Assessment, TWE, pp. 229, 230
MiniLab, TWE, p. 234
Section Assessment, SE, pp. 230, 236, 243
Chapter Assessment, SE, pp. 247-249

Skill Assessment
Assessment, TWE, pp. 233, 240
Problem-Solving Lab, TWE, p. 241

2 Teach

Problem-Solving Lab 9-1

Purpose

Students will determine that fat, rather than carbohydrates, is the preferred compound for energy storage in humans.

Process Skills

acquire information, compare and contrast, think critically, draw a conclusion

Background

Fats yield more ATPs than carbohydrates because they have more C–H bonds. A six-carbon fat fragment has a molecular weight of about 100, while the same carbohydrate size has a molecular weight of 180. Fats are hydrophobic while carbohydrates are hydrophilic.

Teaching Strategies

■ Emphasize that this lab discusses the storage of excess energy and reiterate that carbohydrates are also important compounds.

■ Elicit from students if they believe early humans were typically very agile. *Heavy body weight would not have been an asset to the survival of hunters. Therefore, if early humans were storing energy as fat, they were not likely very agile.*

Thinking Critically

1. Because the metabolism of water yields zero ATP, water is "excess baggage." Fat, with no water, carries less "excess baggage," helping to make it more efficient.
2. Because we store excess energy as fat, we do not carry the weight of water that is associated with carbohydrates.

Problem-Solving Lab 9-1 — Recognizing Cause and Effect

Why is fat the choice?
Humans store their excess energy as fat rather than as carbohydrates. Why is this? From an evolutionary and efficiency point of view, fats are better for storage than carbohydrates. Find out why.

Analysis
The following facts compare certain characteristics of fats and carbohydrates:

A. When broken down by the body, each six-carbon molecule of fat yields 51 ATP molecules. Each six-carbon carbohydrate molecule yields 38 ATP molecules.
B. Carbohydrates bind and store water. The metabolism of water yields zero ATP. Fat has zero grams of water bound to it.
C. An adult who weighs 70 kg can survive on the energy derived from stored fat for 30 days without eating. The same person would have to weigh nearly 140 kg to survive 30 days on stored carbohydrates.

Thinking Critically

1. From an ATP production viewpoint, use fact B to make a statement regarding the efficiency of fats vs. carbohydrates.
2. Explain why the average weight for humans is close to 70 kg and not 140 kg.

Word Origin

mono-, di-, tri
From the Latin words *mono, di,* and *tri,* meaning "one," "two," and "three," respectively. Adenosine triphosphate contains three phosphate groups.

controlling your entire body. This work cannot be done without energy. Read the *Problem-Solving Lab* on this page and think about how the human body stores energy.

When you finish strenuous physical exercise, such as running cross country, your body wants a quick source of energy, so you may eat a candy bar. Similarly, there is a molecule in your cells that is a quick source of energy for any organelle in the cell that needs it. This energy is stored in the chemical bonds of the molecule and can be used quickly and easily by the cell.

The name of this energy molecule is **adenosine triphosphate** (uh DEN uh seen • tri FAHS fayt), or **ATP** for short. ATP is composed of an adenosine molecule with three phosphate groups attached. Recall that phosphate groups are charged molecules, and remember that molecules with the same charge do not like being too close to each other.

Forming and Breaking Down ATP

The charged phosphate groups act like the positive poles of two magnets. If like poles of a magnet are placed next to each other, it is difficult to force the magnets together. Likewise, bonding phosphate groups to adenosine requires considerable energy. When only one phosphate group is attached, a small amount of energy is required and the chemical bond does not store much energy. A molecule of this sort is called adenosine monophosphate (AMP). When a second phosphate is added, a more substantial amount of energy is required to force the two phosphate groups together. A molecule of this sort is called **adenosine diphosphate**, or **ADP**. When the third phosphate group is added, a tremendous amount of energy is required to force the third charged phosphate group close to the two other phosphate groups. The third phosphate group is so eager to get away from the other two that, when that bond is broken, a great amount of energy is released.

The energy of ATP becomes available when the molecule is broken down. In other words, when the chemical bond between phosphate groups in ATP is broken, energy is released and the resulting molecule is ADP. At this point, ADP can reform

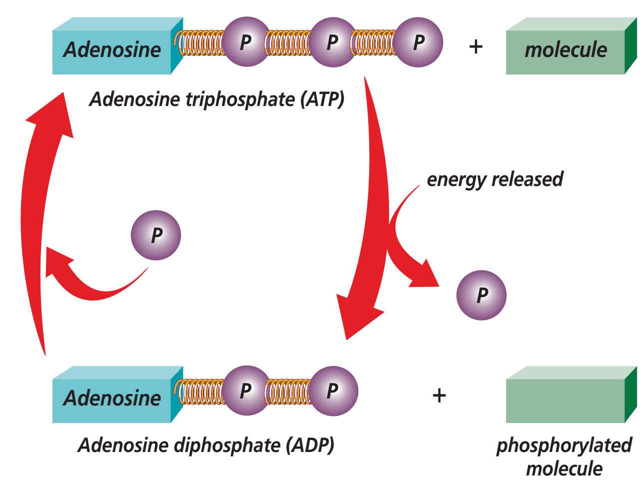
ATP by bonding with another phosphate group. This creates a renewable cycle of ATP formation and breakdown. ***Figure 9.2*** illustrates the chemical reactions that are involved in the cycle.

The formation/breakdown recycling activity is important because it relieves the cell of having to store all of the ATP it needs. As long as phosphate molecules are available, the cell has an unlimited supply of energy. Another benefit of the formation/breakdown cycle is that ADP can also be used as an energy source. Although most cell functions require the amount of energy in ATP, some cell functions do not require as much energy and can use the energy stored in ADP.

How cells tap into the energy stored in ATP

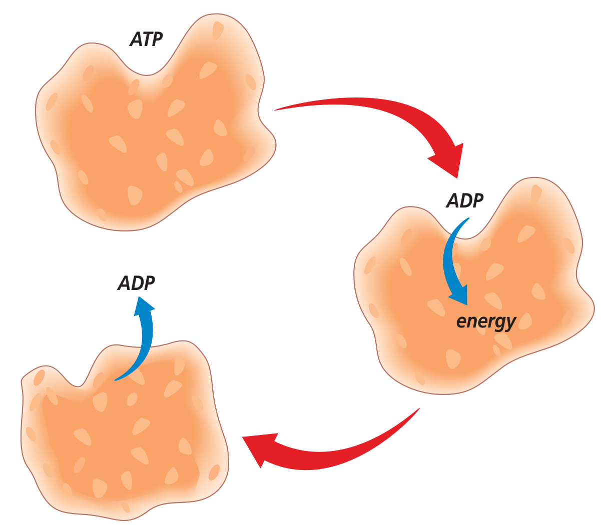
When ATP is broken down and the energy is released, cells must have a way to capture that energy and use it efficiently. Otherwise, it is wasted. ATP is a small compound. Cellular proteins have a specific site where ATP can bind. Then, when the phosphate bond is broken and the energy released, the cell can use the energy for activities such as making a protein or transporting molecules through the plasma membrane. This cellular process is similar to the way energy in batteries is used by a radio. Batteries sitting on a table are of little use if the energy stored within the batteries cannot be accessed. When the batteries are snapped into the holder on the radio, the radio then has access to the stored energy and can use it. Likewise, when the energy in the batteries has been used, the batteries can be taken out, recharged, and replaced in the holder. In a similar fashion in a cell, when ATP has been broken down to ADP, ADP is

Figure 9.2
The addition and release of a phosphate group on adenosine diphosphate creates a cycle of ATP formation and breakdown.



released from the binding site in the protein and the binding site may then be filled by another ATP molecule. ATP binding and energy release in a protein is shown in ***Figure 9.3***.

Figure 9.3
To access the energy stored in ATP, proteins bind ATP and allow the phosphate group to be released. The ADP that is formed is released, and the protein binding site can once again bind ATP.



Assessment

Knowledge Have students explain in their own words how energy is stored within an ATP molecule. L2

Quick Demo

To demonstrate the transfer of energy in small amounts, heat a potato in boiling water or in a microwave oven in the school cafeteria. When it is cool enough to handle safely, have students pass the heated potato to one another. Ask students who first handle the potato to describe its temperature as hot, warm, cool, or cold. Have a student near the end make the same observation.

GLENCOE TECHNOLOGY

VIDEODISC
The Secret of Life
ATP Structure

ATP Function

ATP Serves as an Energy Carrier

Resource Manager

Reinforcement and Study Guide, p. 37 L2
Content Mastery, p. 42 L1
Tech Prep Applications, p. 15 L2

Assessment

Performance Have students research where fat is stored within the human body, including any differences between male and female. Have students write three questions about what they have learned. Use the Performance Task Assessment List for Asking Questions in **PASC**, p. 19. L3

Portfolio

Modeling Chemical Compounds

Kinesthetic Provide students with toothpicks and gumdrops of different sizes and colors. Have them use the materials to make models of ATP and ADP. Have students include in their portfolios a description of how the molecules differ from each other and how these differences relate to energy. L2 P

Biology Journal

Surviving Without Bread or Water

Linguistic Have students find out how long a person can survive without food and without water. Have students report their findings and evaluate why people perish without water before they perish without food. L2

Meeting Individual Needs

Hearing Impaired

Intrapersonal Give hearing impaired students a photograph of an organism from a magazine or similar source and ask them to list the activities of the organism that require energy from ATP. L1

3 Assess

Check for Understanding

Ask students why energy must be stored in small amounts and relate the answer to paying for a small purchase with a $1 bill rather than with a $50 bill.

Reteach

Kinesthetic Have students join like poles of four small magnets to simulate the storage of energy in ATP. Explain how energy is released when the magnets are pulled apart. L1 ELL

Extension

Linguistic Have interested students write a report about a bioluminescent organism and include facts about that organism's energy requirements. L2

Assessment

Knowledge Ask students to summarize how each organism or structure in Figure 9.4 uses energy. L2

4 Close

Demonstration

Burn a peanut to demonstrate that energy is stored in food. Impale a peanut on the end of a dissection needle. Stick the other end of the needle into a cork. Ignite the peanut with a Bunsen burner. Ask students to describe the form of energy released during burning. *Energy is released as light and heat.*

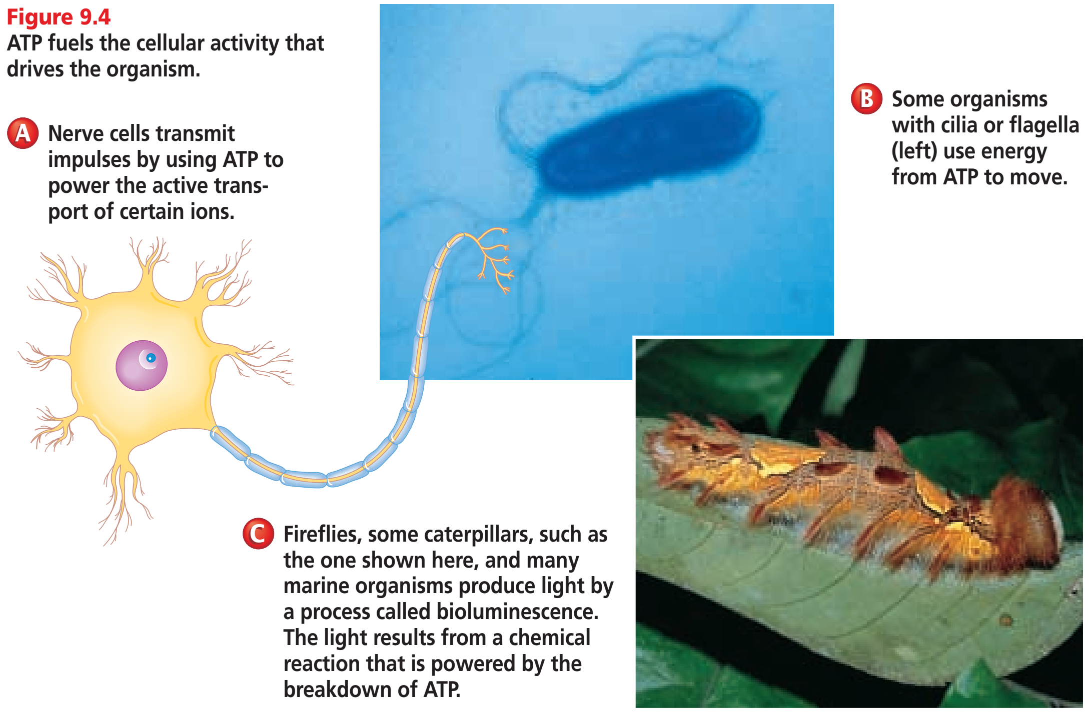


Figure 9.4
ATP fuels the cellular activity that drives the organism.

A Nerve cells transmit impulses by using ATP to power the active transport of certain ions.

B Some organisms with cilia or flagella (left) use energy from ATP to move.

C Fireflies, some caterpillars, such as the one shown here, and many marine organisms produce light by a process called bioluminescence. The light results from a chemical reaction that is powered by the breakdown of ATP.

Uses of Cell Energy

You can probably think of hundreds of physical activities that require energy, but energy is equally important at the cellular level for nearly all of the cell's activities.

Making new molecules is one way that cells use energy. Some of these molecules are enzymes, which carry out chemical reactions. Other molecules build membranes and cell organelles. Cells use energy to maintain homeostasis. Kidneys use energy to move molecules and ions in order to eliminate waste substances while keeping needed substances in the bloodstream. ***Figure 9.4*** shows several organisms and activities that illustrate ways that cells use energy.

Section Assessment

Understanding Main Ideas

1. What processes in the cell need energy from ATP?
2. How does ATP store energy?
3. How can ADP be "recycled" to form ATP again?
4. How do proteins in your cells access the energy stored in ATP?

Thinking Critically

5. Phosphate groups in ATP repel each other because they have negative charges. What charge might be present in the ATP binding site of proteins to attract another ATP molecule?

Skill Review

6. **Observing and Inferring** When animals shiver in the cold, muscles move almost uncontrollably. Suggest how shivering helps an animal survive in the cold. For more help, refer to *Thinking Critically* in the **Skill Handbook**.

Section

9.2 Photosynthesis: Trapping the Sun's Energy

Have you ever admired a beautiful rainbow shimmering in the air after a rainstorm? You may not have realized that the colors you saw represent the sun's energy broken into different wavelengths, which our eyes interpret as color. To leaves on a tree, the wavelengths of light represent a source of energy to be stored and used.

Photosynthesis requires sunlight.

SECTION PREVIEW

Objectives

Relate the structure of chloroplasts to the events in photosynthesis.

Describe the light-dependent reactions.

Explain the reactions and products of the light-independent Calvin cycle.

Vocabulary

photosynthesis
light-dependent reactions
light-independent reactions
pigments
chlorophyll
electron transport chain
NADP+
photolysis
Calvin cycle

Trapping Energy from Sunlight

To use the energy of the sun's light, plant cells must trap light energy and store it in a form that is readily usable by cell organelles—that form is ATP. However, light energy is not available 24 hours a day, so the plant cell must also store some of the energy for the dark hours. **Photosynthesis** is the process plants use to trap the sun's energy and build carbohydrates, called glucose, that store energy. To accomplish this, photosynthesis happens in two phases. The **light-dependent reactions** convert light energy into chemical energy. The molecules of ATP produced in the light-dependent reactions are then used to fuel the **light-independent reactions** that produce glucose. The general equation for photosynthesis is written as follows:

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

The *BioLab* at the end of this chapter describes an experiment you can perform to investigate the rate of photosynthesis.

The chloroplast and pigments

Recall that the chloroplast is the cell organelle where photosynthesis occurs. It is in the membranes of the thylakoid discs in chloroplasts that the light-dependent reactions take place.

WORD Origin

photosynthesis
From the Greek words *photo*, meaning "light," and *syntithenai*, meaning "to put together." Photosynthesis puts together sugar molecules using energy from light, water, and carbon dioxide.

Section 9.2

Prepare

Key Concepts

Students will relate the structure of the chloroplast to the process of photosynthesis. They will also explore the overall reactions that occur in the light reactions and the Calvin cycle.

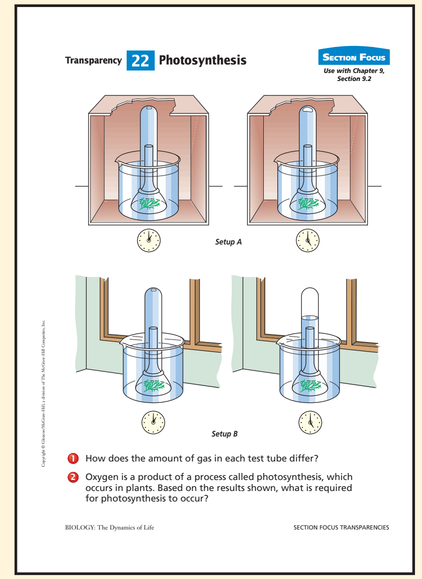
Planning

- Acquire a prism to use in the Quick Demo.
- Acquire colored lights for the plant growth project.
- Purchase *Elodea* for the BioLab.
- Collect objects to model photosynthesis for MiniLab 9-1.
- Obtain leaves and acetone for the leaf pigment project.

1 Focus

Bellringer

Before presenting the lesson, display **Section Focus Transparency 22** on the overhead projector and have students answer the accompanying questions. L1 ELL



Section Assessment

1. Active transport, movement and protein synthesis are examples.
2. ATP stores energy in its phosphate–phosphate bonds.
3. A phosphate group can be added to ADP, reforming ATP.
4. They may have a pocket that ATP will fit into so that when ATP releases energy, the protein can use it.
5. Opposite charges attract, so an ATP binding site might have a positive charge.
6. When muscles move during shivering, heat is generated. This heat helps to warm the animal.

Meeting Individual Needs

Gifted

Linguistic The citric acid cycle is sometimes called the Krebs cycle. Have students research the work of Melvin Calvin or Hans Krebs and write a report. L3

Resource Manager

Section Focus Transparency 22 and Master L1 ELL
Concept Mapping, p. 9 L3 ELL
Basic Concepts Transparency 12 and Master L2 ELL

2 Teach

Problem-Solving Lab 9-2

Purpose

Students will examine the effect of increasing light intensity on the rate of photosynthesis.

Process Skills

recognize cause and effect, interpret data, analyze data

Background

Plants depend on the energy derived from light to synthesize organic compounds from carbon dioxide and water.

Teaching Strategies

- Ask students how horticulturists increase light intensity, especially during winter. *They use grow lights and sun reflectors.*
- Ask students why keeping temperature constant during the experiment is important. *This avoids introducing another variable.*

Thinking Critically

The rate of photosynthesis increases with increasing light intensity until another factor limits the rate. Limiting factors include the availability of water, carbon dioxide, phosphate, ADP, and enzymes.

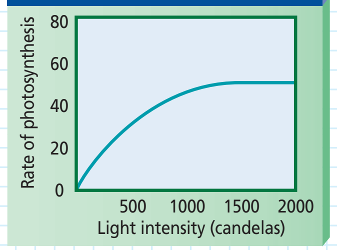
Assessment

Performance Have students work in groups to design and carry out an experiment that uses grow lights to test whether increasing light intensity increases the rate of photosynthesis. Use the Performance Task Assessment List for Designing an Experiment in **PASC,** p. 23. L2 COOP LEARN

Problem-Solving Lab 9-2 — Drawing Conclusions

How does photosynthesis vary with light intensity? Photosynthesis is the process by which green plants synthesize organic compounds from water and carbon dioxide using energy absorbed by chlorophyll from sunlight.

Light Intensity and Photosynthesis



Analysis

Green plants were exposed to increasing light intensity, as measured in candelas, and the rate of photosynthesis was measured. The temperature of the plants was kept constant during the experiment. The graph shown here depicts the data obtained.

Thinking Critically

Considering the overall equation for photosynthesis, make a statement summarizing what the graph shows. Under normal field conditions, what factors may limit the relative rate of photosynthesis when the light intensity is increased and temperature remains constant?

Figure 9.5
The red, yellow, and purple pigments are visible in the autumn when trees reabsorb chlorophyll.

Word Origin

chlorophyll
From the Greek words *chloros,* meaning "pale yellowish-green," and *phyllon,* meaning "leaf." Chlorophyll is a green pigment found in leaves.

To trap the energy in the sun's light, the thylakoid membranes contain **pigments,** molecules that absorb specific wavelengths of sunlight. The most common pigment in chloroplasts is **chlorophyll.** Chlorophyll in forms *a* and *b* absorbs most wavelengths of light except for green. Because chloroplasts have no means to absorb this wavelength, it is reflected, giving leaves a green appearance. In the fall, trees reabsorb chlorophyll from the leaves and other pigments are visible, giving leaves like those in ***Figure 9.5*** a wide variety of colors. Read the *Chemistry Connection* at the end of this chapter to find out more about biological pigments.

Light-Dependent Reactions

The first phase of photosynthesis requires sunlight. As sunlight strikes the chlorophyll molecules in the thylakoid membrane, the energy in the light is transferred to electrons. These highly energized, or excited, electrons are passed from chlorophyll to an **electron transport chain,** a series of proteins embedded in the thylakoid membrane. Use the *Problem-Solving Lab* shown here to consider how light intensity affects photosynthesis.

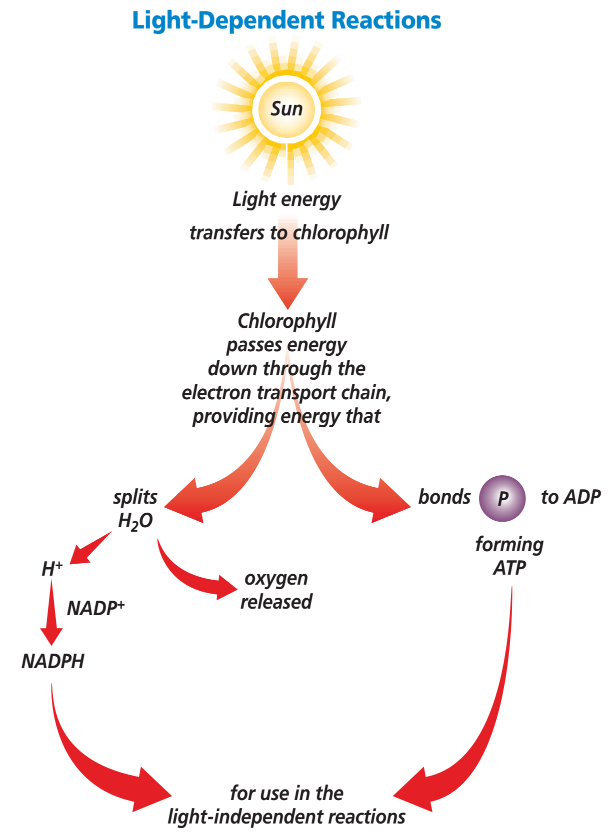
Each protein in the chain passes energized electrons along from protein to protein, similar to a bucket brigade in which a line of people pass a bucket of water from person to person to fight a fire. At each step along the transport chain, the electron loses energy, just as some of the water might be spilled from buckets in the fire-fighting chain. The electron transport chain allows small amounts of the electron's energy to be released at a time. This energy can be used to form ATP from ADP, or to pump hydrogen ions into the center of the thylakoid disc.

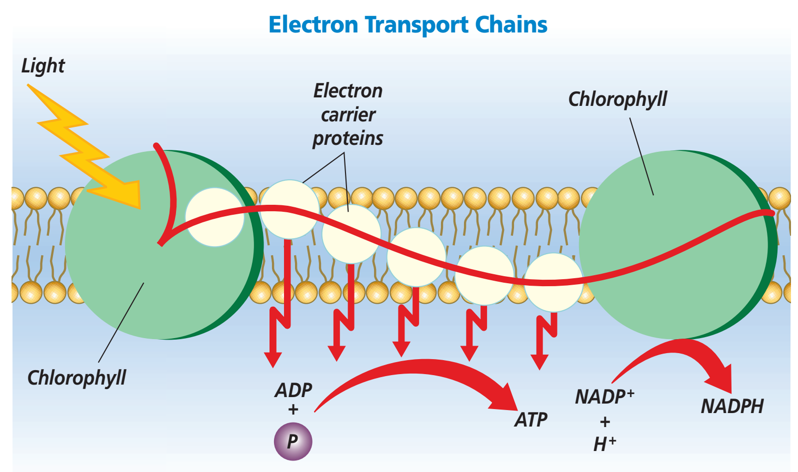
After the electron has traveled down the first electron transport chain, it is passed down a second electron transport chain. Following the second electron transport chain, the electron is still very energized. So that this energy is not wasted, the electron is transferred to the stroma of the chloroplast. To do this, an electron carrier molecule called **NADP⁺** (nicotinamide adenine dinucleotide phosphate) is used. When carrying the excited electron, $NADP^+$ combines with a hydrogen ion and becomes NADPH.

Just as proteins contain a binding site where they can bind ATP, so the $NADP^+$ molecule and other electron carrier molecules like it have a binding site for energized electrons. However, in this case, NADPH does not use the energy present in the energized electron; it simply stores the energy until it can transfer it to another series of reactions that will take place in the stroma. There, NADPH will play an important role in the formation of carbohydrates. The light-dependent reactions are summarized in ***Figure 9.6.***

Figure 9.6
The Light Reactions

A Chlorophyll molecules absorb light energy and energize electrons for producing ATP or NADPH.





B This expanded view shows energized electrons lose some energy as they are passed from protein to protein through the electron transport chain. This energy can be used to form ATP or NADPH.

CD-ROM
View an animation of the light-dependent reactions in the Presentation Builder of the Interactive CD-ROM.

Assessment

Skill Have students write the equation that summarizes photosynthesis. Ask them to identify the raw materials (reactants) in the process and the products. *Carbon dioxide and water are the raw materials; simple sugars and oxygen are the products.* Guide students to an understanding of what the equation means in terms of energy capture and conversion. L2

Quick Demo

Use a prism to show how visible light can be separated into a spectrum. Students may recall from their study of physical science that the different colors of the visible spectrum represent different wavelengths of light.

The BioLab at the end of the chapter can be used at this point in the lesson.

INTERNET BioLab

GLENCOE TECHNOLOGY

CD-ROM
Biology: The Dynamics of Life
Animation: *The Light Reactions*
Disc 1

VIDEODISC
Biology: The Dynamics of Life
Light Reactions (Ch. 26)
Disc 1, Side 1, 51 sec.

Portfolio

Communicating about Science

Interpersonal Divide the class into three groups. Ask each group to discuss chloroplasts, the light reactions, or the Calvin cycle and present a short report. Individual students should place copies of their group report in their portfolios. L2

P COOP LEARN

GLENCOE TECHNOLOGY

VIDEODISC
The Secret of Life
Chloroplast Membrane Structure

PROJECT

Growing Plants in Colored Light

Kinesthetic Have students place a plant in each of several closed boxes containing a colored light bulb. Using caution, tape the opening through which the electric cord passes so no outside light can enter. Provide the plants in each box with equal amounts of water. Have students hypothesize how the plants in each box will grow compared with a control plant.

Ask students to write a summary of the experiment. Students should include results and observations and an evaluation of the hypothesis. L2

MiniLab 9-1

Purpose
Students will build a model to trace the fate of molecules involved in photosynthesis.

Process Skills
analyze information, define operationally, formulate models, think critically, predict

Teaching Strategies
■ Models may be constructed from colored beads, Legos, Tinkertoys, or colored clay. Make sure that students provide a key (probably by color) to show the molecules being referenced. L1 ELL
■ If materials for modeling are not available, students can trace molecules from the left to right side of the equation by using lines and arrows.

Expected Results
Student models will show that all carbon from carbon dioxide ends up in glucose (CH_2O); all oxygen from carbon dioxide ends up in glucose and water; all hydrogen from water (on the left side) ends up in glucose and water.

Analysis
1. Student answers may vary. Isotopes are radioactive and thus can be traced by their radioactivity.
2. a. incorporated into glucose or water
   b. incorporated into glucose
   c. incorporated into glucose and water

Assessment
Knowledge Have students model the equation for photosynthesis starting with an isotope of hydrogen in the water molecule to the left of the arrow. Use the Performance Task Assessment List for Model in **PASC,** p. 51. L2

MiniLab 9-1 Formulating Models


van Niel

Use Isotopes to Understand Photosynthesis C. B. van Niel discovered the steps of photosynthesis when he used radioactive isotopes of oxygen as tracers. Radioactive isotopes are used to follow a particular molecule through a chemical reaction.

Procedure
1. Study the following equation for photosynthesis that resulted from the van Niel experiment:
   $$6CO_2 + 6H_2O^* \rightarrow C_6H_{12}O_6 + 6O_2^*$$
2. Radioactive water, water tagged with an isotope of oxygen as a tracer (shown with the *), was used. Note where the tagged oxygen in water ends up on the right side of the chemical reaction.
3. Assume that van Niel repeated his experiment, but this time he put a radioactive tag on the oxygen in CO_2.
4. Using materials provided by your teacher, model what you would predict the appearance of his results would be. Your model must include a "tag" to indicate the oxygen isotope on the left side of the arrow as well as where it ends up on the right side of the arrow.
5. You must use labels or different colors in your model to indicate also the fate of carbon and hydrogen.

Analysis
1. Explain how an isotope can be used as a tag.
2. Using your model, predict:
   a. the fate of all oxygen molecules that originated from carbon dioxide.
   b. the fate of all carbon molecules that originated from carbon dioxide.
   c. the fate of all hydrogen molecules that originated from water.

Restoring electrons to chlorophyll

Although some of the light-energized electrons may be returned to chlorophyll after they've moved through the electron transport chain, many leave with NADPH for the light-independent reactions. If these electrons are not replaced, the chlorophyll will be unable to absorb light and the light-dependent reactions will stop, as will the production of ATP.

To replace the lost electrons, molecules of water are split. Each water molecule produces one-half molecule of oxygen gas, two hydrogen ions, and two electrons. This reaction is shown in *Figure 9.7* and is called **photolysis** (FO tohl ih sis). The oxygen of photolysis supplies the oxygen we breath. The *MiniLab* on this page describes how scientists traced oxygen through photosynthesis.

Light-Independent Reactions

The second phase of photosynthesis does not require light. It is called the **Calvin cycle**, which is a series of reactions that use carbon dioxide to form carbohydrates. The Calvin cycle takes place in the stroma of the chloroplast. What are the stages of the Calvin cycle? To find out, read the *Inside Story.*

Word Origin
photolysis
From the Greek words *photos*, meaning "light," and *lyein*, meaning "to split." Light energy splits water molecules in photolysis.

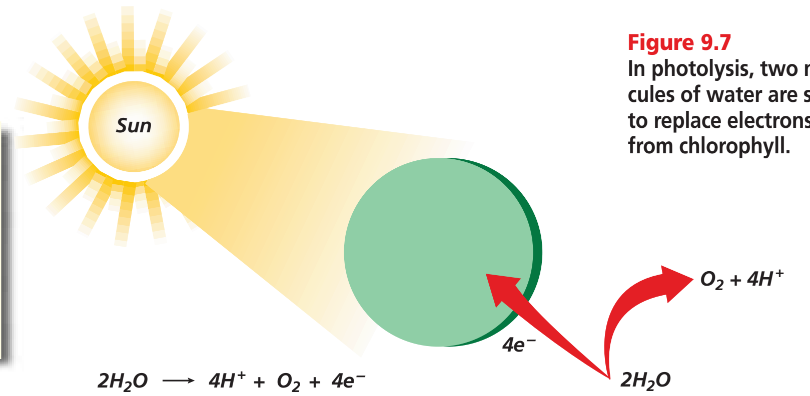


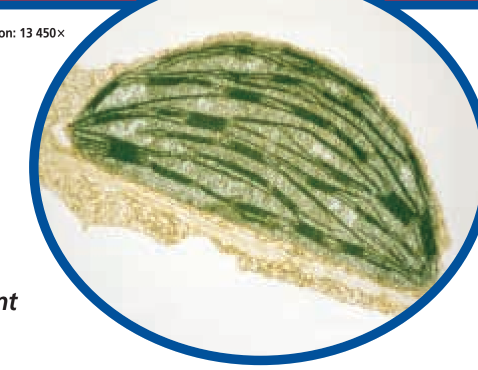
Figure 9.7
In photolysis, two molecules of water are split to replace electrons lost from chlorophyll.

Inside Story

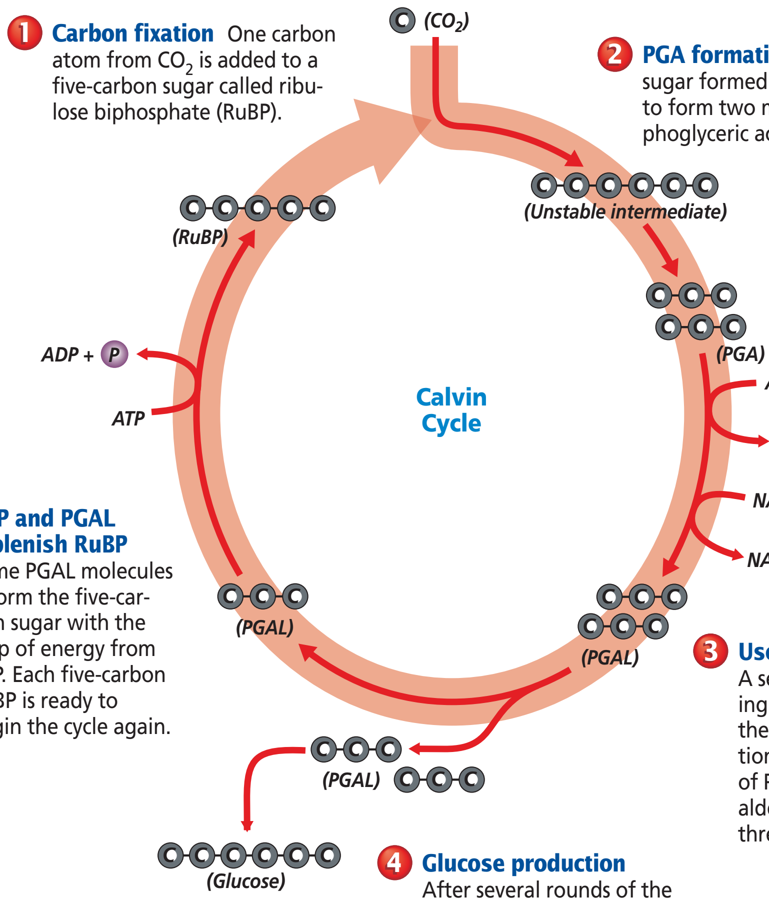
The Calvin Cycle

The Calvin cycle takes the carbon in CO_2 and forms carbohydrates through a series of reactions in the stroma of the chloroplast. NADPH and the ATP produced during the earlier light-dependent reactions are important molecules for this series of reactions.

Critical Thinking *Environmentalists are concerned about the increasing loss of Earth's forests. How is the Calvin cycle connected to this concern?*



The stroma in chloroplasts host the Calvin cycle



1 **Carbon fixation** One carbon atom from CO_2 is added to a five-carbon sugar called ribulose biphosphate (RuBP).

2 **PGA formation** The six-carbon sugar formed in Step 1 is then split to form two molecules of phosphoglyceric acid (PGA).

3 **Use of ATP and NADPH** A series of reactions involving ATP and NADPH from the light-dependent reactions, converts a molecule of PGA into phosphoglyceraldehyde (PGAL), another three-carbon molecule.

4 **Glucose production** After several rounds of the Calvin cycle, two molecules of PGAL leave the cycle to form glucose.

5 **ATP and PGAL replenish RuBP** Some PGAL molecules reform the five-carbon sugar with the help of energy from ATP. Each five-carbon RuBP is ready to begin the cycle again.

Inside Story

Purpose
Students will learn the steps of the Calvin cycle and how CO_2 is used to make glucose.

Background
Energy from the light reactions is used to make sugar molecules that will serve as a long-term storage for energy.

Teaching Strategies
■ Have students identify the main steps of the Calvin cycle.

Visual Learning
■ Have students make a chart of everything required for one round of the Calvin cycle, including the number of molecules. L2

Critical Thinking
The Calvin cycle is critical to photosynthesis and carbohydrate production. If less photosynthesis occurs, fewer food molecules are produced.

3 Assess

Check for Understanding
Students should know the general equation for photosynthesis and understand that the light reactions feed the Calvin cycle. L1

Reteach
Explain that the Calvin cycle uses CO_2 and hydrogen to form the simple sugars that make more complex carbohydrates.

Biology Journal

Oxygen Journey
Linguistic After the class has performed MiniLab 9-1, have the students write a story describing the pathway taken by the radioactively labeled oxygen in the van Niel experiment. Encourage creativity while at the same time conveying biological accuracy. L2

Resource Manager

Reinforcement and Study Guide pp. 38-39 L2
BioLab and MiniLab Worksheets, p. 39 L2
Critical Thinking/Problem Solving, p. 9 L3

Project

Extracting and Testing Pigments
Have students soak ground, fresh leaves in warm alcohol and apply the extract to a 12-cm-long strip of filter paper in a narrow band about 2 cm from the bottom of the strip. Place the filter paper into a test tube containing a small amount of acetone (clear fingernail polish remover). Tightly seal the test tube. Just the bottom edge of the paper should dip into the solvent; the leaf extract should not be immersed.

As the solvent is drawn up the paper, less soluble compounds remain near the bottom and more soluble compounds are carried higher. Remove the paper strip before the solvent reaches the top. L3

Glencoe Technology
VIDEODISC
The Secret of Life
The Calvin Cycle

Extension

Intrapersonal Have students research the difference between the chlorophyll of plants and the light-capturing pigments of photosynthetic bacteria. **L3**

Assessment

Performance Ask students to write a paragraph summarizing the citric acid cycle. **L2**

CAREERS IN BIOLOGY

Career Path

Courses in high school: chemistry, mathematics, biology, other science

College: bachelor's and master's degree in biochemistry, chemistry; doctorate required for advanced research or management

Career Issue

Debate whether biochemists should clone animals.

For More Information

Write to the

American Society for
Biochemistry and
Molecular Biology
9650 Rockville Pike
Bethesda, MD 20814.

4 Close

Discussion

Ask students where the energy in their food comes from. Students should trace energy to the sun. Work through some simple food chains as part of the discussion. **L1**

CAREERS IN BIOLOGY

Biochemist

If you are curious about what makes plants and animals grow and develop, consider a career as a biochemist. The basic research of biochemists is to understand how processes in an organism work to ensure the organism's survival.

Skills for the Job

A bachelor's degree in chemistry or biochemistry will qualify you to be a lab assistant. For a more involved position, you will need a master's degree; advanced research requires a Ph.D. Some biochemists work with genes to create new plants and new chemicals from plants. Others research the causes and cures of diseases or the effects of poor nutrition. Still others investigate solutions for urgent problems, such as finding better ways of growing, storing, and caring for crops.

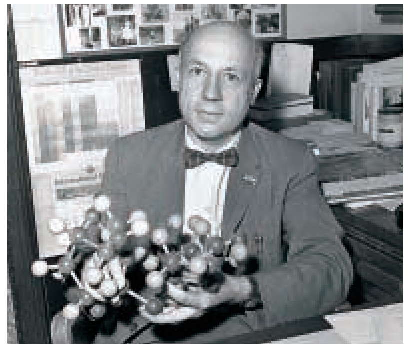
interNET CONNECTION To find out more about careers in biology and related fields, visit the Glencoe Science Web Site. **www.glencoe.com/sec/science**

The Calvin cycle

The Calvin cycle, named after Melvin Calvin shown in ***Figure 9.8***, is called a cycle because one of the last molecules formed in the series of chemical reactions is also one of the molecules needed for the first reaction of the cycle. Therefore, one of the products can be used again to initiate the cycle.

In the electron transport chain, you learned that an energized electron is passed from protein to protein and the energy is slowly released. You can imagine that making a complex carbohydrate from a molecule of CO_2 would be a large task for a cell, so the light-independent reactions in the stroma of the chloroplast break down the complicated process into small steps. Each sugar molecule made by the Calvin cycle contains six carbon atoms, and because only one molecule of CO_2 is added to the cycle each time, it takes a total of six rounds of the cycle to form one sugar.

Figure 9.8
Melvin Calvin



Section Assessment

Understanding Main Ideas

1. Why do you see green when you look at a leaf on a tree? Why do you see other colors in the fall?
2. How do the light-dependent reactions of photosynthesis relate to the Calvin cycle?
3. What is the function of water in photosynthesis? Explain the reaction that achieves this function.
4. How does the electron transport chain transfer light energy in photosynthesis?

Thinking Critically

5. In photosynthesis, is chlorophyll considered a reactant, a product, or neither? How does the role of chlorophyll compare with those of CO_2 and H_2O?

SKILL REVIEW

6. **Designing an Experiment** Design an experiment that would simulate photosynthesis. For more help, refer to *Practicing Scientific Methods* in the **Skill Handbook.**

Section
9.3 Getting Energy to Make ATP

SECTION PREVIEW

Objectives

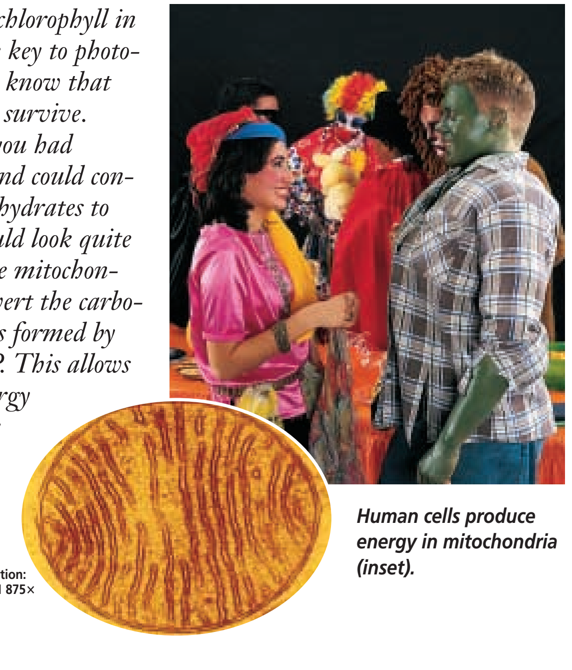
Compare and contrast cellular respiration and fermentation.

Explain how cells obtain energy from cellular respiration.

Vocabulary

cellular respiration
anaerobic
aerobic
glycolysis
citric acid cycle
lactic acid fermentation
alcoholic fermentation

You know that the chlorophyll in green plants is the key to photosynthesis. You also know that your body needs energy to survive. What would it be like if you had chlorophyll in your skin and could convert light energy to carbohydrates to produce ATP? People would look quite different. Fortunately, the mitochondria in your cells can convert the carbohydrates that green plants formed by the Calvin cycle into ATP. This allows you to access the sun's energy through the work done by plant cells.



Human cells produce energy in mitochondria (inset).

Cellular Respiration

The process by which mitochondria break down food molecules to produce ATP is called **cellular respiration.** There are three stages of cellular respiration: glycolysis, the citric acid cycle, and the electron transport chain. The first stage, glycolysis, is **anaerobic**—no oxygen is required. The last two stages are **aerobic** and require oxygen to be completed.

Glycolysis

Glycolysis (gli KOL ih sis) is a series of chemical reactions in the cytoplasm of a cell that break down glucose, a six-carbon compound, into two molecules of pyruvic (pie RUE vik) acid, a three-carbon compound. Because two molecules of ATP are used to start glycolysis, and only four ATP molecules are produced, glycolysis is not very efficient, giving a net profit of only two ATP molecules for each glucose molecule broken down.

In the electron transport chain of photosynthesis, an electron carrier called $NADP^+$ was described as carrying energized electrons to another location in the cell for further chemical reactions. Glycolysis also uses an

WORD Origin

anaerobic
From the Greek words *an*, meaning "without," and *aeros*, meaning "air." Anaerobic organisms can live without oxygen.

Section 9.3

Prepare

Key Concepts

Students will learn the similarities and differences between cellular respiration and anaerobic processes that release energy. They will also learn how these reactions are related to photosynthesis.

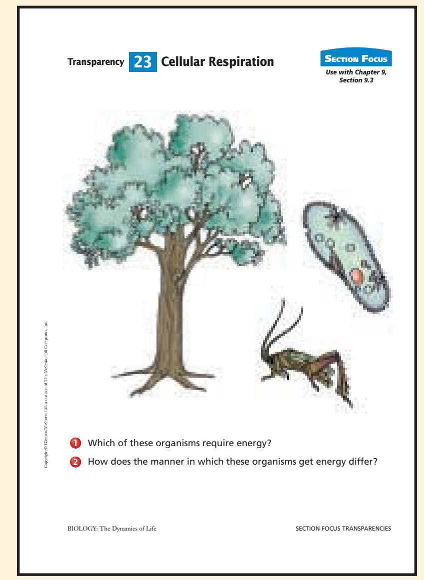
Planning

- Purchase baker's yeast for the Quick Demo and MiniLab 9-2.
- Obtain *Coleus* plants and iodine solution and other materials for the Alternative Lab.

1 Focus

Bellringer

Before presenting the lesson, display **Section Focus Transparency 23** on the overhead projector and have students answer the accompanying questions. **L1 ELL**



Section Assessment

1. The chlorophyll in the leaf reflects green and yellow while absorbing other colors. In the fall, chlorophyll is absorbed, revealing other leaf pigments.
2. ATP and hydrogen ions from the light reactions are used in the Calvin cycle.
3. Photolysis splits water to provide hydrogen ions for the Calvin cycle and restore electrons to chlorophyll.
4. Proteins convey energized electrons through the chloroplast.
5. Chlorophyll is neither a reactant nor a product. It contributes electrons to photosynthesis but is not changed during the reaction. CO_2 and H_2O are reactants.
6. Students could demonstrate how solar panels convert sunlight to electricity.

Cultural Diversity

Severo Ochoa

Have students research the efforts of Spanish-American biochemist Severo Ochoa (1905–1993) toward the modern understanding of the citric acid cycle and photosynthesis. Ochoa showed how the oxidation of one glucose molecule could yield 38 ATP molecules. He also elucidated the mechanisms of the citric acid cycle and photosynthesis by identifying the function of key enzymes.

Ochoa's research in cellular respiration in the 1930s and 1940s resulted ultimately in the discovery of the mechanisms of RNA and DNA synthesis, for which Ochoa and colleague Arthur Kornberg received a Nobel prize in 1959. **L3**

2 Teach

Concept Development

Read a recipe for making bread. Explain to students that the yeast used in the recipe are microorganisms classified as fungi. Discuss how, unlike most organisms, yeast carry out processes that release energy in the absence of oxygen. Explain that bakers use yeast in their recipes for almost all breads, because as yeast function anaerobically, they release CO_2, which causes the bread to rise.

Quick Demo

Prepare a sugar solution by mixing a tablespoon of sugar with a cup of warm water in a deep jar or flask. Add some baker's yeast a few hours before class. Have students note the odor of alcohol and the bubbles of carbon dioxide. Point out that these products result as the yeast carry out alcoholic fermentation.

Reinforcement

Make sure students understand that pyruvic acid is the intermediate product for both types of fermentation. Challenge students to explain how pyruvic acid changes in each type of fermentation.

Concept Development

For students having difficulty with the concepts of this chapter, review the roles of a producer and consumer. Relate the processes in this chapter to the concepts of Unit 2, Ecology.

Resource Manager

Section Focus Transparency 23 and Master L1 ELL
Basic Concepts Transparency 13 and Master L2 ELL

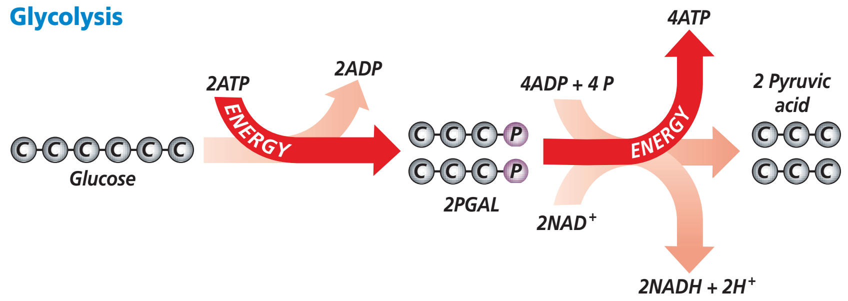


Figure 9.9 Glycolysis breaks down a molecule of glucose into two molecules of pyruvic acid. In the process, it forms a net profit of two molecules of ATP, two molecules of NADH, and two hydrogen ions.

electron carrier called NAD^+ (nicotinamide adenine dinucleotide). NAD forms NADH when it is carrying an electron. Glycolysis is an anaerobic process as you can see by the absence of oxygen in the equation shown in *Figure 9.9*.

Following glycolysis, the pyruvic acid molecules move to the mitochondria, the organelles that produce ATP for the cell. In the presence of oxygen, two more stages complete cellular respiration: the citric acid cycle (also known as the Krebs cycle) and the electron transport chain of the mitochondrion. Before these two stages can begin, however, pyruvic acid undergoes a series of reactions in which it loses a molecule of CO_2 and combines with coenzyme A to form acetyl-CoA. The reaction with coenzyme A produces a molecule of NADH and H^+. These reactions are shown in *Figure 9.10*.

The citric acid cycle

The **citric acid cycle** is a series of chemical reactions similar to the Calvin cycle in that one of the molecules needed for the first reaction is also one of the end products. However, in the Calvin cycle, glucose molecules are formed; in the citric acid cycle, glucose is broken down. What is the first compound that acetyl-CoA combines with in the citric acid cycle? To learn the answer, look at the *Inside Story*.

In the process of breaking down glucose, one molecule of ATP is produced for every turn of the cycle. Two electron carriers are used, NAD^+ and FAD (flavin adenine dinucleotide). A total of three NADH + H^+ molecules and one $FADH_2$ molecule are formed. These electron carriers pass the energized electrons along to the electron transport chain in the inner membrane of the mitochondrion.

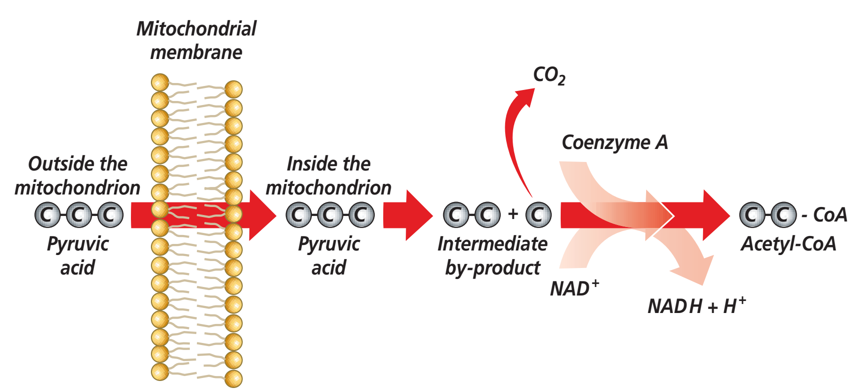


Figure 9.10 As a result of the reactions that convert pyruvic acid to acetyl-CoA within the mitochondrion, a molecule of NADH and H^+ are formed.

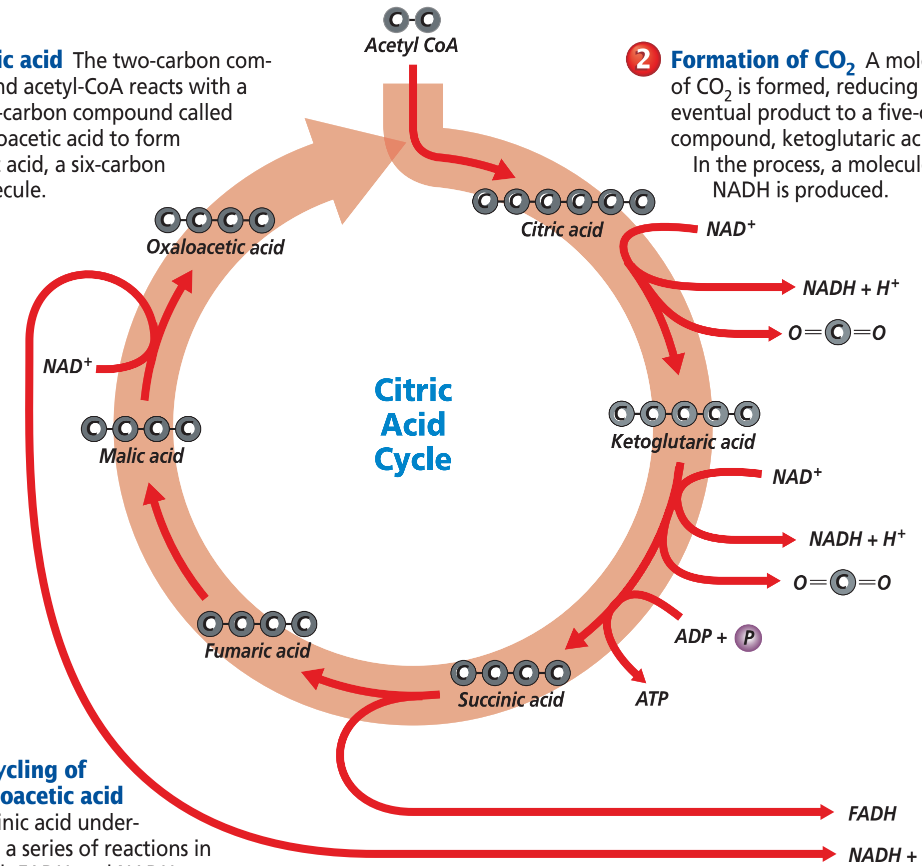
INSIDE STORY

The Citric Acid Cycle

The citric acid cycle takes a molecule of acetyl-CoA and breaks it down, forming ATP and CO_2. The electron carriers NAD^+ and FAD pick up energized electrons and pass them to the electron transport chain in the inner mitochondrial membrane.

The mitochondria host the citric acid cycle.

Critical Thinking *How many ATP molecules are produced by a single turn of the citric acid cycle?*



1. **Citric acid** The two-carbon compound acetyl-CoA reacts with a four-carbon compound called oxaloacetic acid to form citric acid, a six-carbon molecule.

2. **Formation of CO_2** A molecule of CO_2 is formed, reducing the eventual product to a five-carbon compound, ketoglutaric acid. In the process, a molecule of NADH is produced.

3. **Formation of the second CO_2** Another molecule of CO_2 is released, forming a four-carbon compound, succinic acid. One molecule of ATP and a molecule of NADH are also produced.

4. **Recycling of oxaloacetic acid** Succinic acid undergoes a series of reactions in which FADH and NADH are formed and oxaloacetic acid is again made available for the cycle.

INSIDE STORY

Purpose

To teach students the main events of the citric acid cycle that break down acetyl CoA to form ATP, NADH, $FADH_2$, and carbon dioxide.

Background

Glycolysis initiates the breakdown of glucose. Pyruvate, the end product of glycolysis, undergoes a series of reactions to form acetyl CoA, which enters the citric acid cycle. The citric acid cycle is important for its large energy yield.

Teaching Strategies

- Ask students to describe the four stages of the citric acid cycle. Include the products for each stage. L2

Visual Learning

Make a table with the following headings: ATP, NADH, and $FADH_2$. Under the headings list one round of the citric acid cycle. Have the students fill in the number of each molecule produced during one round.

Critical Thinking

Each round produces:
1 ATP = 1 ATP
3 NADH × 3 ATP/NADH = 9 ATP
1 $FADH_2$ × 2 ATP/$FADH_2$ = 2 ATP
TOTAL = 12 ATP

Meeting Individual Needs

Gifted

Intrapersonal Have students research the role of the inner mitochondrial membrane in cellular respiration. L3

GLENCOE TECHNOLOGY

VIDEODISC
The Secret of Life
Cell Energy: Cell Respiration

Glycolysis

Breakdown of Pyruvic Acid

Portfolio

Cycle Comparison

Visual-Spatial Have students make a poster of the citric acid cycle. Compare it to the Calvin cycle. Note that the Calvin cycle uses ATP and electron carriers such as NADP to produce glucose while the citric acid cycle produces ATP and electron carriers, including NADH and $FADH_2$, as it burns glucose. L2

GLENCOE TECHNOLOGY

VIDEODISC
The Secret of Life
Citric Acid Cycle

Assessment

Skill Make a table summarizing the production and usage of ATP molecules in various stages of respiration. L2

TECHPREP

Deforestation

Many forests, especially tropical rain forests, are being leveled to provide fuel and uncover farmland. Scientists are considering how the massive clearance of forested lands will affect the balance between photosynthesis and respiration in the biosphere. Have students use the Internet to investigate scientific models of deforestation and develop a plan to ease the imbalance. L2

GLENCOE TECHNOLOGY

VIDEODISC
The Secret of Life
Electron Transport Chain

Resource Manager

Reteaching Skills Transparencies 14 and 15 and Masters L1 ELL

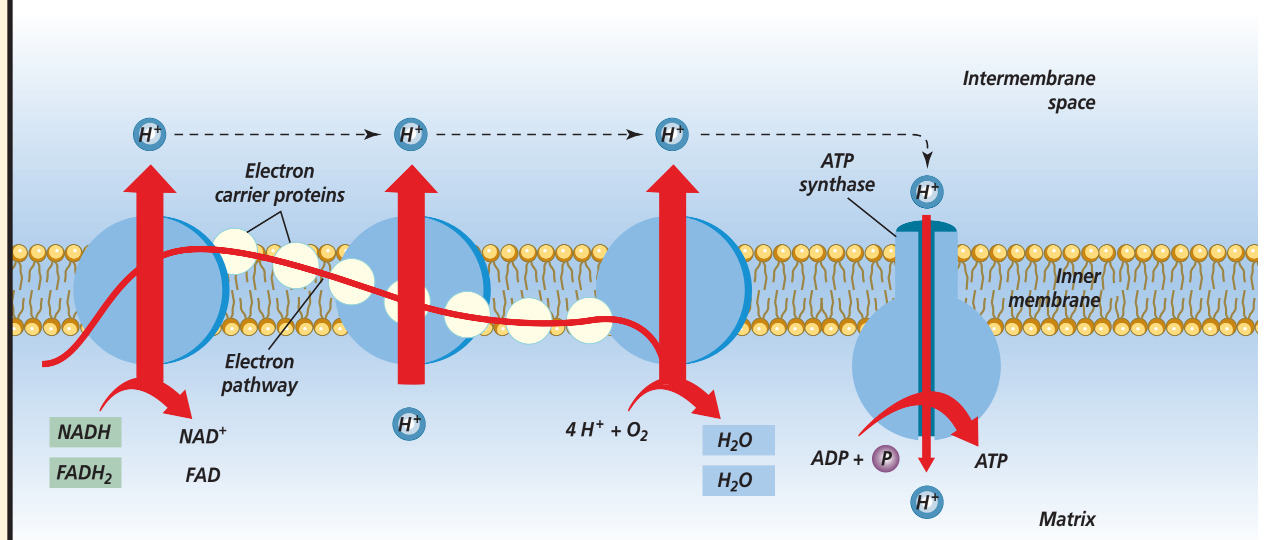


Figure 9.11
In the electron transport chain, the carrier molecules NADH and $FADH_2$ give up electrons that pass through a series of reactions. Oxygen is the final electron acceptor.

The electron transport chain

The electron transport chain in the inner membrane of the mitochondrion is very similar to the electron transport chain of the thylakoid membrane in the chloroplast of plant cells during photosynthesis. NADH and $FADH_2$ pass energized electrons from protein to protein within the membrane, slowly releasing small amounts of the energy contained within the electron. Some of that energy is used directly to form ATP; some is used to pump H^+ ions into the center of the mitochondrion. Consequently, the mitochondrion inner membrane becomes positively charged because of the high concentration of positively charged hydrogen ions. At the same time, the exterior of the membrane is negatively charged, which further attracts hydrogen ions. The gradient that results is both electrical and chemical: electrical because of the charge difference; chemical because of the concentration difference.

The inner membrane of the mitochondrion forms ATP from this electrochemical gradient of H^+ ions across the membrane, just as the thylakoid membranes did in the chloroplasts. The electron transport chain and the formation of ATP are shown in *Figure 9.11.*

The final electron acceptor in the chain is oxygen, which reacts with four hydrogen ions ($4H^+$) to form two molecules of water (H_2O). This is why oxygen is so important to our bodies. Without oxygen, the proteins in the electron transport chain cannot pass along the electrons. If a protein can't pass an electron along, it cannot accept another electron either. Very quickly, the entire chain becomes blocked and the aerobic processes of cellular respiration cannot occur.

Overall, the electron transport chain produces 32 ATP molecules. Obviously, the aerobic method of ATP production is very effective. However, an anaerobic process can produce ATP for short periods of time in the absence of oxygen, but it is not efficient enough to generate sufficient quantities of ATP for all of the cell's needs.

Fermentation

There are times when your cells are without oxygen for a short period of time. When this happens, an anaerobic process called fermentation follows glycolysis and provides a means to continue producing ATP until oxygen is available again. Some organisms exist in anaerobic environments and use fermentation to produce energy. There are two major types of fermentation: lactic acid fermentation and alcoholic fermentation. *Figure 9.12* and *Table 9.1* compare the two processes. Perform the *Problem-Solving Lab* shown here to further compare and contrast cellular respiration and fermentation.

Problem-Solving Lab 9-3 Acquiring Information

Is cellular respiration better than fermentation? The methods by which organisms derive ATP from their food may differ; however, the result, the production of ATP molecules, is similar.

Analysis

Study *Table 9.1* and evaluate cellular respiration, lactic acid fermentation, and alcoholic fermentation.

Thinking Critically

1. Describe some of the reasons why cellular respiration produces so much more ATP than does fermentation.
2. Describe a situation when a human would use more than one of the above processes.
3. Think of an organism that might generate ATP only by fermentation and consider why fermentation is the best process for the organism.

Figure 9.12
Fermentation produces ATP when oxygen for respiration is scarce.

A Lactic acid and alcoholic fermentation are comparable in the production of ATP, but compared to cellular respiration, it is obvious that fermentation is far less efficient in ATP production.

Table 9.1 Comparison of lactic acid and alcoholic fermentation

Lactic acid	Alcoholic	Cellular respiration
glucose	glucose	glucose
↓	↓	↓
glycolysis (pyruvic acid)	glycolysis (pyruvic acid)	glycolysis (pyruvic acid)
↓	↓	↓
	carbon dioxide	carbon dioxide
	+	+
lactic acid	alcohol	water
+	+	+
2 ATP	2 ATP	38 ATP

B Lactic acid fermentation occurs in some bacteria, in plants, and in most animals, including humans.

Problem-Solving Lab 9-3

Purpose

Students will compare and contrast the process of aerobic respiration, lactic acid fermentation, and alcoholic fermentation.

Process Skills

think critically, compare and contrast, acquire information, analyze information, sequence, define operationally

Teaching Strategies

■ It will be necessary for students to review the sections dealing with aerobic respiration, lactic acid fermentation, and alcoholic fermentation before they attempt to complete this lab.

Thinking Critically

1. The chemical reactions of the citric acid cycle provide more ATP than does fermentation. Cellular respiration better meets the energy requirements of complex organisms.
2. Humans normally carry out cellular respiration. During a time of intense exercise, we revert to lactic acid fermentation.
3. For an organism that lives in anaerobic conditions and uses small amounts of energy, cellular respiration may not be economical if fermentation consistently provides sufficient energy.

Assessment

Skill Provide an incomplete table similar to Table 9.1 and have the students complete it. Use the Performance Task Assessment List for Data Table in **PASC,** p. 37. L1

Alternative Lab

Carbon Fixation

Purpose

Students will demonstrate that without light carbon fixation slows or stops.

Materials

black paper, labels, iodine solution, *Coleus* plants, paper clip, hot plate, beaker, 95% alcohol, small bowl

Procedure

1. Cut out two identical pieces of black paper in the shape of a small square.
2. Stick a label on one piece and write your initials and the date on it.
3. Use a paper clip to fasten the black shapes to the top and bottom surfaces of a Coleus leaf so that they are matched up exactly.
4. Leave the plant in sunlight for 7 days. Then remove the leaf that was partially covered and take off the paper clip and papers.
5. Place the leaf into a beaker of boiling 95% alcohol enclosed in a fume hood and boil it until it turns white. **CAUTION:** ***Do not use a heat source that has an open flame or a hot plate with an unsealed element.***
6. Remove the leaf and place it in a small bowl. Pour iodine solution on the leaf and let it absorb the iodine for a few minutes. **CAUTION:** ***Iodine is an irritant. Rinse thoroughly if iodine gets on skin or clothing.***
7. Rinse the leaf with tap water and observe.

Analysis

1. What happens when the leaf is boiled in alcohol? *Its chlorophyll dissolves.*
2. In what part of the leaf did carbon fixation slow or stop? *The covered part received no light and therefore could not carry on photosynthesis, which is a carbon fixation process.*

Assessment

Performance Have students write a summary of the lab. Use the Performance Task Assessment List for Lab Report in **PASC,** p. 47. L2

MiniLab 9-2

Purpose
Students will observe the production of CO_2 resulting from yeast fermenting sugar.

Process Skills
observe and infer, interpret data, experiment, analyze data

Safety Precautions
Have students wear aprons and safety goggles.

Teaching Strategies
■ Ask students to brainstorm and list the uses of industrial alcoholic fermentation. Ask them which products (alcohol or CO_2) of the process are important.

Expected Results
Students will see gas bubbles coming from the yeast/apple juice mixture.

Analysis
1. CO_2
2. The rate would increase.
3. Warm water increases the metabolic rate of the yeast.
4. Anaerobic, because no oxygen is available in the bulb of the pipette covered with water.

Assessment

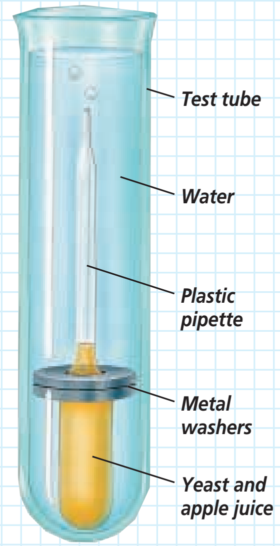
Performance Have students prepare a summary of the MiniLab in their journals. Use the Performance Task Assessment List for Lab Report in **PASC**, p. 47. L2

Resource Manager

Laboratory Manual, pp. 61-68 L2
Reinforcement and Study Guide, p. 40 L2
Content Mastery, pp. 41, 43-44 L1
BioLab and MiniLab Worksheets, p. 40 L2

MiniLab 9-2 Predicting

Determine if Apple Juice Ferments Organisms such as yeast have the ability to break down food molecules and synthesize ATP when no oxygen is available. When the appropriate food is available, yeast can carry out alcoholic fermentation, producing CO_2. Thus, the production of CO_2 can be used to judge whether alcoholic fermentation is taking place.



Procedure
1. Carefully study the diagram and set up the experiment as shown.
2. Hold the test tube in a beaker of warm (not hot) water and observe.

Analysis
1. What were the gas bubbles that came from the plastic pipette?
2. Predict what would happen to the rate of bubbles given off if more yeast were present in the mixture.
3. Why was the test tube placed in warm water?
4. On the basis of your observations, was this process aerobic or anaerobic?

Figure 9.13
Alcoholic fermentation by the yeast in a bread recipe produces CO_2 bubbles that raise the bread dough.

Lactic acid fermentation

Lactic acid fermentation is one of the processes that supplies energy when oxygen is scarce. You know that under anaerobic conditions, the electron transport chain backs up because oxygen is not present as the final electron acceptor. As NADH and $FADH_2$ arrive with energized electrons from the citric acid cycle and glycolysis, they cannot release their energized electrons to the electron transport chain. The citric acid cycle and glycolysis cannot continue without a steady supply of NAD^+ and FAD.

The cell does not have a method to replace FAD during anaerobic conditions; however, NAD^+ can be replaced through lactic acid fermentation. In lactic acid fermentation, two molecules of pyruvic acid use NADH to form two molecules of lactic acid. This releases NAD^+ to be used in glycolysis, allowing two ATP molecules to be formed for each glucose molecule. The lactic acid is transferred from muscle cells, where it is produced during strenuous exercise, to the liver that converts it back to pyruvic acid. The lactic acid that builds up in muscle cells results in muscle fatigue.

Alcoholic fermentation

Another type of fermentation, **alcoholic fermentation,** is used by, among others, yeast cells to produce CO_2 and ethyl alcohol. When making bread, like that shown in *Figure 9.13*, yeast cells produce CO_2 that forms bubbles in the dough. Eventually the heat of baking the bread kills the yeast and the bubble pockets are left to lighten the bread. You can do the activity in the *MiniLab* on this page to examine fermentation in apple juice.

Comparing Photosynthesis and Cellular Respiration

The production and breakdown of food molecules are accomplished by distinct processes that bear certain similarities. Both photosynthesis and cellular respiration use electron carriers and a cycle of chemical reactions to form ATP. Both use an electron transport chain to form ATP and to create a chemical and a concentration gradient of H^+ within a cell. This hydrogen gradient can be used to form ATP by an alternative process.

However, despite using such similar tools, the two cellular processes accomplish quite different tasks. Photosynthesis produces high-energy carbohydrates and oxygen from the sun's energy, whereas cellular respiration uses oxygen to break down carbohydrates to form ATP and compounds with a much lower level of energy. Also, one of the end products of cellular respiration is CO_2, which is one of the beginning products for photosynthesis. The oxygen produced during photosynthesis is a critical molecule necessary for cellular respiration. *Table 9.2* in *Figure 9.14* compares these complementary processes.

Table 9.2 Comparison of photosynthesis and cellular respiration

Photosynthesis	Cellular Respiration
food accumulated	food broken down
energy from sun stored in glucose	energy of glucose released
carbon dioxide taken in	carbon dioxide given off
oxygen given off	oxygen taken in
produces glucose from PGAL	produces CO_2 and H_2O
goes on only in light	goes on day and night
occurs only in presence of chlorophyll	occurs in all living cells

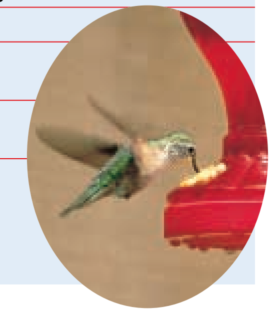


Figure 9.14
Photosynthesis and cellular respiration are complementary processes. The requirements of one process are the products of the other.

Section Assessment

Understanding Main Ideas
1. Compare the ATP yields of glycolysis and aerobic respiration.
2. How do alcoholic and lactic acid fermentation differ?
3. How is most of the ATP from aerobic respiration produced?
4. When is lactic acid fermentation important to the cell?

Thinking Critically
5. Compare the energy-producing processes in a jogger's leg muscles with those of a sprinter's leg muscles. Which is likely to build up more lactic acid? Which runner is more likely to be out of breath after running? Explain.

Skill Review
6. **Making and Using Tables** Use the section called Comparing Photosynthesis and Cellular Respiration to make a set diagram summarizing the similarities and differences between the two processes. For more help, refer to *Organizing Information* in the **Skill Handbook.**

3 Assess

Check for Understanding

Visual-Spatial Provide students with a list of the major substances discussed and the names of the associated processes (glycolysis, respiration, alcoholic fermentation, lactic acid fermentation, and electron transport chain). Have students construct a table that identifies whether each substance is a product or reactant of each process. L2

Reteach

Provide students with unlabeled diagrams of glycolysis, alcoholic fermentation, and lactic acid pathways. Have them fill in the labels as you discuss the processes. L2

Extension

Have students find out and report on how cyanide affects respiration. L3

Assessment

Portfolio Ask students to write summaries of glycolysis, citric acid cycle, electron transport chain, and fermentation. L2

4 Close

Discussion

Tech Prep

Discuss the importance of lactic acid fermentation in the food industry. Ask students to research the production of particular foods prior to the discussion. L2

Internet Address Book

internet CONNECTION Note Internet addresses that you find useful in the space below for quick reference.

GLENCOE TECHNOLOGY

VIDEODISC
The Infinite Voyage: *The Champion Within, Physiology of Consistent Performance* (Ch. 5)
3 min. 30 sec.
Glycogen: Fuel for Muscles (Ch. 6)
5 min. 30 sec.

Section Assessment

1. Glycolysis produces 2 ATP molecules; aerobic respiration, as many as 38.
2. Alcoholic fermentation produces alcohol and carbon dioxide. Lactic acid fermentation produces lactic acid.
3. Most of the ATP is produced by the reactions of the electron transport chain.
4. When oxygen is unavailable.
5. Aerobic respiration occurs in the leg muscles of both runners. The sprinter may build up more lactic acid and be out of breath because of an oxygen debt associated with the quick burst of energy.
6. *Differences:* Photosynthesis forms sugars and oxygen, uses water and CO_2. Respiration uses oxygen to break down sugar, forms water and CO_2. Photosynthesis uses light to form chemical bond energy. Respiration uses chemical bond energy to form ATP. *Similarities:* Both are complex reactions, require enzymes, occur in specific organelles, and involve electron transport chains.

INTERNET BioLab

Time Allotment
One class period

Process Skills
use variables and controls, think critically, observe and infer, collect data, interpret data

Safety Precautions
Students should always wear goggles in the lab. Be sure hands and work areas are dry when handling electrical equipment and have students wash hands at the end of the lab.

Preparation

Prepare sodium hydrogen carbonate solution by mixing 2.5 g sodium hydrogen carbonate with 1000 mL of water.

Alternative Materials
- If *Elodea* is unavailable, you can use any other green aquatic plant.
- Students can use the classroom clock if the second hand is visible.

Resource Manager
BioLab and MiniLab Worksheets, p. 41 L2

INTERNET BioLab

What factors influence photosynthesis?

Oxygen is one of the products of photosynthesis. Because oxygen is only slightly soluble in water, aquatic plants such as Elodea *give off visible bubbles of oxygen as they carry out photosynthesis. By measuring the rate at which bubbles form, you can measure the rate of photosynthesis.*

Preparation

Problem
How do different wavelengths of light a plant receives affect its rate of photosynthesis?

Objectives
In this BioLab, you will:
- **Observe** photosynthesis in an aquatic organism.
- **Measure** the rate of photosynthesis.
- **Observe** how various wavelengths of light influence the rate of photosynthesis.
- **Use the Internet** to collect and compare data from other students.

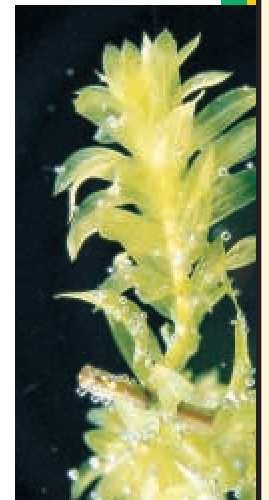
Materials
1000-mL beaker
three *Elodea* plants
string
washers
colored cellophane, assorted colors
lamp with reflector and 150-watt bulb
0.25% sodium hydrogen carbonate (baking soda) solution
watch with second hand

Safety Precautions
Always wear goggles in the lab.

Skill Handbook
Use the **Skill Handbook** if you need additional help with this lab.

Procedure

1. Construct a basic setup like the one shown opposite.
2. Create a data table to record your measurements. Be sure to include a column for each color of light you will investigate and a column for the control experiment.
3. Place the *Elodea* plants in the beaker, then completely cover the plants with water. Add some of the baking soda solution. The solution provides CO_2 for the aquarium plants. **Be sure to use the same amount of water and solution for each trial.**
4. Conduct a control experiment by directing the lamp (without colored cellophane) on the plant and notice when you see the bubbles.
5. Observe and record the number of oxygen bubbles that *Elodea* generates in five minutes.
6. Repeat steps 4 and 5 with a piece of colored cellophane. Record your observations.
7. Repeat steps 4 and 5 with a different color of cellophane and record your observations.
8. Go to the Glencoe Science Web Site at the address shown below to **post your data.**



Data Table

	Control	Color 1	Color 2
Bubbles observed in five minutes			

Analyze and Conclude

1. **Interpreting Observations** From where did the bubbles of oxygen emerge? Why?
2. **Making Inferences** Explain how counting bubbles measures the rate of photosynthesis.
3. **Using the Internet** Make a graph of your data and data posted by other students with the rate of photosynthesis per minute plotted against the wavelength of light you tested for both the control and experimental setups. Write a sentence or two explaining the graph.

Sharing Your Data
interNET CONNECTION Find this BioLab on the Glencoe Science Web Site at **www.glencoe.com/sec/science**. Post your data in the data table provided for this activity. Use the additional data from other students who tested wavelengths other than those you tested to expand your graph.

INTERNET BioLab

Analyze and Conclude

1. The bubbles emerged from the end of the stem of the *Elodea* plant.
2. Oxygen is an end product of photosynthesis. As the rate of photosynthesis changes, so will the rate at which oxygen is produced.
3. The rate for the control setup should be the greatest and therefore the highest line. The rates corresponding to colored, filtered light will be lower than the control. Results will vary depending on the color of cellophane the students use.

Assessment
Portfolio Have students write an evaluation of the lab. Their evaluations should include an overview of the experiment, data analysis, and conclusion statements. Have them also write hypotheses about how photosynthesis might be affected if another condition, such as temperature, were changed. Use the Performance Task Assessment List for Formulating a Hypothesis in **PASC**, p. 21. L2

Procedure

Teaching Strategies
- Place the *Elodea* sprigs in a large bowl and place them under a lamp for about 10 minutes before students begin the lab. This reduces the time the students will wait to begin seeing evidence of photosynthesis.
- You may wish to circulate through the room during this activity to ensure that the setups are constructed properly and that the students are seeing evidence of photosynthesis.

Data and Observations
Students should record data under control conditions and then under experimental conditions for the same amount of time—at least 5 minutes.

Sharing Your Data
interNET CONNECTION To navigate the Internet BioLabs, choose the Biology: The Dynamics of Life icon at the site. Click on the student site icon, then the Biolabs icon. The advantage of using the Internet for an experiment of this nature is that students can collect considerably more and varied data than they could collect on their own in the allotted time. They also gain the experience of communicating scientific information using a technology that was originally intended for the dissemination of scientific knowledge.

Chemistry Connection

Purpose
Students should recognize the role that pigments such as chlorophyll play in the process of photosynthesis.

Background
There are far more chlorophyll molecules in a green leaf than carotenoids, and for most of the growing season, chlorophyll masks the presence of those accessory pigments. In the autumn, however, chlorophyll breaks down and the other pigments in leaves are visible as "fall colors." The cause of this chlorophyll breakdown is not completely understood, but it seems to be tied to the gradual reduction in daylight that takes place as summer ends.

Teaching Strategies
- Have students examine live (or preserved) specimens of green, brown, and red algae to observe the difference in pigments. L2 ELL
- Melanin is a pigment in animals that absorbs ultraviolet radiation and protects skin and other tissues from sun damage. Have students research melanin along with a plant pigment and create posters that compare the two. L3

Connection to Biology
Accessory pigments have made it possible for photosynthetic organisms to use a broader range of the visible light spectrum, and in so doing, survive in places where the amount or quality of visible light is minimal.

Chemistry Connection

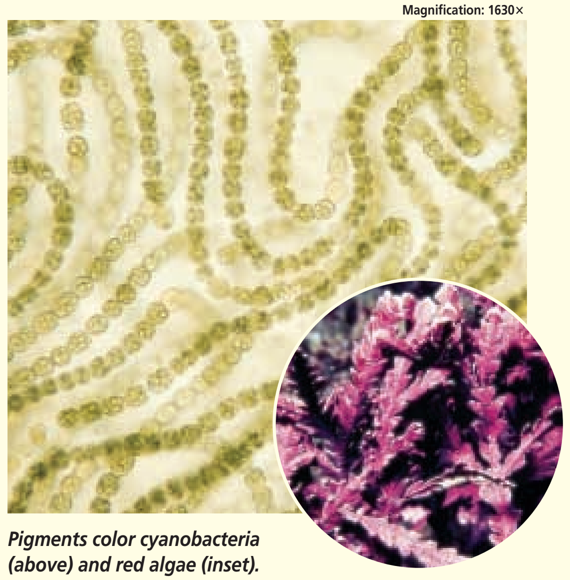
Plant Pigments

In photosynthesis, light energy is converted into chemical energy. To begin the process, light is absorbed by colorful pigment molecules contained in chloroplasts.

A pigment is a substance that can absorb the various wavelengths of visible light. You can observe the colors of these wavelengths by letting sunlight pass through a prism to create a "rainbow," or spectrum, that has red light on one end, violet on the other, and orange, yellow, green, and blue light in between.

Every photosynthetic pigment is distinctive in that it absorbs certain wavelengths in the visible light spectrum.

Magnification: 1630×



Pigments color cyanobacteria (above) and red algae (inset).

Chlorophylls *a* and *b* The principal pigment of photosynthesis is chlorophyll. Chlorophyll exists in two forms designated as *a* and *b*. Chlorophyll *a* and *b* both absorb light in the violet to blue and red to red-orange parts of the spectrum, although at somewhat different wavelengths. These pigments also reflect green light, which is why plant leaves appear green.

When chlorophyll *b* absorbs light, it transfers the energy it acquires to chlorophyll *a*, which then feeds that energy into the chemical reactions that lead to the production of ATP and NADP. In this way, chlorophyll *b* acts as an "accessory" pigment by making it possible for photosynthesis to occur over a broader spectrum of light than would be possible with chlorophyll *a* alone.

Carotenoids and phycobilins Carotenoids and phycobilins are other kinds of accessory pigments that absorb wavelengths of light different from those absorbed by chlorophyll *a* and *b*, and so extend the range of light that can be used for photosynthesis.

Carotenoids are yellow-orange pigments. They are found in all green plants, but their color is usually masked by chlorophyll. Carotenoids are also found in cyanobacteria and in brown algae. A particular carotenoid called fucoxanthin gives brown algae their characteristic dark brown or olive green color.

Phycobilins are blue and red. Red algae get their distinctive blood-red coloration from phycobilins. Some phycobilins can absorb wavelengths of green, violet, and blue light that penetrate into deep water. One species of red algae that contains these pigments is able to live at ocean depths of 269 meters (884 feet). The algae's pigments absorb enough of the incredibly faint light that penetrates to this depth—only 0.0005 percent of what is available at the water's surface—to power photosynthesis.

Connection to Biology
How do you think accessory pigments may have influenced the spread of photosynthetic organisms into diverse habitats such as the deep sea?

interNET CONNECTION To find out more about pigments, visit the Glencoe Science Web Site.
www.glencoe.com/sec/science

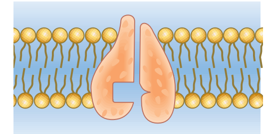
Internet Address Book

interNET CONNECTION Note Internet addresses that you find useful in the space below for quick reference.

Chapter 9 Assessment

Summary

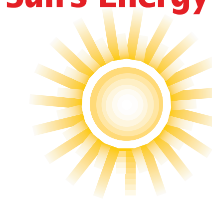
Section 9.1
ATP in a Molecule



Main Ideas
- ATP is the molecule that stores energy for easy use within the cell.
- ATP is formed when a phosphate group is added to ADP. When ATP is broken down, ADP and phosphate are formed and energy is released.
- ATP is the main link between energy-releasing and energy-using reactions.

Vocabulary
(ADP) adenosine diphosphate (p. 228)
(ATP) adenosine triphosphate (p. 228)

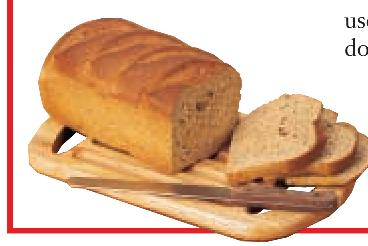
Section 9.2
Photosynthesis: Trapping the Sun's Energy



Main Ideas
- Photosynthesis is the process by which cells use light energy to make carbohydrates.
- Chlorophyll in the chloroplasts of plant cells traps light energy needed for photosynthesis.
- The light reactions of photosynthesis produce ATP and result in the splitting of water molecules.
- The reactions of the Calvin cycle make carbohydrates using CO_2 along with ATP and hydrogen from the light reactions.

Vocabulary
Calvin cycle (p. 234)
chlorophyll (p. 232)
electron transport chain (p. 232)
light-dependent reactions (p. 231)
light-independent reactions (p. 231)
$NADP^+$ (p. 233)
photolysis (p. 234)
photosynthesis (p. 231)
pigments (p. 232)

Section 9.3
Getting Energy to Make ATP



Main Ideas
- Cellular respiration is the process by which cells break down carbohydrates to release energy.
- Cellular respiration takes place in mitochondria, uses oxygen, and yields many more ATPs than do anaerobic processes.
- Energy can be released anaerobically by glycolysis followed by alcoholic or lactic acid fermentation.

Vocabulary
aerobic respiration (p. 237)
alcoholic fermentation (p. 242)
anaerobic respiration (p. 237)
cellular respiration (p. 237)
citric acid cycle (p. 238)
glycolysis (p. 237)
lactic acid fermentation (p. 242)

Understanding Main Ideas

1. Which of the following is a product of the Calvin cycle?
   a. carbon dioxide
   b. $NADP^+$
   c. oxygen
   d. $FADH_2$
2. _______ processes require oxygen, whereas _______ processes do not.
   a. anaerobic—aerobic
   b. aerobic—anaerobic
   c. photolysis—aerobic
   d. aerobic—respiration

Summary
Summary statements can be used by students to review the major concepts of the chapter.

Using the Vocabulary
To reinforce chapter vocabulary, use the Content Mastery Booklet and the activities in the Interactive Tutor for Biology: The Dynamics of Life on the Glencoe Science Web Site:
www.glencoe.com/sec/science

THE PRINCETON REVIEW *All Chapter Assessment questions and answers have been validated for accuracy and suitability by The Princeton Review.*

Understanding Main Ideas
1. b
2. b

GLENCOE TECHNOLOGY

VIDEOTAPE
MindJogger Videoquizzes
Chapter 9: *Energy in a Cell*
Have students work in groups as they play the videoquiz game to review key chapter concepts.

Resource Manager

Chapter Assessment, pp. 49-54
MindJogger Videoquizzes
Computer Test Bank
BDOL Interactive CD-ROM, Chapter 9 quiz

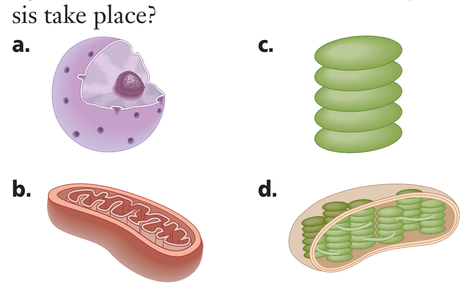
3. c
4. a
5. d
6. d
7. b
8. b
9. a
10. a
11. carbon dioxide; oxygen
12. chlorophyll
13. thylakoid; mitochondrion
14. Photolysis
15. Citric acid cycle
16. Electron transport chain
17. lactic acid; ethanol
18. phosphates; repel
19. Lactic acid fermentation; alcoholic fermentation
20. Pigments

Applying Main Ideas

21. During physical activity, muscle cells must release energy at a higher rate than skin cells.
22. Photosynthesis stores energy, whereas respiration releases energy, and the products of one process are the reactants of the other process.
23. Other pigments in the plant absorb some of the light of other wavelengths and pass the energy to chlorophyll for use in photosynthesis. The remaining light that is not trapped is reflected or absorbed as heat.
24. Possible answer: The amount of oxygen in the atmosphere would start to decrease because it would be used up in respiration and not replaced.

Chapter 9 Assessment

3. During all energy conversions, some of the energy is converted to _______.
   a. carbon dioxide — c. heat
   b. water — d. sunlight
4. Four molecules of glucose would give a net yield of _______ ATP following glycolysis.
   a. 8 — c. 4
   b. 16 — d. 12
5. In which of the following structures do the light-independent reactions of photosynthesis take place?



6. What is the first process in the cell to be affected by anaerobic conditions?
   a. citric acid cycle
   b. fermentation
   c. glycolysis
   d. electron transport chain
7. Which molecule provides the most accessible source of energy for cell organelles?
   a. glucose — c. starch
   b. ATP — d. carbon dioxide
8. Which of the following uses no energy?
   a. glycolysis — c. light reactions
   b. Calvin cycle — d. muscle contraction
9. Which of the following transports high-energy electrons in photosynthesis?
   a. $NADP^+$ — c. FAD
   b. NAD^+ — d. ATP
10. When yeast ferments the sugar in a bread mixture, what is produced that causes the bread dough to rise?
    a. carbon dioxide — c. ethyl alcohol
    b. water — d. oxygen
11. Plants must have a constant supply of _______ for photosynthesis, but they provide _______ for cellular respiration.
12. _______ is the first molecule to provide electrons for photosynthesis.
13. The _______ membrane is the site of photosynthesis, whereas the _______ is the site for cellular respiration.
14. _______ is the process by which electrons are restored to chlorophyll after photosynthesis.
15. _______ acts as a source of CO_2 in cellular respiration.
16. _______ occurs in the inner membrane of the mitochondrion.
17. In fermentation, pyruvic acid can form _______ or _______ in addition to NAD^+.
18. ATP stores energy because the three _______ have a negative charge and they _______ each other.
19. _______ produces muscle soreness, whereas _______, another type of fermentation, produces ethyl alcohol.
20. _______ such as chlorophyll are the chemical substances that give color to plants.

THE PRINCETON REVIEW — Test-Taking Tip

Take 5 and Stay Sharp
Wanting to perform well on your exam is praiseworthy. But if you study for long periods of time, you could actually end up hurting your chances for a good score. Remember to take frequent short breaks in your studies to keep your mind

Applying Main Ideas

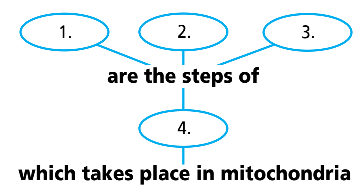
21. Why would human muscle cells contain many more mitochondria than skin cells?
22. How are cellular respiration and photosynthesis complementary processes?
23. What happens to sunlight that strikes a leaf but is not trapped by photosynthesis?
24. What might happen to Earth's atmosphere if photosynthesis suddenly stopped?

Chapter 9 Assessment

25. If you were planning on studying the compounds that could possibly be the source of the oxygen released during photosynthesis, which compounds would you need to consider?

Thinking Critically

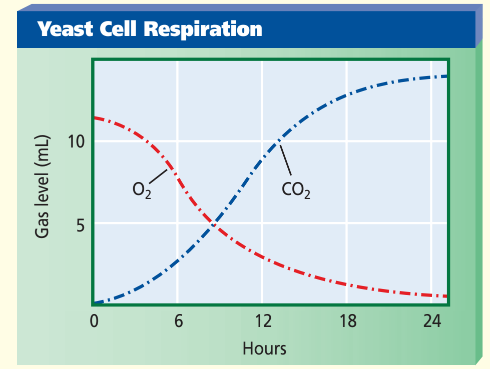
26. **Formulating Hypotheses** *Elodea* sprigs were placed under a white light, and the rate of photosynthesis was measured by counting the number of oxygen bubbles per minute for ten minutes. Predict the rate of photosynthesis if a piece of red cellophane were placed over the white light.
27. **Observing and Inferring** Yeast cells must be forced to ferment by placing them in an environment without any oxygen. Why would the yeast cells carry out aerobic respiration rather than fermentation when oxygen is present?
28. **Recognizing Cause and Effect** A window plant native to the desert of South Africa has leaves that grow almost entirely underground with only the transparent tip of the leaf protruding above the soil surface. Suggest how this adaptation aids the survival of this plant.
29. **Concept Mapping** Make a concept map using the following vocabulary terms: cellular respiration, glycolysis, citric acid cycle, electron transport chain.



CD-ROM
For additional review, use the assessment options for this chapter found on the ***Biology: The Dynamics of Life Interactive CD-ROM*** and on the Glencoe Science Web Site.
www.glencoe.com/sec/science

Assessing Knowledge & Skills

Yeast cells and sucrose were placed in a test tube, and the tube was then plugged. The yeast–sucrose mixture incubated for 24 hours. Gas bubbles began to rise to the top of the tube. After 24 hours, no sucrose was left in the solution.



Interpreting Data Use the graph to answer the questions below.

1. What process was the yeast using to digest the sucrose at the beginning of the experiment?
   a. photosynthesis
   b. anaerobic respiration
   c. aerobic respiration
   d. light-dependent reactions
2. Which of the following would be left in the solution after 24 hours?
   a. sucrose — c. oxygen
   b. lactic acid — d. ethyl alcohol
3. What gas would be found in the top of the tube after the incubation period?
   a. carbon dioxide — c. hydrogen
   b. oxygen — d. nitrogen
4. **Making a Table** Construct a table from the graph showing the oxygen levels and carbon dioxide levels.

Chapter 9 Assessment

Thinking Critically

25. carbon dioxide and water
26. Photosynthetic rate would decrease. Although the cellophane transmits red light, it would cut down the light in the blue end of the spectrum that is also used in photosynthesis.
27. Aerobic respiration is a much more efficient process and produces many more ATPs per sugar molecule.
28. This adaptation conserves water while allowing the plant to get light for photosynthesis, thereby solving the main problem of desert plants.
29. 1. Glycolysis; 2. Citric acid cycle; 3. Electron transport chain; 4. Cellular respiration

Assessing Knowledge & Skills

1. c
2. d
3. a
4. Student tables should be consistent with the information in the graph.

National Science Education Standards: UCP.1, UCP.2, UCP.3, UCP.5, B.3, B.6, C.1, C.5, F.1, G.1, G.3

Prepare

Purpose

This BioDigest can be used as an introduction to or as an overview of the structure and function of the cell. If time is limited, you may wish to use this unit summary to teach about the cell in place of the chapters in the Cell unit.

Key Concepts

Students will learn that chemistry is an integral component of living organisms. According to the cell theory, the cell is the basic unit of organization of all living matter. This means that even a complex organism, such as a tree or an elephant, is made up of cells. Students will learn that the structure and function of a cell and its parts are similar, even for cells that serve very different functions. The concepts of how a cell transforms energy from the sun and food sources and how a cell reproduces will also be described.

1 Focus

Bellringer

Display an overhead transparency of a eukaryotic cell. Point out each of the organelles and ask students to identify the functions of each organelle. L1 ELL

For a **preview** of the cell unit, study this BioDigest before you read the chapters. After you have studied the cell chapters, you can use the BioDigest to **review** the unit.

The Life of a Cell

All organisms are made up of cells, and each cell is like a complex, self-contained machine that can perform all of the life functions of the cell. Yet as small as they are, all of the mechanisms and processes of these little machines are not fully known, and scientists continue to unravel the marvelous mysteries of the living cell.

Cells are microscopic machines

The Chemistry of Life

Although you are studying biology, chemistry is fundamental to all biological functions. Understanding some of the basic concepts of chemistry will enhance your understanding of the biological world.

Elements and Atoms

Every substance in and on Earth is a combination of elements. An atom, the smallest component of an element, is formed by layers of electrons around a nucleus made of protons and neutrons. Atoms come together to form molecules.

Vital Statistics

Carbon Isotopes
Isotopes of carbon contain different numbers of neutrons.
Carbon 12: six protons and six neutrons
Carbon 13: six protons and seven neutrons
Carbon 14: six protons and eight neutrons

Focus on History

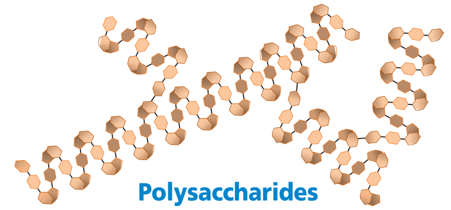
The Cell Theory

van Leeuwenhoek might have viewed microorganisms like these found in a droplet of pond water.

In the 1600s, Anton van Leeuwenhoek was the first person to view living organisms through a microscope. Another scientist, Robert Hooke, named the structures cells. Two hundred years later, several scientists, including Matthias Schleiden, Theodor Schwann, and Rudolph Virchow continued to study animal and plant tissues under the microscope. Conclusions from all scientists were combined to form the cell theory:

1. All organisms are composed of one or more cells.
2. The cell is the basic unit of organization of organisms.
3. All cells come from preexisting cells.

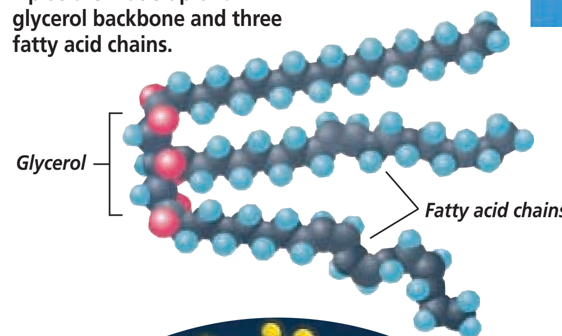
A polysaccharide is a type of carbohydrate made up of a chain of monosaccharides.

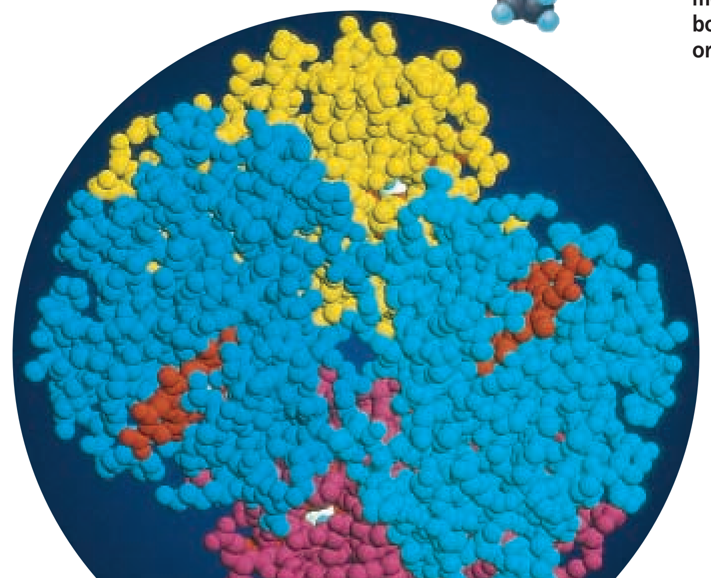


Organic Compounds

Carbohydrates are chemical compounds made up of carbon, hydrogen, and oxygen molecules. Common carbohydrates include sugars, starches, and cellulose. Lipids, known as fats and oils, contain a glycerol backbone and three fatty acid chains. Proteins are a combination of amino acids connected by peptide bonds.

Lipids are made up of a glycerol backbone and three fatty acid chains.

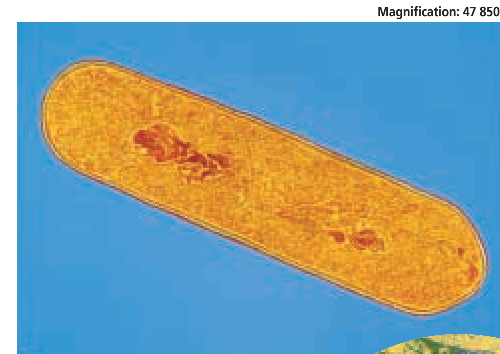




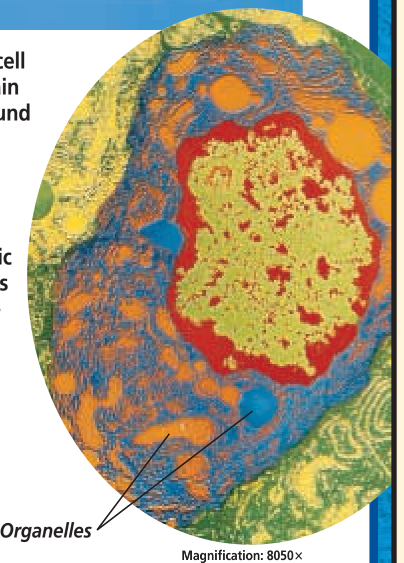
Amino acids can be joined with peptide bonds to form proteins.

Eukaryotes and Prokaryotes

All cells are surrounded by a plasma membrane. Eukaryotic cells contain membrane-bound structures within the cell called organelles. Cells without internal membrane-bound structures are called prokaryotic cells.



A prokaryotic cell does not contain membrane-bound organelles.



A eukaryotic cell contains membrane-bound organelles.

2 Teach

Assessment

Portfolio Have students cut out pictures of trees from magazines and place them in their portfolios. Then have them write about the tree from a cellular point of view. They should include details such as whether the cells of the trees are eukaryotic or prokaryotic, a list of organelles that may be present, information about cells and photsynthesis, ideas on cellular growth and reproduction, and cellular differentiation within the tree. Then have the students write a comparison with an animal cell using the same information. L2 P

Quick Demo

Bring in food items to demonstrate organic compounds. A potato or bread can demonstrate carbohydrates, meat can demonstrate proteins, and vegetable oil or shortening can demonstrate lipids. Combine this experience with a molecular model of a lipid and relate the model to the example lipid and to the overall structure of the plasma membrane.

National Geographic

VIDEODISC
STV: The Cell
Viewing the Cell
Early Pioneers - Unit 1
38 sec.
Cell Theorists - Unit 1
1 min. 15 sec.

Multiple Learning Styles

Look for the following logos for strategies that emphasize different learning modalities.

Kinesthetic Meeting Individual Needs, p. 253
Visual-Spatial Portfolio, p. 252; Microscope Activity, p. 252, 253
Intrapersonal Project, p. 254
Linguistic Biology Journal, p. 252; Check for Understanding, p. 255; Extension, p. 255

Assessment Planner

Portfolio Assessment
Assessment, TWE, p. 251
Performance Assessment
Assessment, TWE, p. 252
Knowledge Assessment
BioDigest Assessment, SE, p. 255
Skill Assessment
Assessment, TWE, p. 255

GLENCOE TECHNOLOGY

VIDEODISC
The Infinite Voyage *Unseen Worlds, Studying the Basic Building Blocks: The Atom* (Ch. 9) 2 min.
The Scanning Tunneling Microscope: Observing Atomic Particles (Ch. 10) 2 min.

Microscope Activity

Visual-Spatial Set up microscopes with slides demonstrating animal and plant cells. Have students look at the cells and identify differences between the two cells.

Help the students by explaining that animal cells have centrioles and plant cells do not. Centrioles play a role during cell division and in the formation of microtubules. Also explain that plant cells contain a cell wall outside the plasma membrane and only one or two large vacuoles that store water. Make sure the students understand that animal cells also have vacuoles, but there are more of them and they are smaller than those found in plants. L2 ELL

Assessment

Performance Have students look at slides of animal and plant cells and identify the structures.

GLENCOE TECHNOLOGY

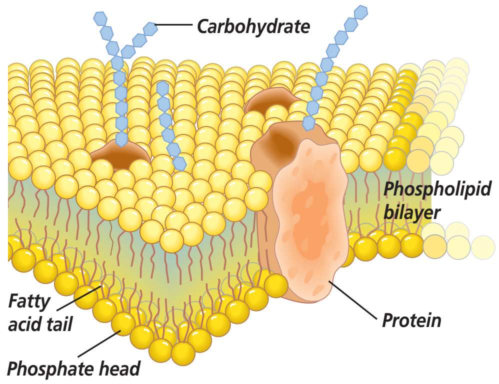
CD-ROM
Biology: The Dynamics of Life
Exploration: *Parts of the Cell*
Disc 1
BioQuest: *Cellular Pursuit*
Disc 1

Cell Organelles

The organelles of a cell work together to carry out the functions necessary for cell survival.

Plasma Membrane

According to the fluid mosaic model, the plasma membrane is formed by two layers of phospholipids with the fatty acid chains back-to-back; the phosphate groups face the external environment, and proteins are embedded in the membrane.



The plasma membrane is composed of a lipid bilayer with embedded proteins.

Control of Cell Functions

The nucleus contains the master plans for proteins, which are then produced by organelles called ribosomes. The nucleus also controls cellular functions.

Assembly, Transport, and Storage

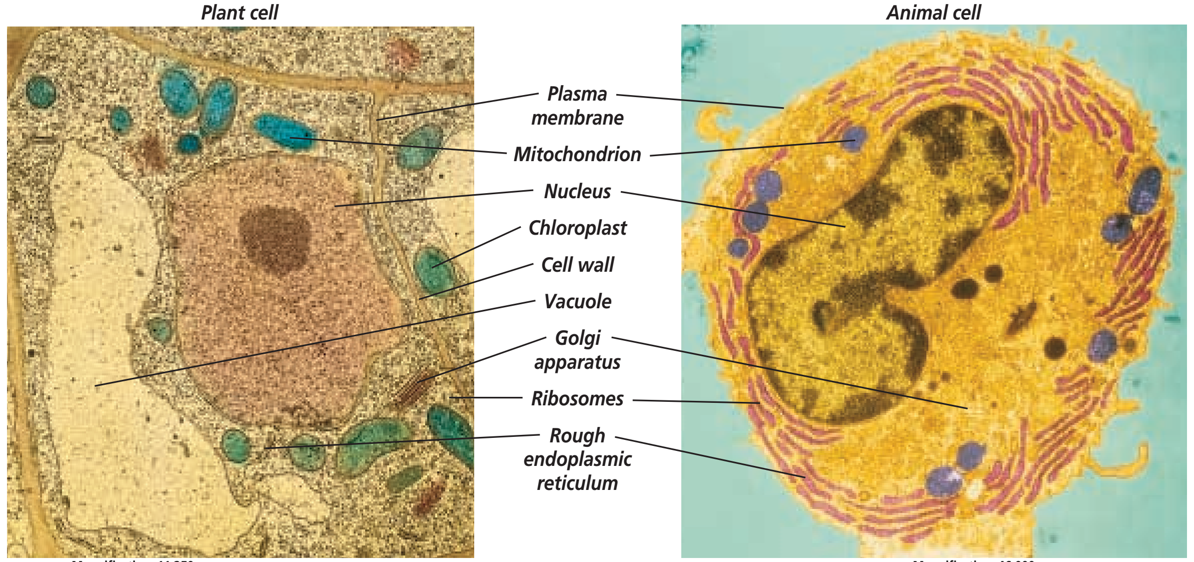
The cytoplasm suspends the cell's organelles, including endoplasmic reticulum, Golgi apparatus, vacuoles, and lysozomes. The endoplasmic reticulum and Golgi apparatus transport and modify proteins.

Energy Transformers

Chloroplasts are found in plant cells and capture the sun's light energy so it can be transformed into useable chemical energy. Mitochondria are found in both animal and plant cells and transform the food you eat into a useable energy form.

Support and Locomotion

A network of microfilaments and microtubules attach to the plasma membrane to give the cell structure. Cilia are short, numerous projections that move like a wave. Flagella are longer projections that move in a whiplike fashion to propel a cell.



Diffusion and Osmosis

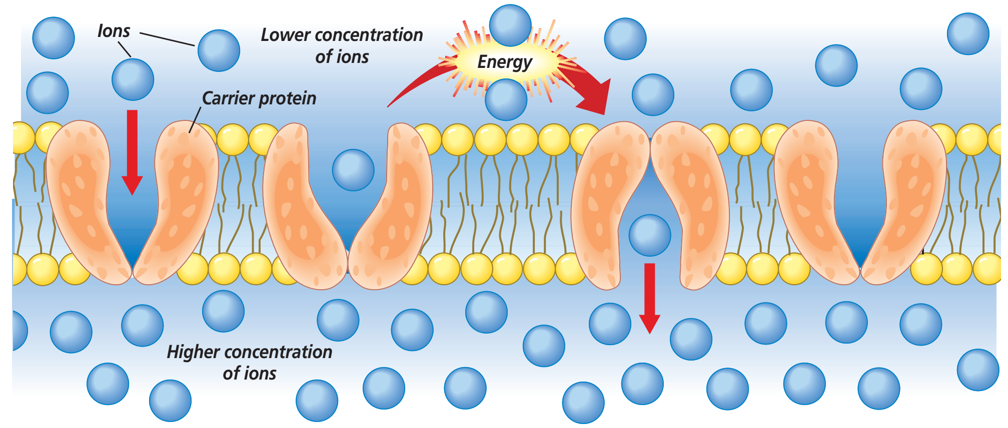
The selectively permeable plasma membrane allows only certain substances to cross. Diffusion is the movement of a substance from an area of higher concentration to an area of lower concentration. Diffusion of water across a selectively permeable membrane is called osmosis.

Simple diffusion across a membrane occurs by random movement. Facilitated diffusion requires proteins to bind and help move molecules across the membrane. Active transport requires energy to move molecules across a concentration gradient.

Vital Statistics

Cellular Environments
Isotonic solution: same number of molecules inside and outside the cell
Hypotonic solution: more molecules inside the cell; water enters the cell
Hypertonic solution: fewer molecules inside the cell; water leaves the cell

Membrane proteins can transport substances against the concentration gradient in active transport.

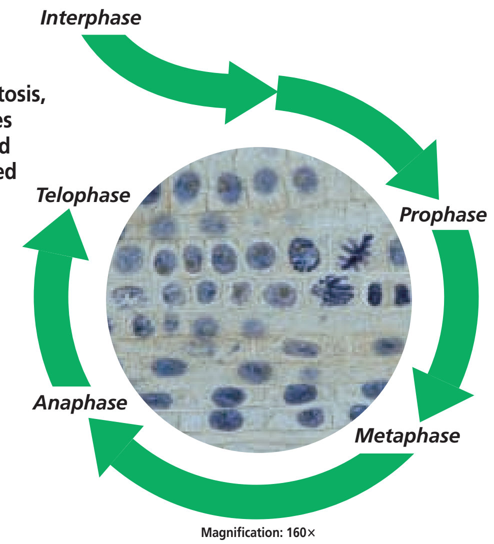


Mitosis

As cells grow, they reach a size where the plasma membrane cannot transport enough nutrients and wastes to maintain cell growth. At this point, the cell undergoes mitosis and divides.

Prior to mitosis is a period of intense metabolic activity called interphase. The first stage of mitosis is prophase, when the duplicated chromosomes condense and the mitotic spindle forms on the two opposite ends of the cell. The chromosomes line up in the center of the cell during metaphase and slowly separate during anaphase. In telophase the nucleus divides followed by cytokinesis, which separates the daughter cells.

During the stages of mitosis, chromosomes are replicated and separated into two daughter cells.



Demonstration

Linguistic Use this demonstration to simulate osmosis in hypotonic, isotonic, and hypertonic solutions. Fill three pieces of dialysis tubing with red 15% sucrose solution. Tie the top of each dialysis bag around a hollow piece of glass tubing. Clamp each bag/tubing apparatus to a ring stand and place in one of three solutions: distilled water (hypotonic), 15% clear sucrose solution (isotonic), and a 30% sucrose solution (hypertonic). At the beginning of the demonstration, mark the initial level of the red sucrose in the glass tubing. At regular intervals, such as the end of each class period, again mark the level of the red sucrose solution. Use the changes in volume of the three dialysis bags to quantify osmosis in hypotonic, isotonic, and hypertonic solutions.

Microscope Activity

Visual-Spatial Set up a series of microscopes with prepared slides of onion root tip demonstrating the stages of mitosis. Have students look at the slides before discussing the stages of mitosis. After naming and discussing the stages, have students look at the slides again and ask them to explain what they see. L2

GLENCOE TECHNOLOGY

CD-ROM
Biology: The Dynamics of Life
Exploration: *Phases of Mitosis*
Disc 1

Portfolio

The Plasma Membrane

Visual-Spatial In their portfolios, have students draw a plasma membrane. They should include phospholipids showing the polar head and fatty acid tails forming a bilayer with the heads and tails properly oriented. Have them include several transmembrane proteins. L1 ELL P

Biology Journal

Organelles

Linguistic Have students write a paragraph about how the cellular organelles act like a factory to produce proteins and energy. They should include how organelles regulate the intake of necessary materials and the export of products and wastes. L2

Meeting Individual Needs

Visually Impaired

Kinesthetic Tie pairs of socks together in the middle to simulate chromosomes undergoing mitosis. Create a series of cells and place the pairs of socks in the appropriate places to mimic the stages of mitosis. Have visually impaired students manipulate the sock chromosomes. L1 ELL

GLENCOE TECHNOLOGY

VIDEODISC
The Secret of Life
Cell Membranes: Membranes and Transport

Classroom Activity

Use play money to demonstrate the analogy that ATP is the currency for energy. Assign a cost to several objects in the classroom and point out that some items "cost" more than others. Have students purchase these objects using large bills such as $100s or $500s to demonstrate that large denominations must be broken down to smaller amounts. Then relate the cost to the energy expense to perform cellular activity. An example of an inexpensive transaction in a cell is transporting two Na+ ions outside of the cell. An example of an expensive activity is making a protein. Relate that glucose is a large denomination of energy currency that cells break down into smaller amounts to fuel cellular activity.

Visual Learning

Display overheads of the Calvin cycle and the citric acid cycle. Explain that the cycles can be repeated again and again to produce different products.

GLENCOE TECHNOLOGY

VIDEODISC
The Secret of Life
Cell Energy: Cell Respiration

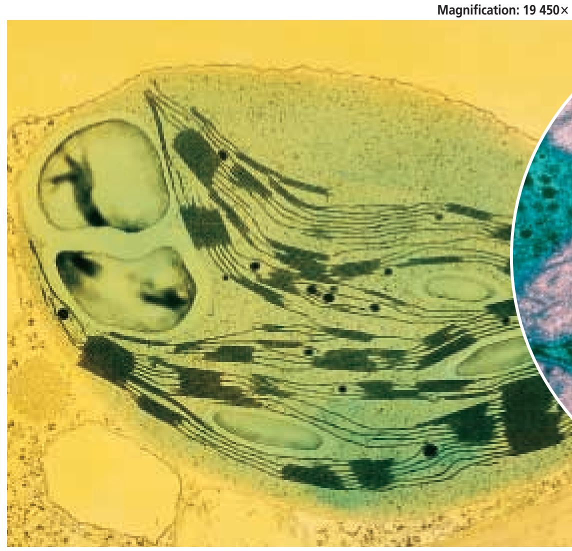
Energy in a Cell

Adenosine triphosphate (ATP) is the most commonly used source of energy in a cell. Two organelles are involved in forming ATP from other sources of energy.

Chloroplasts in plant cells harvest energy from the sun's rays and convert it to ATP using light-dependent reactions. Light-independent reactions convert energy into carbohydrates such as starch through the Calvin cycle.

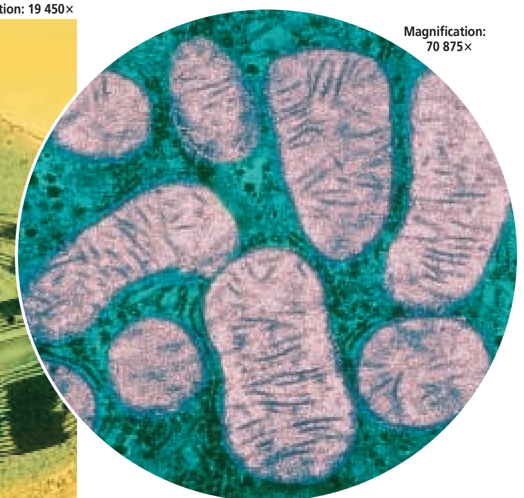
Mitochondria, found in both plant and animal cells, convert food energy into ATP through a series of chemical reactions that include glycolysis, the citric acid cycle, and the electron transport chain.

Magnification: 19 450×



In chloroplasts, the Calvin cycle allows the sun's energy to be stored as carbohydrates for later use.

Magnification: 70 875×



In mitochondria, the citric acid cycle allows the breakdown of food sources to form ATP.

Focus on Health

Cancer

Cancer is one condition that can result when a cell can no longer control the rate of mitosis. Cancer may be due to factors inside the cell, such as enzyme overproduction or production at the wrong time. Cancer can also be a result of environmental factors.

In recent years, much emphasis has been placed on healthy lifestyles that can help prevent cancer. Eating diets rich in fruits and vegetables, exercising regularly, and quitting or avoiding smoking can all help reduce the incidence of cancer.

This melanoma is an example of skin cancer.

Vital Statistics

ATP production for each molecule of glucose

Glycolysis: produces a net gain of two ATP, two NADH, and two H^+
Acetyl-CoA formation: produces two NADH
Citric acid cycle (Krebs cycle): produces two ATP, six NADH, and two FADH
Electron transport chain: produces 32 ATP from NADH and FADH
Lactic acid fermentation: produces two ATP

Energy from ATP

BioDigest Assessment

Understanding Main Ideas

1. What is a starch?
   a. a lipid
   b. a carbohydrate
   c. a protein
   d. a peptide
2. The building blocks of proteins are ________.
   a. fatty acids
   b. monosaccharides
   c. amino acids
   d. glycerol
3. A cell that does not contain internal, membrane-bound structures is a ________.
   a. prokaryote
   b. eukaryote
   c. yeast cell
   d. a cell with organelles
4. The organelle that produces proteins is the ________.
   a. nucleus
   b. lysozome
   c. ribosomes
   d. vacuole
5. What structure is part of the cell's skeleton?
   a. Golgi apparatus
   b. nucleus
   c. endoplasmic reticulum
   d. microfilaments
6. The movement of a substance across the plasma membrane against the concentration gradient by binding to a protein is ________.
   a. facilitated transport
   b. osmosis
   c. simple diffusion
   d. active transport
7. What structure is involved in movement?
   a. cilia
   b. lysozomes
   c. vacuole
   d. chloroplasts
8. The stage of mitosis when the chromatids separate and move to opposite sides of the cell is ________.
   a. prophase
   b. metaphase
   c. anaphase
   d. telophase
9. The organelle that transforms light energy to ATP is ________.
   a. mitochondrion
   b. endoplasmic reticulum
   c. chloroplast
   d. nucleus
10. Which is involved in capturing light energy from the sun?
    a. light-dependent reactions
    b. Citric acid cycle
    c. Calvin cycle
    d. light-independent reactions

Thinking Critically

1. **Compare and contrast** the functions of chloroplasts and mitochondria in energy transformation.
2. **Describe** the organelles of a eukaryotic cell.
3. **Relate** transport across the plasma membrane in isotonic, hypertonic, and hypotonic solutions to changes in cell shape due to water movement across the membrane.

PROJECT

Cancer Facts Research

Intrapersonal Have students research one type of cancer that can be prevented by a lifestyle such as not smoking, sun avoidance, exercise, or diet. Have students present their report to the class. L3

BioDigest Assessment

Understanding Main Ideas

1. b
2. c
3. a
4. c
5. d
6. d
7. a
8. c
9. c
10. a

Thinking Critically

1. Chloroplasts trap light energy and store it by producing complex sugars. Mitochondria break down sugars to release ATP. Both are involved in energy production for the cell.
2. Most organelles of a eukaryotic cell are surrounded by a membrane. This membrane allows very different chemical reactions to be carried out in a cell at the same time.
3. In an isotonic solution, the concentration of solutes on both sides of the membrane is the same, so there will be no net movement across the membrane and the cell shape will not change. In a hypertonic solution, there is a greater concentration of solutes outside the cell, there is a net movement of water from the cell into the surrounding fluid, and the cell size will shrink. In a hypotonic solution, there is a greater concentration of solutes inside the cell; therefore, water will flow into the cell and the cell size will increase.

3 Assess

Check for Understanding

Linguistic Ask students to name as many organelles as they can and identify the function of each. L1

Reteach

Put up an overhead of the stages of mitosis and have students identify the stages and describe the events. L2

Extension

Linguistic Have students research melanoma and prepare a presentation illustrating its occurrence and treatment. Have them also develop a prevention plan. L3

Assessment

Skill Ask students to describe what will happen to a cell's volume if it is placed in a hypotonic, isotonic, or hypertonic environment. L2

4 Close

Discussion

Discuss how a plant cell obtains energy and stores it and how an animal cell obtains energy and transforms it to a usable form for cell organelles.

Resource Manager

Reinforcement and Study Guide, pp. 41-42 L2
Content Mastery, pp. 45-48 L1