Chapter 8

Cellular Transport and the Cell Cycle

Color-enhanced TEM Magnification: 1600×

What You'll Learn

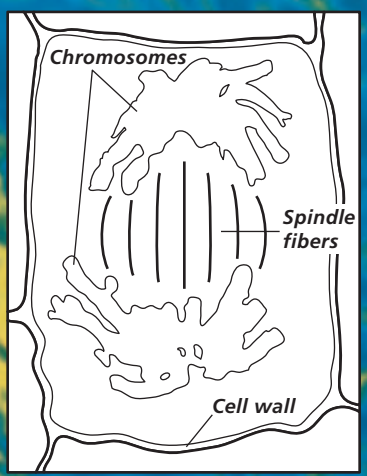
- You will discover how molecules are transported across the plasma membrane.
- You will sequence the stages of cell division.
- You will identify the relationship between the cell cycle and cancer.

Why It's Important

Transportation of molecules and particles through the plasma membrane and cell reproduction are two important functions that help cells maintain homeostasis and keep you healthy.

Understanding the Photo

This photo shows a cell in a plant's root tip in one stage of the cell cycle. Color enhancement helps distinguish the chromosomes, which appear yellow in this photo.



Biology Online

Visit bdol.glencoe.com to

- study the entire chapter online
- access Web Links for more information and activities on the cell cycle
- review content with the Interactive Tutor and self-check quizzes

Jean Claude Revy/Phototake, NYC

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Section 8.1

Cellular Transport

SECTION PREVIEW

Objectives

Explain how the processes of diffusion, passive transport, and active transport occur and why they are important to cells.

Predict the effect of a hypotonic, hypertonic, or isotonic solution on a cell.

Review Vocabulary

plasma membrane: the boundary between the cell and its environment (p. 175)

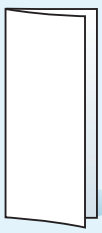
New Vocabulary

osmosis
isotonic solution
hypotonic solution
hypertonic solution
passive transport
facilitated diffusion
active transport
endocytosis
exocytosis

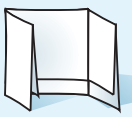
FOLDABLES Study Organizer

Osmosis Make the following Foldable to help identify what you already know about osmosis, and what you learned about how osmosis affects cells.

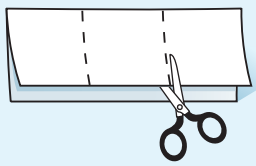
STEP 1 **Fold** a vertical sheet of paper from side to side. Make the back edge about 2 cm longer than the front edge.



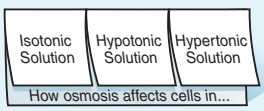
STEP 2 **Turn** lengthwise and **fold** into thirds.



STEP 3 **Unfold and cut** only the top layer along both folds to make three tabs.



STEP 4 **Label** each tab.



Answer Questions Before you read Chapter 8, write under each tab what you already know about how osmosis affects cells. After you read the chapter, list what you learned about how osmosis affects cells in each type of solution listed on your Foldable.

Osmosis: Diffusion of Water

Although the plasma membrane of a cell can act as a dam or pump for water-soluble molecules that cannot pass freely through the membrane, it does not limit the diffusion of water. Recall that diffusion is the movement of particles from an area of higher concentration to an area of lower concentration. In a cell, water always moves to reach an equal concentration on both sides of the membrane. The diffusion of water across a selectively permeable membrane is called **osmosis** (ahs MOH sus). Regulating the water flow through the plasma membrane is an important factor in maintaining homeostasis within the cell.

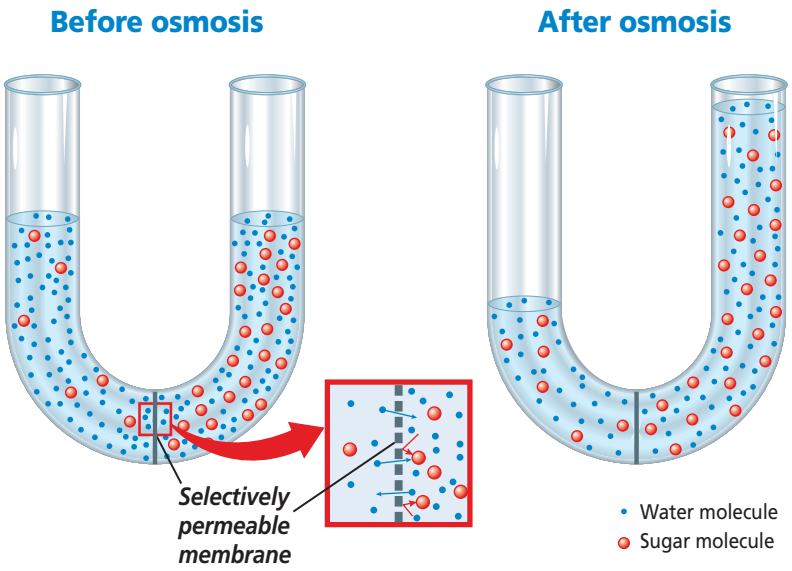
Word Origin

osmosis from the Greek word *osmos,* meaning "pushing"; Osmosis can push out a cell's plasma membrane.

What controls osmosis?

If you add sugar to water, the water becomes sweeter as you add more sugar. If a strong sugar solution and a weak sugar solution are placed in direct contact, water molecules diffuse in one direction and sugar molecules diffuse in the other direction until all molecules are evenly distributed throughout.

Figure 8.1
During osmosis, water diffuses across a selectively permeable membrane. Notice that the number of sugar molecules did not change on each side of the membrane, but the number of water molecules on either side of the membrane did change.



If the two solutions are separated by a selectively permeable membrane that allows only water to diffuse across it, water flows to the side of the membrane where the water concentration is lower. The water continues to diffuse until it is in equal concentration on both sides of the membrane, as shown in ***Figure 8.1.*** Therefore, we know that unequal distribution of particles, called a concentration gradient, is one factor that controls osmosis.

Word Origin

iso-, hypo-, hyper- from the Greek words *isos,* meaning "equal," *hypo,* meaning "under," and *hyper,* meaning "over," respectively.

Cells in an isotonic solution

It is important to understand how osmosis affects cells. Most cells, whether in multicellular or unicellular organisms, are subject to osmosis because they are surrounded by water solutions. In an **isotonic solution,** the concentration of dissolved substances in the solution is the same as the concentration of dissolved substances inside the cell. Likewise, the concentration of water in the solution is the same as the concentration of water inside the cell.

Cells in an isotonic solution do experience osmosis, but because water diffuses into and out of the cells at the same rate, the cells retain their normal shape, as shown in ***Figure 8.2.***

Cells in a hypotonic solution

In the **hypotonic solution** in ***Figure 8.3A,*** the concentration of dissolved substances is lower in the solution outside the cell than the concentration inside the cell. Therefore, there is more water outside the cell than inside. Cells in a hypotonic solution experience osmosis. Water moves through the plasma membrane into the cell. The cell swells and its internal pressure increases.

As the pressure increases inside animal cells, the plasma membrane swells, like the red blood cells shown in ***Figure 8.3B.*** If the solution is extremely hypotonic, the plasma membrane may be unable to withstand this pressure and may burst.

Because plant cells contain a rigid cell wall that supports the cell, they do not burst when in a hypotonic solution. As the pressure increases inside the cell, the plasma membrane is pressed against the cell wall, as shown in ***Figure 8.3C.*** Instead of bursting, the plant cell becomes more firm. Grocers keep produce looking fresh by misting the fruits and vegetables with water.

Cells in a hypertonic solution

In a **hypertonic solution,** the concentration of dissolved substances outside the cell is higher than the concentration inside the cell. Cells in a hypertonic solution experience osmosis that causes water to flow out.

Animal cells in a hypertonic solution shrivel because of decreased pressure in the cells.

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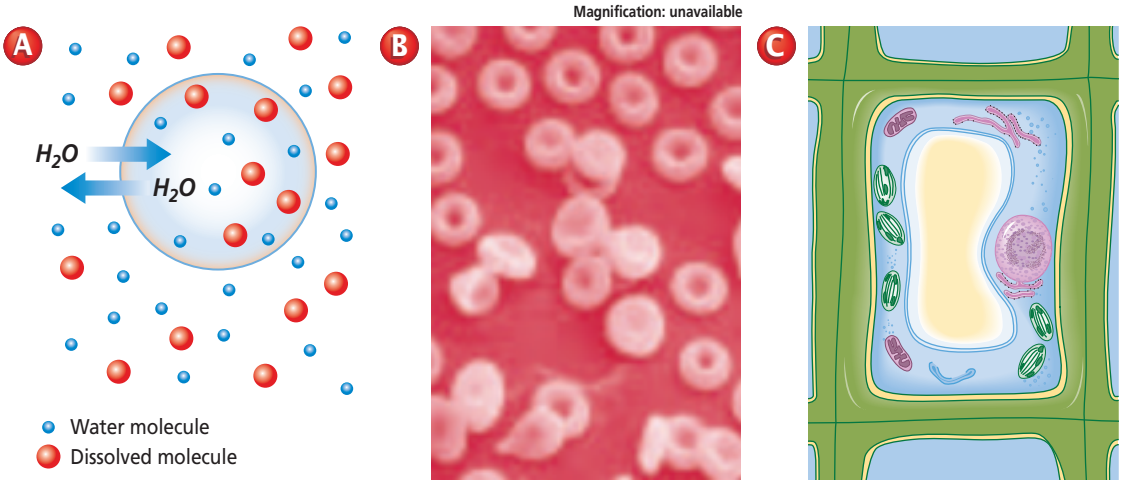

Figure 8.2
In an isotonic solution, water molecules move into and out of the cell at the same rate, and cells retain their normal shape **(A).** Notice the concave disc shape of a red blood cell **(B).** A plant cell has its normal shape and pressure in an isotonic solution **(C).**

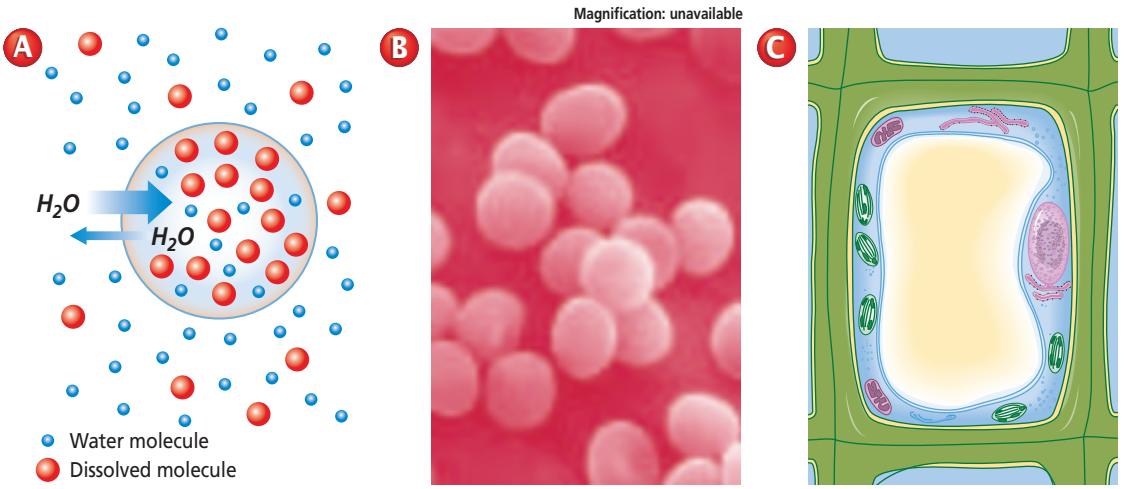

Figure 8.3
In a hypotonic solution, water enters a cell by osmosis, causing the cell to swell **(A).** Animal cells, like these red blood cells, may continue to swell until they burst **(B).** Plant cells swell beyond their normal size as pressure increases **(C).**

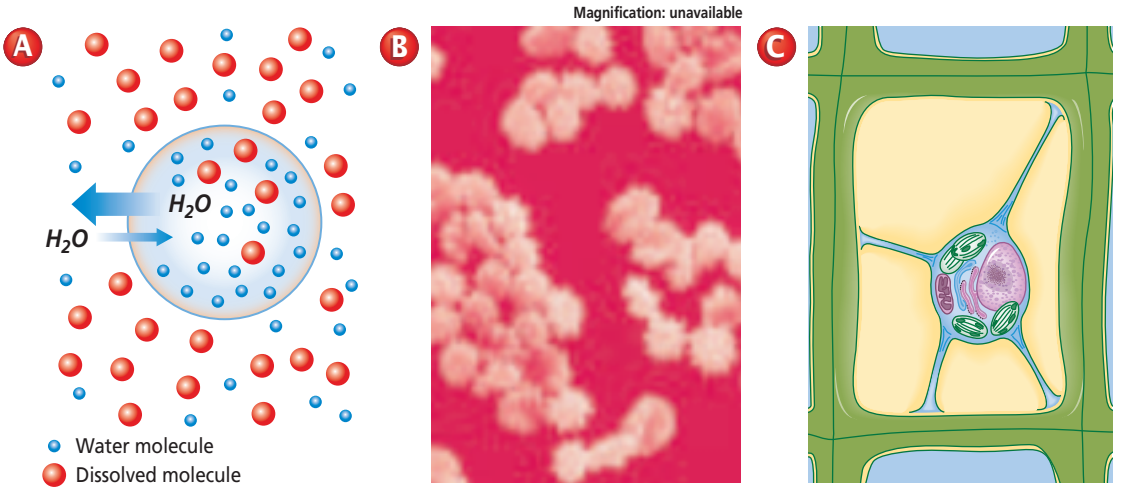

Figure 8.4
In a hypertonic solution, water leaves a cell by osmosis, causing the cell to shrink **(A).** Animal cells like these red blood cells shrivel up as they lose water **(B).** Plant cells lose pressure as the plasma membrane shrinks away from the cell wall **(C).**

MiniLab 8.1

Formulate Models

Cell Membrane Simulation In this experiment, a plastic bag is used to model a selectively permeable membrane. Starch is placed inside of the bag. When iodine and starch molecules come in contact with one another, a dark purple color results.

Procedure

1. Fill a plastic bag with 50 mL of starch. Seal the bag with a twist tie.
2. Fill a beaker with 50 mL of iodine solution. **CAUTION:** ***Rinse with water if iodine gets on skin. Iodine is toxic.***
3. Note and record the color of the starch and iodine.
4. Place the bag into the beaker. **CAUTION:** ***Wash your hands with soap after handling lab materials.***
5. Note and record the color of the starch and iodine 24 hours later.

Analysis

1. **Describe** Compare the color of the iodine and starch at the start and at the conclusion of the experiment.
2. **Observe** Which molecules crossed the membrane? What is your evidence?
3. **Think Critically** Evaluate whether or not a plastic bag is an adequate model of a selectively permeable membrane.

Plant cells in a hypertonic environment lose water, mainly from the central vacuole. The plasma membrane and cytoplasm shrink away from the cell wall, as shown in ***Figure 8.4C.*** Loss of water in a plant cell results in a drop in pressure and explains why plants wilt.

Passive Transport

Some molecules, like water, can pass through the plasma membrane by simple diffusion, as shown in ***Figure 8.5A.*** The cell uses no energy to move these particles; therefore, this movement of particles across the membrane is classified as **passive transport.** You can investigate passive transport by performing the *MiniLab* on this page.

Passive transport by proteins

Recall that transport proteins help substances move through the plasma membrane. Passive transport of materials across the membrane using transport proteins is called **facilitated diffusion.**

Some transport proteins, called channel proteins, form channels that allow specific molecules to flow through, as illustrated in ***Figure 8.5B.***

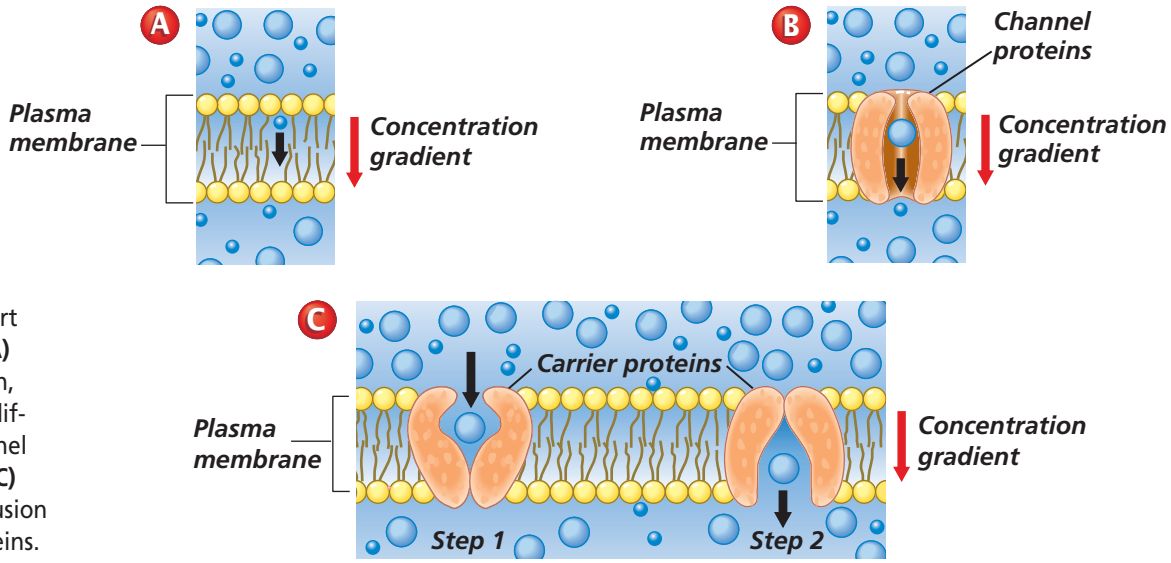

Figure 8.5
Passive transport can occur by **(A)** simple diffusion, **(B)** facilitated diffusion by channel proteins, and **(C)** facilitated diffusion by carrier proteins.

Table 8.1 Transport Through the Cell Membrane

Type of Transport	Transport Protein Used?	Direction of Movement	Requires Energy Input from Cell?	Classification of Transport
Simple Diffusion	No	With concentration gradient	No	Passive
Facilitated Diffusion	Yes—channel proteins or carrier proteins	With concentration gradient	No	Passive
Active Transport	Yes—carrier proteins	Against concentration gradient	Yes	Active

The movement is with the concentration gradient, and requires no energy input from the cell.

Carrier proteins are another type of transport protein. Carrier proteins change shape to allow a substance to pass through the plasma membrane, as shown in ***Figure 8.5C.*** In facilitated diffusion by carrier protein, the movement is with the concentration gradient and requires no energy input from the cell.

Active Transport

A cell can move particles from a region of lower concentration to a region of higher concentration, but it must expend energy to counteract the force of diffusion that is moving the particles in the opposite direction. Movement of materials through a membrane against a concentration gradient is called **active transport** and requires energy from the cell.

How active transport occurs

In active transport, a transport protein called a carrier protein first binds with a particle of the substance to be transported. In general, each type of carrier protein has a shape that fits a specific molecule or ion. When the proper molecule binds with the protein, chemical energy allows the cell to change the shape of the carrier protein so that the particle to be moved is released on the other side of the membrane, something like the opening of a door. Once the particle is released, the protein's original shape is restored, as illustrated in ***Figure 8.6.*** Active transport allows particle movement into or out of a cell against a concentration gradient.

Transport of substances across the cell membrane is required for cells to maintain homeostasis. The types of transport are summarized in ***Table 8.1.***

Reading Check **Compare and contrast** active and passive transport across the cell membrane.

Figure 8.6
Carrier proteins are used in active transport to pick up ions or molecules from near the cell membrane, carry them across the membrane, and release them on the other side. **Think Critically** ***Why does active transport require energy?***

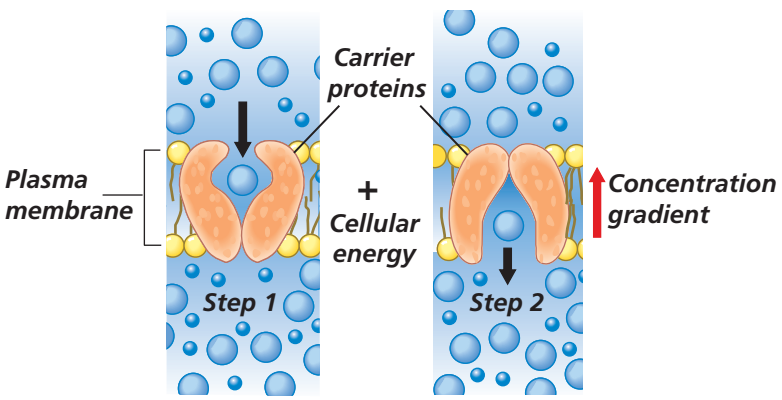

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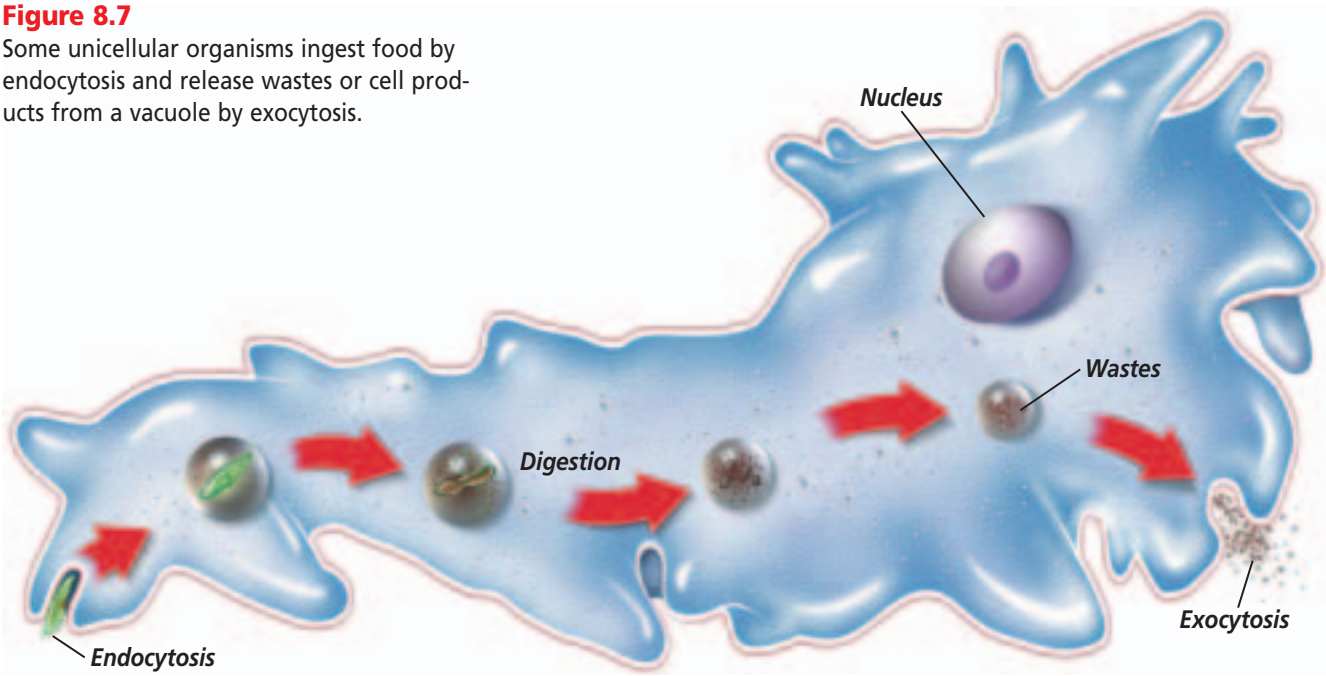
Figure 8.7
Some unicellular organisms ingest food by endocytosis and release wastes or cell products from a vacuole by exocytosis.



Transport of Large Particles

Word Origin

endo-, exo- from the Greek words *endon,* meaning "within," and *exo,* meaning "out"; Endocytosis moves materials into the cell; exocytosis moves materials out of the cell.

Some cells can take in large molecules, groups of molecules, or even whole cells. **Endocytosis** is a process by which a cell surrounds and takes in material from its environment as shown in ***Figure 8.7.*** This material does not pass directly through the membrane. Instead, it is engulfed and enclosed by a portion of the cell's plasma membrane. That portion of the membrane then breaks away, and the resulting vacuole with its contents moves to the inside of the cell.

Figure 8.7 also shows the reverse process of endocytosis, called exocytosis. **Exocytosis** is the expulsion or secretion of materials from a cell. Cells use exocytosis to expel wastes. They also use this method to secrete substances, such as hormones produced by the cell. Because endocytosis and exocytosis both move masses of material, they both require energy.

With the various mechanisms the cell uses to transport materials in and out, cells must also have mechanisms to regulate size and growth.

Section Assessment

Understanding Main Ideas

1. What factors affect the diffusion of water through a membrane by osmosis?
2. How do animal cells and plant cells react differently in a hypotonic solution?
3. Compare and contrast active transport and facilitated diffusion.
4. How do carrier proteins facilitate passive transport of molecules across a membrane?

Thinking Critically

5. A paramecium expels water when it is in freshwater. What can you conclude about the concentration gradient in the organism's environment?

Skill Review

6. **Observe and Infer** What effect do you think a temperature increase has on osmosis? For more help, refer to *Observe and Infer* in the **Skill Handbook.**

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Section 8.2

Cell Growth and Reproduction

SECTION PREVIEW

Objectives

Sequence the events of the cell cycle.

Relate the function of a cell to its organization in tissues, organs, and organ systems.

Review Vocabulary

organelle: the membrane-bound structures within eukaryotic cells (p. 173)

New Vocabulary

chromosome
chromatin
cell cycle
interphase
mitosis
prophase
sister chromatid
centromere
centriole
spindle
metaphase
anaphase
telophase
cytokinesis
tissue
organ
organ system

What makes up your body?

Using an Analogy Where do you live? This question sounds simple enough, but it has many answers. You live at a certain address, which is a part of a city. Many cities and towns form the state in which you live. The states form a country. Some tasks are performed by the country as a whole, while others are performed by states, cities, or individuals. In the same way, your body cells are parts of tissues, organs, organ systems, and the body as a whole.

Compare and Contrast *Cells in multicellular and unicellular organisms undergo cell division. Which type of cells do you think is more specialized?*

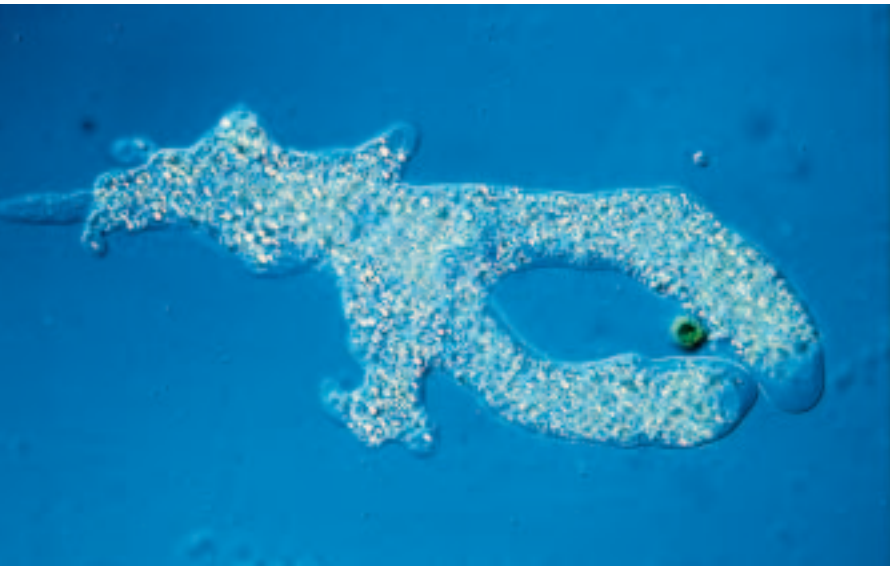
Cell Size Limitations

The cells that make up a multicellular organism come in a wide variety of sizes and shapes. Some cells, such as red blood cells, measure only 8 μm (micrometers) in diameter. Other cells, such as nerve cells in large animals, can reach lengths of up to 1 m but have small diameters. The cell with the largest diameter is the yolk of an ostrich egg measuring 8 cm. Most living cells, however, are between 2 and 200 μm in diameter. Considering this wide range of cell sizes, why then can't most organisms be just one giant cell?

Diffusion limits cell size

You know that the plasma membrane allows nutrients to enter the cell and wastes to leave. Within the cell, nutrients and wastes move by diffusion.

Although diffusion is a fast and efficient process over short distances, it becomes slow and inefficient as the distances become larger. Imagine a mitochondrion at the center of a cell with a diameter of 20 cm. It would have to wait months before receiving molecules entering the cell. Because of the slow rate of diffusion, organisms can't be just one giant-sized cell.



LM Magnification: 100×

Figure 8.8
This giant amoeba is only several millimeters in diameter, but it can have up to 1000 nuclei. **Explain** ***How does this benefit the organism?***

DNA limits cell size

You have learned that the nucleus contains blueprints for the cell's proteins. Proteins are used throughout the cell by almost all organelles to perform critical cell functions. But there is a limit to how quickly the blueprints for these proteins can be copied in the nucleus and made into proteins in the cytoplasm. The cell cannot survive unless there is enough DNA to support the protein needs of the cell.

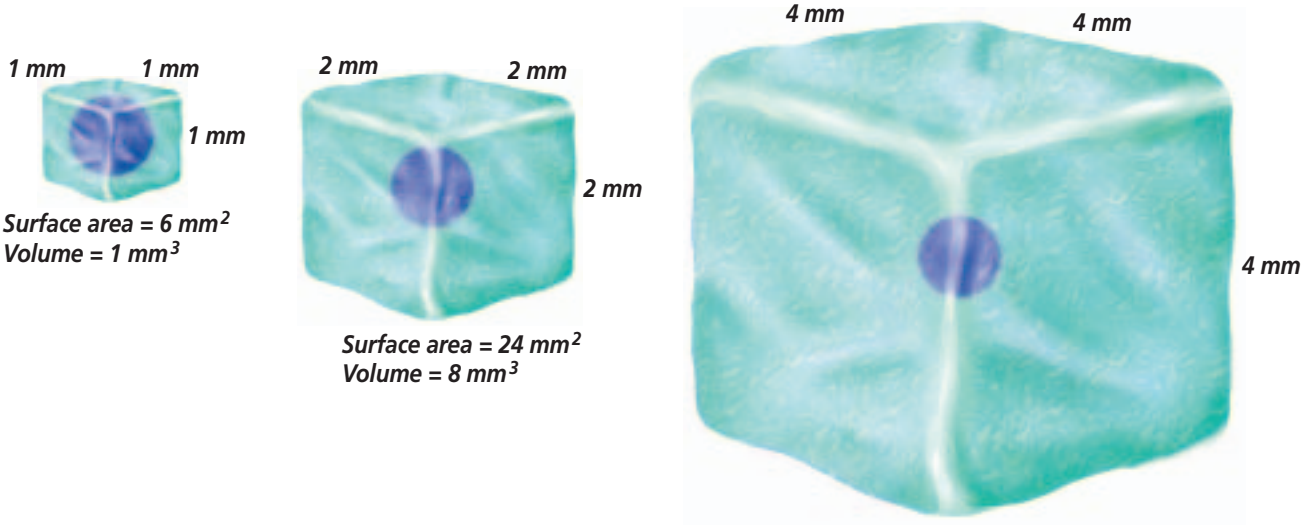
What happens in larger cells where an increased amount of cytoplasm requires increased supplies of enzymes? In many large cells, such as the giant amoeba *Pelomyxa* shown in ***Figure 8.8***, more than one nucleus is present. Large amounts of DNA in many nuclei ensure that cell activities are carried out quickly and efficiently.

Surface area-to-volume ratio

Another size-limiting factor is the cell's surface area-to-volume ratio. As a cell's size increases, its volume increases much faster than its surface area. Picture a cube-shaped cell like those shown in ***Figure 8.9***. The smallest cell has 1 mm sides, a surface area of 6 mm^2, and a volume of 1 mm^3. If the side of the cell is doubled to 2 mm, the surface area will increase fourfold to $6 \times 2 \times 2 = 24$ mm^2. Observe what happens to the volume; it increases eightfold to 8 mm^3.

What does this mean for cells? How does the surface area-to-volume ratio affect cell function? If cell size doubled, the cell would require eight times more nutrients and would have eight times more waste to excrete.

Figure 8.9
Surface area-to-volume ratio is one of the factors that limits cell size. Note how the surface area and the volume change as the sides of a cell double in length from 1 mm to 2 mm.



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The surface area, however, would increase by a factor of only four. Thus, the plasma membrane would not have enough surface area through which oxygen, nutrients, and wastes could diffuse. The cell would either starve to death or be poisoned from the buildup of waste products. You can investigate surface area-to-volume ratios yourself in the *Problem-Solving Lab* shown here.

Because cell size can have dramatic and negative effects on a cell, cells must have some method of maintaining optimum size. In fact, cells divide before they become too large to function properly. Cell division accomplishes other purposes, too, as you will read next.

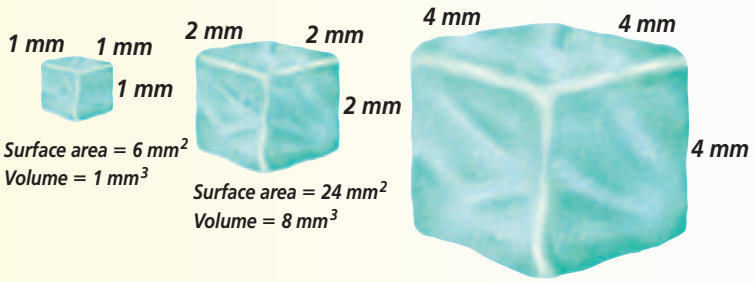
Problem-Solving Lab 8.1

Draw Conclusions

What happens to the surface area of a cell as its volume increases? One reason cells are small is that they need a large surface area as compared to volume so nutrients can diffuse in and wastes can diffuse out.

Solve the Problem

Look at the cubes shown below. Note the size and magnitude of difference in surface area and volume.



Thinking Critically

1. **Estimate** How many small cubes (1 mm) do you think it would take to fill the largest cube (4 mm)?
2. **Use Models** Using the cubes as models, describe how a cell is affected by its size.
3. **Infer** Explain how a small change in cell size can have a huge impact on cellular processes.

Cell Reproduction

Recall that the cell theory states that all cells come from preexisting cells. Cell division is the process by which new cells are produced from one cell. Cell division results in two cells that are identical to the original, parent cell. Right now, as you are reading this page, many of the cells in your body are growing, dividing, and dying. Old cells on the soles of your feet and on the palms of your hands are being shed and replaced, cuts and bruises are healing, and your intestines are producing millions of new cells each second. New cells are produced as tadpoles become frogs, and as an ivy vine grows and wraps around a garden trellis. All organisms grow and change; worn-out tissues are repaired or are replaced by newly produced cells.

Reading Check **Explain** two reasons why cell division is a required cell process.

The discovery of chromosomes

Early biologists observed that just before cell division, several short, stringy structures suddenly appeared in the nucleus. Scientists also noticed that these structures seemed to vanish soon after division of a cell. These structures, which contain DNA and become darkly colored when stained, are called **chromosomes** (KROH muh sohmz).

Eventually, scientists learned that chromosomes are the carriers of the genetic material that is copied and passed from generation to generation of cells. This genetic material is crucial to the identity of the cell. Accurate transmission of chromosomes during cell division is critical.

Word Origin

chromosome from the Greek words *chroma,* meaning "colored," and *soma,* meaning "body"; Chromosomes are dark-staining structures that contain genetic material.

The structure of eukaryotic chromosomes

For most of a cell's lifetime, chromosomes exist as **chromatin,** long strands of DNA wrapped around proteins called histones. Under an electron microscope, chromatin looks like beads on a string. Each bead is a group of histones called a nucleosome. Before a cell can divide, the long strands of chromatin must be reorganized, just as you would coil a long strand of rope before storing it. As the nucleus begins to divide, chromosomes take on a different structure in which the chromatin becomes tightly packed. Look at ***Figure 8.10*** for more information on chromosome structure.

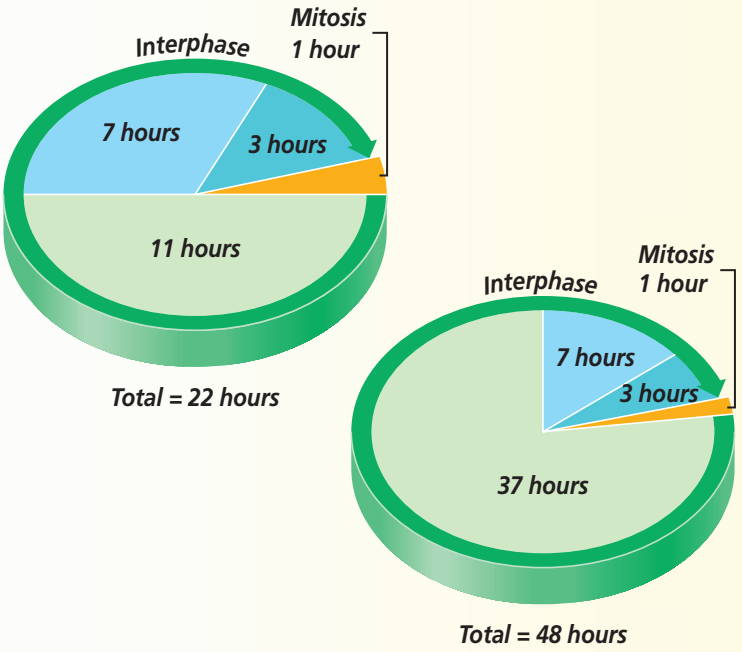
Problem-Solving Lab 8.2

Observe and Infer

How does the length of the cell cycle vary? The cell cycle varies greatly in length from one kind of cell to another. Some kinds of cells divide rapidly, while others divide more slowly.

Solve the Problem

Examine the cell cycle diagrams of two different types of cells. Observe the total length of each cell cycle and the length of time each cell spends in each phase of the cell cycle.



Thinking Critically

1. **Make and Use Graphs** Which part of the cell cycle is most variable in length?
2. **Infer** What can you infer about the functions of these two types of cells?
3. **Think Critically** Why do you think the cycle of some types of cells is faster than in others? Explain your answer.

The Cell Cycle

Fall follows summer, night follows day, and low tide follows high tide. Many events in nature follow a recurring, cyclical pattern. Living organisms are no exception. One cycle common to most living things is the cycle of the cell. The **cell cycle** is the sequence of growth and division of a cell.

As a cell proceeds through its cycle, it goes through two general periods: a period of growth and a period of division. The majority of a cell's life is spent in the growth period known as **interphase.** During interphase, a cell grows in size and carries on metabolism. Also during this period, chromosomes are duplicated in preparation for the period of division.

Following interphase, a cell enters its period of nuclear division called **mitosis** (mi TOH sus). Mitosis is the process by which two daughter cells are formed, each containing a complete set of chromosomes. Interphase and mitosis make up the bulk of the cell cycle. Following mitosis, the cytoplasm divides, separating the two daughter cells. You can use the *Problem-Solving Lab* on this page and the *BioLab* at the end of this chapter to investigate the rate of mitosis.

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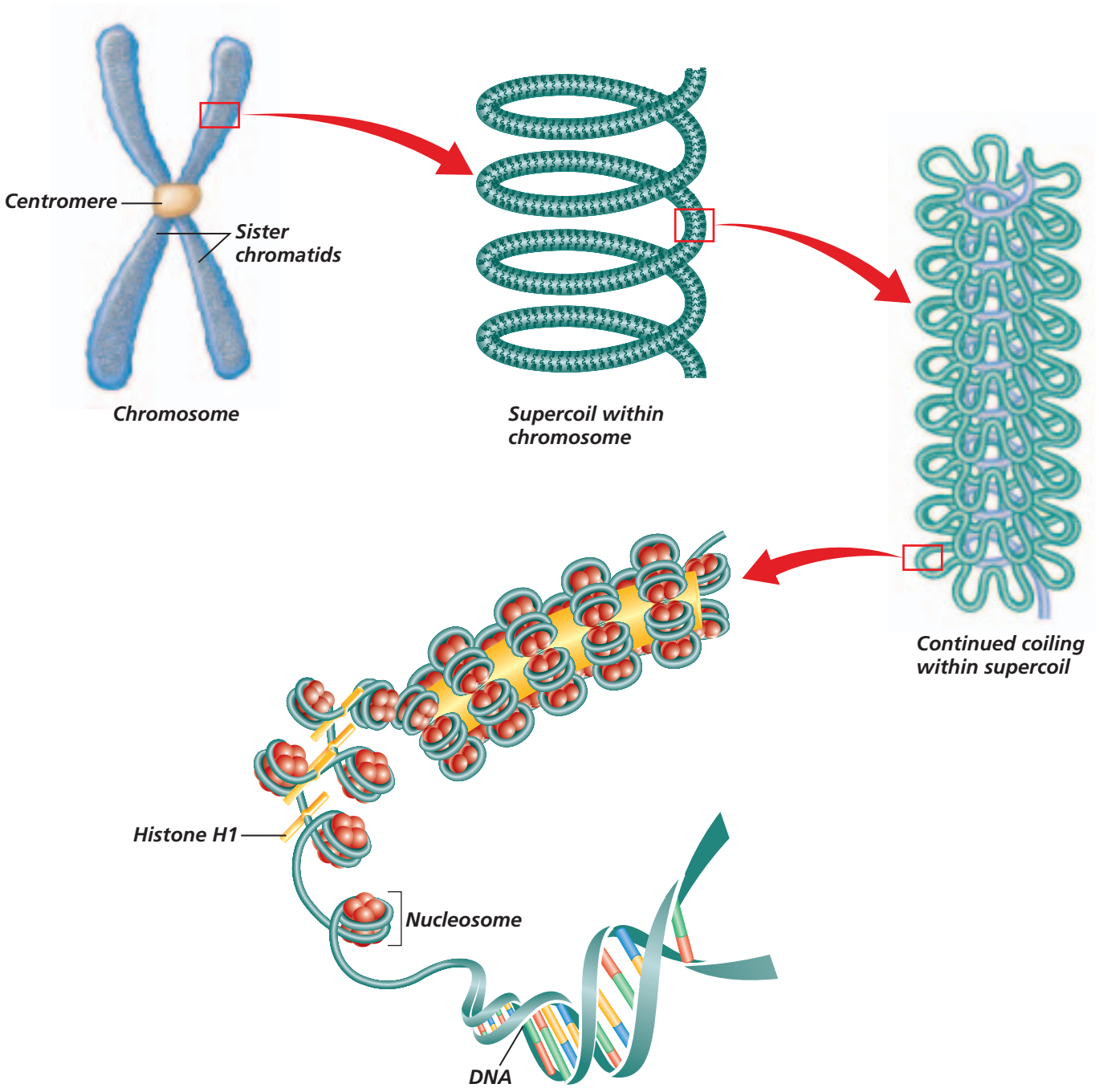
INSIDE STORY

Chromosome Structure

Figure 8.10

The chromosomes of a eukaryotic cell undergo changes in shape and structure during the different phases of the cell cycle. A metaphase chromosome is a compact arrangement of DNA and proteins. During interphase, the chromosomes are long and tangled, resembling a plate of spaghetti. **Critical Thinking** ***Why is it important for the chromosomes to be compact and untangled during mitosis?***



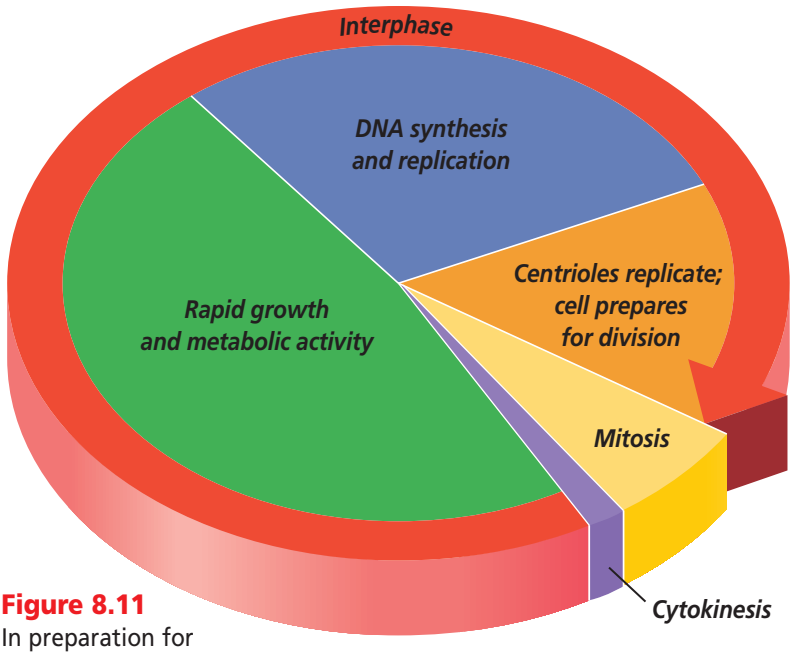


Figure 8.11
In preparation for mitosis, most of the time spent in the cell cycle is in interphase. The process of mitosis, represented here by the yellow wedge, is shown in detail in ***Figure 8.13.***

Interphase: A Busy Time

Interphase, the busiest phase of the cell cycle, is divided into three parts as shown in ***Figure 8.11.*** During the first part, the cell grows and protein production is high. In the next part of interphase, the cell copies its chromosomes. DNA synthesis does not occur all through interphase but is confined to this specific time. After the chromosomes have been duplicated, the cell enters another shorter growth period in which mitochondria and other organelles are manufactured and cell parts needed for cell division are assembled. Following this activity, interphase ends and mitosis begins.

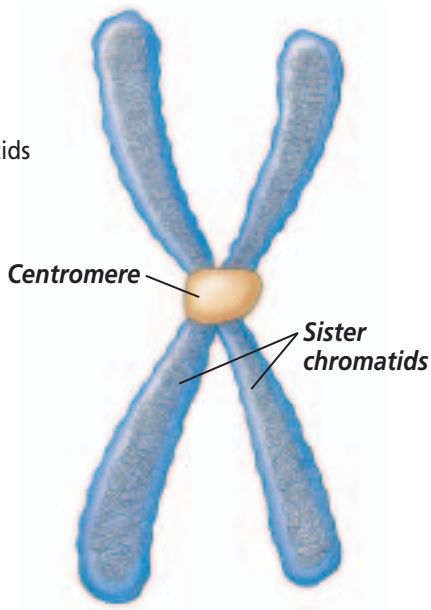


Figure 8.12
The two sister chromatids are held together by a centromere.

The Phases of Mitosis

Cells undergo mitosis as they approach the maximum cell size at which the nucleus can provide blueprints for proteins, and the plasma membrane can efficiently transport nutrients and wastes into and out of the cell.

Although cell division is a continuous process, biologists recognize four distinct phases of mitosis—each phase merging into the next. The four phases of mitosis are prophase, metaphase, anaphase, and telophase. Refer to ***Figure 8.13*** to help you understand the process as you read about mitosis.

Prophase: The first phase of mitosis

During **prophase,** the first and longest phase of mitosis, the long, stringy chromatin coils up into visible chromosomes. As you can see in ***Figure 8.12,*** each duplicated chromosome is made up of two halves. The two halves of the doubled structure are called **sister chromatids.** Sister chromatids and the DNA they contain are exact copies of each other and are formed when DNA is copied during interphase. Sister chromatids are held together by a structure called a **centromere,** which plays a role in chromosome movement during mitosis. By their characteristic location, centromeres also help scientists identify and study chromosomes.

As prophase continues, the nucleus begins to disappear as the nuclear envelope and the nucleolus disintegrate.

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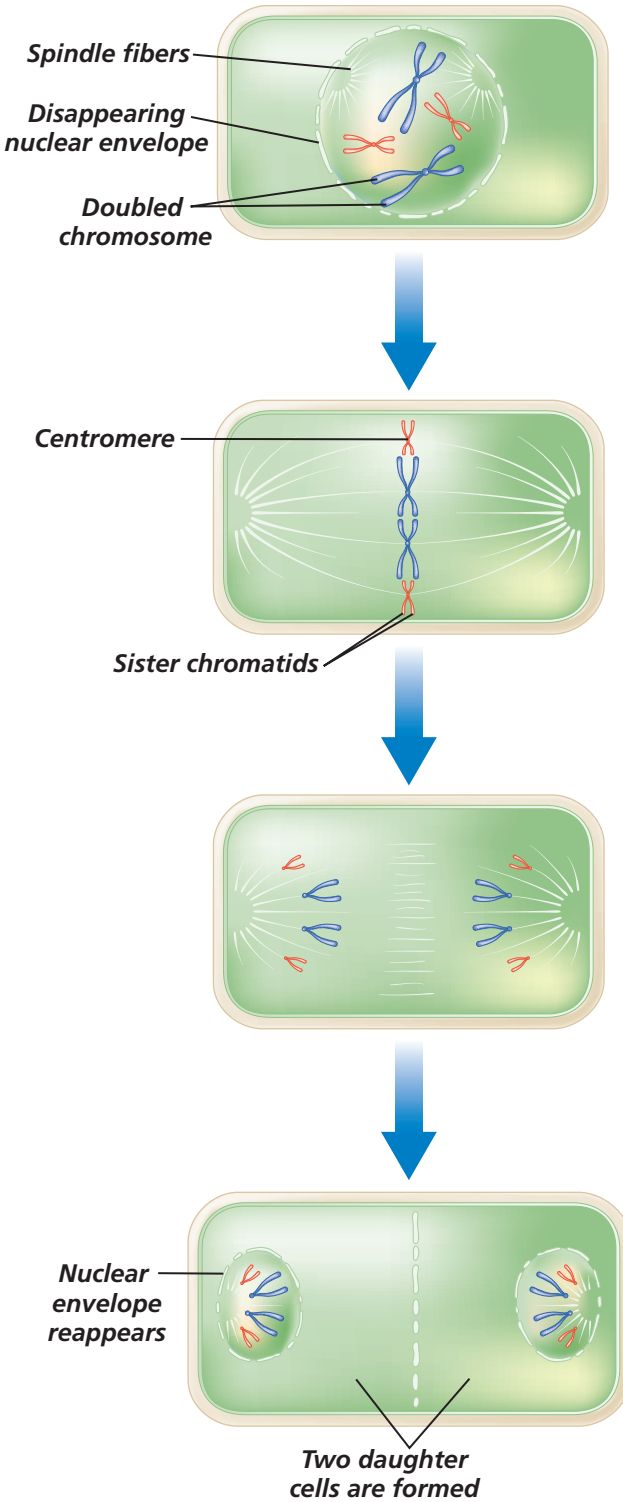
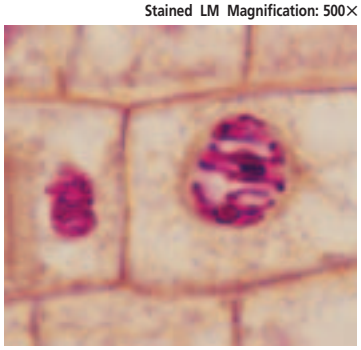
Figure 8.13
Mitosis begins after interphase. Follow the stages of mitosis as you read the text. The diagrams and the photos show mitosis in plant cells.



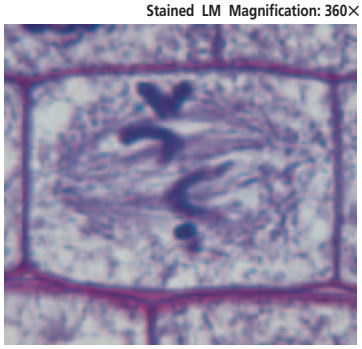
A Prophase
The chromatin coils to form visible chromosomes.

Stained LM Magnification: 500×



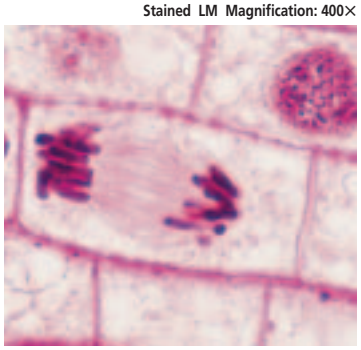
B Metaphase
The chromosomes move to the equator of the spindle.

Stained LM Magnification: 360×



C Anaphase
The centromeres split and the sister chromatids are pulled apart to opposite poles of the cell.

Stained LM Magnification: 400×



D Telophase
Two distinct daughter cells are formed. The cells separate as the cell cycle proceeds into the next interphase.

Stained LM Magnification: 640×

By late prophase, these structures are completely absent. In animal cells, two important pairs of structures, the centrioles, begin to migrate to opposite ends of the cell. **Centrioles** are small, dark, cylindrical structures that are made of microtubules and are located just outside the nucleus, as shown in ***Figure 8.14.*** Centrioles play a role in chromatid separation.

As the pairs of centrioles move to opposite ends of the cell, another important structure, called the spindle, begins to form between them. The **spindle** is a football-shaped, cagelike structure consisting of thin fibers made of microtubules. In plant cells, the spindle forms without centrioles. The spindle fibers play a vital role in the separation of sister chromatids during mitosis.

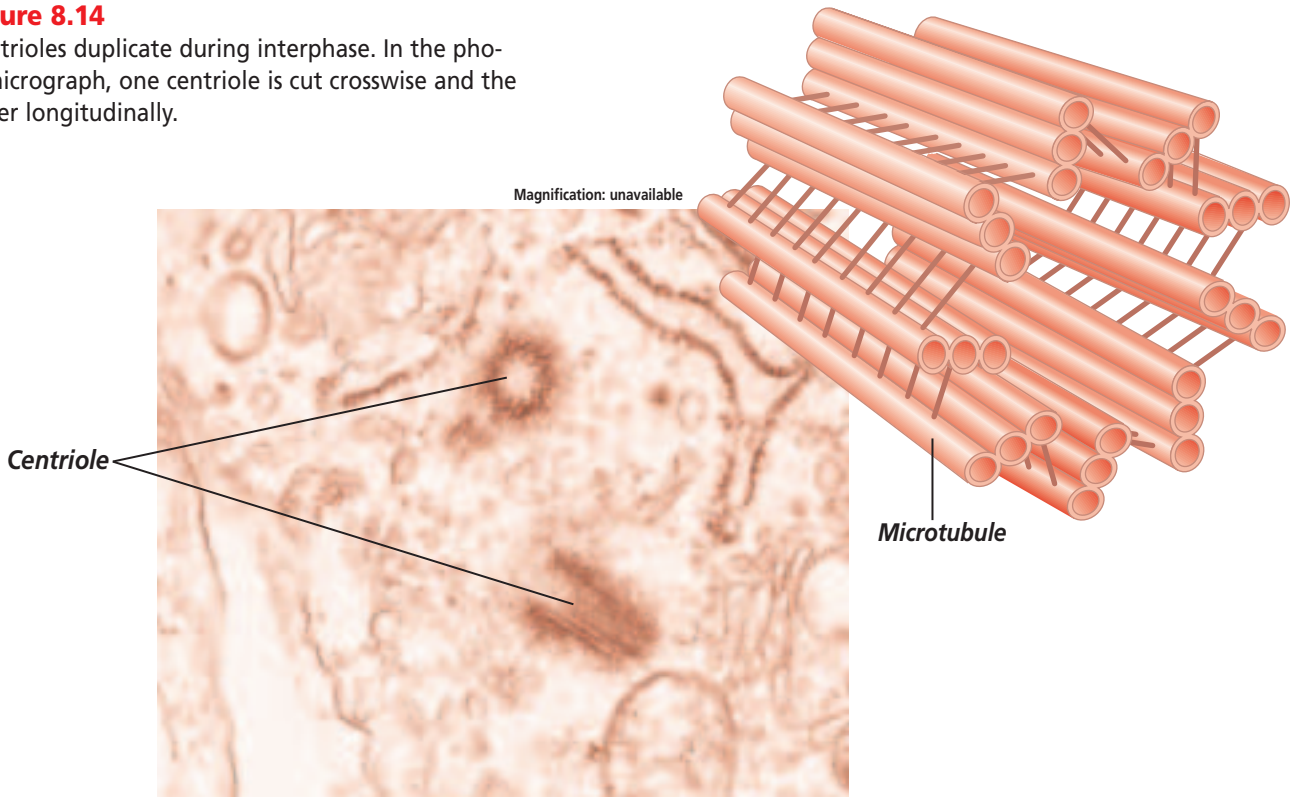
Metaphase: The second stage of mitosis

During **metaphase,** the short second phase of mitosis, the doubled chromosomes become attached to the spindle fibers by their centromeres. The chromosomes are pulled by the spindle fibers and begin to line up on the midline, or equator, of the spindle. Each sister chromatid is attached to its own spindle fiber. One sister chromatid's spindle fiber extends to one pole, and the other extends to the opposite pole. This arrangement is important because it ensures that each new cell receives an identical and complete set of chromosomes.

Anaphase: The third phase of mitosis

The separation of sister chromatids marks the beginning of **anaphase,** the third phase of mitosis. During anaphase, the centromeres split apart and chromatid pairs from each chromosome separate from each other. The chromatids are pulled apart by the shortening of the microtubules in the spindle fibers.

Figure 8.14
Centrioles duplicate during interphase. In the photomicrograph, one centriole is cut crosswise and the other longitudinally.



Telophase: The fourth phase of mitosis

The final phase of mitosis is **telophase.** Telophase begins as the chromatids reach the opposite poles of the cell. During telophase, many of the changes that occurred during prophase are reversed as the new cells prepare for their own independent existence. The chromosomes, which had been tightly coiled since the end of prophase, now unwind so they can begin to direct the metabolic activities of the new cells. The spindle begins to break down, the nucleolus reappears, and a new nuclear envelope forms around each set of chromosomes. Finally, a new double membrane begins to form between the two new nuclei.

Cytokinesis

Following telophase, the cell's cytoplasm divides in a process called **cytokinesis** (si toh kih NEE sus). Cytokinesis differs between plants and animals. Toward the end of telophase in animal cells, the plasma membrane pinches in along the equator as shown in ***Figure 8.15.*** As the cell cycle proceeds, the two new cells are separated. Find out more about mitosis in animal cells in the *MiniLab.*

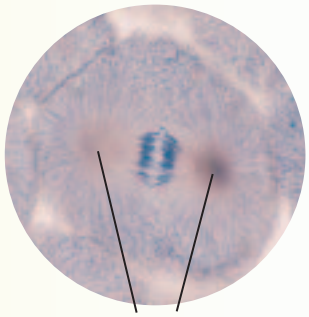
Plant cells have a rigid cell wall, so the plasma membrane does not pinch in. Rather, a structure known as the cell plate is laid down across the cell's equator. A cell membrane forms around each cell, and new cell walls form on each side of the cell plate until separation is complete.

MiniLab 8.2

Compare and Contrast

Seeing Asters The result of the process of mitosis is similar in plant and animal cells. However, animal cells develop structures called asters that are thought to serve as a brace for the spindle fibers, while plant cells do not develop asters.

Stained LM Magnification: 250×



Procedure

1. Examine a slide showing fish mitosis under low- and high-power magnification. **CAUTION:** ***Use care when handling prepared slides.***
2. Find cells that are undergoing mitosis. You will be able to see dark-stained rodlike structures within certain cells. These structures are chromosomes.
3. Note the appearance and location of asters. They will appear as ray or starlike structures at opposite ends of cells that are in metaphase.
4. Asters may also be observed in cells that are in other phases of the cell cycle.

Analysis

1. **Describe** What is the location of asters in cells that are in prophase?
2. **Infer** How do you know that asters are not critical to mitosis?
3. **Use Models** Sketch and label a plant cell and an animal cell in prophase.

Color-enhanced SEM Magnification: 25×

Figure 8.15
The furrow, created when proteins positioned under the plasma membrane at the equator of this frog cell contracted and slid past each other, will deepen until the cell is pinched in two.

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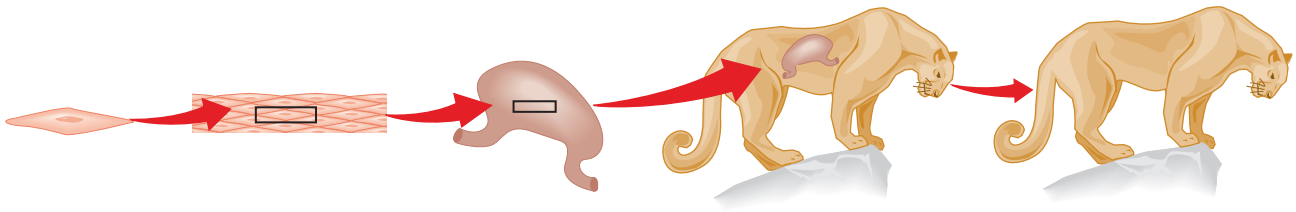
Figure 8.16
Cells of complex multicellular organisms are organized into tissues, organs, and organ systems. **Sequence** ***What levels of organization is a human blood cell a part of?***



Results of Mitosis

Mitosis is a process that guarantees genetic continuity, resulting in the production of two new cells with chromosome sets that are identical to those of the parent cell. These new daughter cells will carry out the same cellular processes and functions as those of the parent cell and will grow and divide just as the parent cell did.

When mitosis is complete, unicellular organisms remain as single cells—the organism simply multiplied. In multicellular organisms, cell growth and reproduction result in groups of cells that work together as **tissue** to perform a specific function. Tissues organize in various combinations to form **organs** that perform more complex roles within the organism. For example, cells make up muscle tissue, then muscle tissue works with other tissues in the organ called the stomach to mix up food. Multiple organs that work together form an **organ system.** The stomach is one organ in the digestive system, which functions to break up and digest food.

All organ systems work together for the survival of the organism, whether the organism is a fly or a human. ***Figure 8.16*** shows an example of cell specialization and organization for a complex organism. In addition to its digestive system, the panther has a number of other organ systems that have developed through cell specialization. It is important to remember that no matter how complex the organ system or organism becomes, the cell is still the most basic unit of that organization.

Section Assessment

Understanding Main Ideas

1. Describe how a cell's surface area-to-volume ratio limits its size.
2. Why is it necessary for a cell's chromosomes to be distributed to its daughter cells in such a precise manner?
3. Relate cells to each level of organization in a multicellular organism.
4. In multicellular organisms, describe two cellular specializations that result from mitosis.

Thinking Critically

5. At one time, interphase was referred to as the resting phase of the cell cycle. Why do you think this description is no longer used?

Skill Review

6. **Get the Big Picture** Make a table sequencing the phases of the cell cycle. Mention one important event that occurs at each phase. For more help, refer to *Get the Big Picture* in the **Skill Handbook.**

bdol.glencoe.com/self_check_quiz

CONTENTS

Section 8.3

Control of the Cell Cycle

SECTION PREVIEW

Objectives

Describe the role of enzymes in the regulation of the cell cycle.

Distinguish between the events of a normal cell cycle and the abnormal events that result in cancer.

Identify ways to potentially reduce the risk of cancer.

Review Vocabulary

protein: a large complex polymer composed of carbon, hydrogen, oxygen, nitrogen, and usually sulfur (p. 160)

New Vocabulary

cancer
gene

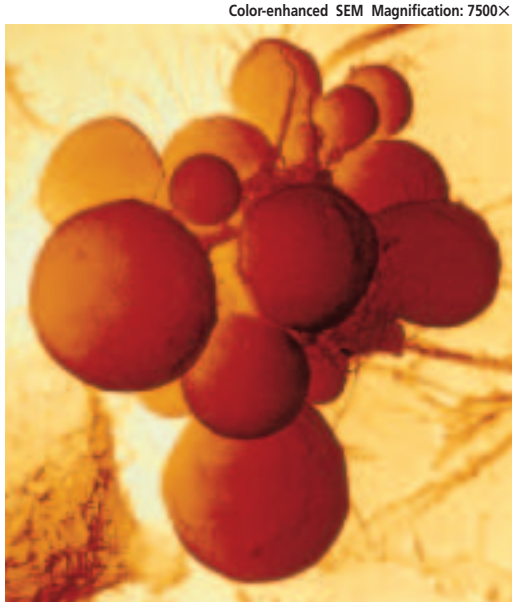
Getting Control

Finding Main Ideas As you read through the section on control of the cell cycle, answer the following questions.

Study Organizer

1. Enzymes control the cell cycle. What controls enzyme production?
2. What are two environmental factors that contribute to the development of cancer? List any possible ways you can influence these factors.
3. How does a person's diet relate to the chances of getting cancer?

Color-enhanced SEM Magnification: 7500×



This tumor is developing due to a mistake in the cell cycle.

Normal Control of the Cell Cycle

Why do some types of cells divide rapidly, while others divide slowly? What tells a cell when it is time to leave one part of the cell cycle and begin the next?

Proteins and enzymes control the cell cycle

The cell cycle is controlled by proteins called cyclins and a set of enzymes that attach to the cyclin and become activated. The interaction of these molecules, based on conditions both in the cell's environment and inside the cell, control the cell cycle. Occasionally, cells lose control of the cell cycle. This uncontrolled dividing of cells can result from the failure to produce certain enzymes, the overproduction of enzymes, or the production of other enzymes at the wrong time. **Cancer** is a malignant growth resulting from uncontrolled cell division. This loss of control may be caused by environmental factors or by changes in enzyme production.

Enzyme production is directed by genes located on the chromosomes. A **gene** is a segment of DNA that controls the production of a protein.

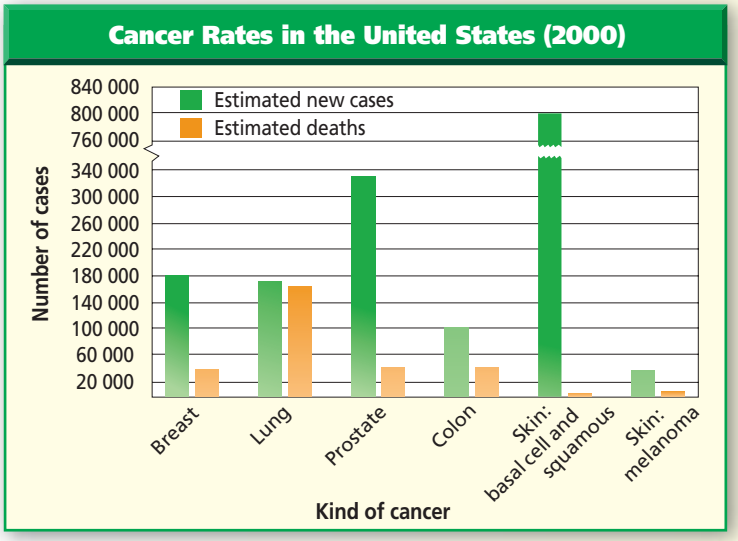
Many studies point to the portion of interphase just before DNA replication as being a key control period in the cell cycle. Scientists have identified several enzymes that trigger DNA replication.

CONTENTS

Problem-Solving Lab 8.3

Interpret Data

How does the incidence of cancer vary? Cancer affects many different body organs. In addition, the same body organ, such as our skin, can be affected by several different types of cancer. Some types of cancer are more treatable than others. Use the following graph to analyze the incidence of cancer.



Thinking Critically

1. **Make and Use Graphs** Which cancer type is most common? Least common?
2. **Interpret Data** Which cancer type seems to be least treatable? Most treatable?
3. **Interpret Data** Using breast cancer as an example, calculate the percent of survival for this cancer type.
4. **Use Numbers** Approximately what percentage of new cancer cases in the United States in 2000 were lung cancer?

Cancer: A Mistake in the Cell Cycle

Currently, scientists consider cancer to be a result of changes in one or more of the genes that produce substances that are involved in controlling the cell cycle. These changes are expressed as cancer when something prompts the damaged genes into action. Cancerous cells form masses of tissue called tumors that deprive normal cells of nutrients. In later stages, cancer cells enter the circulatory system and spread throughout the body, a process called metastasis, forming new tumors that disrupt the function of organs, organ systems, and ultimately, the organism.

Cancer is the second leading cause of death in the United States, exceeded only by heart disease. Cancer can affect any tissue in the body. In the United States, lung, colon, breast, and prostate cancers are the most prevalent types. Use the *Problem-Solving Lab* on this page to estimate the number of people in the United States who will develop these kinds of cancers in this decade, and how many people are expected to die from cancers. The *Connection to Health* feature at the end of this chapter further discusses skin cancer.

Reading Check **Infer** why cancer is difficult to treat in later stages.

The causes of cancer

The causes of cancer are difficult to pinpoint because both genetic and environmental factors are involved. The environmental influences of cancer become obvious when you consider that people in different countries develop different types of cancers at different rates. For example, the rate of breast cancer is relatively high in the United States, but relatively low in Japan. Similarly, stomach cancer is common in Japan, but rare in the United States.

Other environmental factors, such as cigarette smoke, air and water pollution, and exposure to ultraviolet radiation from the sun, are all known to damage the genes that control the cell cycle. Cancer may also be caused by viral infections that damage the genes.

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Cancer prevention

From recent and ongoing investigations, scientists have established a clear link between a healthy lifestyle and the incidence of cancer.

Physicians and dietary experts agree that diets low in fat and high in fiber content can reduce the risk of many kinds of cancer. For example, diets high in fat have been linked to increased risk for colon, breast, and prostate cancers, among others. People who consume only a minimal amount of fat reduce the potential risk for these and other cancers and may also maintain a healthy body weight more easily. In addition, recent studies suggest that diets high in fiber are associated with reduced risk for cancer, especially colon cancer. Fruits, vegetables, and grain products are excellent dietary options because of their fiber content and because they are naturally low in fat. The foods displayed in ***Figure 8.17*** illustrate some of the choices that are associated with cancer prevention.

Vitamins and minerals may also help prevent cancer. Key in this category are carotenoids, vitamins A, C, and E, and calcium. Carotenoids are found in foods such as yellow and orange vegetables and green leafy vegetables. Citrus fruits are a great source of vitamin C, and many dairy products are rich in calcium.

In addition to diet, other healthy choices such as daily exercise and not using tobacco also are known to reduce the risk of cancer.

Figure 8.17
A healthy diet may reduce your risk of cancer. **Classify** ***What types of food make up a diet that reduces the risk of cancer?***

Section Assessment

Understanding Main Ideas

1. Do all cells complete the cell cycle in the same amount of time?
2. Describe how enzymes control the cell cycle.
3. How can disruption of the cell cycle result in cancer?
4. How does cancer affect normal cell functioning?

Thinking Critically

5. What evidence shows that the environment influences the occurrence of cancer?

Skill Review

6. **Recognize Cause and Effect** Although not all cancers are preventable, some lifestyle choices, such as a healthy diet and regular exercise, can decrease your cancer risk. Give a summary of how these two lifestyle choices could be implemented by teens. For more help, refer to *Recognize Cause and Effect* in the **Skill Handbook.**

KS Studios/Bob Mullenix

INVESTIGATE

BioLab

Where is mitosis most common?

Before You Begin

Mitosis and the resulting multiplication of cells are responsible for the growth of an organism. Does mitosis occur in all areas of an organism at the same rate, or are there certain areas within an organism where mitosis occurs more often? You will answer this question in this BioLab. Your organism will be an onion, and the areas you are going to investigate will be different locations in its root.

PREPARATION

Problem

Does mitosis occur at the same rate in all of the parts of an onion root?

Objectives

In this BioLab, you will:

- **Observe** cells in two different root areas.
- **Identify** the stages of mitosis in each area.

Materials

prepared slide of onion root tip
microscope

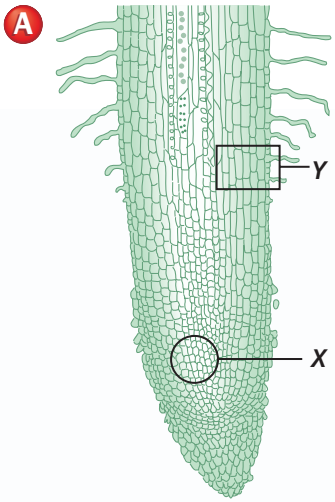
Skill Handbook

If you need help with this lab, refer to the **Skill Handbook.**

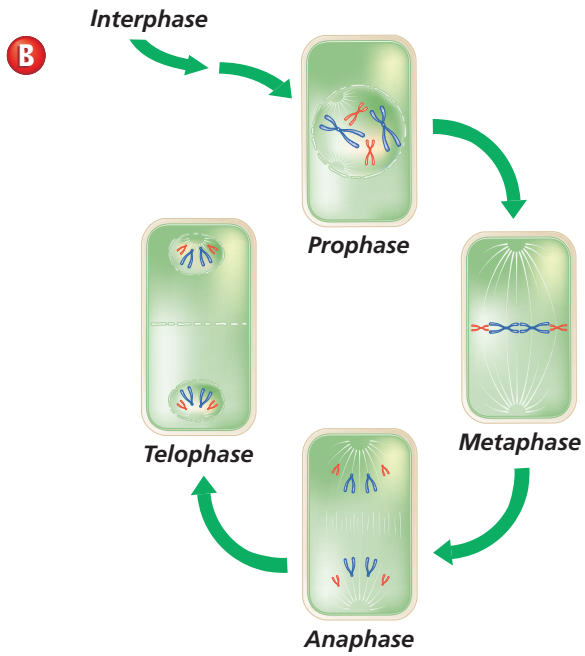
Safety Precautions

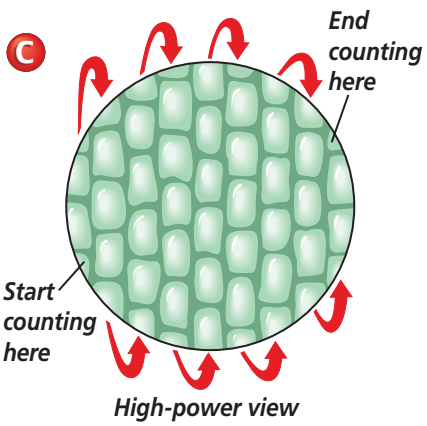
CAUTION: ***Report any glass breakage to your teacher.***

PROCEDURE



1. Using diagram **A** as a guide, locate area X on a prepared slide of onion root tip.
2. Place the prepared slide under your microscope and use low power to locate area X. **CAUTION:** ***Use care when handling prepared slides.***
3. Switch to high power.
4. Using diagram **B** as a guide:
   a. Identify those cells that are in mitosis and those cells that are in interphase.
   b. Create a data table. Record the number of cells observed in each phase of mitosis and interphase for area X. Note: It will be easier to count and keep track of cells by following rows. See diagram **C** as a guide to counting.
5. Using diagram **A** again, locate area Y on the same prepared slide.





6. Place the prepared slide under your microscope and use low power to locate area Y.
7. Switch to high power.
8. Using diagram **B** as a guide:
   - **a.** Identify those cells that are in mitosis and those that are in interphase.
   - **b.** Record in the data table the number of cells observed in each phase of mitosis and interphase for area Y.
9. **CLEANUP AND DISPOSAL** Clean all equipment as instructed by your teacher, and return everything to its proper place.

ANALYZE AND CONCLUDE

1. **Observe** Which area of the onion root tip (X or Y) had the greatest percentage of cells undergoing mitosis? The lowest? Use specific totals from your data table to support your answer.
2. **Predict** If mitosis is associated with rapid growth, where do you believe is the location of most rapid root growth, area X or Y? Explain your answer.
3. **Apply** Where might you look for cells in the human body that are undergoing mitosis?
4. **Think Critically** Assume that you were not able to observe cells in every phase of mitosis. Explain why this might be, considering the length of each phase.
5. **ERROR ANALYSIS** What factors might cause misleading results? How could you avoid these problems?

Apply Your Skill

Make and Use Graphs Prepare a circle graph that shows the total number of cells counted in area X and the percentage of cells in each phase of mitosis.

Web Links To find out more about mitosis, visit bdol.glencoe.com/mitosis

connection to Health

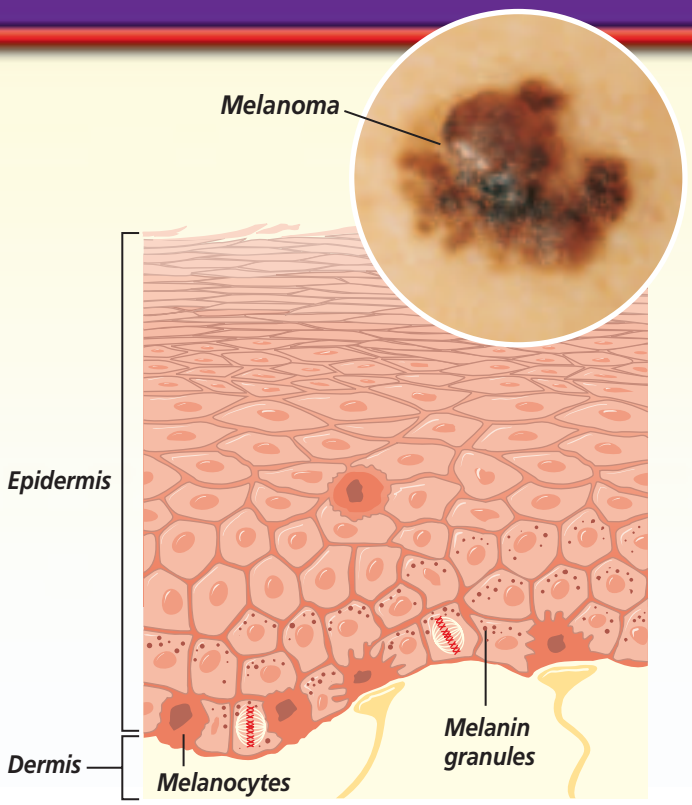
Skin Cancer

Skin cancer accounts for one-third of all malignancies diagnosed in the United States, and the incidence of skin cancer is increasing. Most cases are caused by exposure to harmful ultraviolet rays emitted by the sun, so skin cancer most often develops on the exposed face or neck. The people most at risk are those whose fair skin contains smaller amounts of a protective pigment called melanin.

Skin is composed of two layers of tissue, the epidermis and the dermis. The epidermis is the part that we see on the surface of our bodies and is composed of multiple layers of closely packed cells. As the cells reach the surface, they die and become flattened. Eventually they flake away. To replace the loss, cells on the innermost layer of the epidermis are constantly dividing.

Your body has a natural protection system to shield skin cells from potentially harmful rays of the sun. A pigment called melanin is produced by cells called melanocytes and absorbs the UV rays before they reach basal cells.

Types of skin cancers Uncontrolled division of epidermal cells leads to skin cancer. Squamous cell carcinoma is a common type of skin cancer that affects cells throughout the epidermis. Squamous cell cancer takes the form of red or pink tumors that can grow rapidly and spread. Precancerous growths produced by sun-damaged basal cells can become basal cell carcinoma, another common type of skin cancer. In basal cell carcinoma, the cancerous cells are from the layer of the epidermis that replenishes the shed epithelial cells. Both squamous cell carcinoma and basal cell carcinoma are usually discovered when they are small and can be easily removed in a doctor's office. Both types also respond to treatment such as surgery, chemotherapy, and radiation therapy.



Structure of the skin

The most lethal skin cancer is malignant melanoma. Melanomas are cancerous growths of the melanocytes that normally protect other cells in the epithelium from the harmful rays of the sun. An important indication of a melanoma can be a change in color of an area of skin to a variety of colors including black, brown, red, dark blue, or gray. A single melanoma can have several colors within the tumor. Melanomas can also form at the site of moles. Melanomas can be dangerous because cancerous cells from the tumor can travel to other areas of the body before the melanoma is detected. Early detection is essential, and melanomas can be surgically removed.

Writing About Biology

Describe Scientists know that the UV rays of sunlight can contribute to skin cancer. Write a paragraph describing how you can minimize the risk.

To find out more about skin cancer, visit bdol.glencoe.com/health

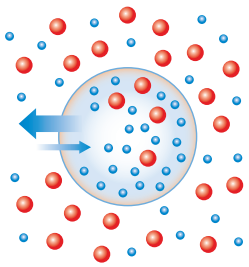
CONTENTS

Chapter 8 Assessment

Study Guide

Section 8.1

Cellular Transport



Key Concepts

- Osmosis is the diffusion of water through a selectively permeable membrane.
- Passive transport moves a substance with the concentration gradient and requires no energy from the cell.
- Active transport moves materials against the concentration gradient and requires energy to overcome the flow of materials opposite the concentration gradient.
- Large particles may enter a cell by endocytosis and leave by exocytosis.

Vocabulary

active transport (p. 199)
endocytosis (p. 200)
exocytosis (p. 200)
facilitated diffusion (p. 198)
hypertonic solution (p. 196)
hypotonic solution (p. 196)
isotonic solution (p. 196)
osmosis (p. 195)
passive transport (p. 198)

Section 8.2

Cell Growth and Reproduction

Key Concepts

- Cell size is limited largely by the diffusion rate of materials into and out of the cell, the amount of DNA available to program the cell's metabolism, and the cell's surface area-to-volume ratio.
- The life cycle of a cell is divided into two general periods: a period of active growth and metabolism known as interphase, and a period that leads to cell division known as mitosis.
- Mitosis is divided into four phases: prophase, metaphase, anaphase, and telophase.
- The cells of most multicellular organisms are organized into tissues, organs, and organ systems.

Vocabulary

anaphase (p. 208)
cell cycle (p. 204)
centriole (p. 208)
centromere (p. 206)
chromatin (p. 204)
chromosome (p. 203)
cytokinesis (p. 209)
interphase (p. 204)
metaphase (p. 208)
mitosis (p. 204)
organ (p. 210)
organ system (p. 210)
prophase (p. 206)
sister chromatid (p. 206)
spindle (p. 208)
telophase (p. 209)
tissue (p. 210)

Section 8.3

Control of the Cell Cycle

Color-enhanced SEM
Magnification: 7500×

Key Concepts

- The cell cycle is controlled by key enzymes that are produced at specific points in the cell cycle.
- Cancer is caused by genetic and environmental factors that change the genes that control the cell cycle.

Vocabulary

cancer (p. 211)
gene (p. 211)

FOLDABLES Study Organizer

To help you review osmosis, use the Organizational Study Fold on page 195.

Chapter 8 Assessment

Vocabulary Review

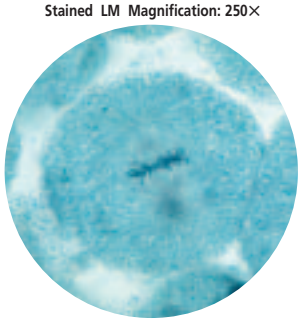
Review the Chapter 8 vocabulary words listed in the Study Guide on page 217. Determine if each statement is true or false. If false, replace the underlined word with the correct vocabulary word.

1. Mitosis is the result of uncontrolled division of cells.
2. Small, dark cylindrical structures that are made of microtubules and located just outside the nucleus are called genes.
3. Diffusion of water across a selectively permeable membrane is called cytokinesis.
4. In a hypotonic solution, the concentration of dissolved substances inside cells is higher than the concentration outside the cell.
5. Cancer is a period of nuclear division in a cell.

Understanding Key Concepts

6. What kind of environment is described when the concentration of dissolved substances is greater outside the cell than inside?
   A. hypotonic **C.** isotonic
   B. hypertonic **D.** saline
7. How is osmosis defined?
   A. as active transport
   B. as diffusion of water through a selectively permeable membrane
   C. as an example of facilitated diffusion
   D. as requiring a transport protein
8. An amoeba ingests large food particles by what process?
   A. osmosis **C.** endocytosis
   B. diffusion **D.** exocytosis
9. Of what are chromosomes composed?
   A. cytoplasm **C.** RNA and proteins
   B. centrioles **D.** DNA and proteins
10. Which of the following does NOT occur during interphase?
    A. excretion of wastes
    B. cell repair
    C. protein synthesis
    D. nuclear division

Stained LM Magnification: 250×



11. During metaphase, the chromosomes move to the equator of what structure (shown here)?
    A. poles
    B. cell plate
    C. centriole
    D. spindle
12. All but which of the following factors limit cell size?
    A. time required for diffusion
    B. elasticity of the plasma membrane
    C. presence of only one nucleus
    D. surface area-to-volume ratio
13. Which of the following is NOT a known cause of cancer?
    A. environmental influences
    B. certain viruses
    C. cigarette smoke
    D. bacterial infections

Constructed Response

14. **Open Ended** How would you expect the number of mitochondria in a cell to be related to the amount of active transport it carries out?
15. **Open Ended** Suppose that all of the enzymes that control the normal cell cycle were identified. Suggest some ways that this information might be used to fight cancer.
16. **Open Ended** Substance A's molecules are small. Substance B's molecules, which react with substance A to produce a blue-black color, are larger in comparison. If a solution of substance A is placed inside a selectively permeable bag, and the bag is placed in a solution of substance B, what will happen?

Thinking Critically

17. **Predict** What do you think will happen when a freshwater paramecium is placed in salt water?

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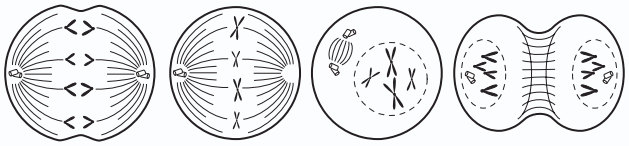
18. **REAL WORLD BIOCHALLENGE** Cystic fibrosis is a genetic disorder that results from the inability of cells to properly transport some materials. Visit bdol.glencoe.com to investigate cystic fibrosis. Write an essay that explains what you have learned about cystic fibrosis and present it to your class.

Standardized Test Practice

All questions aligned and verified by The Princeton Review

Part 1 Multiple Choice

Use the following illustration to answer questions 19–23.



19. Which drawing indicates a cell in metaphase of mitosis?
A. A **C.** C
B. B **D.** D

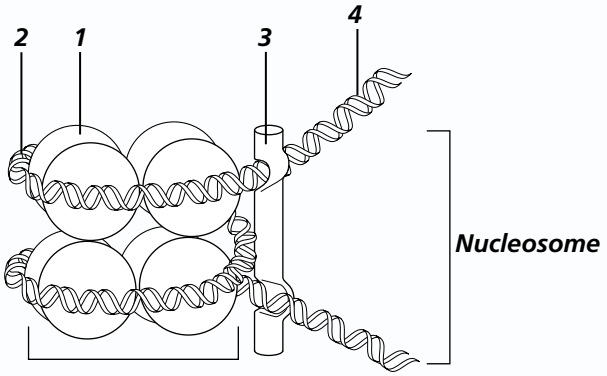
20. During which stage do the chromatids of chromosomes separate?
A. A **C.** C
B. B **D.** D

21. Which drawing indicates a cell whose nuclear membrane is dissolving?
A. A **C.** C
B. B **D.** D

22. Which of the following indicates the correct order of mitosis in animal cells?
A. A-B-C-D **C.** C-A-D-B
B. B-C-A-D **D.** C-B-A-D

23. Which drawing shows a cell in anaphase?
A. A **C.** C
B. B **D.** D

24. A biologist notes that some cells are growing faster than others in a tissue culture. A week later, the fast-growing cells have tripled in number. This observation is a clue that the fast-growing cells _____.
A. have killed the slow-growing cells
B. might be unable to control mitosis
C. were exposed to radiation or chemicals
D. contain an unknown enzyme



25. Which parts of the nucleosome are made of DNA?
A. 1 and 2 **C.** 2 and 3
B. 1 and 3 **D.** 2 and 4

26. Which parts of the nucleosome are made of protein?
A. 1 and 2 **C.** 2 and 3
B. 1 and 3 **D.** 2 and 4

Part 2 Constructed Response/Grid In

Record your answers on your answer document.

27. **Open Ended** The cell cycle can be affected by internal and external factors. Injury to a tissue can prompt changes in the cell cycle of the cells near the injury site. Formulate a testable hypothesis concerning a specific type of cell's response to injury. State your hypothesis, plan an investigative procedure to test your hypothesis, and list the steps.

28. **Open Ended** Explain why drinking quantities of ocean water is dangerous to humans.