CHAPTER

3 Cell Division

the BIG idea

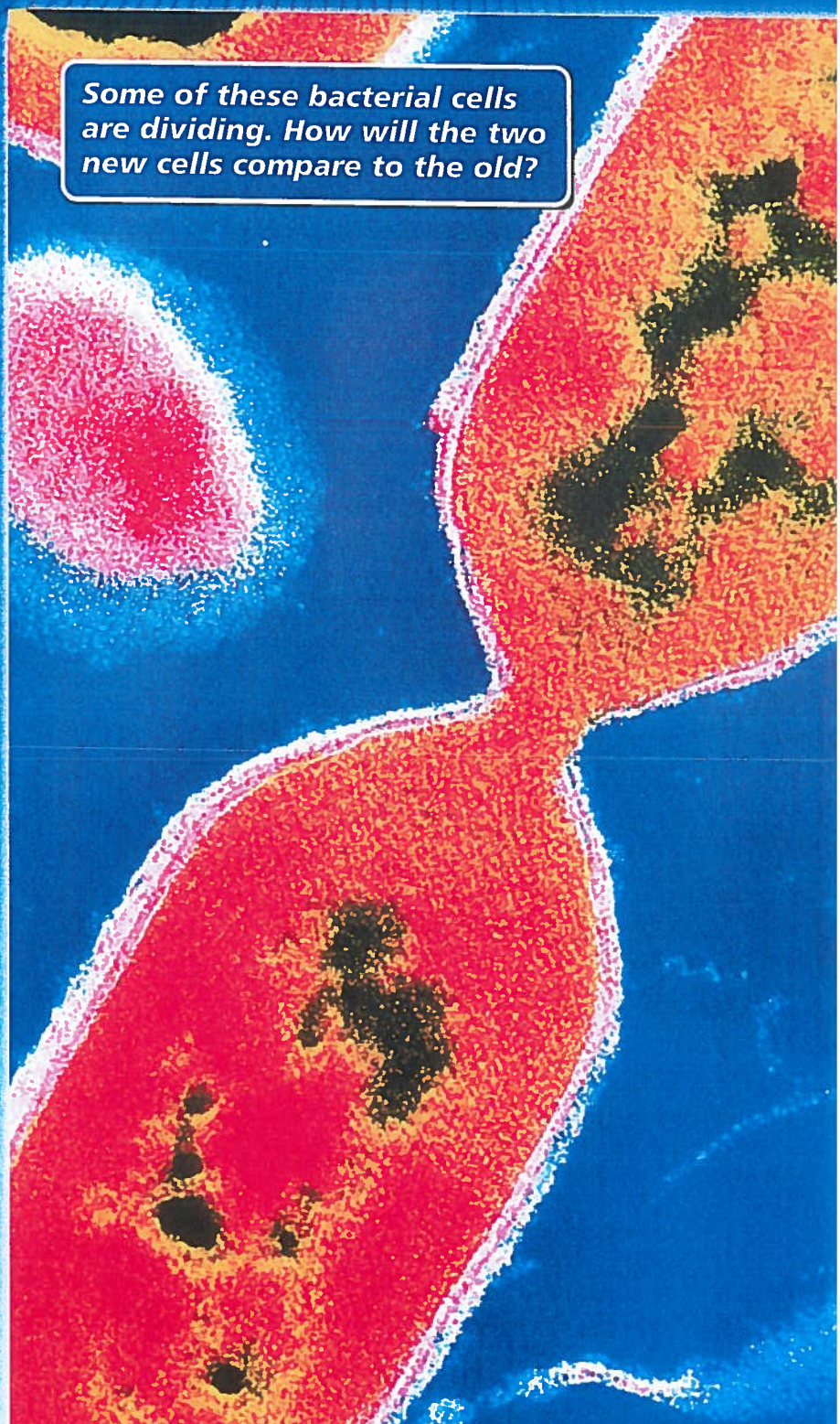
Organisms grow, reproduce, and maintain themselves through cell division.

Key Concepts

SECTION 1 **Cell division occurs in all organisms.**
Learn about the functions of cell division.

SECTION 2 **Cell division is part of the cell cycle.**
Learn about the cell cycle and the process of mitosis.

SECTION 3 **Both sexual and asexual reproduction involve cell division.**
Learn how sexual reproduction compares with asexual reproduction.

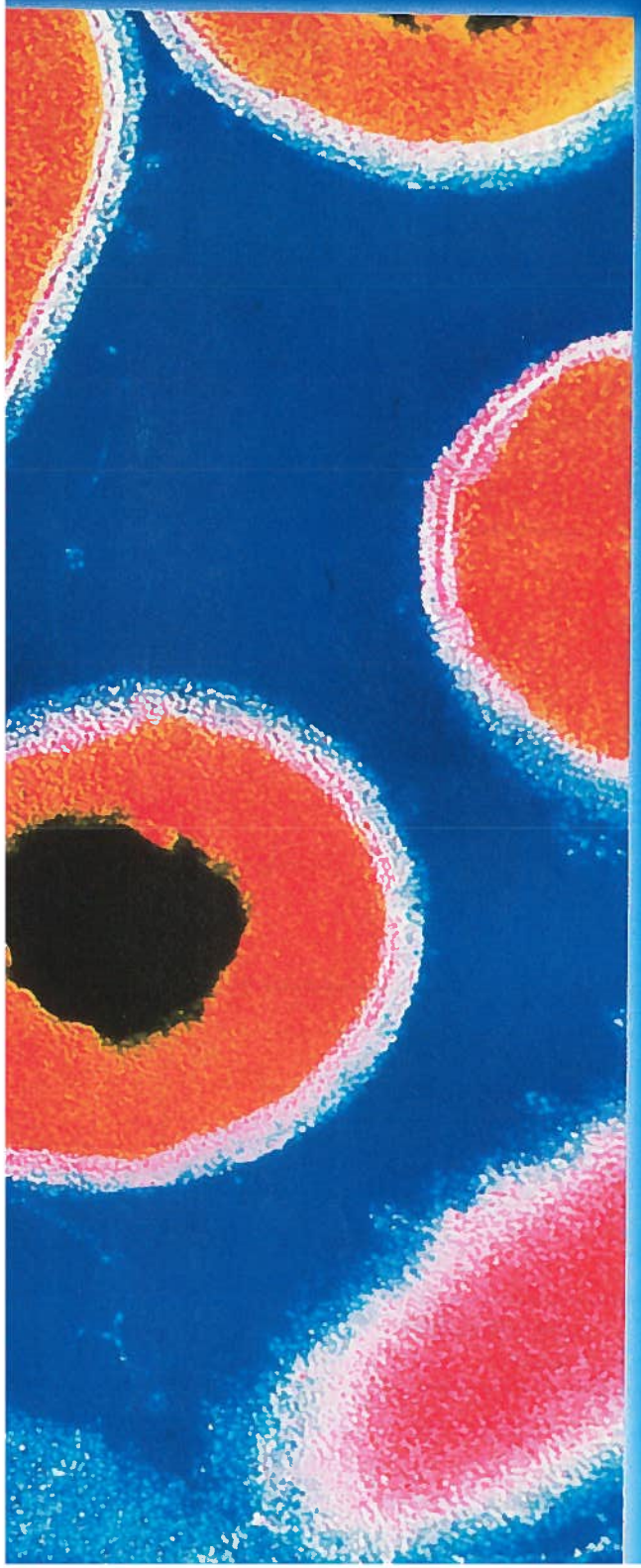


Some of these bacterial cells are dividing. How will the two new cells compare to the old?

California ClassZone

CLASSZONE.COM

Chapter 3 online resources: Content Review, Simulation, Visualization, three Resource Centers, Math Tutorial, Test Practice

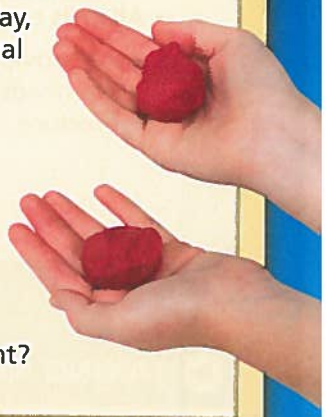


EXPLORE the BIG idea

Division and Volume

7.1.e Students know cells divide to increase their numbers through a process of mitosis, which results in two daughter cells with identical sets of chromosomes.

Take a piece of clay and divide it in half. Now you have two pieces of clay, each half the size of the original piece. Divide each of the two new pieces in half, producing four pieces, each a quarter of the original piece in size.



Observe and Think What will happen if you keep dividing the pieces in half? How might the division of the cells in living things be different?

Internet Activity: Cell Division

7.1.e Students know cells divide to increase their numbers through a process of mitosis, which results in two daughter cells with identical sets of chromosomes.

Go to **ClassZone.com** to match images of cells dividing with the different stages of cell division.

Observe and Think At which stage do the two daughter cells first appear? Are the stages the same for plant and animal cells?

NSTA SCILINKS
scilinks.org
Cellular Mitosis **Code: MDL033**

CHAPTER 3

Getting Ready to Learn

CONCEPT REVIEW

- The cell is the basic unit of structure and function in living things.
- All cells come from other cells.
- DNA provides the instructions a cell needs to function and reproduce.

VOCABULARY REVIEW

cell membrane p. 20

nucleus p. 20

cycle *See Glossary.*

CONTENT REVIEW
CLASSZONE.COM

Review concepts and vocabulary.

TAKING NOTES

COMBINATION NOTES

To take notes about a new concept, first make an informal outline of the information. Then make a sketch of the concept and label it so you can study it later.

VOCABULARY STRATEGY

Write each new vocabulary term in the center of a **frame game** diagram. Decide what information to frame it with. Use examples, descriptions, sentences that use the term in context, or pictures. You can change the frame to fit each term.

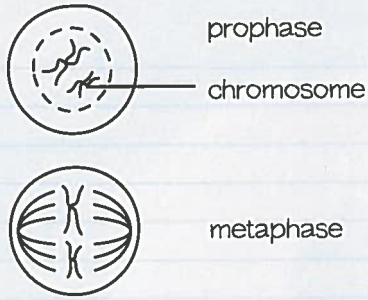
See the Note-Taking Handbook on pages R45–R51.

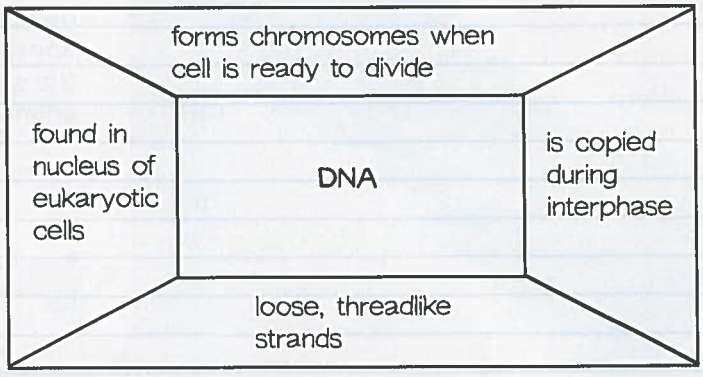
SCIENCE NOTEBOOK

NOTES

Mitosis has four phases.

- prophase: chromosomes become visible
- metaphase: chromosomes line up in middle





KEY CONCEPT

3.1 Cell division occurs in all organisms.

CALIFORNIA Content Standards

7.1.c Students know the nucleus is the repository for genetic information in plant and animal cells.

7.2.e Students know DNA (deoxyribonucleic acid) is the genetic material of living organisms and is located in the chromosomes of each cell.

BEFORE, you learned

- Cells come from other cells
- Cells take in and release energy and materials
- In a multicellular organism, cells specialize

NOW, you will learn

- How genetic material is organized in cells
- About the functions of cell division in multicellular organisms

VOCABULARY

DNA p. 74
chromosome p. 75

EXPLORE Cell Division (7.1.e)

How is organization helpful?

PROCEDURE

1. Work with two other students. Ask your teammates to put on blindfolds.
2. Give the unpaired socks to one teammate and the paired socks to the other teammate.
3. Tell your teammates to separate the socks into two identical piles of single socks. Each pile should have one sock from each pair. Allow your teammates two minutes to work on this task.

MATERIALS

- 2 blindfolds
- groups of paired and unpaired socks
- stopwatch

WHAT DO YOU THINK?

Which group of socks was more accurately separated into two identical sets? Why?

Cell division is involved in many functions.

REMINDER

Most multicellular organisms are made up of eukaryotic cells. A eukaryotic cell has a nucleus that contains genetic material.

Cell division occurs in all organisms, but performs different functions. Unicellular organisms reproduce through cell division. Cell division helps multicellular organisms grow, develop, repair themselves, and reproduce.

You are probably bigger this year than you were last year. One characteristic of all living things is that they grow. Your body is made up of cells. Although cells themselves grow, most growth in multicellular organisms occurs when cells produce new cells. In this chapter you will read about cell division in eukaryotic cells.

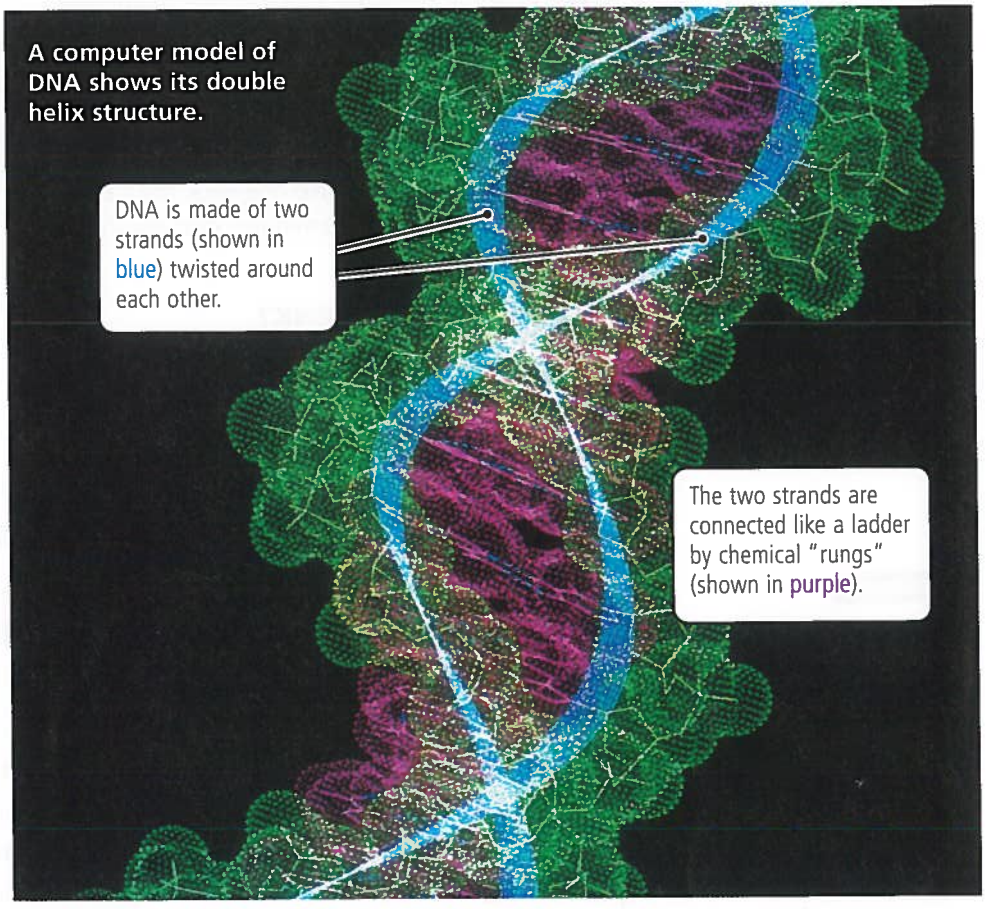
The genetic material of eukaryotic cells is organized in chromosomes.

The genetic material of a cell contains information needed for the cell's growth and other activities. When a cell divides into two new cells, each new cell receives a full set of genetic material. The genetic material in cells is contained in DNA molecules.

DNA

The genetic material in cells is called DNA—deoxyribonucleic acid (dee-AHK-see-RY-boh-noo-KLEE-ihk). **DNA** is a molecule that contains information for an organism's growth and functions. You read in Chapter 1 that James Watson and Francis Crick worked with other scientists to build a model of DNA in 1953. They showed that DNA is made of two strands joined like a twisted ladder, or a double helix. You will learn more about DNA in Chapter 4.

CHECK YOUR READING What is DNA?



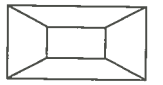
Chromosomes

In a eukaryotic cell, most of the cell's DNA is in the nucleus. During most of a cell's life cycle, DNA exists as a mass of loose strands. While the DNA is spread throughout the nucleus, the cell performs the functions needed for survival. During this time, the DNA is replicated, or copied.

DNA is wrapped around proteins like thread around a spool and compacted into structures called **chromosomes** (KROH-muh-SOHMZ). Before a cell divides, the chromosomes compact more. They become visible under a light microscope. During cell division, a replicated chromosome can be seen as two identical structures called chromatids that are held together by a centromere.

Within each species of organism, the number of chromosomes is constant. For example, humans have 46 chromosomes. Fruit flies, however, have 8 chromosomes, and ferns may have more than 100.

VOCABULARY
Make a frame game diagram in your notebook for the term *chromosome*.

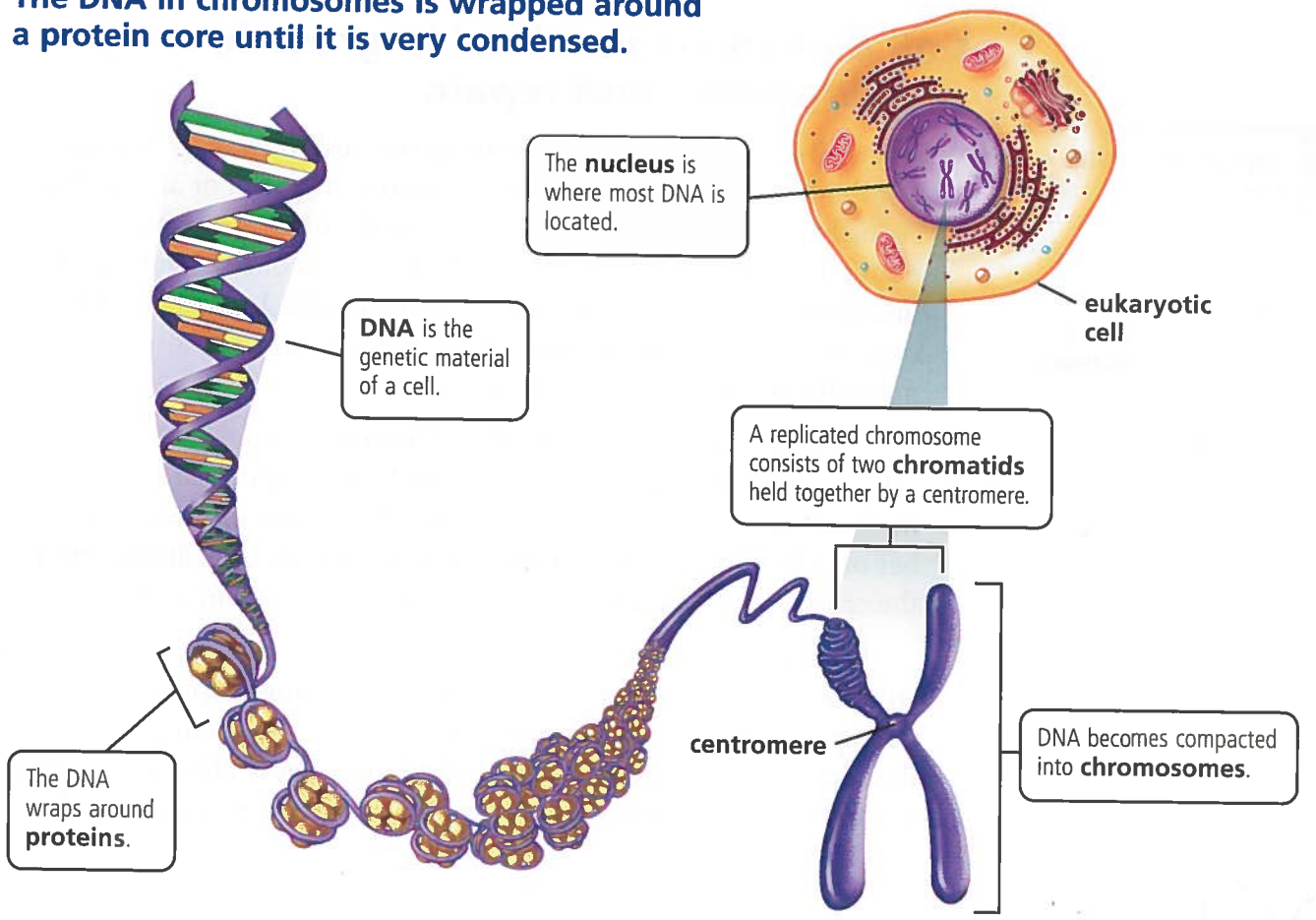


CHECK YOUR READING Describe the relationship between DNA and chromosomes.

READING TIP
Compare the diagram of DNA below with the computer model on page 74.

Organization of Genetic Material

The DNA in chromosomes is wrapped around a protein core until it is very condensed.



INVESTIGATE Chromosomes

How does DNA fit inside the nucleus?

SKILL FOCUS
Modeling (7.1.c)

MATERIALS
- yarn
- craft sticks

TIME
20 minutes

PROCEDURE

1. Select four pieces of yarn of different colors and four craft sticks. Push the yarn together into a loose ball. Observe how much space it takes up and how the individual pieces are organized.
2. Wrap each piece of yarn around a craft stick. Wrap the yarn so that the coils are tightly packed but do not overlap.

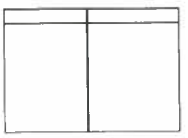
WHAT DO YOU THINK?

- What did you observe about the loosely balled yarn?
- What does the loosely balled yarn represent?
- What does the yarn on the craft sticks represent?
- Why does the yarn on the craft sticks take up less space than the ball of yarn?

CHALLENGE How does the yarn's being wrapped on the craft sticks make it easier to separate the different colors?

Cell division is involved in growth, development, and repair.

COMBINATION NOTES
Remember to take notes and draw sketches to help you understand the main idea: *Cell division is involved in growth, development, and repair.* Be sure to include the red heads in your notes.



Multicellular organisms vary greatly in size and complexity. You may not think that you have much in common with an ant or an oak tree. Actually, you share many characteristics with these organisms. For example, both you and they are made of trillions of cells. But, like most organisms, you and they started out as single cells. In multicellular organisms, cell division is essential for reproduction and three other major functions: growth, development, and repair.

Through cell division, a single cell becomes two cells. Those two cells divide into four, the four cells divide into eight, and so on. A multicellular organism grows because cell division increases the number of cells in it. As the organism develops and its cells divide, many of the cells become specialized. Most of them continue to divide.

Even when growth and development appear to stop, cell division is still occurring. When an organism ages or is injured, the worn-out or damaged cells need to be replaced by new cells. For example, the cells that make up the lining of your throat have a short life span—only a few days. These cells are constantly dividing and replacing the cells that have died.

Growth

In general, a large organism does not have larger cells than a small organism; it simply has many more cells than the small organism. When you were small, your body contained fewer cells than it has now. By the time you reach adulthood, your body will be made up of about 100 trillion cells.

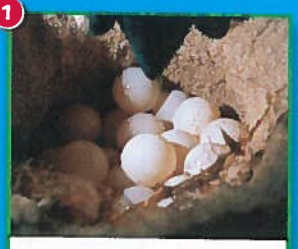
Individual cells grow in size, but there are limits to the size that cells can reach. As you learned in Chapter 2, cells need a high ratio of surface area to volume in order to function. As a cell grows, that ratio decreases. When the cell divides into two smaller cells, the ratio of surface area to volume for each cell increases.

Scientists are still searching for answers about how cell size is related to the control of cell division. Some scientists think that there is no single factor that controls cell division. Instead, they think that many cell processes added together control when a cell divides.

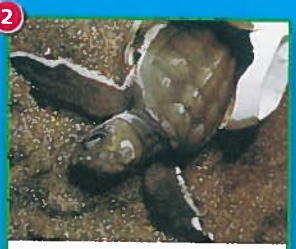
CHECK YOUR READING Describe how the number of cells in a multicellular organism changes as the organism grows.

Growth and Development

Multicellular organisms, such as this sea turtle, grow and develop through cell division.

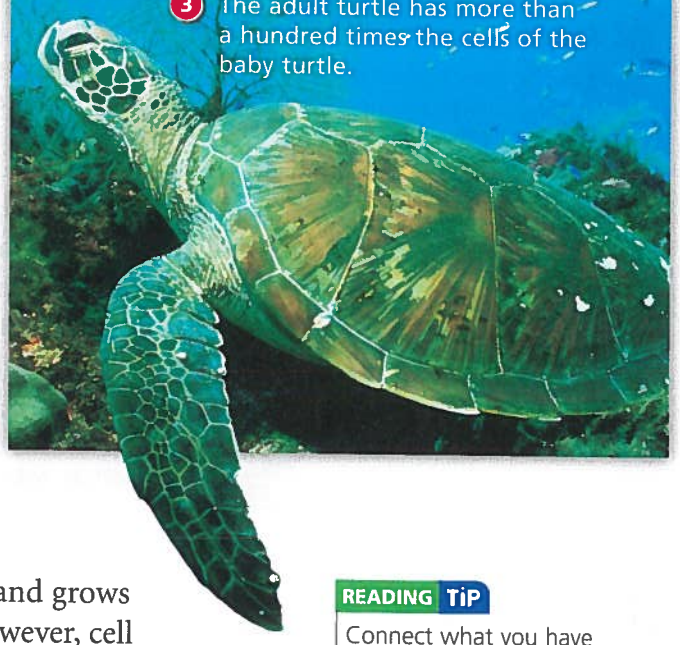
1 

The embryo growing inside this egg started as a single cell.

2 

When it hatches, the baby turtle has trillions of cells.

3 The adult turtle has more than a hundred times the cells of the baby turtle.



Development

A multicellular organism begins as a single cell and grows into a larger organism through cell division. However, cell division alone does not allow an organism to develop. If cell division were the only process occurring, the organism would end up as a group of identical cells. But during development, cells become specialized to perform particular functions.

These cells may take on shapes or structures that help them perform their functions. Some cells might become skin cells, while others might become nerve cells. These cells still have the same set of genetic material as all the other cells in an organism's body, but as the organism develops, they specialize.

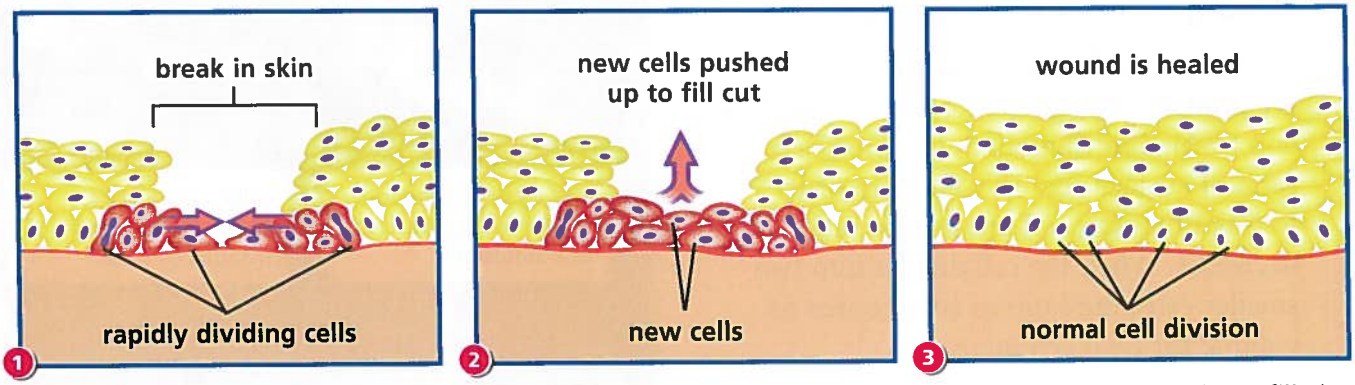
CHECK YOUR READING Give two examples of specialized cells from the paragraph above.

READING TIP

Connect what you have read about growth and development with the photographs above.

Repair

You may have cut yourself at one time or another. Perhaps you have even broken a bone in your arm or leg. The body repairs injuries such as these by means of cell division. For example, when your skin is cut, skin cells on either side of the cut make new cells to heal the wound. You can see the process of healing in the diagram below.



1 Cells in the lower layer begin to divide quickly and move into the break in the skin.

2 The area is filled as new cells continue to divide.

3 Once the break in the skin is filled, the cells stop dividing rapidly.

As cells age and die, they need to be replaced. In the human body—which is made up of about 200 different types of cells—cells are replaced at different rates. Your skin cells wear out quickly, so they need to be replaced often. Every minute or so, your skin loses thousands of cells, which are replaced with new ones. In contrast, most of the cells in your brain live a long time and do not divide very often.

CHECK YOUR READING What role does cell division play in healing the body?

3.1 Review

KEY CONCEPTS

1. Why is cell division important? (7.2.e)
2. How is genetic material organized in eukaryotic cells? (7.2.e)
3. Explain how cell division is involved in the growth, development, and repair of an organism. (7.2.e)

CRITICAL THINKING

4. **Summarize** Explain how DNA compacts before a eukaryotic cell divides.
5. **Infer** Why do you think that injuries to the skin generally heal faster than injuries to the brain?

CHALLENGE

6. **Apply** Large cuts often form scars, which are made of a different type of skin cell. What characteristic might scar cells have to help them heal large cuts?

CONNECTING SCIENCES

LIFE SCIENCE AND PHYSICAL SCIENCE

Dyes Show Nerve Growth

7.1.f Students know that as multicellular organisms develop, their cells differentiate.

Scientists used to think that, by the end of childhood, a person had all the brain cells he or she would ever have. They thought that the brain could not replace damaged nerve cells.

However, a surprising discovery has shown that new nerve cells do grow in the brains of both adult monkeys and adult humans!

Dr. Elizabeth Gould noticed that new nerve cells can grow in adult monkey brains.

The Discovery

The discovery involves a chemical known as bromodeoxyuridine (BrdU), which can be used to detect new cancer cells.

- BrdU highlights the DNA of cells that are reproducing, such as cancer cells.
- BrdU also makes it possible to count the new cells that are being created, because they stand out as well.
- The cells that have been highlighted with BrdU can be seen under a microscope when they are illuminated with a special light.

When scientists used this technique to examine certain areas in the brains of monkeys and of adult humans who had died of cancer, they found that new nerve cells had grown in the brains of each. Thus, the chemical properties of BrdU allowed scientists to discover new nerve cells growing in places where scientists had previously never expected to see them.

Hope for the Future

If new nerve cells grow in these tissues, it may be possible to stimulate growth in damaged nerve tissue such as that in the spinal cord. If researchers discover how growth in nerve cells is triggered, there may be new hope for people who have nervous systems damaged by accidents or by diseases such as Parkinson's disease.

EXPLORE

1. **SYNTHESIZE** How could you use chemicals, such as small dots of ink, in an experiment to show how your fingernails grow?
2. **CHALLENGE** What are some possible effects of the growth of new nerve cells?

RESOURCE CENTER
CLASSZONE.COM
Find out more about new nerve cell growth.

KEY CONCEPT

3.2 Cell division is part of the cell cycle.

CALIFORNIA Content Standards

7.1.c Students know the nucleus is the repository for genetic information in plant and animal cells.

7.1.e Students know cells divide to increase their numbers through a process of mitosis, which results in two daughter cells with identical sets of chromosomes.

BEFORE, you learned

- Cells come from other cells through cell division
- A cell must have a full set of genetic material to function
- Cell division enables multicellular organisms to develop, grow, and repair themselves

NOW, you will learn

- About two main stages in the cell cycle
- About the changes that occur in cells before mitosis
- About the events that take place during mitosis

VOCABULARY

cell cycle p. 80
interphase p. 81
mitosis p. 81
cytokinesis p. 81

THINK ABOUT

What is a cycle?

Many things in your everyday life are cycles. A cycle is any activity or set of events that regularly repeats. Cycles can be short, like the sequence of events that make your heart beat, or they can be very long, like the turning of our galaxy. One example of a cycle is shown at the right. The photographs show a tree during four seasons in a northern climate. How are these seasons a cycle?

The cell cycle includes interphase and cell division.

Living things grow, reproduce, and die in a process called a life cycle. The life cycle of a tree, for example, begins with a seed. Under the right conditions, the seed begins to grow. It produces a very small plant, which may grow over many years into a towering tree. When it is mature, the tree makes its own seeds, and the cycle begins again.

Cells have a life cycle too, called the cell cycle. The **cell cycle** is the normal sequence of development and division of a cell. The cell cycle consists of two main phases. The cell carries out its normal functions during a phase called interphase. The second general phase involves cell division. When a eukaryotic cell divides, its nucleus must also divide. This process is called mitosis. Each phase in the cell cycle requires a certain period of time—from hours to days or years, depending on the type of cell.

RESOURCE CENTER
CLASSZONE.COM
Learn about the cell cycle.

Interphase

Interphase is the part of the cell cycle during which a cell is not dividing. Much activity takes place in this phase of the cell's life. During interphase, the cell grows to about twice the size it was when it was first produced. The cell also engages in normal life activities, such as transporting materials in and transporting wastes out. Also, cellular respiration occurs, which provides the energy the cell needs.

Changes that occur during interphase prepare a cell for division. Before a cell can divide, it replicates its DNA exactly. Correct copying of the DNA is very important. It ensures that, after cell division, each new cell gets a complete set of DNA. Organelles also duplicate.

CHECK YOUR READING What cell processes occur during interphase?

VOCABULARY
Make a frame game diagram for *interphase*.

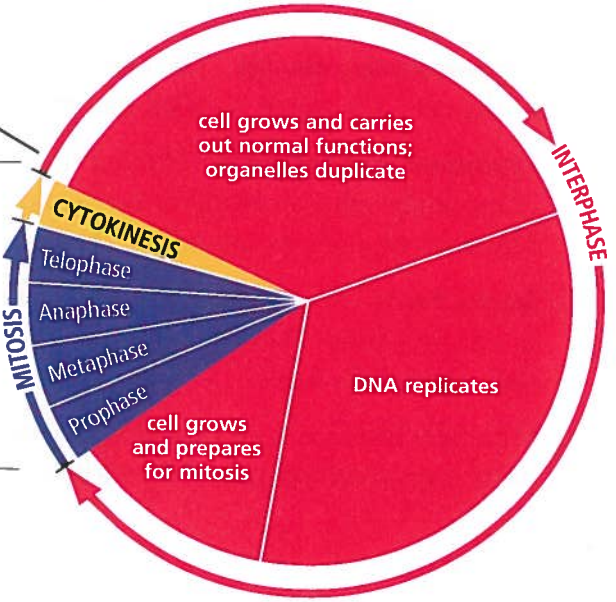
Cell Division Phase

Mitosis is the part of the cell cycle during which the nucleus divides. Prokaryotes do not go through mitosis because they have no nucleus. In most cells, mitosis is the shortest period in the life cycle. The function of mitosis is to move the DNA and other material in the parent cell into position for cell division. When the cell divides, each new cell gets a full set of DNA and other cell structures. **Cytokinesis** (SY-toh-kuh-NEE-sihs) is the division of the parent cell's cytoplasm, including mitochondria and other structures. Cytokinesis occurs immediately after mitosis.

Cell Cycle

The events that happen during the life of a cell are called the cell cycle.

1. **Interphase** The **cell cycle** begins with interphase, which is the longest part of the cell cycle.
2. **Cell Division Phase** After **mitosis** and **cytokinesis,** there are two cells. The cell cycle then begins again for each cell.



READING TiP
The arrows in the diagram represent the passage of time. Interphase is shown in red, mitosis in purple, and cytokinesis in yellow.

As a result of mitosis and cytokinesis, the original—or parent—cell splits into two genetically identical daughter cells. In this case, the term *daughter cell* does not mean that it's female. It is a term scientists use to refer to these new cells. Each daughter cell receives a complete set of DNA from the parent cell.

Cell division produces two genetically identical cells.

Recall that many cells in your body are continually dividing into new cells. The new cells help your body grow, develop, and replace worn-out parts. Though your body cells divide at different rates, the same process—mitosis—divides their genetic material.

Cell division produces daughter cells that are genetically identical to each other. They are genetically identical to their parent cell, which no longer exists. A skin cell, for example, divides and produces two new skin cells genetically identical to the original skin cell.

CHECK YOUR READING How are daughter cells like the parent cell?

Steps of Mitosis

The process of mitosis divides the genetic material evenly between the daughter cells. Mitosis is a continuous process, but scientists divide the events of mitosis into four smaller phases.

VISUALIZATION CLASSZONE.COM
Watch the process of mitosis in action.

READING TIP
For each numbered step, find the matching number in the diagram on page 83. For example, find the chromatids in step 1.

1. **Chromosomes appear.** During prophase, the DNA in the nucleus of a cell condenses. The resulting chromosomes become visible. Each chromosome consists of two identical chromatids held together by a centromere. The membrane around the nucleus breaks down.
2. **Chromosomes line up.** The chromosomes line up in the middle of the cell. This stage is called metaphase.
3. **Chromosomes separate.** During the stage called anaphase, the chromatids split, resulting in two separate, identical chromosomes. These chromosomes are pulled to opposite sides of the cell.
4. **Nuclei form.** A new nuclear membrane forms around each group of chromosomes during telophase. The chromosomes return to their threadlike form.

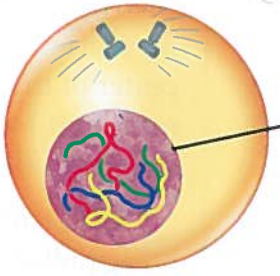
Mitosis is finished, and the cell's genetic material has been divided. The next step in cell division is cytokinesis.

Cell Division

Before mitosis, the cell's DNA is copied during interphase.

Interphase

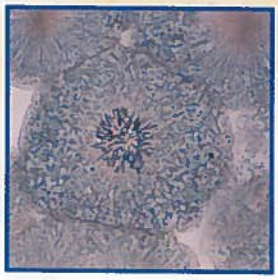
The cell has grown and is ready to divide.



The nucleus contains two complete copies of DNA.

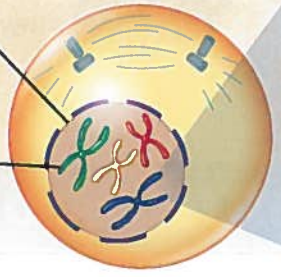
Mitosis produces two new cells with identical copies of DNA.

1 Chromosomes appear.
Prophase



The nuclear membrane breaks down.

Long strands of DNA condense to distinct chromosomes, each with two chromatids that are exact copies of each other.

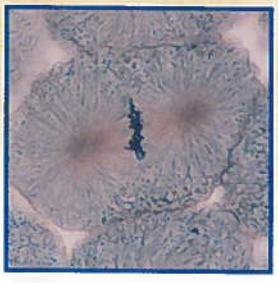


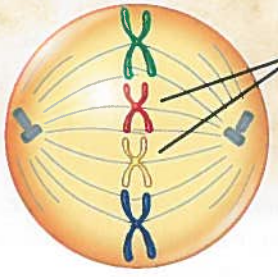
Chromosome

chromatids

centromere

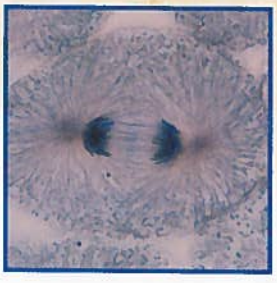
2 Chromosomes line up.
Metaphase



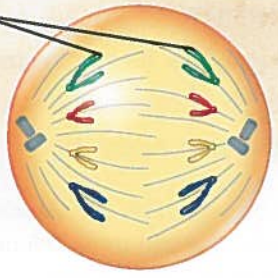


Chromosomes line up in the middle of the cell.

3 Chromosomes separate.
Anaphase

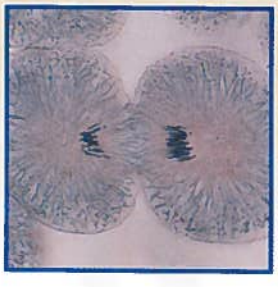


Chromatids of each chromosome split into two separate chromosomes.

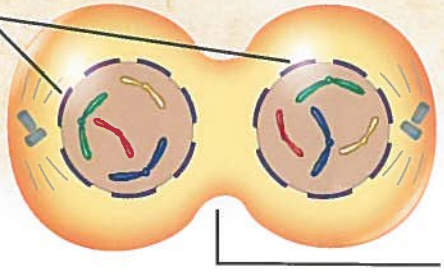


Separated chromosomes are pulled to opposite sides of the cell.

4 Nuclei form.
Telophase, Cytokinesis



New nuclear membranes form.



Cell pinches and divides.

Division of the Cytoplasm

READING TiP
As you read about cytokinesis, refer to the images of plant and animal cells on page 85.

Cytokinesis, or the division of the parent cell's cytoplasm, immediately follows mitosis in most eukaryotic cells. Cytokinesis differs slightly in animal cells and plant cells.

During cytokinesis in an animal cell, a fiber ring forms in the center of the dividing cell. The fiber ring contracts, pulling the cell membrane inward. Eventually, the cell is pinched into two daughter cells.

In a plant cell, the cell wall prevents the cell membrane from being pulled inward. A structure called a cell plate grows between the two new nuclei. The cell plate develops into a membrane and eventually becomes part of the cell wall of each of the new cells.

CHECK YOUR READING How does cytokinesis differ in plant cells and animal cells?

INVESTIGATE Cell Division

How can you model the cell cycle?

SKILL FOCUS
Making models (7.1.e)

MATERIALS
- poster board
- markers
- pipe cleaners
- packing peanuts
- glue
- scissors
- yarn

TIME
30 minutes

PROCEDURE

1. Divide the poster board into six spaces, and draw arrows from one space to the next to indicate a cycle. Label the spaces, in order, "Interphase," "Prophase," "Metaphase," "Anaphase," "Telophase," and "Cytokinesis."
2. In each space, make a model of a cell and its DNA in the indicated phase. Make sure you represent the cell membrane, the nuclear membrane—when it is present—and the DNA.

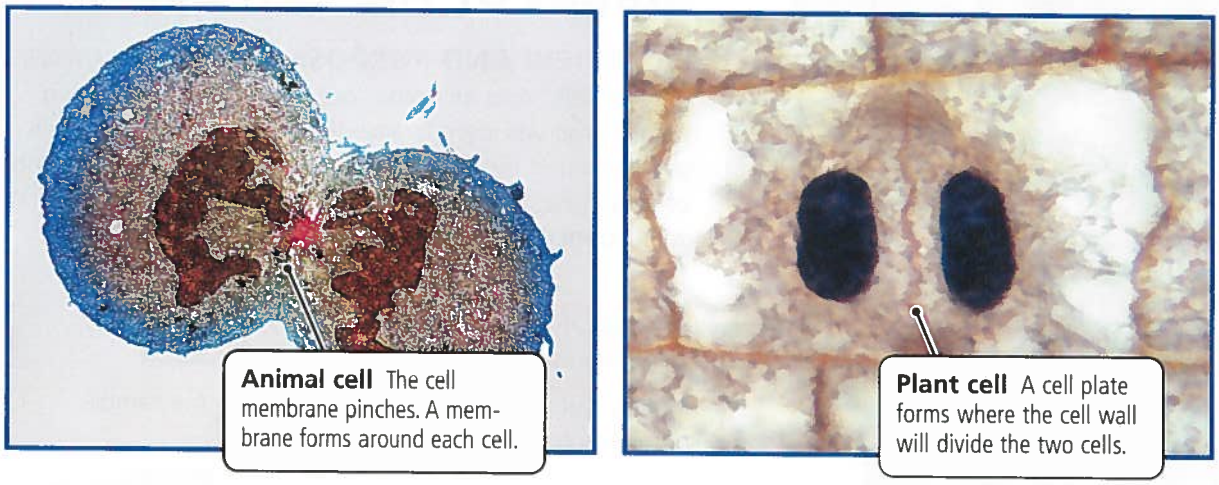
WHAT DO YOU THINK?

- In which phase is the nuclear membrane present?
- In which phases are the chromosomes condensed?
- What do the arrows in your model show?

CHALLENGE How do you think cell division would differ in prokaryotic cells? Do you think cell division in prokaryotic cells would be more or less complex than in eukaryotic cells? Make drawings to show how you think a prokaryotic cell might divide.

Cytokinesis

Cytokinesis happens in both plant and animal cells.



Animal cell The cell membrane pinches. A membrane forms around each cell.

Plant cell A cell plate forms where the cell wall will divide the two cells.

READING VISUALS **COMPARE AND CONTRAST** How does the process of cytokinesis in the animal cell on the left compare with that of the plant cell on the right?

At the end of cytokinesis, the two daughter cells are completely separated. Each is surrounded by a cell membrane. Each daughter cell has some of its parent cell's cytoplasm, including organelles. Although daughter cells are genetically identical to their parent cell, they are smaller. The daughter cells are now in interphase. DNA is threadlike in the nucleus and replicates. The cells may enter a period of growth. At that time they take in resources they need to increase the amount of their cytoplasm and to grow to full size. When cells are fully grown, they are about the same size as the parent cell was before division.

CHECK YOUR READING What happens to cells after cytokinesis?

3.2 Review

KEY CONCEPTS

1. What are the two main parts of the cell cycle? (7.1.e)
2. Describe the state of a cell about to start mitosis. (7.1.e)
3. How is the genetic material in two daughter cells similar to the genetic material in the original parent cell? (7.1.e)

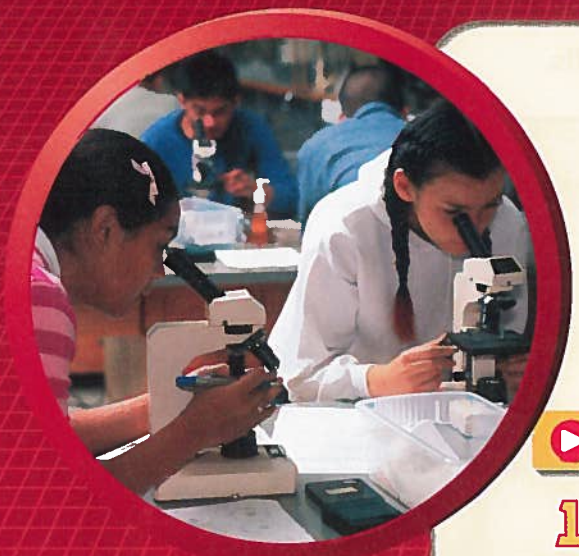
CRITICAL THINKING

4. **Sequence** Describe in order the steps that occur during mitosis.
5. **Compare and Contrast** How is the cell cycle like the cycle of the seasons? How does it differ?

CHALLENGE

6. **Infer** You know that mitosis does not happen in prokaryotes. Do you think cytokinesis happens in prokaryotes? Explain your answer.

CHAPTER INVESTIGATION



Stages of the Cell Cycle

OVERVIEW AND PURPOSE In this activity you will observe cells from an onion root tip that are undergoing mitosis. You will identify and draw cells in different stages of mitosis and the cell cycle. Then you will count the number of cells in each stage. Remember to record this information in your **Science Notebook.**

MATERIALS
- prepared slides of onion root tip cells
- light microscope

7.1.c, 7.1.e, 7.7.a

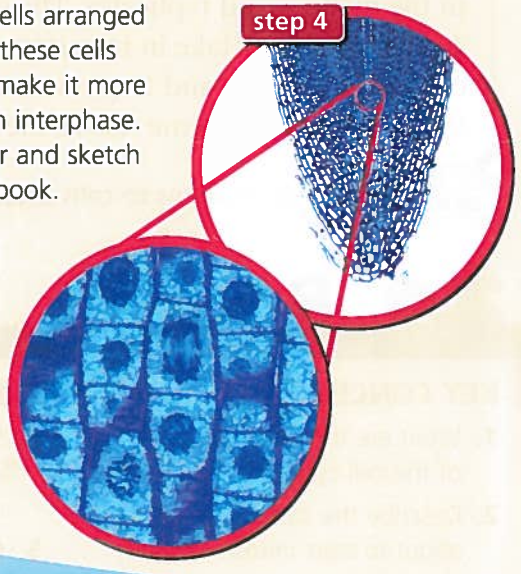
Procedure

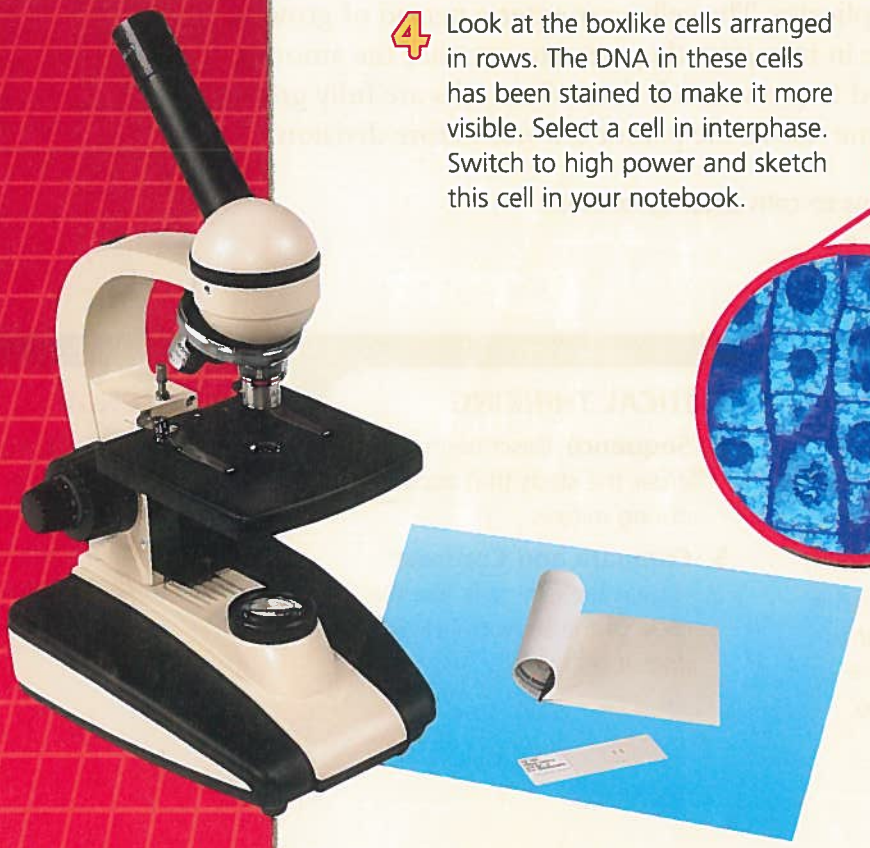
1. Make a data table like the one shown on the sample notebook page.

2. Obtain a prepared slide of an onion root tip. Place the slide on the microscope stage. Using the low-power objective, adjust the focus until the root tip is clear.

3. Move the slide until you are looking at the region just above the root tip. The cells in this area were in the process of mitosis when the slide was made.

4. Look at the boxlike cells arranged in rows. The DNA in these cells has been stained to make it more visible. Select a cell in interphase. Switch to high power and sketch this cell in your notebook.





Content Standard
7.1.e Students know cells divide to increase their numbers through a process of mitosis, which results in two daughter cells with identical sets of chromosomes.

Investigation Standard
7.7.a Select and use appropriate tools and technology (including calculators, computers, balances, spring scales, microscopes, and binoculars) to perform tests, collect data, and display data.

5 Repeat step 3 for cells in the various stages of mitosis: prophase, metaphase, anaphase, and telophase. Refer to the diagram on page 83 to identify cells in each stage.

6 Under low-power magnification, choose 25 cells at random. Decide which stage of the cell cycle each cell is in. Record the number of cells in each stage in your data table.

Observe and Analyze

Write It Up

1. **OBSERVE** Look at your sketches of the stages of mitosis. Describe the events in each stage.
2. **ANALYZING DATA** Was there any one stage of the cell cycle that was occurring in the majority of cells you observed? If so, which was it?

Conclude

Write It Up

1. **INFER** What might the differences in the number of cells in each stage of the cell cycle mean?
2. **IDENTIFY LIMITS** Were there any cells that were difficult to classify as being in one particular phase of the cell cycle? What do these cells suggest to you about the process of mitosis?
3. **APPLY** Where does new root growth take place? Explain your answer.

INVESTIGATE Further

CHALLENGE From your data table, calculate the percent of cells in each stage of the cell cycle. Use those numbers to predict how much time a cell spends in each stage. You can base your calculation on a total cell cycle of 24 hours.

Stages of the Cell Cycle

Table 1. Number of Cells in Each Stage of the Cell Cycle

Stage	Sketch	Number of Cells Observed
Interphase		
Prophase		
Metaphase		
Anaphase		
Telophase		

KEY CONCEPT

3.3 Both sexual and asexual reproduction involve cell division.

CALIFORNIA Content Standard

7.2.a Students know the differences between the life cycles and reproduction methods of sexual and asexual organisms.

BEFORE, you learned

- Cells go through a cycle of growth and division
- Mitosis produces two genetically identical cells

NOW, you will learn

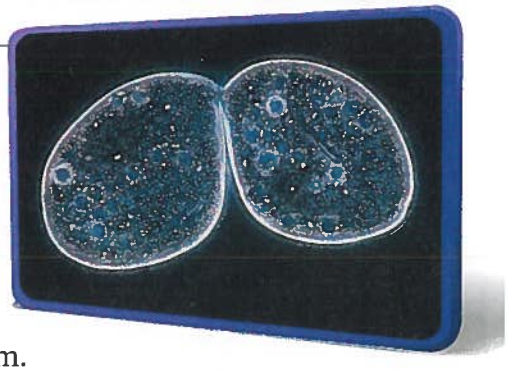
- About cell division and asexual reproduction
- How sexual reproduction and asexual reproduction compare

VOCABULARY

asexual reproduction p. 88
binary fission p. 89
regeneration p. 90

THINK ABOUT

How does cell division affect single-celled organisms?



In multicellular organisms, cell division functions in growth, repair, and development. But in unicellular organisms, each cell is itself an organism. Unicellular organisms, like this paramecium, also undergo cell division. What are some possible results of cell division in unicellular organisms? How might they compare with the results of cell division in multicellular organisms?

COMBINATION NOTES

Begin taking notes on the main idea: *Asexual reproduction involves one parent.* Be sure to include sketches of each method of reproducing.

Asexual reproduction involves one parent.

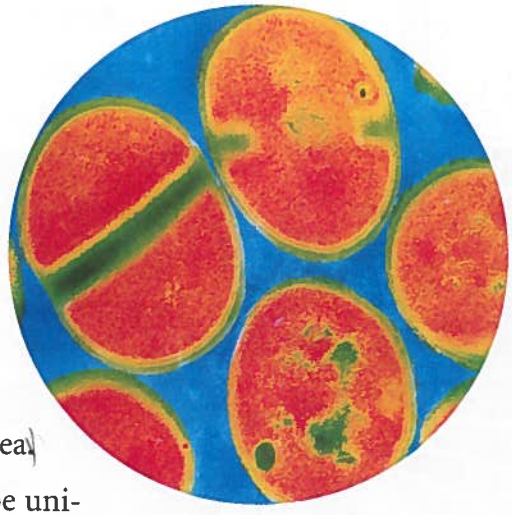
You have learned how cells divide to produce two daughter cells. If each cell is a whole organism—a unicellular organism—then cell division produces two new organisms. In other words, the organism reproduces. Each new organism can live independently and is called an offspring. This form of reproduction is called asexual reproduction. In **asexual reproduction** a parent organism produces offspring that are genetically identical to the parent—the offspring's genes are an identical copy of the parent's genes.

In multicellular organisms, cell division produces two daughter cells. It does not usually produce offspring. For example, a skin cell divides to produce two new skin cells. The new cells are part of the skin—part of the organism—and do not live apart from the body. You will read later how multicellular organisms reproduce.

Cell Division in Unicellular Organisms

Cell division is one form of asexual reproduction. It occurs in two main ways that depend on whether the cell has a nucleus or not. In both processes, the parent divides into two offspring. The offspring are genetically identical to the parent.

Remember that a unicellular organism without a nucleus is called a prokaryote. A prokaryote can reproduce by a simple form of cell division. **Binary fission** occurs when the parent organism replicates its DNA and then splits in two, producing two offspring. Prokaryotes that reproduce by binary fission include unicellular organisms such as bacteria and archaea.

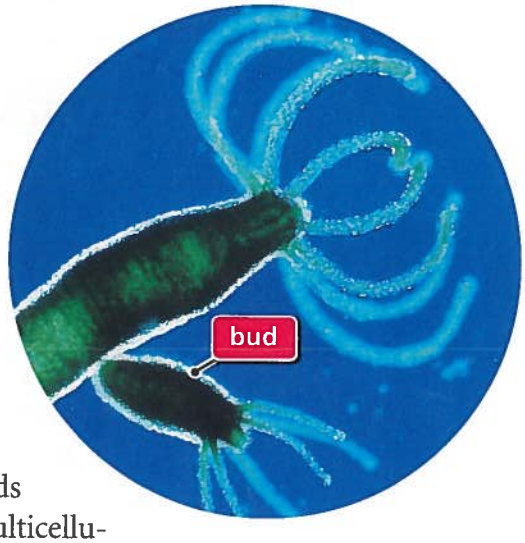


Binary fission results in two nearly equal, independent cells, as shown in these bacteria.

Eukaryotes—organisms whose cells have a nucleus—can be unicellular or multicellular. In unicellular eukaryotes, reproduction can occur by mitosis and cytokinesis—the other form of cell division. The organism undergoes mitosis, replicating and separating its chromosomes. Then its cytoplasm is divided through cytokinesis. Examples of single-celled eukaryotic organisms that reproduce by cell division include algae, some yeasts, and protozoans such as paramecia.

Budding

Another form of asexual reproduction is called budding. Budding is a process in which an organism develops tiny outgrowths, called buds. The organism may have more than one bud at once. Each bud forms from a parent's cell, so the buds are genetically identical to the parent. The bud grows until it forms a complete or nearly complete new organism. The organism may remain attached to its parent. Most often, when a bud reaches a certain size, it breaks free of the parent and becomes a separate organism.

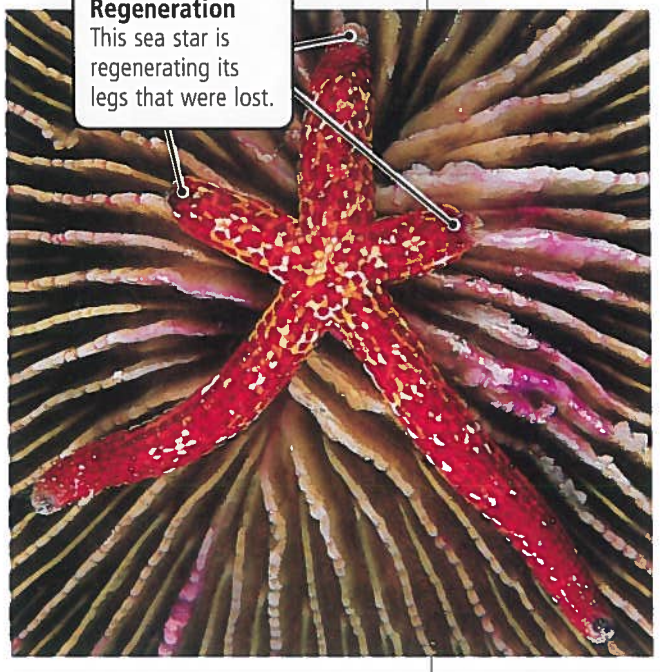


Budding Hydras reproduce by pinching off small buds.

Some unicellular and some multicellular organisms reproduce by budding. In some of these multicellular organisms, buds can form from any cell of the body. For example, hydras are multicellular eukaryotes that live in fresh water and reproduce by budding. In other multicellular organisms, only specialized cells in the body develop buds. For example, plants called kalanchoe (KAL-uhn-KOH-ee) produce tiny buds only from the tips of the leaves. Each kalanchoe bud has genes identical to its parent and can develop into an independent kalanchoe plant.

CHECK YOUR READING How is budding similar to binary fission?

Regeneration



Some multicellular organisms can reproduce by regeneration. **Regeneration** is a process in which missing body parts are replaced by the growth of new tissue. Regeneration is a form of healing. However, sometimes a body part that has broken off grows into a whole new organism. The new organism is genetically identical to the original organism. Thus, regeneration can be a form of asexual reproduction.

Regeneration can be observed in sea stars. If a sea star is cut in half, each half can regenerate its missing body parts. Sometimes a sea star will drop off one of its limbs. The animal will eventually grow a new limb. In a few species of sea stars the limb grows into a new animal.

Many plants can reproduce by regeneration. Even though the tissues in a leaf, root, or stem are specialized, many can produce tissues of other types. People use this ability of plants when they take cuttings, such as a stem, from a plant. Cells near the cut produce different types of tissues that grow into roots and other missing parts.

CHECK YOUR READING Describe the process of regeneration in sea stars.

Asexual Reproduction and Health

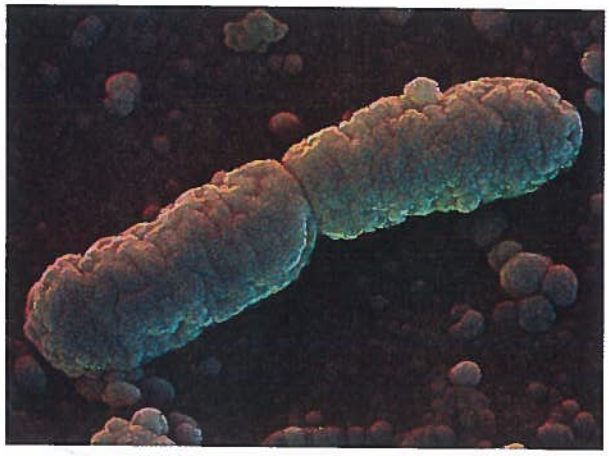
RESOURCE CENTER
CLASSZONE.COM
Learn more about asexual reproduction.

You have probably had the following experience. In the morning you feel fine. By afternoon, you have a strange feeling that something is not quite right, but you are well enough to function normally. You may even continue to feel well at dinner, and you eat heartily. Then, later that evening, it hits you. You're sick. That tickle in your throat has become a sore throat. How did you get so sick so fast?

A harmful type of bacteria may have caused your illness. Remember that bacteria are unicellular prokaryotes. They reproduce by binary fission, which can occur very fast. After a cell divides, it takes a while before the new cells can divide. Each time the cells divide, they produce a new generation of cells. The time it takes for offspring to grow and produce new offspring is called the generation time. Some types of bacteria can produce a new generation in less than 30 minutes.

With each generation, the number of bacteria can double. Two bacteria become four, then eight, then sixteen. After twenty-four generations, there can be millions of bacteria. The type of bacteria that causes strep throat can multiply so fast that you might become sick within a day or so. A sample of the bacteria from your throat can be placed in a Petri dish, where it quickly produces enough bacteria to analyze.

The fast growth of other bacteria can be good for your health. If you have to take an antibiotic medicine to kill the harmful bacteria, the medicine will also kill the bacteria that are normally in your body to help you digest food. However, when you finish the medicine, the helpful bacteria can grow back quickly.



Asexual reproduction
A single bacterium divides into two bacteria during asexual reproduction.

INVESTIGATE Asexual Reproduction

Which parts of plants can reproduce?

Some organisms can regenerate offspring from any part of their body. Others can regenerate offspring from only one specialized body part. In this activity, you will discover if a houseplant regenerates from various parts.

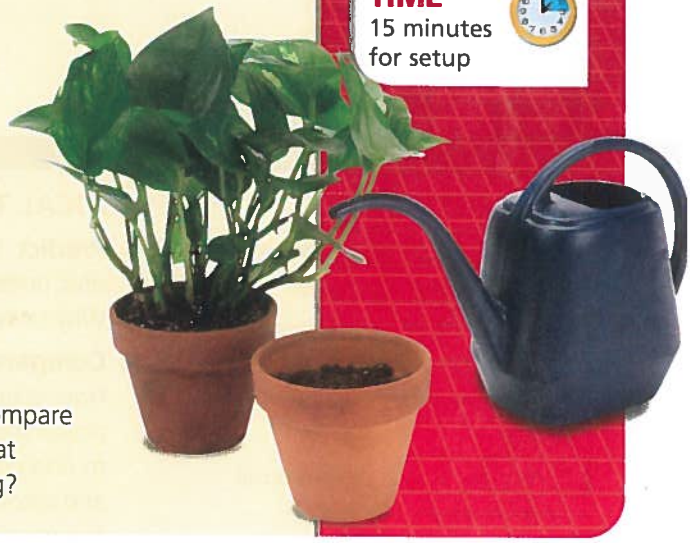
SKILL FOCUS
Drawing conclusions (7.2.a)

MATERIALS
- plant part
- flowerpot
- soil
- water

TIME
15 minutes for setup

PROCEDURE

1. Obtain a plant part (leaf, stem, stem with leaf, or root) from your teacher. Also get one flowerpot filled with potting soil. Label your flowerpot.
2. Dip the plant part in water and set it into the soil, about 2 cm deep. Make sure that most of the plant part is above the level of the soil. Water the soil lightly.
3. Place all of the class's pots on the same windowsill. Observe your plant part every day for two to three weeks. Record your observations.



WHAT DO YOU THINK?

- Which plant parts, if any, were able to regenerate a new plant?
- What can you conclude about the ability of different plant parts to grow into new plants?

CHALLENGE How does the plant in the experiment compare with the kalanchoe plant you read about in the text? What accounts for plants' different abilities to produce offspring?

Sexual reproduction involves two parent organisms.

CALIFORNIA Focus

The Mather Field Vernal Pools of Sacramento County appear with the winter rains, become green for a few short months, and then dry out for the rest of the year. Many organisms in the pools reproduce sexually as the water vanishes. Eggs, seeds, and other forms start growing when the water becomes available again.

You have read how one organism can produce offspring through asexual reproduction. The offspring are genetically identical to the parent. In contrast, many multicellular organisms reproduce by sexual reproduction. In sexual reproduction, the genes of two parent organisms are combined to produce offspring that are not exactly the same as either parent. A plant that grows from a seed and an animal that grows from an egg each have genetic material from two parents. The table below compares and contrasts the two types of reproduction.

Asexual and Sexual Reproduction

Asexual Reproduction	Sexual Reproduction
One parent organism	Two parent organisms
Offspring's genes are identical to parent's genes.	Offspring's genes are combined from two parents.
Can reproduce quickly	Usually reproduce more slowly

The combining of genes in sexual reproduction has resulted in much of the diversity of life on Earth. However, sexual reproduction usually takes more steps than asexual reproduction. Genes from two parents have to be combined in a way that gives the offspring the right number and types of genes to become the same type of organism. Cells have to divide and combine in special ways. In the next chapter, you will read about cell processes involved in sexual reproduction.

CHECK YOUR READING List two major differences between asexual and sexual reproduction.

3.3 Review

KEY CONCEPTS

1. How does binary fission relate to cell division? (7.2.a)
2. What is a bud, and where does it form on an organism that reproduces asexually? (7.2.a)
3. Compare sexual and asexual reproduction. (7.2.a)

CRITICAL THINKING

4. **Predict** Do you think prokaryotes undergo regeneration? Why or why not?
5. **Compare and Contrast** How is binary fission in prokaryotic organisms similar to and different from mitosis and cytokinesis in single-celled eukaryotic organisms?

CHALLENGE

6. **Synthesize** Some bacteria can exchange pieces of genetic material with one another through a process called conjugation. What effect might this exchange have on the offspring of the bacteria that underwent conjugation?

MATH in SCIENCE

SKILL: USING EXPONENTS

Divide and Multiply

MATH TUTORIAL
CLASSZONE.COM
Click on Math Tutorial for more help with exponents.

Math 7.MR.2.5
Science 7.1.e

Each time a parent cell divides, the result is two new cells. The new cells are a new generation that in turn divides again. The increase in the number of cells can be shown using exponents. Each cell of each new generation produces two cells. This type of increase in the number of objects is often called exponential growth.

Example

What is the numerical sequence when cells divide to form new cells? You can model this type of progression by using a plain piece of paper.

(1) To represent the first division, fold the piece of paper in half.

(2) Fold it in half again, and it will show the second division. Fold it again and again to represent succeeding divisions.

(3) Write the sequence that shows the number of boxes on the paper after each fold.

2, 4, 8, 16, . . .

(4) Notice that after one division (fold), there are 2 cells (boxes), or 2^1 cells. Two divisions yield $2 \cdot 2$ cells, or 2^2 cells. And after three divisions, there are $2 \cdot 2 \cdot 2$ cells, or 2^3 cells.

ANSWER The sequence can be written with exponents: $2^1, 2^2, 2^3, 2^4, \ldots$

Answer the following questions.

1. Suppose the cells divide for one more generation after the 4 described above. How can this be written as an exponent of 2? How many cells will there be?

2. How many cells would exist in the tenth generation? Write the number using an exponent.

3. Suppose you took the paper in the example and folded it in thirds each time, rather than in half. Make a table showing the number of boxes after each folding. Use numbers with exponents to write the sequence.

4. Write the following number sequence as a sequence of numbers with exponents: 5, 25, 125, 625, . . .

5. Write the following number sequence as a sequence of numbers without exponents: $10^1, 10^2, 10^3, 10^4, \ldots$

CHALLENGE Before you begin folding, you have a single sheet of paper, or 1 unit. The parent cell is also a single unit. Use this information to explain why $2^0 = 3^0$.

3 Chapter Review

the BIG idea

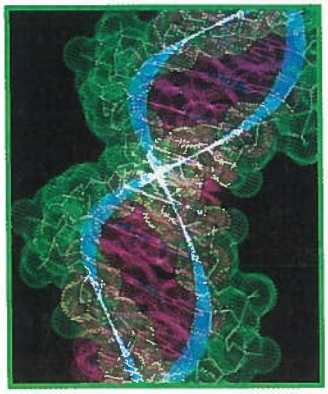
Organisms grow, reproduce, and maintain themselves through cell division.

CONTENT REVIEW
CLASSZONE.COM

KEY CONCEPTS SUMMARY

1 Cell division occurs in all organisms.

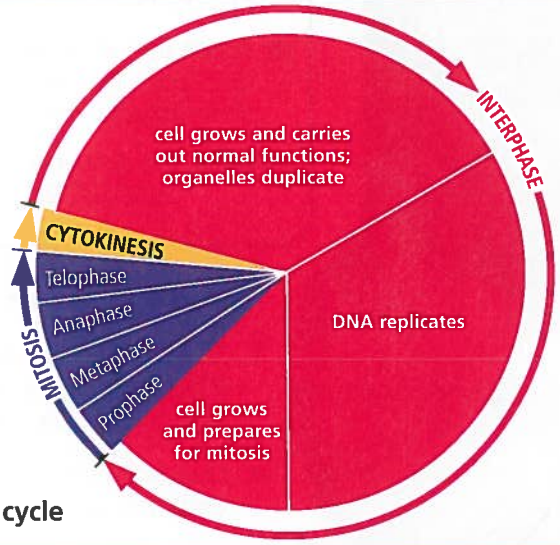
- In unicellular organisms the function of cell division is reproduction.
- In multicellular organisms the functions of cell division include growth, development, and repair.



VOCABULARY
DNA p. 74
chromosome p. 75

2 Cell division is part of the cell cycle.

The **cell cycle** has two main phases, **interphase** and **mitosis.** Most of the life cycle of a cell is spent in interphase. During mitosis, the nucleus divides.



Cell cycle

VOCABULARY
cell cycle p. 80
interphase p. 81
mitosis p. 81
cytokinesis p. 81

3 Both sexual and asexual reproduction involve cell division.

Some organisms reproduce asexually. Both asexual and sexual reproduction involve cell division.

Asexual and Sexual Reproduction

Asexual Reproduction	Sexual Reproduction
One parent organism	Two parent organisms
Offspring's genes are identical to parent's genes.	Offspring's genes are combined from two parents.
Can reproduce quickly	Usually reproduce more slowly

VOCABULARY
asexual reproduction p. 88
binary fission p. 89
regeneration p. 90

Reviewing Vocabulary

On a separate sheet of paper, write a sentence describing the relationship between the terms in each pair.

1. cell cycle, interphase
2. mitosis, cytokinesis
3. chromosome, DNA
4. parent, offspring

Reviewing Key Concepts

Multiple Choice *Choose the letter of the best answer.*

5. Most of the growth in your body occurs because your cells (7.1.e)
   - **a.** join together
   - **b.** take in oxygen
   - **c.** make proteins
   - **d.** divide

6. The stage in a cell's life when it is not in the process of dividing is called (7.1.e)
   - **a.** interphase
   - **b.** the cell cycle
   - **c.** mitosis
   - **d.** cell division

7. What wraps around proteins and then compacts to form visible chromosomes? (7.2.e)
   - **a.** carbohydrates
   - **b.** prokaryotes
   - **c.** the nucleus
   - **d.** DNA

8. What ratio increases when a cell divides into two smaller cells? (7.1.e)
   - **a.** volume to length
   - **b.** length to width
   - **c.** surface area to volume
   - **d.** width to surface area

9. The cytoplasm contains mitochondria and other organelles. During which process is the cytoplasm divided into daughter cells? (7.1.e)
   - **a.** mitosis
   - **b.** photosynthesis
   - **c.** cytokinesis
   - **d.** replication

10. During what part of the cell cycle are organelles copied? (7.1.e)
    - **a.** prophase
    - **b.** synthesis
    - **c.** anaphase
    - **d.** interphase

11. Pairs of connected chromatids become visible just before cell division. A pair of chromatids is (7.2.e)
    - **a.** two copies of DNA that will separate
    - **b.** one copy of DNA that will be replicated
    - **c.** two different strands of DNA that were stuck together
    - **d.** two wrinkles in the cell membrane

12. Binary fission is similar to mitosis and cytokinesis because (7.2.a)
    - **a.** the new cell stays attached to the parent
    - **b.** the nucleus divides into two copies
    - **c.** a cell wall forms between the daughter cells
    - **d.** the parent cell divides into two daughter cells

13. If a sea star is cut in half, it can regrow the missing part of its body through (7.2.a)
    - **a.** binary fission
    - **b.** budding
    - **c.** sexual reproduction
    - **d.** regeneration

14. Which of these is always a form of reproduction? (7.2.a)
    - **a.** binary fission
    - **b.** mitosis
    - **c.** cytokinesis
    - **d.** cell division

15. Which sequence is correct for mitosis? (7.1.e)
    - **a.** chromosomes appear, chromosomes separate, chromosomes line up, nuclei form
    - **b.** chromosomes appear, chromosomes line up, chromosomes separate, nuclei form
    - **c.** chromosomes line up, nuclei form, chromosomes separate, chromosomes appear
    - **d.** chromosomes separate, chromosomes appear, nuclei form, chromosomes line up

Short Answer *Write a short answer to each question.*

16. What is the difference between cytokinesis in plant and animal cells? (7.1.c)

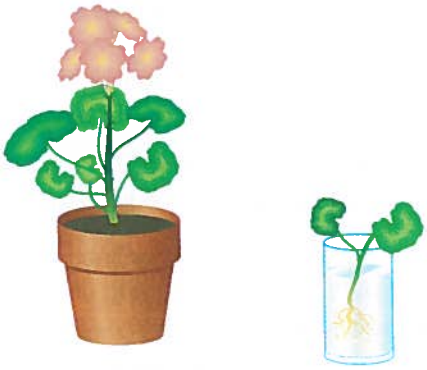
17. Describe what happens in a cell during interphase. Your answer should mention DNA. (7.2.e)

18. Describe the functions of cell division in both unicellular and multicellular organisms. (7.1.e)

Thinking Critically

19. IDENTIFY CAUSE Describe some of the reasons that cells divide. (7.1.e)

This illustration shows a plant and the cutting that was taken from it, which is growing in a container of water. Use the illustration to answer the next six questions.



20. OBSERVE From which part of the plant was the cutting taken? (7.2.a)

21. INFER Where did the cutting get the genetic information that controls its development? (7.1.c)

22. INFER What is the genetic relationship between the original plant and the cutting? (7.2.a)

23. SYNTHESIZE What process causes both the cutting and the original plant to grow? (7.2.a)

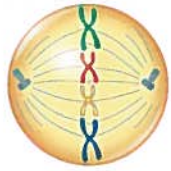
24. SUMMARIZE Write a brief summary of the process that causes growth in both plants. (7.2.a)

25. PREDICT These plants can also reproduce using seeds. How is the cutting the same as the plant that would grow from a seed? How is the cutting different? (7.2.a)

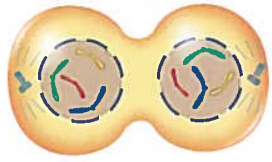
26. CALCULATE A single bacterium enters your body at 10:00 A.M. This type of bacteria reproduces at a rate of one generation every 30 minutes. How many bacteria of this type will be in your body by 8:00 P.M. that evening? Hint: Every 30 minutes the number of bacteria doubles.

The diagrams below show 4 parts of a process. Use them to answer the following three questions.

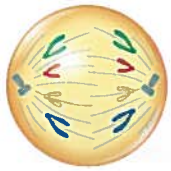
a.



c.



b.



d.

27. SEQUENCE What is the correct order of the four diagrams above? (7.1.e)

28. SYNTHESIZE Draw two diagrams, one showing what you would see before the process shown above begins, and one showing what you would see after the conclusion of the process. (7.7.d)

29. MODEL On a separate sheet of paper, draw your own simple model of the process of mitosis. (7.1.e)

the BIG idea

30. SUMMARIZE Look again at the question on the photograph on pages 70–71. Now that you have studied this chapter, how would you change your answer to the question? (7.1.e)

31. SYNTHESIZE How do the concepts in this chapter relate to the concepts in the cell theory? (7.1.e)

UNIT PROJECTS

If you need to do an experiment for your unit project, gather the materials. Be sure to allow enough time to observe results before the project is due.

Standards-Based Assessment

For more practice, go to . . .
TEST PRACTICE
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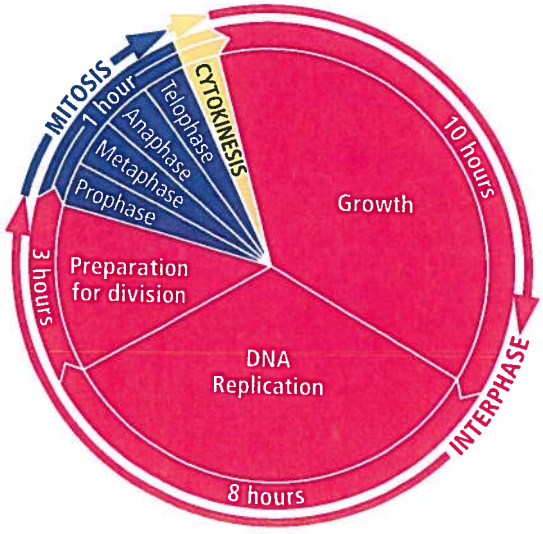
Analyzing Data

7.1.e, 7.2.e

This diagram shows the approximate length of the cell cycle for a typical skin cell in the human body.



Use the diagram to answer the questions below.

1. How long does the growth phase of the cell cycle take?

a. 1 hour
b. 3 hours
c. 8 hours
d. 10 hours

2. How much time does the cell cycle spend in interphase?

a. 1 hour
b. 10 hours
c. 21 hours
d. 22 hours

3. What is the total length of time it takes for the skin cell to complete one full cell cycle?

a. 10 hours
b. 18 hours
c. 21 hours
d. 22 hours

4. What phase of the cell cycle takes about 8 hours?

a. DNA replication
b. mitosis
c. growth
d. preparation for cell division

5. Suppose another type of skin cell takes 44 hours to complete one cell cycle. If all of the phases are proportional to the length of time shown in the diagram, how long will the preparation for cell division phase last?

a. 3 hours
b. 6 hours
c. 10 hours
d. 20 hours

6. According to the diagram, what is the second stage in mitosis?

a. prophase
b. metaphase
c. telophase
d. cytokinesis

Extended Response

Answer the two questions. Include some of the terms shown in the word box. Underline each term you use in your answers.

cell cycle	metaphase	mitosis
anaphase	prophase	telophase

7. A scientist is studying the stages of cell division in the cells of an onion root. The scientist counts 100 cells and identifies which stage of cell division each cell is in at a given moment. He counts a total of 85 cells in interphase, 8 cells in prophase, 3 cells in metaphase, and 2 cells each in anaphase and telophase. A typical onion cell takes about 12 hours to complete the cell cycle. Using the information in the diagram and the data given here, how can you account for these numbers?

8. Your science class is investigating the effect of temperature on the rate of mitosis in onion plants. You hypothesize that the higher the temperature, the faster cells undergo mitosis. How could you set up an experiment to support your hypothesis? Describe the materials you would use and the steps you would take in your procedure.