Chapter 3

From a Cell to an Organism

THE BIG IDEA

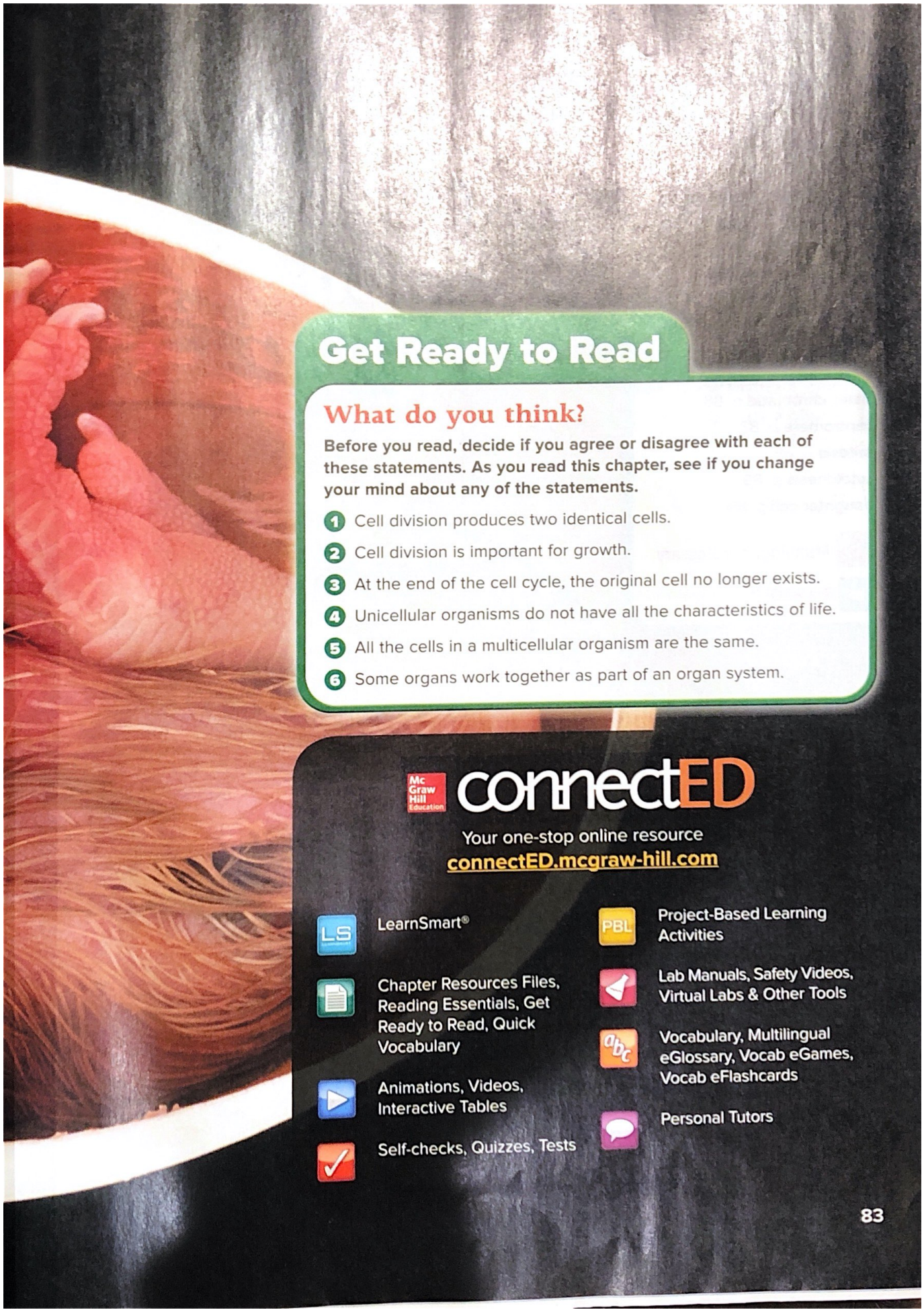
How can one cell become a multicellular organism?

inquiry

What's happening inside?

From the outside, a chicken egg looks like a simple oval object. But big changes are taking place inside the egg. Over several weeks, the one cell in the egg will grow and divide and become a chick.

- How did the original cell change over time?
- What might have happened to the chick's cells as the chick grew?
- How can one cell become a multicellular chick?



Get Ready to Read

What do you think?

Before you read, decide if you agree or disagree with each of these statements. As you read this chapter, see if you change your mind about any of the statements.

1. Cell division produces two identical cells.
2. Cell division is important for growth.
3. At the end of the cell cycle, the original cell no longer exists.
4. Unicellular organisms do not have all the characteristics of life.
5. All the cells in a multicellular organism are the same.
6. Some organs work together as part of an organ system.

Lesson 1

The Cell Cycle and Cell Division

Reading Guide

Key Concepts

ESSENTIAL QUESTIONS

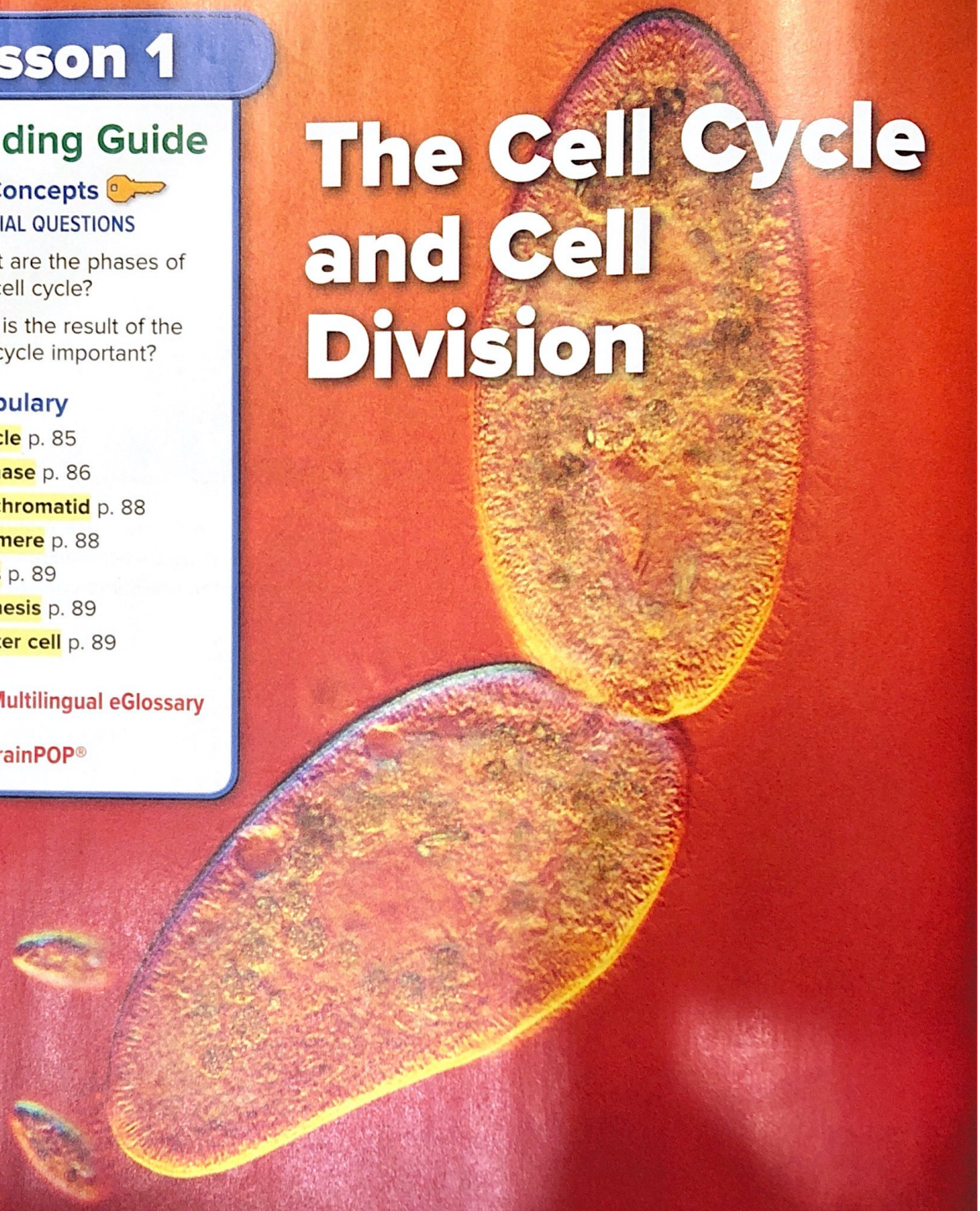
- What are the phases of the cell cycle?
- Why is the result of the cell cycle important?

Vocabulary

cell cycle p. 85
interphase p. 86
sister chromatid p. 88
centromere p. 88
mitosis p. 89
cytokinesis p. 89
daughter cell p. 89

Multilingual eGlossary

BrainPOP®



Inquiry Time to Split?

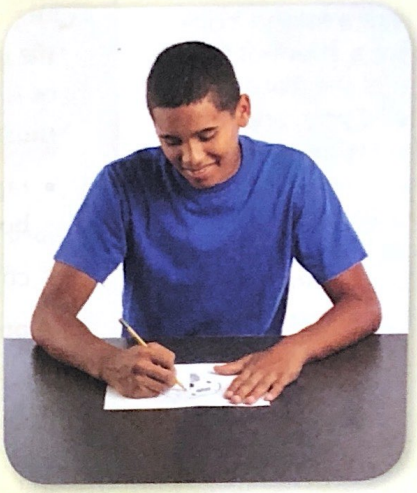
Unicellular organisms such as these reproduce when one cell divides into two new cells. The two cells are identical to each other. What do you think happened to the contents of the original cell before it divided?

Launch Lab

15 minutes

Why isn't your cell like mine?

All living things are made of cells. Some are made of only one cell, while others are made of trillions of cells. Where do all those cells come from?



1. Read and complete a lab safety form.
2. Ask your team members to face away from you. Draw an animal cell on a sheet of **paper.** Include as many organelles as you can.
3. Use **scissors** to cut the cell drawing into equal halves. Fold each sheet of paper in half so the drawing cannot be seen.
4. Ask your team members to face you. Give each team member half of the cell drawing.
5. Have team members sit facing away from each other. Each person should use a **glue stick** to attach the cell half to one side of a sheet of paper. Then, each person should draw the missing cell half.
6. Compare the two new cells to your original cell.

Think About This

1. How did the new cells compare to the original cell?
2. **Key Concept** What are some things that might be done in the early steps to produce two new cells that are more like the original cell?

The Cell Cycle

No matter where you live, you have probably noticed that the weather changes in a regular pattern each year. Some areas experience four seasons–winter, spring, summer, and fall. In other parts of the world, there are only two seasons–rainy and dry. As seasons change, temperature, precipitation, and the number of hours of sunlight vary in a regular cycle.

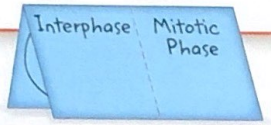
These changes can affect the life cycles of organisms such as trees. Notice how the tree in Figure 1 changes with the seasons. Like changing seasons or the growth of trees, cells go through cycles. *Most cells in an organism go through a cycle of growth, development, and division called the* **cell cycle.** Through the cell cycle, organisms grow, develop, replace old or damaged cells, and produce new cells.

Figure 1 This maple tree changes in response to a seasonal cycle.

Visual Check List the seasonal changes of this maple tree.

FOLDABLES

Make a folded book from a sheet of paper. Label the front *The Cell Cycle*, and label the inside of the book as shown. Open the book completely and use the full sheet to illustrate the cell cycle.



Phases of the Cell Cycle

There are two main phases in the cell cycle–interphase and the mitotic (mi TAH tihk) phase. **Interphase** *is the period during the cell cycle of a cell's growth and development.* A cell spends most of its life in interphase, as shown in **Figure 2.** During interphase, most cells go through three stages:

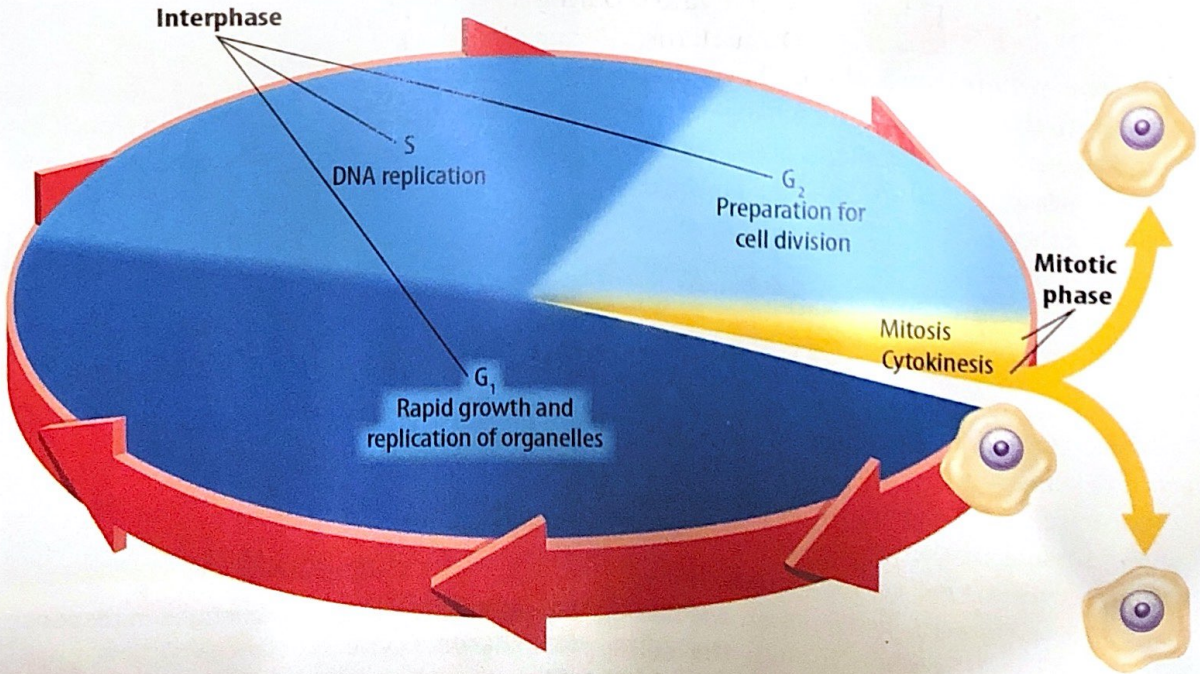
- rapid growth and replication, or copying, of the membrane-bound structures called organelles;
- copying of DNA, the genetic information in a cell; and
- preparation for cell division.

Interphase is followed by a shorter period of the cell cycle known as the mitotic phase. A cell reproduces during this phase. The mitotic phase has two stages, as illustrated in **Figure 2.** The nucleus divides in the first stage, and the cell's fluid, called the cytoplasm, divides in the second stage. The mitotic phase creates two new identical cells. At the end of this phase, the original cell no longer exists.

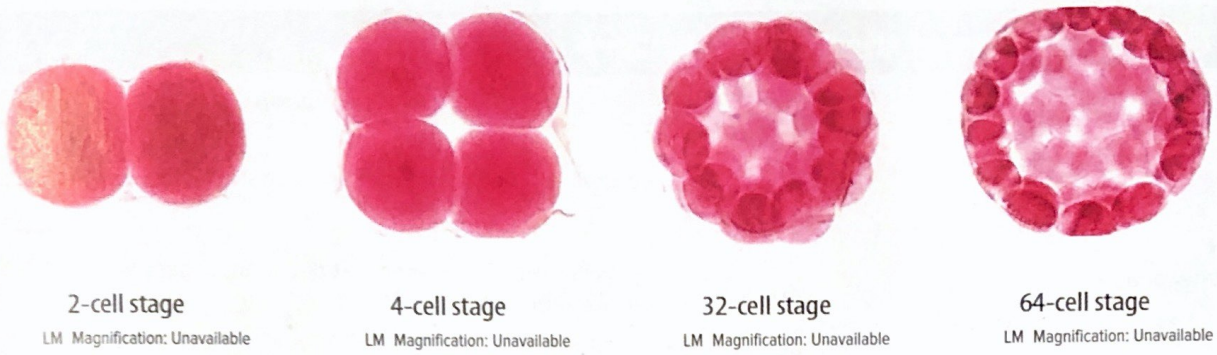
Key Concept Check What are the two main phases of the cell cycle?

The Cell Cycle

Figure 2 A cell spends most of its life growing and developing during interphase.



Visual Check Which stage of interphase is the longest?



2-cell stage
LM Magnification: Unavailable

4-cell stage
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32-cell stage
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64-cell stage
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▲ **Figure 3** The fertilized egg of a sea star divides into 4 cells in about 2 hours. It divides into 1000 cells in about 10 hours.

Length of a Cell Cycle

The time it takes a cell to complete the cell cycle depends on the type of cell that is dividing. Recall that a **eukaryotic** cell has membrane-bound organelles, including a nucleus. For some eukaryotic cells, the cell cycle might last only eight minutes. For other cells, the cycle might take as long as one year. Most dividing human cells normally complete the cell cycle in about 24 hours. As illustrated in **Figure 3,** the cells of some organisms divide very quickly.

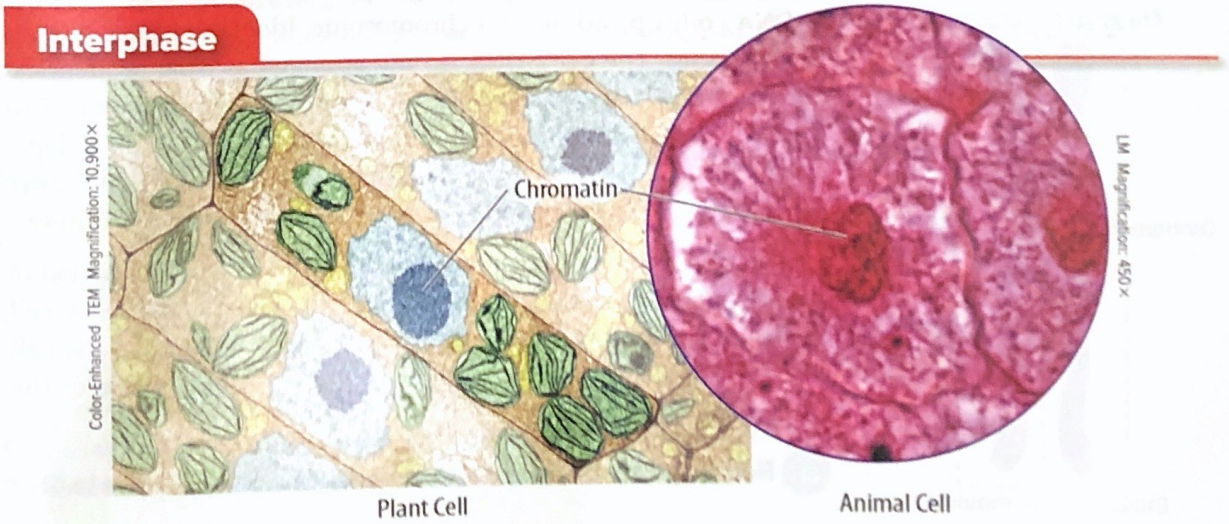
REVIEW VOCABULARY

eukaryotic
a cell with membrane-bound structures

Interphase

As you have read, interphase makes up most of the cell cycle. Newly produced cells begin interphase with a period of rapid growth–the cell gets bigger. This is followed by cellular activities such as making proteins. Next, actively dividing cells make copies of their DNA and prepare for cell division. During interphase, the DNA is called chromatin (KROH muh tun). Chromatin is long, thin strands of DNA, as shown in **Figure 4.** When scientists dye a cell in interphase, the nucleus looks like a plate of spaghetti. This is because the nucleus contains many strands of chromatin tangled together.

Figure 4 During interphase, the nuclei of an animal cell and a plant cell contain long, thin strands of DNA called chromatin. ▼



(t)Science Source; (bl)Biophoto Associates/Photo Researchers; (br)Michael Abbey/Science Source

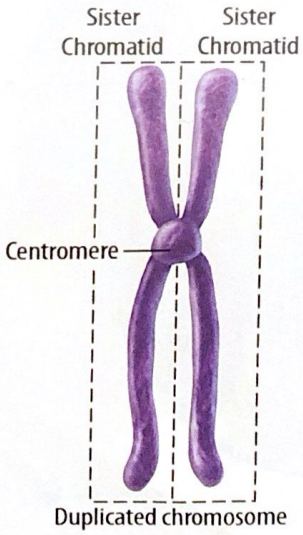
Interactive Table

Table 1 Phases of the Cell Cycle

Phase	Stage	Description
Interphase	G_1	growth and cellular functions; organelle replication
	S	growth and chromosome replication; organelle replication
	G_2	growth and cellular functions; organelle replication
Mitotic phase	mitosis	division of nucleus
	cytokinesis	division of cytoplasm

▲ **Table 1** The two phases of the cell cycle can each be divided into different stages.

Figure 5 The coiled DNA forms a duplicated chromosome made of two sister chromatids connected at the centromere. ▼



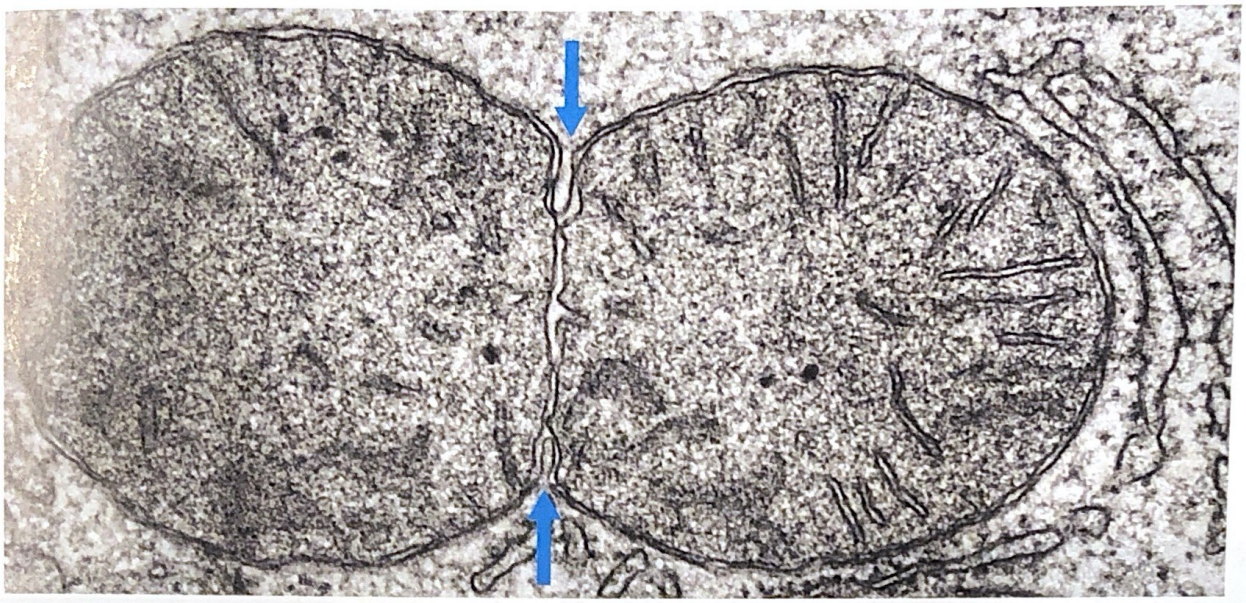
Phases of Interphase

Scientists divide interphase into three stages, as shown in **Table 1.** Interphase begins with a period of rapid growth–the G_1 stage. This stage lasts longer than other stages of the cell cycle. During G_1, a cell grows and carries out its normal cell functions. For example, during G_1, cells that line your stomach make enzymes that help digest your food. Although most cells continue the cell cycle, some cells stop the cell cycle at this point. For example, mature nerve cells in your brain remain in G_1 and do not divide again.

During the second stage of interphase–the S stage–a cell continues to grow and copies its DNA. There are now identical strands of DNA. These identical strands of DNA ensure that each new cell gets a copy of the original cell's genetic information. Each strand of DNA coils up and forms a chromosome. Identical chromosomes join together. The cell's DNA is now arranged as pairs of identical chromosomes. Each pair is called a duplicated chromosome. *Two identical chromosomes, called* **sister chromatids,** *make up a duplicated chromosome,* as shown in **Figure 5.** Notice that the *sister chromatids are held together by a structure called the* **centromere.**

The final stage of interphase–the G_2 stage–is another period of growth and the final preparation for the mitotic phase. A cell uses energy copying DNA during the S stage. During G_2, the cell stores energy that will be used during the mitotic phase of the cell cycle.

Reading Check Describe what happens in the G_2 phase.



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Don W. Fawcett/Photo Researchers

Figure 6 This mitochondrion is in the final stage of dividing.

Organelle Replication

During cell division, the organelles in a cell are distributed between the two new cells. Before a cell divides, it makes a copy of each organelle. This enables the two new cells to function properly. Some organelles, such as the energy-processing mitochondria and chloroplasts, have their own DNA. These organelles can make copies of themselves on their own, as shown in **Figure 6.** A cell produces other organelles from materials such as proteins and lipids. A cell makes these materials using the information contained in the DNA inside the nucleus. Organelles are copied during all stages of interphase.

The Mitotic Phase

The mitotic phase of the cell cycle follows interphase. It consists of two stages: mitosis (mi TOH sus) and cytokinesis (si toh kuh NEE sus). *In* **mitosis,** *the nucleus and its contents divide. In* **cytokinesis,** *the cytoplasm and its contents divide.* **Daughter cells** *are the two new cells that result from mitosis and cytokinesis.*

During mitosis, the contents of the nucleus divide, forming two identical nuclei. The sister chromatids of the duplicated chromosomes separate from each other. This gives each daughter cell the same genetic information. For example, a cell that has ten duplicated chromosomes actually has 20 chromatids. When the cell divides, each daughter cell will have ten different chromatids. Chromatids are now called chromosomes.

In cytokinesis, the cytoplasm divides and forms the two new daughter cells. Organelles that were made during interphase are divided between the daughter cells.

WORD ORIGIN

mitosis
from Greek *mitos,* means "warp thread"; and Latin *-osis,* means "process"

Phases of Mitosis

Like interphase, mitosis is a continuous process that scientists divide into different phases, as shown in Figure 7.

Prophase During the first phase of mitosis, called prophase, the copied chromatin coils together tightly. The coils form visible duplicated chromosomes. The nucleolus disappears, and the nuclear membrane breaks down. Structures called spindle fibers form in the cytoplasm.

Metaphase During metaphase, the spindle fibers pull and push the duplicated chromosomes to the middle of the cell. Notice in Figure 7 that the chromosomes line up along the middle of the cell. This arrangement ensures that each new cell will receive one copy of each chromosome. Metaphase is the shortest phase in mitosis, but it must be completed successfully for the new cells to be identical.

Phases of Mitosis

Animation

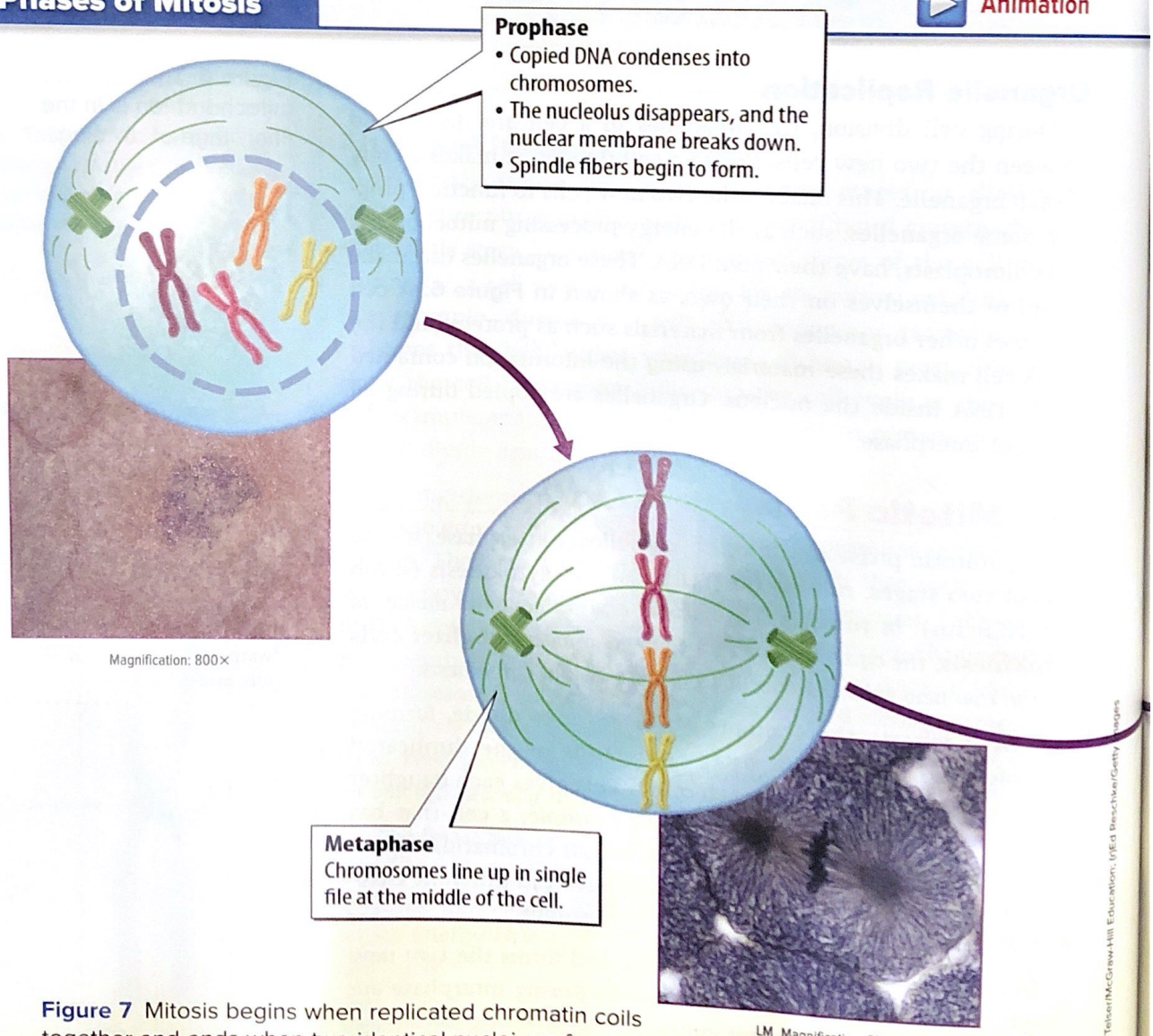
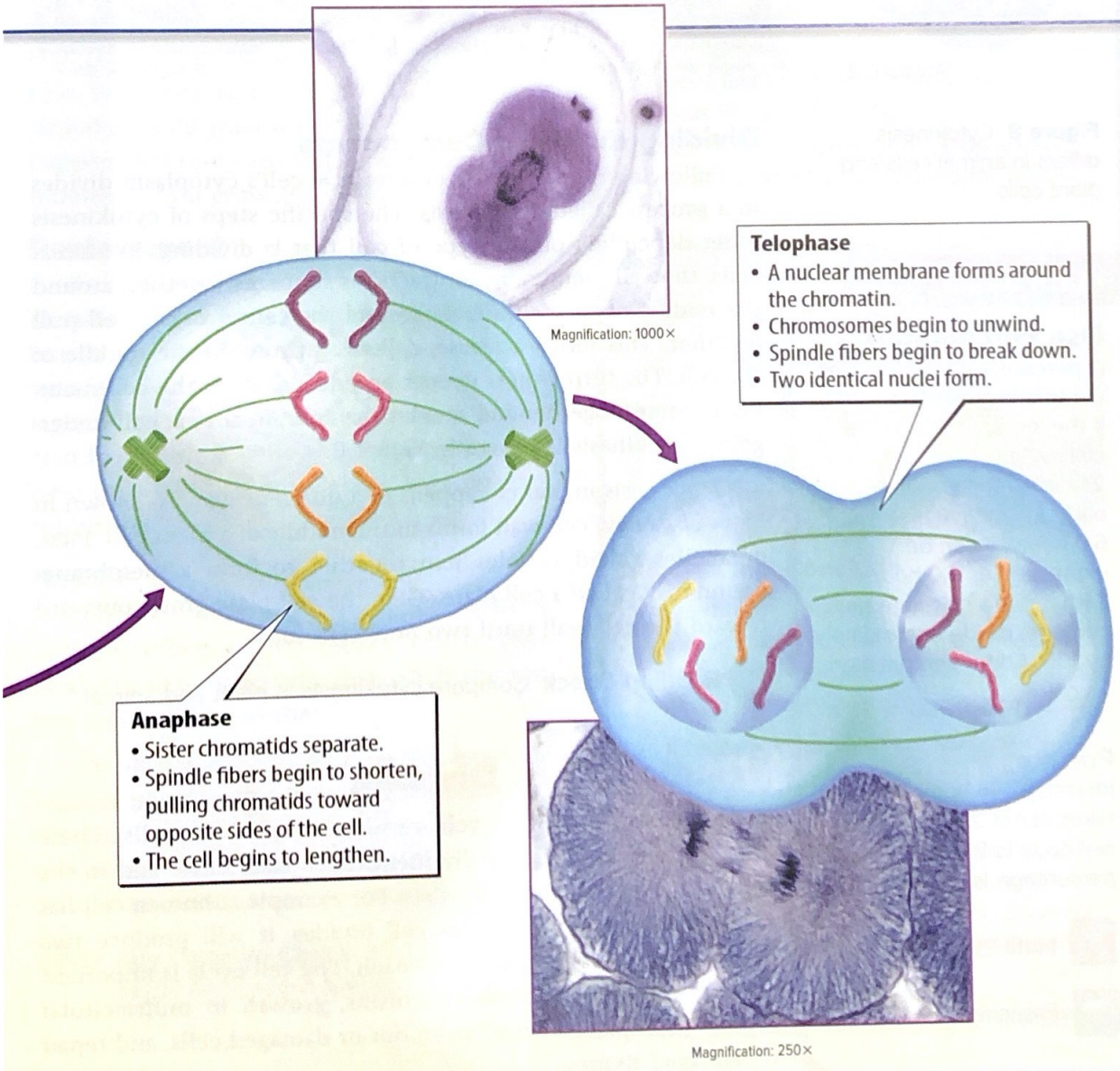


Figure 7 Mitosis begins when replicated chromatin coils together and ends when two identical nuclei are formed.

Anaphase In anaphase, the third stage of mitosis, the two sister chromatids in each chromosome separate from each other. The spindle fibers pull them in opposite directions. Once separated, the chromatids are now two identical single-stranded chromosomes. As they move to opposite sides of a cell, the cell begins to get longer. Anaphase is complete when the two identical sets of chromosomes are at opposite ends of a cell.

Telophase During telophase, the spindle fibers begin to disappear. Also, the chromosomes begin to uncoil. A nuclear membrane forms around each set of chromosomes at either end of the cell. This forms two new identical nuclei. Telophase is the final stage of mitosis. It is often described as the reverse of prophase because many of the processes that occur during prophase are reversed during telophase.

Reading Check What are the phases of mitosis?



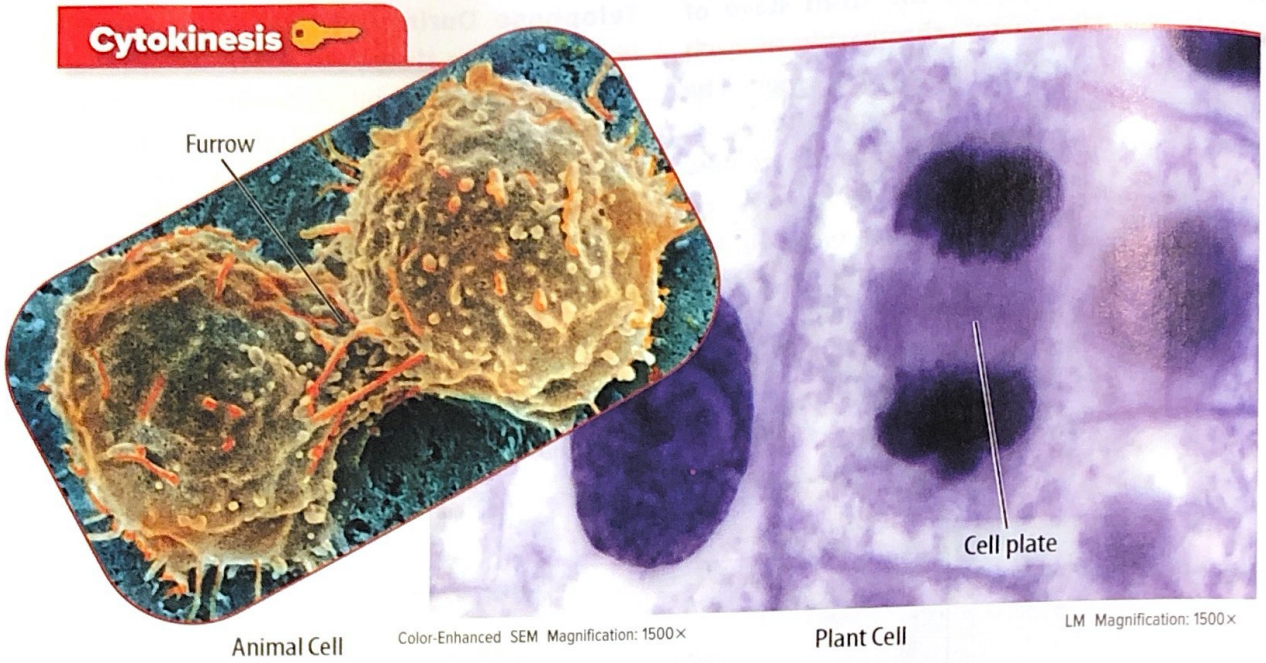


Figure 8 Cytokinesis differs in animal cells and plant cells.

Dividing the Cell's Components

Following the last phase of mitosis, a cell's cytoplasm divides in a process called cytokinesis. The specific steps of cytokinesis differ depending on the type of cell that is dividing. In animal cells, the cell membrane contracts, or squeezes together, around the middle of the cell. Fibers around the center of the cell pull together. This forms a crease, called a furrow, in the middle of the cell. The furrow gets deeper and deeper until the cell membrane comes together and divides the cell. An animal cell undergoing cytokinesis is shown in **Figure 8.**

Cytokinesis in plants happens in a different way. As shown in **Figure 8,** a new cell wall forms in the middle of a plant cell. First, organelles called vesicles join together to form a membrane-bound disk called a cell plate. Then the cell plate grows outward toward the cell wall until two new cells form.

Reading Check Compare cytokinesis in plant and animal cells.

Results of Cell Division

Recall that the cell cycle results in two new cells. These daughter cells are genetically identical to each other and to the original cell that no longer exists. For example, a human cell has 46 chromosomes. When that cell divides, it will produce two new cells with 46 chromosomes each. The cell cycle is important for reproduction in some organisms, growth in multicellular organisms, replacement of worn out or damaged cells, and repair of damaged tissues.

Math Skills

Use Percentages

A percentage is a ratio that compares a number to 100. If the length of the entire cell cycle is 24 hours, 24 hours equals 100%. If part of the cycle takes 6.0 hours, it can be expressed as 6.0 hours/24 hours. To calculate percentage, divide and multiply by 100. Add a percent sign.

$$\frac{6.0}{24} = 0.25 \times 100 = 25\%$$

Practice

Interphase in human cells takes about 23 hours. If the cell cycle is 24 hours, what percentage is interphase?

Math Practice

Personal Tutor

Reproduction

In some unicellular organisms, cell division is a form of reproduction. For example, an organism called a paramecium often reproduces by dividing into two new daughter cells or two new paramecia. Cell division is also important in other methods of reproduction in which the offspring are identical to the parent organism.

Growth

Cell division allows multicellular organisms, such as humans, to grow and develop from one cell (a fertilized egg). In humans, cell division begins about 24 hours after fertilization and continues rapidly during the first few years of life. It is likely that during the next few years you will go through another period of rapid growth and development. This happens because cells divide and increase in number as you grow and develop.

Replacement

Even after an organism is fully grown, cell division continues. It replaces cells that wear out or are damaged. The outermost layer of your skin is always rubbing or flaking off. A layer of cells below the skin's surface is constantly dividing. This produces millions of new cells daily to replace the ones that are rubbed off.

Repair

Cell division is also critical for repairing damage. When a bone breaks, cell division produces new bone cells that patch the broken pieces back together.

Not all damage can be repaired, however, because not all cells continue to divide. Recall that mature nerve cells stop the cell cycle in interphase. For this reason, injuries to nerve cells often cause permanent damage.

Key Concept Check Why is the result of the cell cycle important?

MiniLab 20 minutes

How does mitosis work?

The dolix is a mythical animal whose cells contain just two chromosomes. What happens to a dolix cell nucleus during mitosis?

1. Read and complete a lab safety form.
2. Form four 60-cm lengths of **yarn** into large circles on four separate sheets of **paper.** Each piece of paper represents one phase of mitosis, and the yarn represents the cell membrane.
3. On each sheet of paper, model one phase of mitosis using different colors of yarn to represent the nuclear membrane, the spindles, and the chromosomes. Use **twist ties** to represent centromeres. **Tape** the yarn in place.
4. Label your models, or develop a key to indicate which color is used for which part.

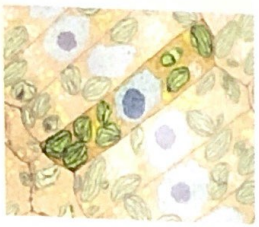
Analyze and Conclude

1. **Identify** If you were to model a dolix cell's nucleus before mitosis began, what would your model look like? Would you be able to see the individual chromosomes?
2. **Integrate** What would a model of your cell look like during the stage immediately following mitosis? What is this stage?
3. **Key Concept** During mitosis, a cell forms two new, identical nuclei. Use your models to explain why, in order to do this, mitosis must occur after events in interphase.

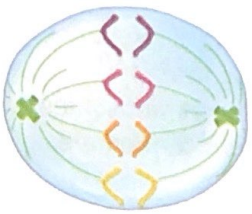
Lesson 1 Review

Online Quiz

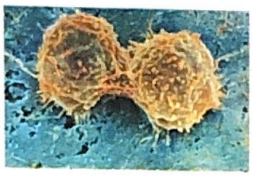
Visual Summary



During interphase, most cells go through periods of rapid growth and replication of organelles, copying DNA, and preparation for cell division.



The nucleus and its contents divide during mitosis.



The cytoplasm and its contents divide during cytokinesis.

FOLDABLES

Use your lesson Foldable to review the lesson. Save your Foldable for the project at the end of the chapter.

What do you think NOW?

You first read the statements below at the beginning of the chapter.

1. Cell division produces two identical cells.
2. Cell division is important for growth.
3. At the end of the cell cycle, the original cell no longer exists.

Did you change your mind about whether you agree or disagree with the statements? Rewrite any false statements to make them true.

Use Vocabulary

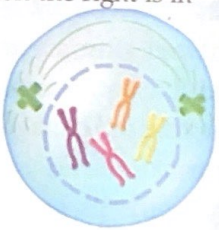
1. **Distinguish** between mitosis and cytokinesis.
2. A duplicated chromosome is made of two _____.
3. **Use the term** *interphase* in a sentence.

Understand Key Concepts

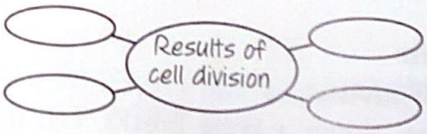
4. Which is NOT part of mitosis?
   - **A.** anaphase
   - **B.** interphase
   - **C.** prophase
   - **D.** telophase
5. **Construct** a table to show the different phases of mitosis and what happens during each.
6. **Give three examples** of why the result of the cell cycle is important.

Interpret Graphics

7. **Identify** The animal cell on the right is in what phase of mitosis? Explain your answer.



8. **Organize** Copy and fill in the graphic organizer below to show the results of cell division.



Critical Thinking

9. **Predict** what might happen to a cell if it were unable to divide by mitosis.

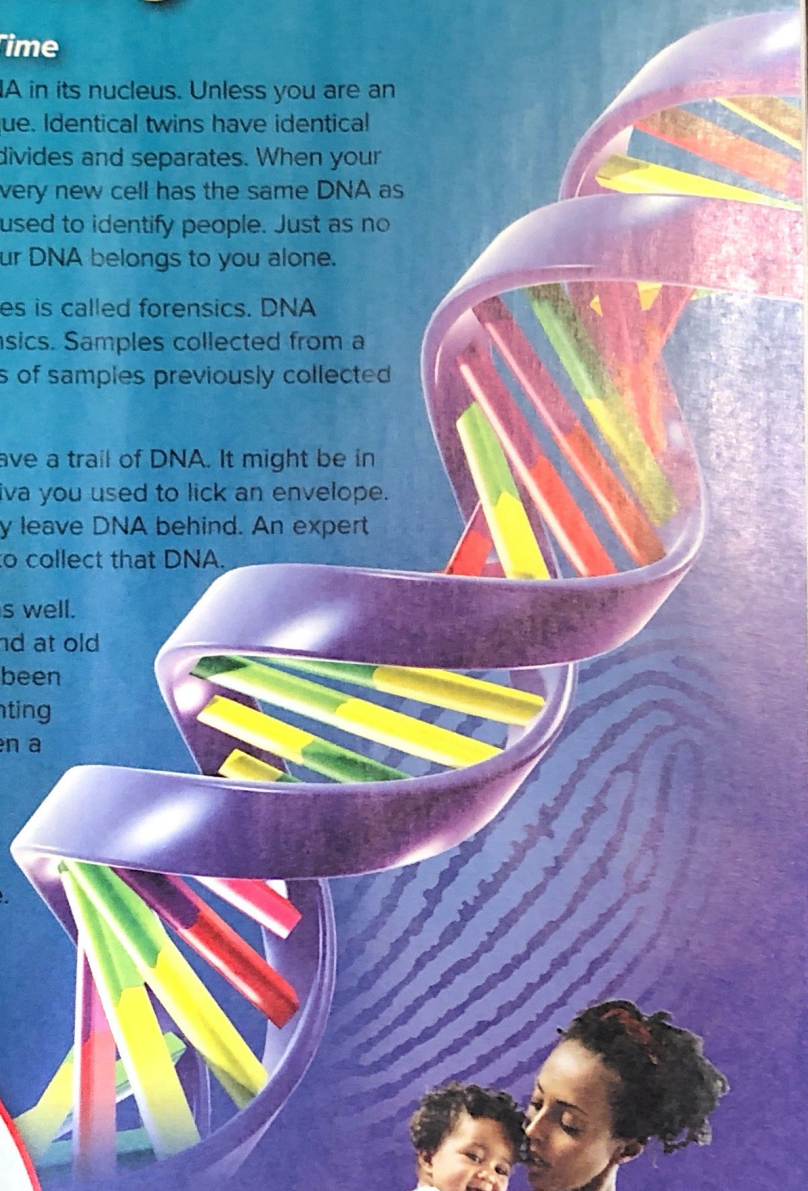
Math Skills — Math Practice

10. The mitotic phase of the human cell cycle takes approximately 1 hour. What percentage of the 24-hour cell cycle is the mitotic phase?

DNA Fingerprinting

SCIENCE & SOCIETY

▼ DNA



Solving Crimes One Strand at a Time

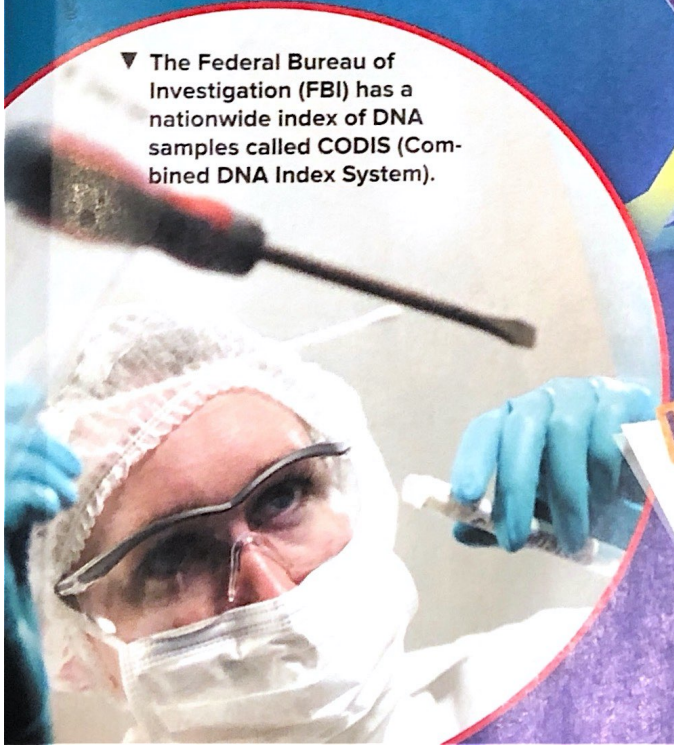
Every cell in your body has the same DNA in its nucleus. Unless you are an identical twin, your DNA is entirely unique. Identical twins have identical DNA because they begin as one cell that divides and separates. When your cells begin mitosis, they copy their DNA. Every new cell has the same DNA as the original cells. That is why DNA can be used to identify people. Just as no two people have the same fingerprints, your DNA belongs to you alone.

Using scientific methods to solve crimes is called forensics. DNA fingerprinting is now a basic tool in forensics. Samples collected from a crime scene can be compared to millions of samples previously collected and indexed in a computer.

Every day, everywhere you go, you leave a trail of DNA. It might be in skin cells. It might be in hair or in the saliva you used to lick an envelope. If you commit a crime, you will most likely leave DNA behind. An expert crime scene investigator will know how to collect that DNA.

DNA evidence can prove innocence as well. Investigators have reexamined DNA found at old crime scenes. Imprisoned persons have been proven not guilty through DNA fingerprinting methods that were not yet available when a crime was committed.

DNA fingerprinting can also be used to identify bodies that had previously been known only as a John or Jane Doe.



▼ The Federal Bureau of Investigation (FBI) has a nationwide index of DNA samples called CODIS (Combined DNA Index System).

It's Your Turn

DISCOVER Your cells contain organelles called mitochondria. They have their own DNA, called mitochondrial DNA. Your mitochondrial DNA is identical to your mother's mitochondrial DNA. Find out how this information is used.