Section 3

Cell Division

CALIFORNIA Standards Focus

S 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.

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

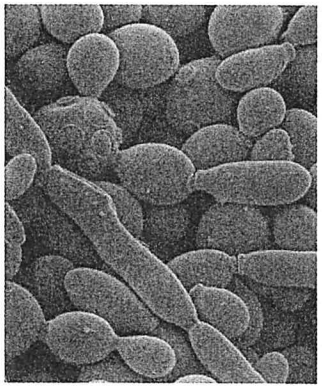
- What events take place during the three stages of the cell cycle?
- How does the structure of DNA help account for the way in which DNA copies itself?

Key Terms

- cell cycle
- interphase
- replication
- mitosis
- chromosome
- cytokinesis

Lab zone Standards Warm-Up

What Are the Yeast Cells Doing?

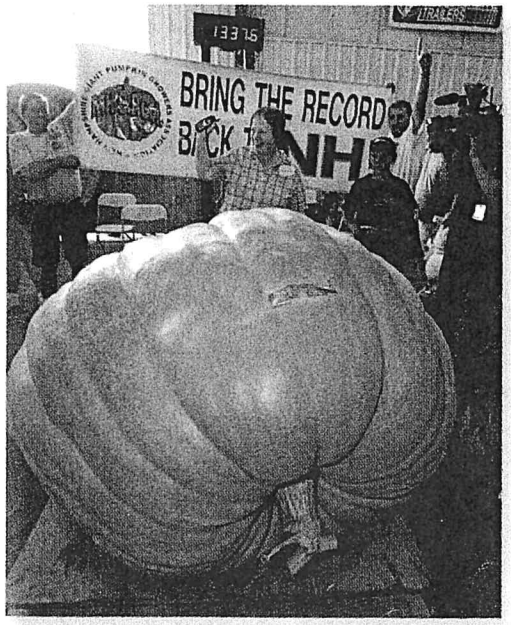


1. Use a plastic dropper to transfer some yeast cells from a yeast culture to a microscope slide. Your teacher has prepared the slide by drying methylene blue stain onto it. Add a coverslip and place the slide under a microscope.
2. Examine the cells on the slide. Use low power first, then high power. Look for what appears to be two cells attached to each other. One cell may be larger than the other. Draw what you see.

Think It Over

Developing Hypotheses What process do you think the "double cells" are undergoing? Develop a hypothesis that might explain what you see.

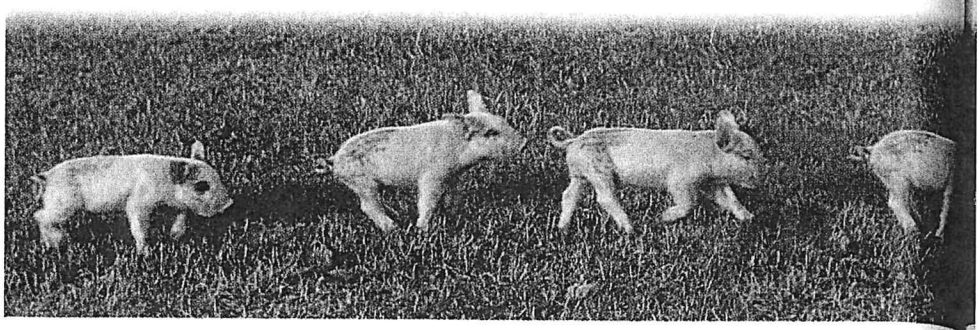
In the early autumn, many local fairs run pumpkin contests. Proud growers enter their largest pumpkins, hoping to win a prize. The pumpkin below has a mass greater than 600 kilograms! This giant pumpkin began as a structure inside a small flower. How did the pumpkin grow so big?



◀ Prize-winning pumpkin

A pumpkin grows in size by increasing both the size and the number of its cells. A single cell grows and then divides, forming two cells. Then two cells grow and divide, forming four, and so on. This process of cell growth and division does not occur only in pumpkins, though. In fact, many cells in your body are dividing as you read this page.

Video Field Trip
Discovery Channel School
Cell Processes and Energy



Stage 1: Interphase

How do little pigs get to be big pigs? Their cells grow and divide, over and over. The regular sequence of growth and division that cells undergo is known as the **cell cycle.** During the cell cycle, a cell grows, prepares for division, and divides into two new cells, which are called "daughter cells." Each of the daughter cells then begins the cell cycle again. You can see details of the cell cycle in Figure 12. Notice that the cell cycle is divided into three main stages: interphase, mitosis, and cytokinesis.

The first stage of the cell cycle is called **interphase.** Interphase is the period before cell division. **During interphase, the cell grows, makes a copy of its DNA, and prepares to divide into two cells.**

Growing During the first part of interphase, the cell grows to its full size and produces structures it needs. For example, the cell makes new ribosomes and produces enzymes. Copies are made of both mitochondria and chloroplasts.

Copying DNA In the next part of interphase, the cell makes an exact copy of the DNA in its nucleus in a process called **replication.** Recall that DNA is found in the thin strands of chromatin in the nucleus. During interphase, the chromatin appears as a dense mass within a clearly defined nucleus.

DNA holds all the information that the cell needs to carry out its functions. Replication of DNA is very important, since each daughter cell must have a complete set of DNA to survive. At the end of DNA replication, the cell contains two identical sets of DNA. You will learn the details of DNA replication later in this section.

Preparing for Division Once the DNA has replicated, preparation for cell division begins. The cell produces structures that it will use to divide into two new cells. At the end of interphase, the cell is ready to divide.

Lab zone Try This Activity

Modeling Mitosis

Refer to Figure 12 as you carry out this activity.

1. Construct a model of a cell that has four chromosomes. Use a piece of construction paper to represent the cell. Use different-colored pipe cleaners to represent the chromosomes. Make sure that the chromosomes look like double rods.
2. Position the chromosomes in the cell where they would be during prophase.
3. Repeat Step 2 for metaphase, anaphase, and telophase.

Making Models How did the model help you understand the events of mitosis?

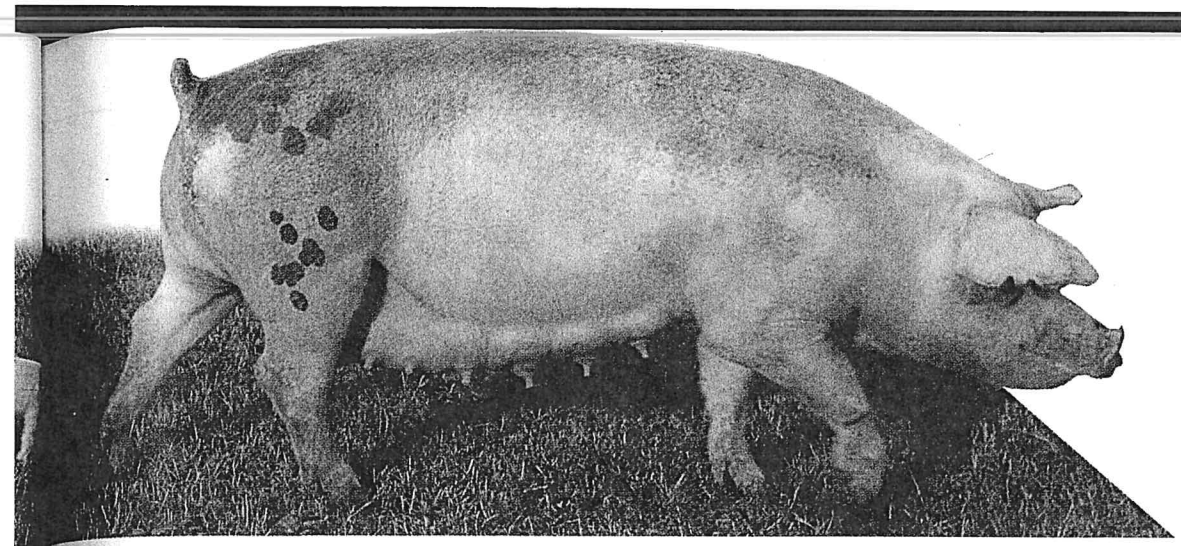


FIGURE 10
Bigger Pig, More Cells
The mother pig has more cells in her body than her small piglets.

Stage 2: Mitosis

Once interphase is complete, the second stage of the cell cycle begins. **Mitosis** (my TOH sis) is the stage during which the cell's nucleus divides into two new nuclei. **During mitosis, one copy of the DNA is distributed into each of the two daughter cells.**

Scientists divide mitosis into four parts, or phases: prophase, metaphase, anaphase, and telophase. During prophase, the threadlike chromatin in the nucleus condenses to form double-rod structures called **chromosomes** (KROH muh sohmz). Each chromosome has two rods because the cell's DNA has replicated, and each rod in a chromosome is an exact copy of the other. Each identical rod in a chromosome is called a chromatid. Notice in Figure 11 that the two chromatids are held together by a structure called a centromere.

As the cell progresses through metaphase, anaphase, and telophase, the chromatids separate from each other and move to opposite ends of the cell. Then two nuclear envelopes form around the new chromosomes at the two ends of the cell.

FIGURE 11
Chromosomes
During mitosis, the chromatin condenses to form chromosomes. Each chromosome consists of two identical rods, or chromatids.
Applying Concepts *During which phase of mitosis do the chromosomes form?*

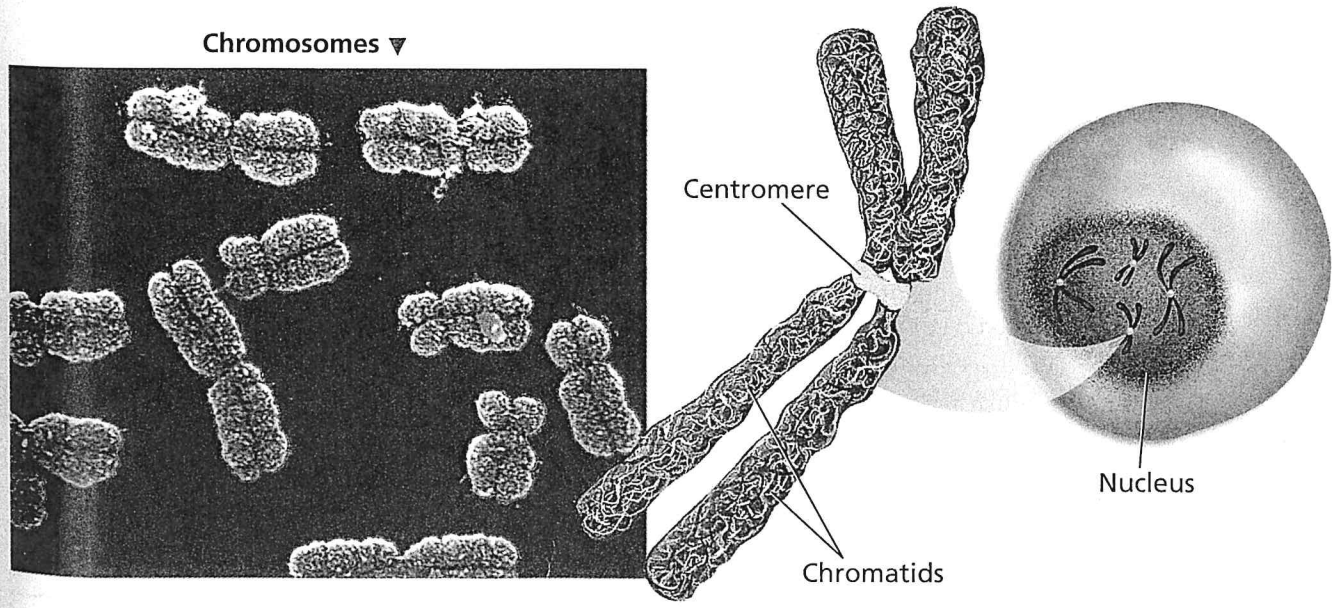
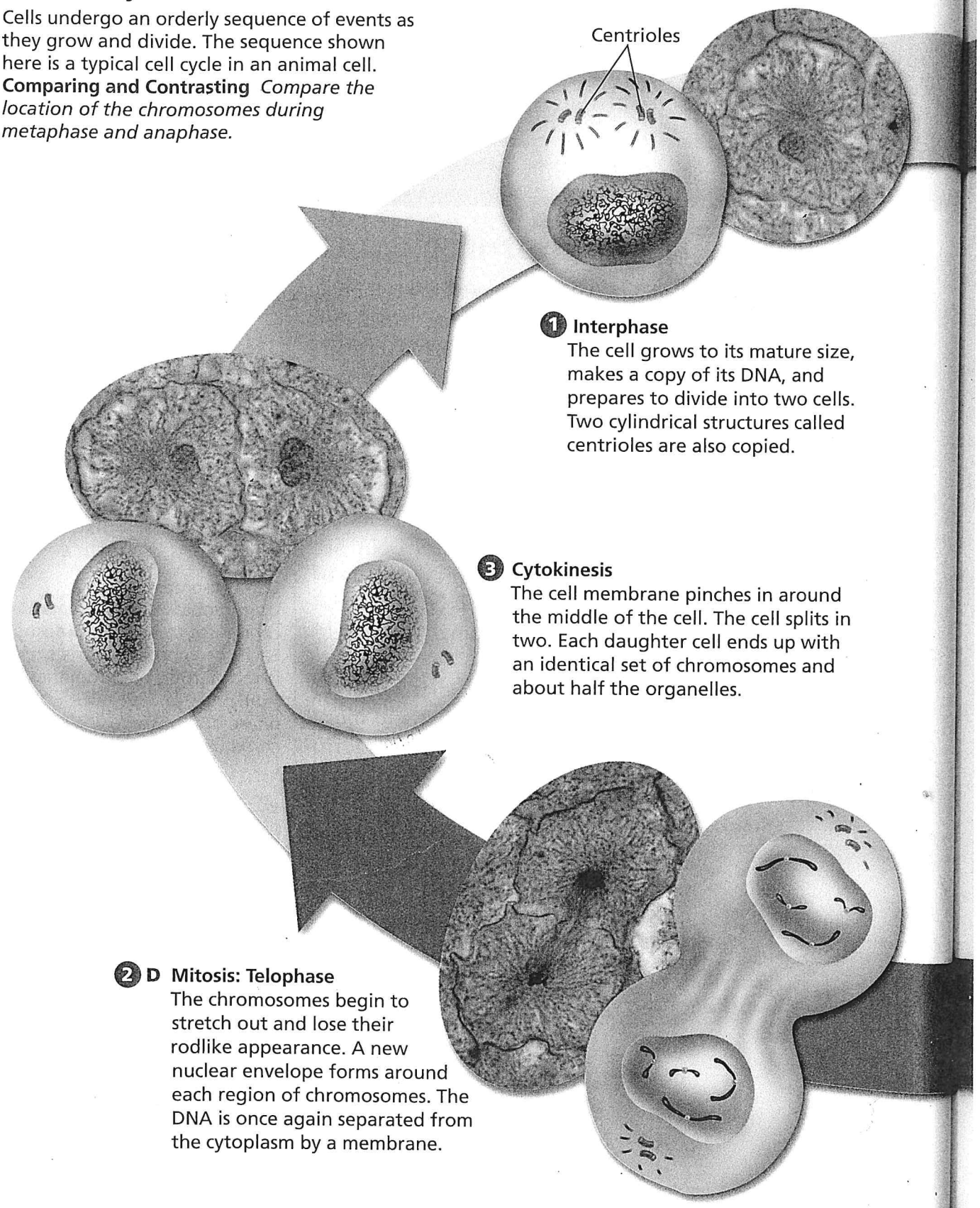


FIGURE 12

The Cell Cycle

Cells undergo an orderly sequence of events as they grow and divide. The sequence shown here is a typical cell cycle in an animal cell.
Comparing and Contrasting *Compare the location of the chromosomes during metaphase and anaphase.*



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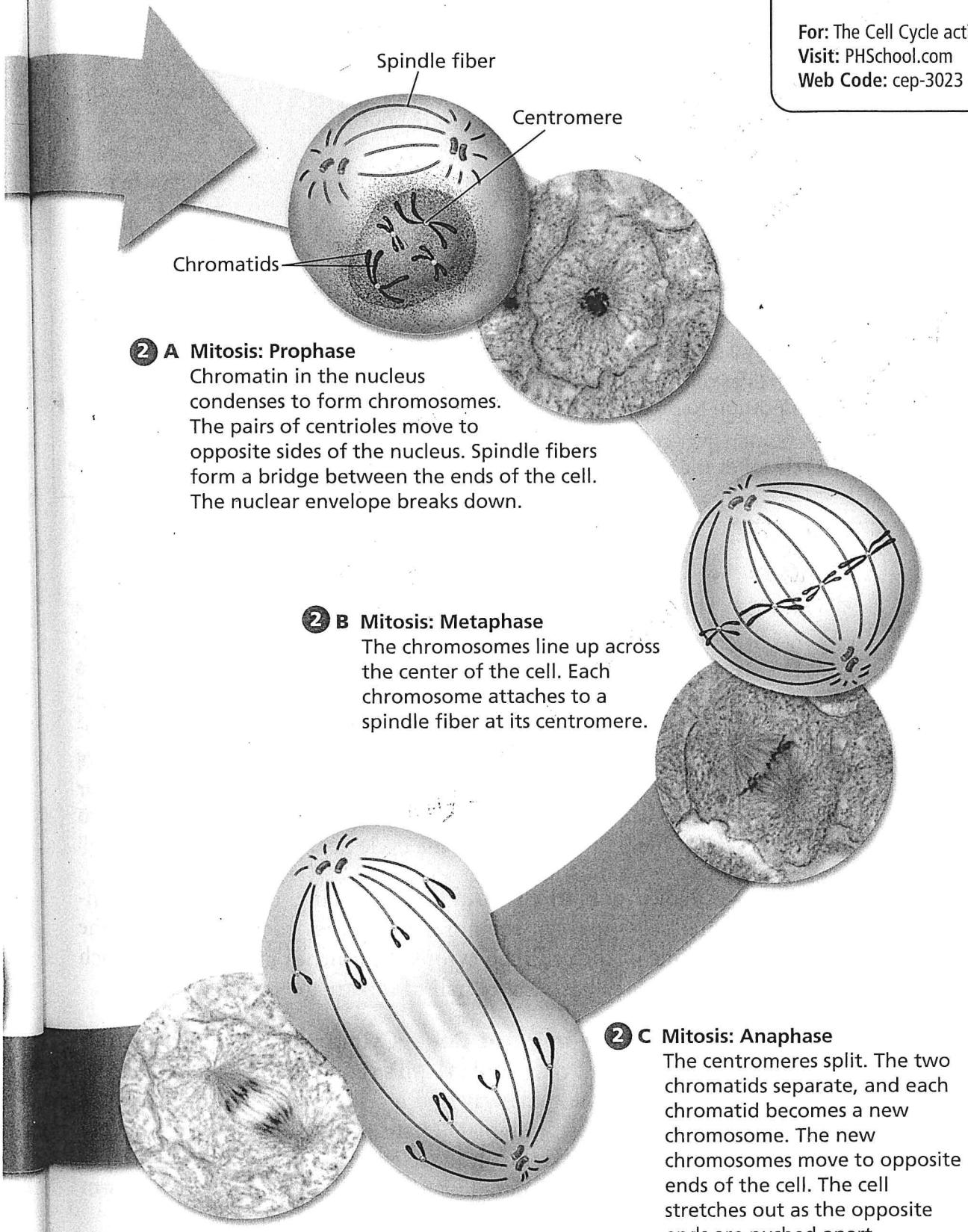


2 A Mitosis: Prophase
Chromatin in the nucleus condenses to form chromosomes. The pairs of centrioles move to opposite sides of the nucleus. Spindle fibers form a bridge between the ends of the cell. The nuclear envelope breaks down.

2 B Mitosis: Metaphase
The chromosomes line up across the center of the cell. Each chromosome attaches to a spindle fiber at its centromere.

2 C Mitosis: Anaphase
The centromeres split. The two chromatids separate, and each chromatid becomes a new chromosome. The new chromosomes move to opposite ends of the cell. The cell stretches out as the opposite ends are pushed apart.

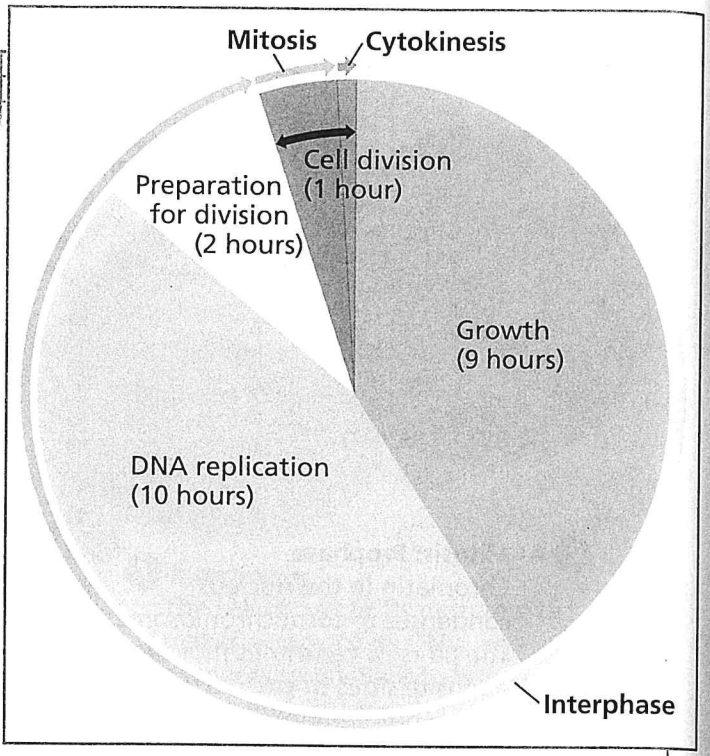
Math: Algebra and Functions 7.1.5

Math Analyzing Data

Length of the Cell Cycle

How long does it take for a cell to go through one cell cycle? It all depends on the cell. A human liver cell, for example, completes one cell cycle in about 22 hours, as shown in the graph. Study the graph and then answer the following questions.

1. **Reading Graphs** What do the three curved arrows outside the circle represent?
2. **Reading Graphs** In what stage of the cell cycle is the wedge representing growth?
3. **Interpreting Data** In human liver cells, how long does it take DNA replication to occur?
4. **Drawing Conclusions** In human liver cells, what stage in the cell cycle takes the longest time?



Stage 3: Cytokinesis

The final stage of the cell cycle, which is called **cytokinesis** (sy toh kih NEE sis), completes the process of cell division. **During cytokinesis, the cytoplasm divides. The organelles are distributed into each of the two new cells.** Cytokinesis usually starts at about the same time as telophase. When cytokinesis is complete, two new cells, or daughter cells, have formed. Each daughter cell has the same number of chromosomes as the original parent cell. At the end of cytokinesis, each cell enters interphase, and the cycle begins again.

Cytokinesis in Animal Cells During cytokinesis in animal cells, the cell membrane squeezes together around the middle of the cell. The cytoplasm pinches into two cells. Each daughter cell gets about half of the organelles.

Cytokinesis in Plant Cells Cytokinesis is somewhat different in plant cells. A plant cell's rigid cell wall cannot squeeze together in the same way that a cell membrane can. Instead, a structure called a cell plate forms across the middle of the cell. The cell plate gradually develops into new cell membranes between the two daughter cells. New cell walls then form around the cell membranes.

Reading Checkpoint **During what phase of mitosis does cytokinesis begin?**

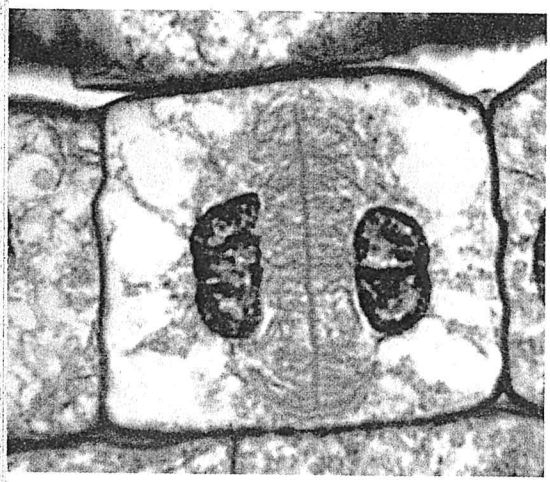


FIGURE 13
Cytokinesis in Plant Cells
During cytokinesis in plant cells, a cell plate forms between the two new nuclei.
Applying Concepts *What is the function of the cell plate?*

Structure and Replication of DNA

DNA replication ensures that each daughter cell will have the genetic information it needs to carry out its activities. Before scientists could understand how DNA replicates, they had to know its structure. In 1952, Rosalind Franklin used an X-ray method to photograph DNA molecules. Her photographs helped James Watson and Francis Crick figure out the structure of DNA in 1953.

The Structure of DNA If you were to unravel a chromosome, you would find that the DNA strands are wound tightly around proteins. The proteins help support the chromosome's structure. Notice in Figure 14 that the strands of the DNA molecule look like a twisted ladder. The two sides of the DNA ladder are made up of molecules of a sugar called deoxyribose, alternating with molecules known as phosphates.

Each rung is made up of a pair of molecules called nitrogen bases. Nitrogen bases are molecules that contain the element nitrogen and other elements. DNA has four kinds of nitrogen bases: adenine (AD uh neen), thymine (THY meen), guanine (GWAH neen), and cytosine (SY tuh seen). The capital letters A, T, G, and C are used to represent the four bases.

The bases on one side of the ladder pair with the bases on the other side. Adenine (A) only pairs with thymine (T), while guanine (G) only pairs with cytosine (C). This pairing pattern is the key to understanding how DNA replication occurs.

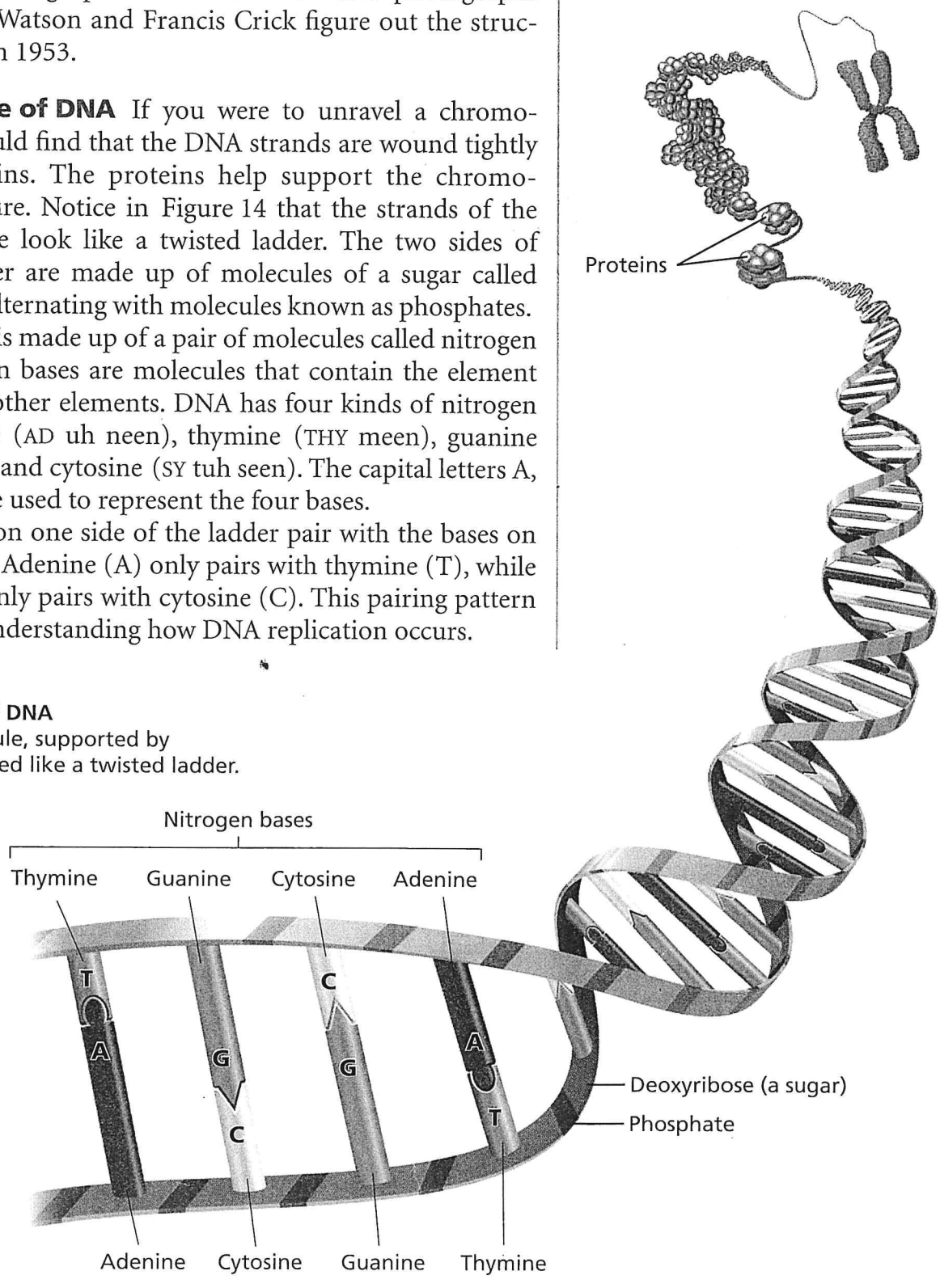


FIGURE 14
The Structure of DNA
The DNA molecule, supported by proteins, is shaped like a twisted ladder.

FIGURE 15
DNA Replication
During DNA replication, a DNA molecule "unzips" between its paired bases. New bases pair with the bases on each old strand. As a result, two identical DNA strands form.

The Replication Process DNA replication begins when the two sides of the DNA molecule unwind and separate, somewhat like a zipper unzipping. As you can see in Figure 15, the molecule separates between the paired nitrogen bases.

Next, nitrogen bases that are floating in the nucleus pair up with the bases on each half of the DNA molecule. **Because of the way in which the nitrogen bases pair with one another, the order of the bases in each new DNA molecule exactly matches the order in the original DNA molecule.** Adenine always pairs with thymine, while guanine always pairs with cytosine. Once the new bases are attached, two new DNA molecules are formed.

Reading Checkpoint **During DNA replication, which base pairs with guanine?**

Section 3 Assessment

S 7.1.e, 7.2.e E-LA: Reading 7.1.2, Writing 7.2.0

Build Science Vocabulary **Greek Word Origins** The Greek word *kinesis* means "motion." During cytokinesis, what motion occurs?

Reviewing Key Concepts

1. a. **Reviewing** What are the three stages of the cell cycle?
   b. **Summarizing** Summarize what happens to chromosomes during the stage of the cell cycle in which the nucleus divides. Include the terms *prophase, metaphase, anaphase,* and *telophase.*
   c. **Interpreting Diagrams** Look at Figure 12. What is the role of spindle fibers during cell division?
2. a. **Listing** List the nitrogen bases in DNA.
   b. **Describing** Describe how the nitrogen bases pair in a DNA molecule.
   c. **Inferring** One section of a strand of DNA has the base sequence AGATTC. What is the base sequence on the other strand?

Writing in Science

Writing Instructions Imagine that you work in a factory where cells are manufactured. Write instructions for newly forming cells on how to carry out cytokinesis. Provide instructions for both plant and animal cells.

Section 4

Cell Differentiation

CALIFORNIA Standards Focus

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

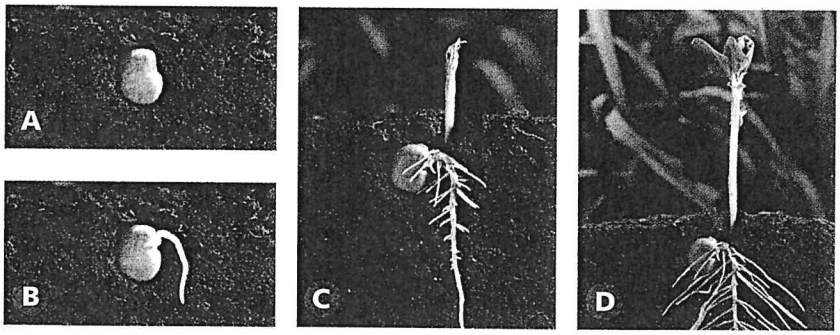
- What is differentiation?
- What factors influence how and when cells differentiate within different organisms?

Key Terms

- differentiation
- stem cell

Lab zone Standards **Warm-Up**

How Is It Different?



1. Study the photos above of a growing bean plant.
2. Write your observations about how the plant changes in structure in each stage of its development.

Think It Over

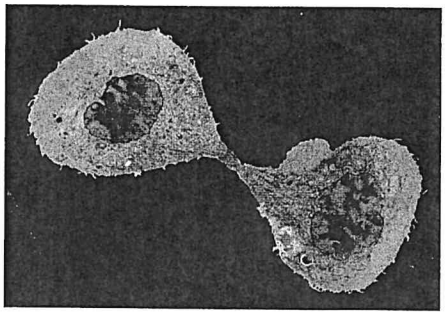
Forming Operational Definitions As the plant grows, its cells divide and undergo a process called differentiation. Based on your observations, what does differentiation mean?

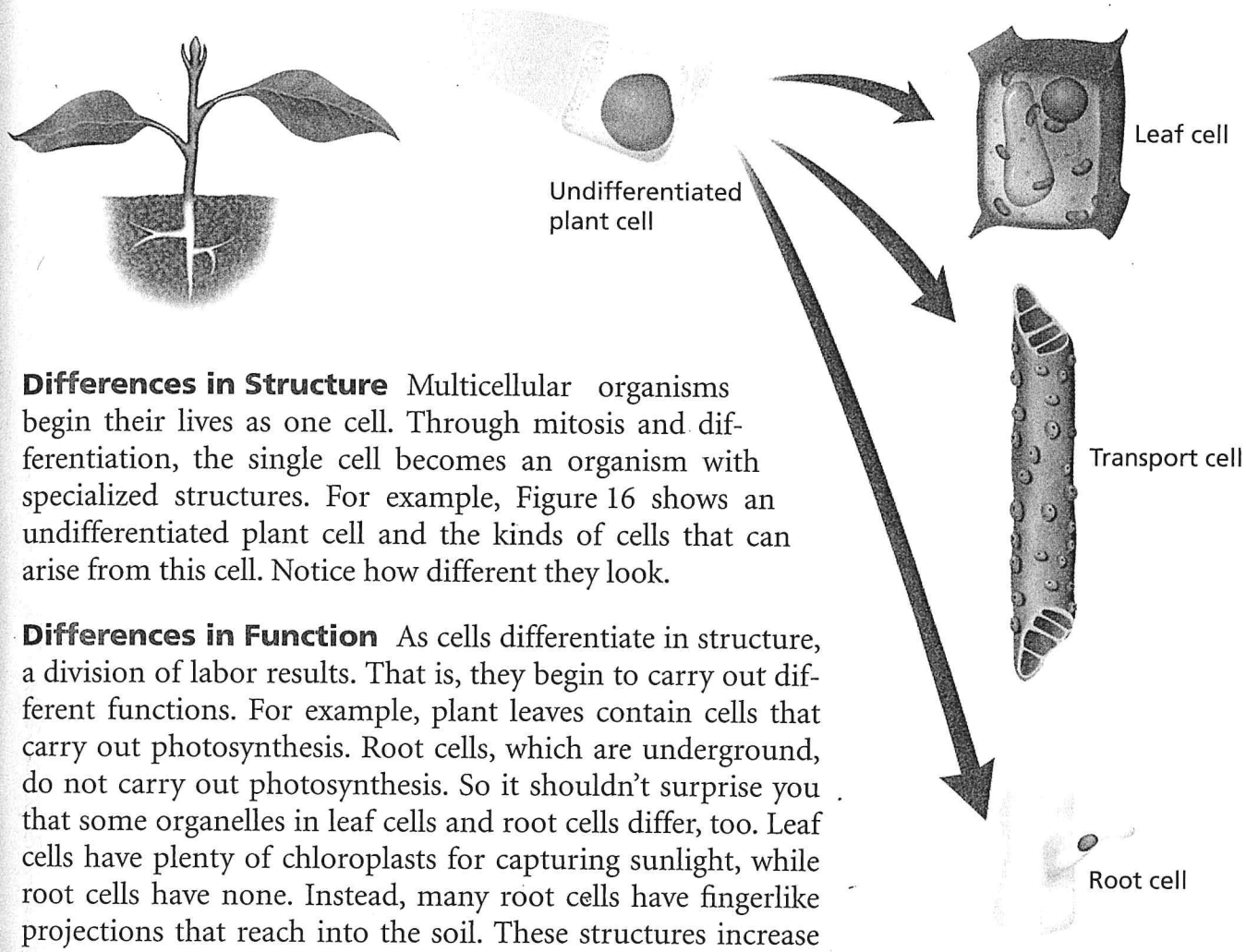
You have learned that the cell theory states that living things are made of cells. Some living things are single-celled, or unicellular, organisms. Other living things are multicellular. They consist of many kinds of cells that differ from one another. The cell theory also says that cells are produced from other cells. When a cell divides by mitosis, it produces two daughter cells with identical sets of chromosomes. So how do cells in multicellular organisms become different from one another?

Differentiation

Cell division alone cannot explain the development of new structures. If cells only divided, the result would merely be a big ball of identical cells. Instead, cells differentiate. **Differentiation** is the process by which cells change in structure and become capable of carrying out specialized functions. **As cells differentiate, they become different from one another. They also form groups made of other, similarly specialized cells. These groups then form tissues and organs.**

A skin cell undergoes mitosis. ▼





Differences in Structure Multicellular organisms begin their lives as one cell. Through mitosis and differentiation, the single cell becomes an organism with specialized structures. For example, Figure 16 shows an undifferentiated plant cell and the kinds of cells that can arise from this cell. Notice how different they look.

Differences in Function As cells differentiate in structure, a division of labor results. That is, they begin to carry out different functions. For example, plant leaves contain cells that carry out photosynthesis. Root cells, which are underground, do not carry out photosynthesis. So it shouldn't surprise you that some organelles in leaf cells and root cells differ, too. Leaf cells have plenty of chloroplasts for capturing sunlight, while root cells have none. Instead, many root cells have fingerlike projections that reach into the soil. These structures increase the amount of water the root cells can absorb from the soil.

Tissues, Organs, and Systems When cells differentiate, they also become organized. At first, they group into tissues. Such cells work together, carrying out specific functions. For example, muscle cells in animals become organized into long strands of muscle tissue that can move legs or arms. Groups of tissues can combine to form organs, such as the roots of a plant or the stomach of an animal. Systems, such as the digestive system, begin to function as organs and tissues work together.

Increasingly Specialized Cells As development continues, more fine-grained differentiation occurs. For example, the retina in your eye consists of two types of cells that are sensitive to light. Rod cells function in dim light but cannot detect color. Cone cells detect color, but require brighter light to function. The cells of your retina differentiated early in your development. Rods and cones differentiated later.

Reading Checkpoint **What is the result of cell differentiation?**

FIGURE 16
Specialized Cells
Plants have undifferentiated cells in their stems and roots that can give rise to different kinds of cells.
Inferring *Can photosynthesis take place in a root cell? Why or why not?*

How Cells Differentiate

During development, cells become fixed—or set—in how they will differentiate. The instructions that determine what will happen to a cell are coded in the DNA in its nucleus. Differentiation occurs when certain sections of DNA are turned off. The active DNA then guides how the cell develops. **Once a cell's future has been determined, when and how much it changes depends on its DNA, its function, and the type of organism.** Some cells differentiate completely during development. Others do not change until later in the life of an organism.

Cell Differentiation Among Animals Did you know that a lizard that loses its tail can grow a new one? Many adult animals, such as insects and some crustaceans and reptiles, can grow a limb or a tail to replace a lost one. Cells at the point of injury can differentiate, forming new muscle, bone, blood, and nerves.

The replacement of lost body parts in lizards and some other animals does not occur in humans. Once human cells differentiate, they usually lose the ability to become other types of cells. A blood cell cannot change into a skin cell, for instance. However, humans do produce certain cells—called **stem cells**—that can differentiate throughout life. Stem cells exist all around the body. These cells can respond to specific needs in the body by becoming specialized. For example, your body needs a constant supply of new blood cells to replace older cells. Every day, stem cells produce a steady supply of blood cells. These include red cells that carry oxygen, white cells that fight infection, and other cells needed in the blood.

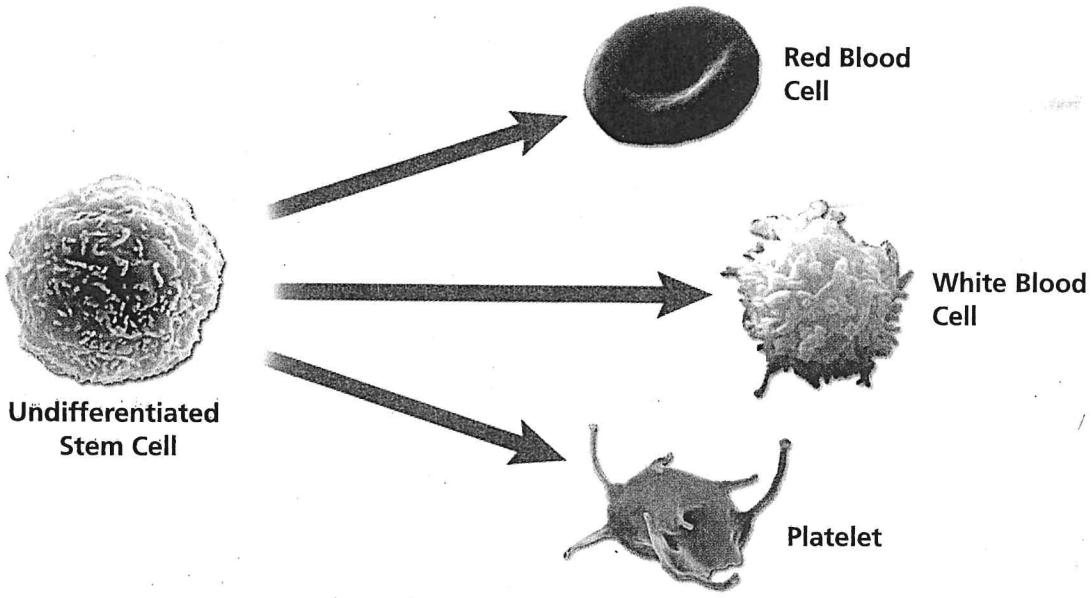
Reading Checkpoint **What kind of cells can stem cells produce in the human body?**

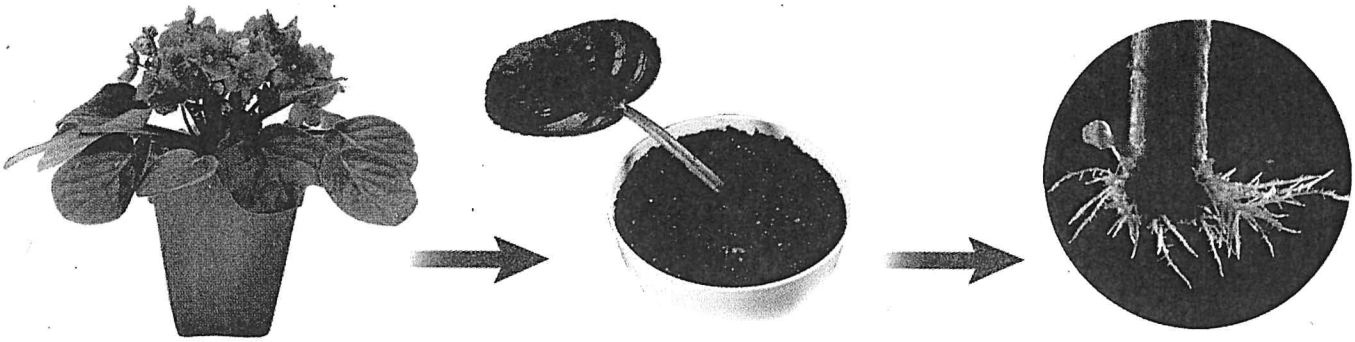
FIGURE 17

A Source of Blood Cells

Different types of blood cells can form when stem cells undergo differentiation.

Observing *How do the structures of red blood cells and white blood cells differ?*





African violet plant

The leaf is cut and transferred to soil.

Cell differentiation leads to new root and leaf tissues.

Cell Differentiation in Plants Cells differentiate in developing plants much the same way they do in animals. Differentiated cells become grouped into the tissues that make up the roots, stems, and leaves. Cells also continue to differentiate further within each kind of organ. For example, some cells in the stem become specialized as the tubes that transport food and water through the plant.

Many plants have the ability to grow throughout their lives. This growth happens because certain cells in the roots and stems of plants are not fixed in their development. These cells can undergo rapid cell division and differentiation, increasing the size of the roots and stems. It can also lead to the growth of new roots, stems, and leaves. For example, if a leaf of an African violet plant is cut off and put into soil or water, its stem will begin to grow roots! Eventually, more cells will differentiate into root cells and stem cells, and a new plant grows. Gardeners use this technique to create many plants from one original plant.

FIGURE 18

A New Plant

The stem of a leaf from an African violet plant gives rise to the structures of a new plant.

Section 4 Assessment

S 7.1.f, E-LA: Reading 7.2.4

Target Reading Skill **Create Outlines** Use your completed outline to help answer the questions below.

Reviewing Key Concepts

1. a. **Describing** What happens to cells when they undergo differentiation?
   b. **Explaining** How does differentiation lead to tissues and organs in a developing organism?
   c. **Applying Concepts** How does the phrase *division of labor* relate to differentiation?
2. a. **Identifying** Name two factors that affect how and when cells differentiate.
   b. **Relating Cause and Effect** What stimulates human stem cells to differentiate into specialized blood cells?
   c. **Comparing and Contrasting** How does the ability of cells to differentiate in humans compare to the ability in plants?

Lab zone At-Home Activity

Model Differences Use a ball of clay to represent a single cell. Divide the "cell" into two smaller ones, and then again into four. Fashion each "cell" into a different shape. Then divide each shape in two, and reshape the new pieces to look like the shape they came from. Explain to a family member how your clay models represent cell differentiation in a developing organism.