

Mitosis is the basis of asexual reproduction.

Have you ever seen a body of water like this? If you have, then you have witnessed an algae bloom or red tide. A single red tide can affect a large area of ocean, such as the coastal waters along the island of Newfoundland. A red tide can produce toxins in organisms such as clams, mussels, and oysters. If eaten, these organisms can cause paralytic shellfish poisoning, which can result in severe illness or death. Red tides are caused by tiny organisms called dinoflagellates. These single-celled algae can reproduce at astounding rates if conditions are favourable. In this chapter, you will explore the method of reproduction that enables dinoflagellates to reproduce so quickly.

What You Will Learn

In this chapter, you will

- **demonstrate** an understanding of the cell cycle
- **explain** what happens to the chromosomes, nucleus, and cell membrane during mitosis
- **describe** some types of asexual reproduction
- **compare** the advantages and disadvantages of asexual reproduction

Why It Is Important

Understanding mitosis and asexual reproduction is important for understanding how our body cells maintain themselves and how certain organisms in our environment reproduce. Such knowledge has been used for centuries to develop food crops and most recently to clone animals.

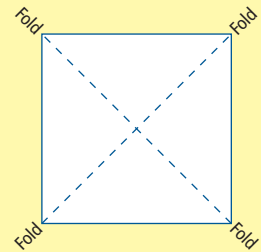
Skills You Will Use

In this chapter, you will

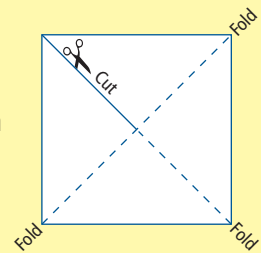
- **model** the cell cycle
- **observe** asexual reproduction
- **graph** results

Make the following Foldable and use it to take notes on what you learn in Chapter 5.

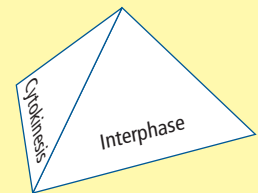
- STEP 1** **Fold** a large square of paper diagonally to form an X as illustrated.



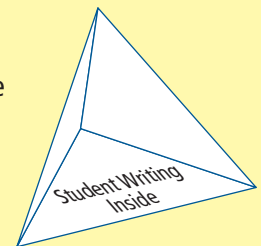
- STEP 2** **Cut** along one of the fold lines, stopping at the centre intersection point. This cut will form two “legs” or sections.



- STEP 3** **Fold** and glue one of these legs under the other to form a three-sided pyramid. Use a computer to generate three labels—Interphase, Mitosis, Cytokinesis—and glue them onto the outer sides of the pyramid.



- STEP 4** **Lay** the pyramid on its side to write notes inside on the triangular sections.



Show a Cycle This pyramid is perfect for illustrating cycles that occur in threes or other information that is always in threes. For example, this pyramid could be used for the water cycle (evaporation, condensation, precipitation); the states of matter (solid, liquid, gas); or the three types of galaxies (irregular, spiral, elliptical).

5.1 The Cell Cycle and Mitosis

There are three stages in the cell cycle. Interphase is the stage in which cells carry out the functions necessary for survival and cells that divide prepare for cell division. Mitosis divides the duplicated contents of the cell's nucleus into two equal parts. Cytokinesis separates the two nuclei and cell contents into two daughter cells. Proteins monitor the activities of the cell at checkpoints in the cell cycle. Cancer may result when errors occur in the cell cycle.

Key Terms

cell cycle
cytokinesis
interphase
mitosis
replication

If you look around your home carefully, you will find some skin cells left behind by your family or friends. That grey dust ball in the corner is mostly human skin. The tiny flakes of skin that we lose on a daily basis create more than 70 percent of the dust in your home and in your classroom. Each day, you shed millions of skin cells per hour (Figure 5.1). Each month, you completely replace the outer layer, or epidermis, of your skin.

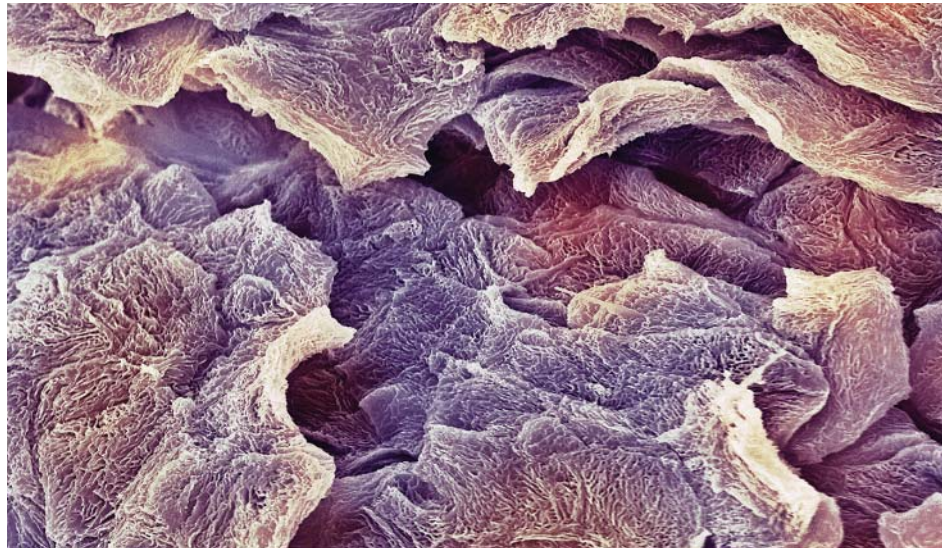


Figure 5.1 Dead skin cells. You are constantly shedding your outer layer of skin cells. Replacement skin cells form underneath this layer.

Word Connect

The word “amphibian” refers to an organism that can live both in water and on land. Amphibian comes from the Greek words *amphi*, which means on both sides, and *bios*, which means life.

When humans shed millions of skin cells each day, it is really not noticeable. Other animals such as snakes and lizards shed their whole skin at once. Replacing worn-out skin cells is an ongoing process for humans. For snakes, shedding occurs several times a year, and each shed takes several days. Newly hatched snakes may shed their skins twice a month, whereas adult snakes shed three to four times a year.

In 2006, scientists reported that a legless, underground-dwelling amphibian, called *Boulengerula taitanus*, develops a new layer of skin for a different reason. *B. taitanus* is found in Kenya, Africa, and hatchlings

are born with specialized teeth for peeling and eating skin. Their mother's skin is thick and rich in fat, and the young strip off and feed on her skin for up to four weeks.

Biologists report that the young press their heads against their mother, move over her body, and repeatedly chew on her skin with their specialized teeth (Figure 5.2A). Some teeth are spoon-shaped for scraping, and some have spiked points for piercing the skin. Other teeth look like grappling hooks with a claw-like structure on one end designed for staying tightly attached to the mother (Figure 5.2B). A mother loses 14 percent of her body weight during this feeding period and does not appear to be harmed.

The process of producing new skin for replacement, for growth, or—in the case of *B. taitanus*—for lunch, requires that cells divide. Cell division is strictly controlled by specialized proteins in the nucleus.

Did You Know?

You have 50 million trillion to 100 million trillion cells in your body. Every minute, your body produces about 300 million new cells.

Suggested Activity

Find Out Activity 5-1A on page 138



Figure 5.2 Young *B. taitanus* feeding on mother's skin (A). Close-up of one of the types of teeth used to strip off the mother's skin (B).

B. taitanus mothers must produce new skin cells to nourish their offspring for up to four weeks. In this activity, you will calculate how many skin cells will result from just one cell that continually divides during a 30 d period.

What to Do

- Copy the cell division chart below into your notebook.

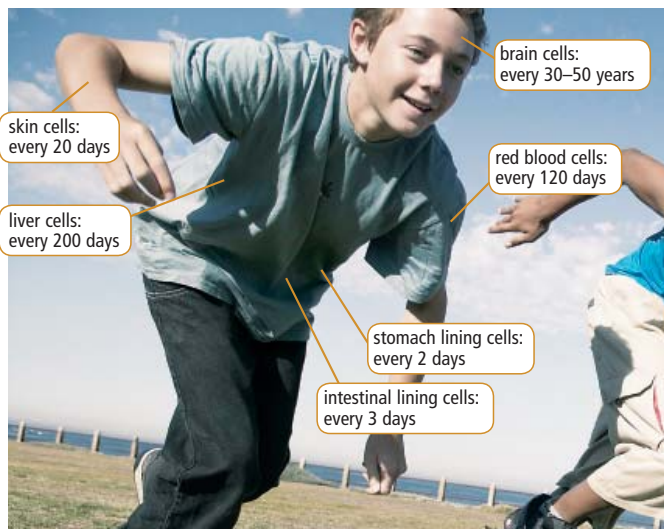
Day	Number of Cells	Day	Number of Cells	Day	Number of Cells
1		11		21	
2		12		22	
3		13		23	
4		14		24	
5		15		25	
6		16		26	
7		17		27	
8		18		28	
9		19		29	
10		20		30	

- Assume that the cells divide once a day. Calculate how many cells will result in 30 d, if the cells do not stop dividing at any time during the 30 d period.
- A mass of cells would become just visible to the eye at about 1 mm in width, which is about 250 000 cells. Calculate approximately on which day the cells would be visible.

- Use the information in your chart to plot a graph of cell number versus time.
- Use your graph to determine approximately how many cells would be present after
 - 5.5 d of growth.
 - 17.5 d of growth.

What Did You Find Out?

- If a scientist detected a tumour 1 cm in width, how many days would the cells have divided for the tumour to reach this size?
- What do you think would happen if all cells in the human body continually divided without stopping?
- Look at the pattern in the numbers you entered in the chart. How could you quickly calculate the number of cells that would be present after a particular number of days had passed?
- Without doing additional calculations, could you predict from your graph approximately how many cells would be present after 40 d of growth?
 - In order to make the estimate in (a), you must assume that the pattern of cell growth will remain the same after 30 d. Do you think it is likely that these skin cells would continue to multiply at the same rate indefinitely?



Cell Replacement and Development

From the time your life began as a fertilized egg, your cells have continued to divide as you have continued to grow. After puberty, your body growth slows. But your body will continue to replace cells that take a lot of wear and tear such as skin cells, stomach cells, and intestinal cells. Cells such as muscle and nerve cells usually do not continue to divide in an adult, but they do continue to carry out functions necessary for survival. Figure 5.3 shows the different life spans of a variety of human body cells.

Figure 5.3 Cells in the human body divide at different rates.

The Cell Cycle

The life of a cell is divided into three stages known as the **cell cycle** (Figure 5.4). The stages of the cell cycle are interphase, mitosis, and cytokinesis.

- Interphase is the stage in which cells carry out the functions necessary for survival and cells that divide prepare for reproduction.
- Mitosis divides the duplicated contents of the cell's nucleus into two equal parts.
- Cytokinesis separates the two nuclei and cell contents into two daughter cells.

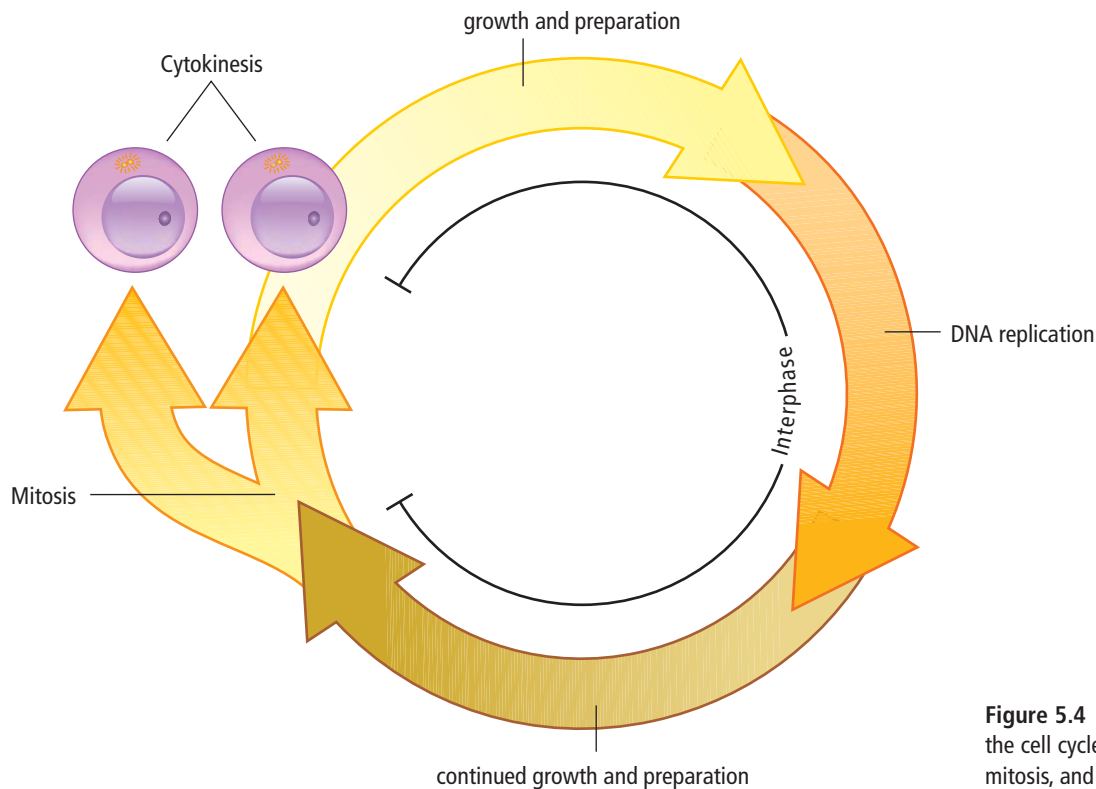


Figure 5.4 The stages of the cell cycle: interphase, mitosis, and cytokinesis

Interphase

Figure 5.4 shows that **interphase** is the longest stage in the cell cycle. This is a time when a cell carries out its various functions within the organism. For example, a cell in your stomach lining might be making and releasing enzyme molecules that aid in digesting the food you eat. During interphase, the cell roughly doubles everything in its cytoplasm.

Growth and preparation

During the first phase of interphase, a cell increases in size and makes the proteins and molecules necessary for the cell to function. Some organelles begin to duplicate.

Replication

In the next phase, DNA copies or makes a “replica” of itself in a process called **replication**. During replication, the cell copies the 3 billion base pairs of DNA information in the nucleus of the cell. Then the cell temporarily has two complete sets of DNA. Enzymes control this process.

To replicate itself, the DNA molecule unwinds and the steps of the DNA ladder break apart as shown in Figure 5.5. Each side then becomes a pattern or a template on which a new side forms. The process of replication results in two new DNA molecules that have the same sequence of bases as the original DNA molecule.

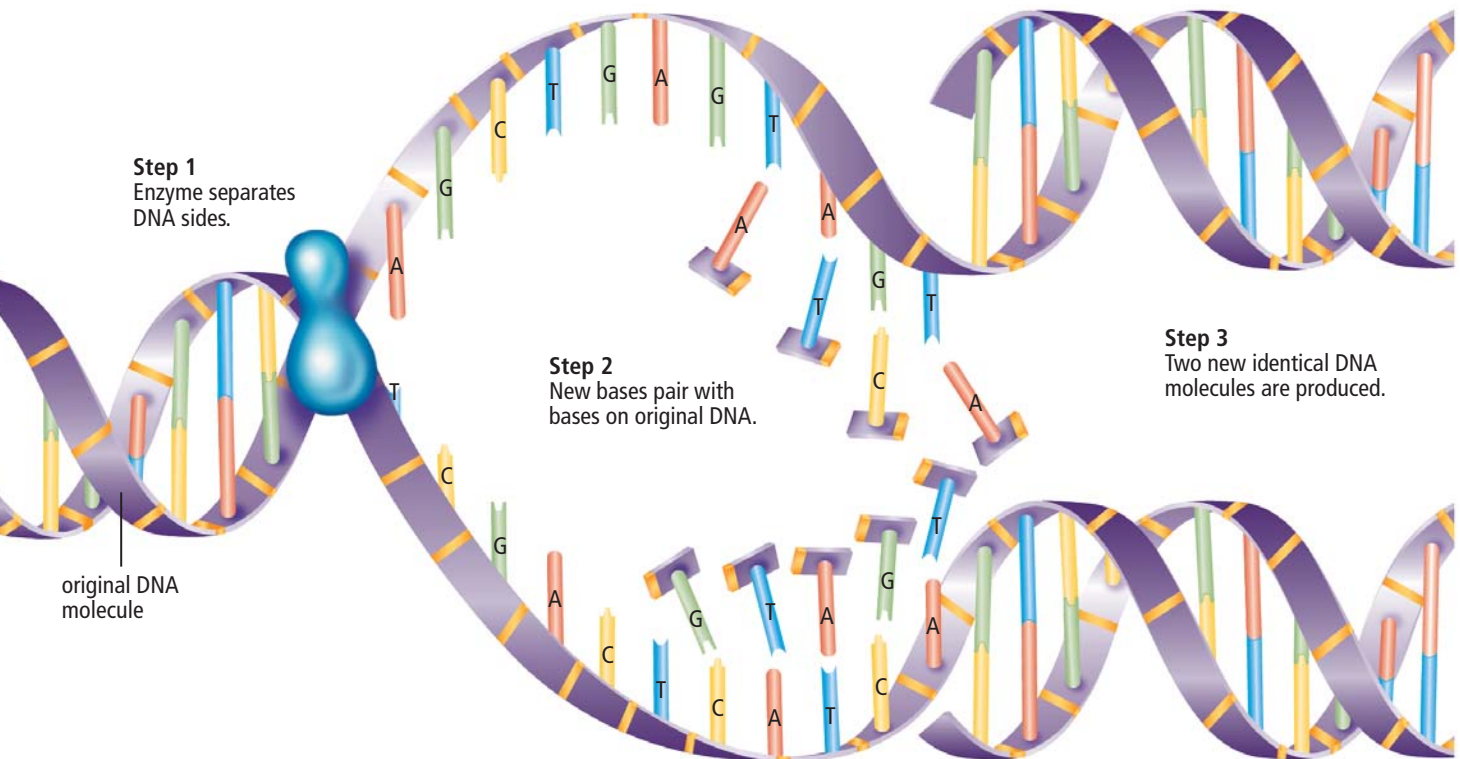


Figure 5.5 During replication, the steps of the DNA ladder break apart with the help of an enzyme.

Replicating DNA ensures that newly formed cells will have an identical copy of the genetic information contained in the original DNA molecule.

Continued growth and preparation

After the DNA replicates, the cell continues to grow and is active making materials such as proteins for the new cells that will be formed after cytokinesis. Early biologists referred to these cells as “daughter cells,” and scientists continue to use this term today. During interphase, the replicated DNA is in a loosely coiled form (Figure 5.6A and Figure 5.6B). In this form, the DNA can be copied so that proteins can be made in preparation for cell division. In addition, during this final phase before cell division, organelles such as mitochondria and chloroplasts will be duplicated.

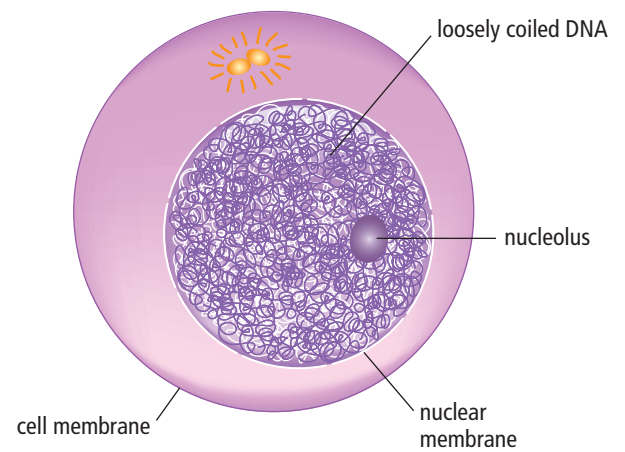


Figure 5.6A Loosely coiled DNA is located in the nucleus.

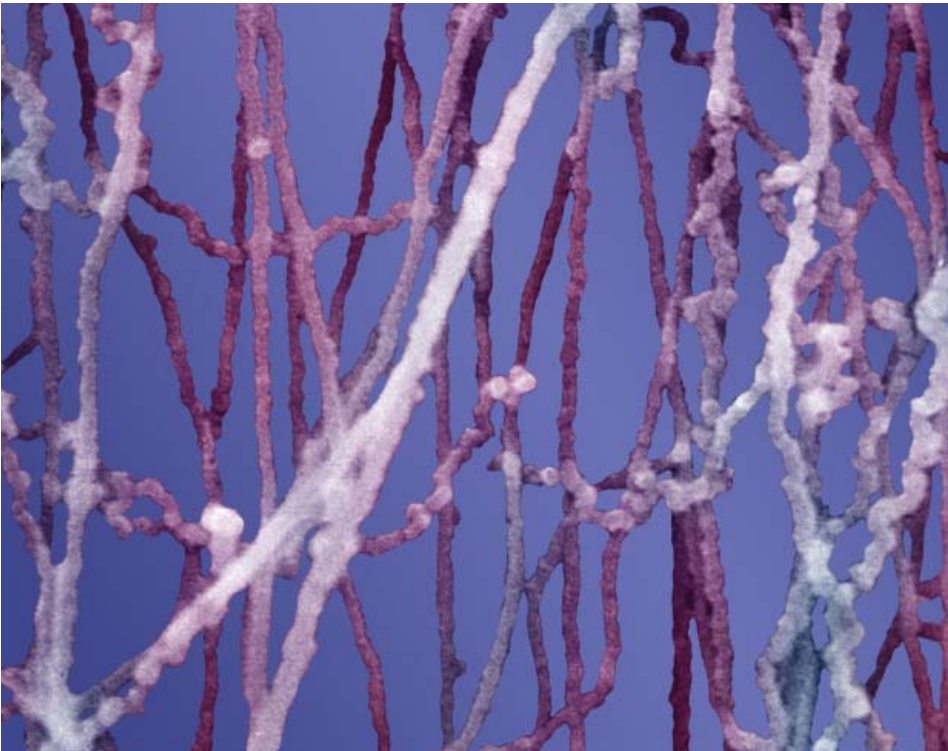


Figure 5.6B DNA is partially uncoiled during interphase so that proteins required for cell division can be made.

Reading Check

1. Explain why the skin cells of an adult must divide.
2. List the three stages of the cell cycle.
3. What are the events that take place during interphase?
4. Why is DNA replication so important?
5. What does DNA look like at the end of interphase?
6. How does the cell prepare for cell division?

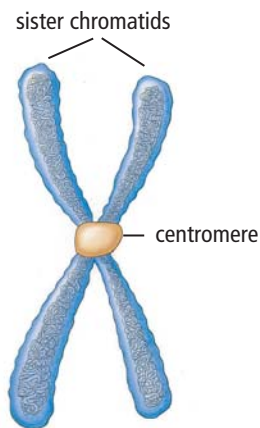


Figure 5.7 The sister chromatids of a replicated chromosome are joined by a centromere.

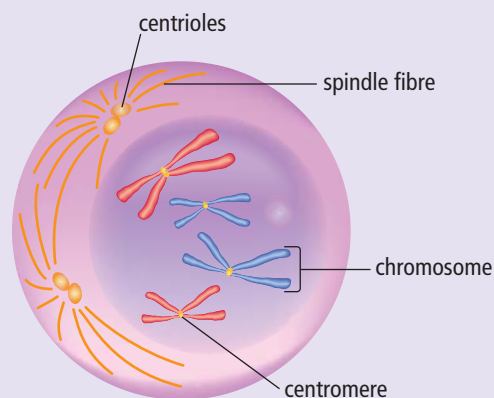
Mitosis

Mitosis is the next stage of the cell cycle and is usually the shortest. Mitosis is the process in which the contents of a cell's nucleus divide. This division results in two daughter nuclei, each with the same number and kinds of chromosomes as the original cell. Occasionally, mistakes are made during replication, but the daughter cells are usually identical to the parent. Therefore, as you learned in section 4.2, most mutations result in little change.

As the nucleus prepares to divide, the DNA molecules that replicated during interphase join together to form the sister chromatids of a chromosome. The sister chromatids join at a point called the centromere, as shown in Figure 5.7.

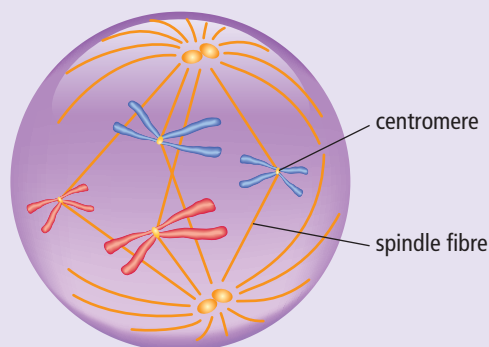
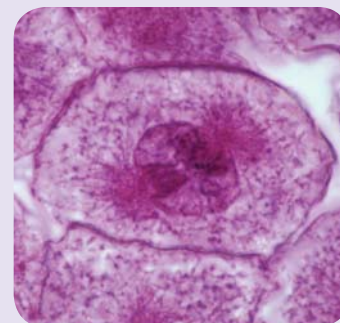
Figure 5.8 shows the phases of mitosis.

Figure 5.8 Mitosis in a typical animal cell. Notice that, at the end of mitosis, each nucleus has the same number and kind of chromosomes.



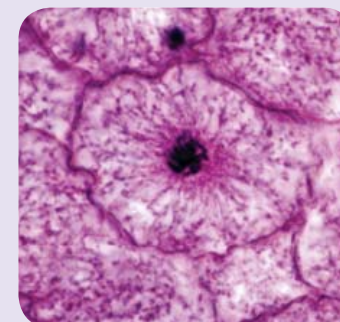
Early prophase

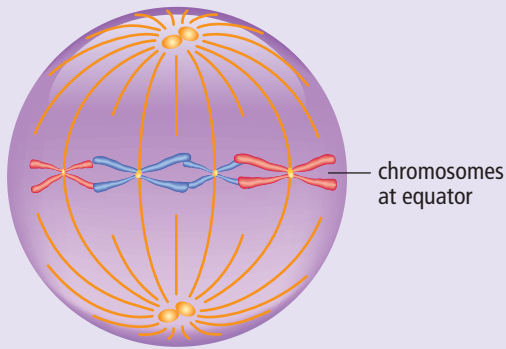
The replicated chromosomes pair up into X-shaped structures and are visible under a light microscope. The nuclear membrane begins to break down. Protein fibres, known as "spindle fibres," begin to form. These fibres begin to stretch across the cell from opposite ends (poles) of the cell.



Late prophase

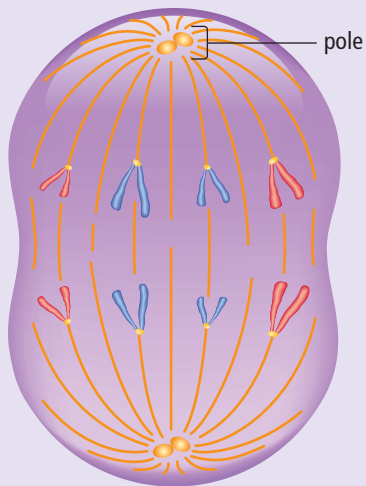
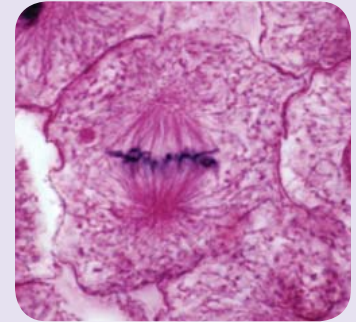
The protein fibres complete forming. These fibres attach to the X-shaped pairs of chromosomes at a point called the centromere. The nuclear membrane breaks down completely.





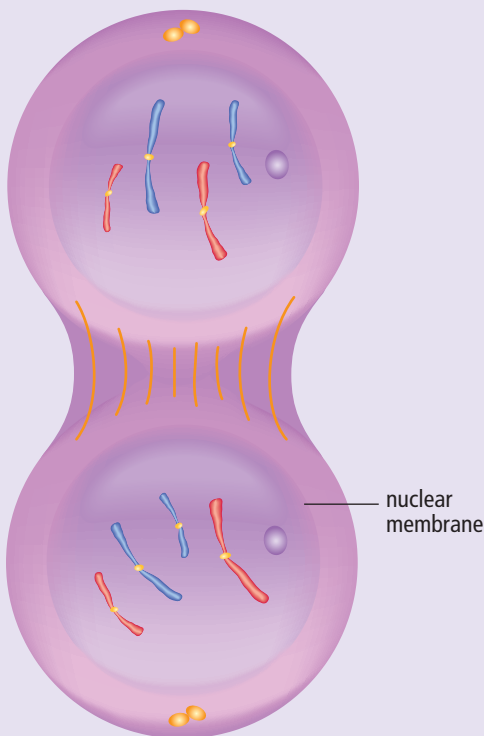
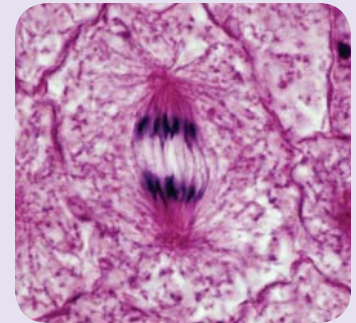
Metaphase

The tugging action of the protein fibres pulls the X-shaped chromosomes into a single line across the middle (or equator) of the cell.



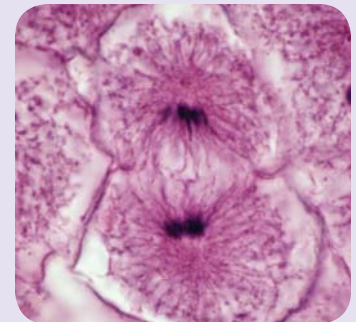
Anaphase

The protein fibres begin to contract and shorten. This action pulls the X-shaped sister chromatids apart and moves the individual chromatids to opposite poles of the cell. Once they separate, each sister chromatid is considered to be a chromosome.



Telophase

In the final stage of mitosis, one complete set of chromosomes is now at each pole of the cell. The protein fibres break down, and a nuclear membrane forms around each set of chromosomes. Now there are two nuclei in one cell, and the cell is ready to divide into two separate cells.



Word Connect

The word “cytokinesis” has two Greek roots: *cyto*, which means cell, and *kinesis*, which means movement.

Cytokinesis

The final stage of the cell cycle is called **cytokinesis**. Cytokinesis separates the two nuclei into two daughter cells. These new cells are identical to the original parent cell. In animal cells, the cell membrane pinches together to divide the cell’s cytoplasm and organelles, as shown in Figure 5.9. In plant cells, a cell plate forms along the centre of the cell to divide the cell into two daughter cells (Figure 5.10).

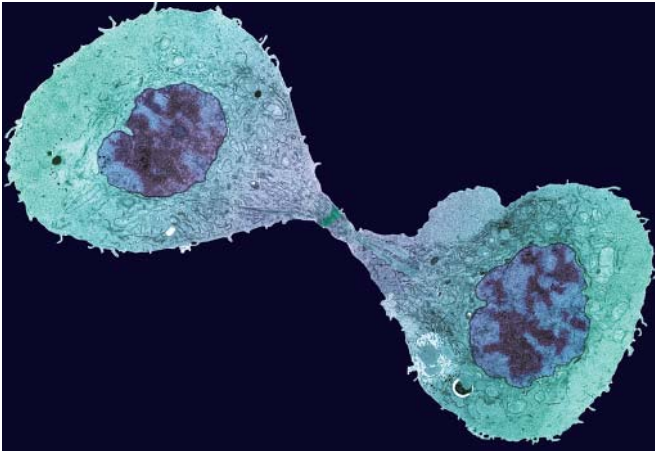


Figure 5.9 Cytokinesis in skin cells. Once mitosis is complete in animal cells, the cell membrane pinches together and the cytoplasm divides.

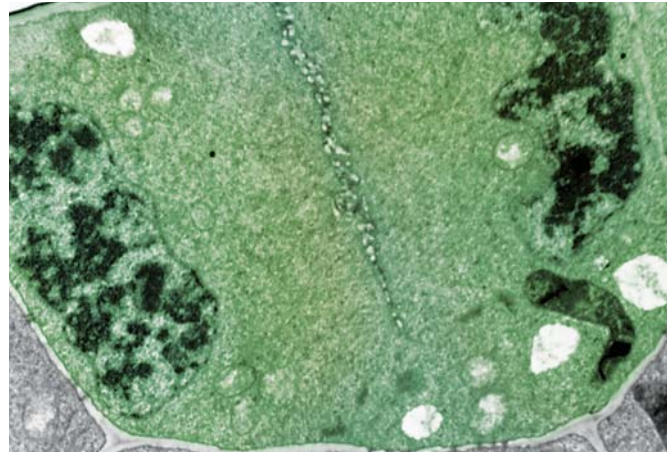


Figure 5.10 Cytokinesis in a coleus plant cell. A cell plate is forming (crossing the middle of the picture) and contains materials to form a new cell wall and membrane.

5-1B The Cell Cycle: A Play in Six Scenes

Find Out ACTIVITY

There are many changes occurring within the cell and cell nucleus during the cell cycle. In this activity, you will increase your understanding of the cell cycle by participating in a play about the cell cycle as an audience member and as an actor.

What to Do

1. Your teacher may assign you to an acting troupe, or you may choose your own group members.
2. Choose **one** of the following events of the cell cycle, which includes the phases of mitosis, for your scene of the play: interphase, prophase, metaphase, anaphase, telophase, or cytokinesis.
3. In your group, review and discuss what the cell would be doing during the event of the cell cycle you have chosen.

4. Prepare a brief script for your cell cycle event. Include a list of props that you will use in your scene.
5. Practise and then perform your scene for the rest of the class.

What Did You Find Out?

1. Is any cell cycle event more active than another event? Explain.
2. To perform a play well, actors must know their lines and where they should stand. How is the process of mitosis similar to what actors must do in a play? What would happen to a cell if chromosomes did not “know” their roles or where they must move during mitosis?
3. What part of developing your group’s scene did you enjoy most? Why?
4. After viewing other groups’ presentations, reflect on how the scene you performed could be improved.

Checkpoints in the Cell Cycle

Activities within the cell during the cell cycle are monitored and controlled at specific stages, or checkpoints. Checkpoints in the life of a cell are like checkpoints during a mountain bike race. Officials monitor racers to ensure that competitors have enough water and food and that no one is hurt. If an official thinks a racer cannot complete the race because of injury, the racer will be removed from the race.

Checkpoints during the cell cycle have a similar function. Special proteins at these checkpoints monitor cell activities and send this information to the nucleus. The nucleus then instructs the cell whether or not to divide. Cells will not divide if:

- There are not enough nutrients to support cell growth.
- DNA within the nucleus has not been replicated.
- DNA is damaged.

Figure 5.11 shows the specific checkpoints in the cell cycle.

internet connect

To find out more about the cell cycle, go to www.discoveringscience9.ca.

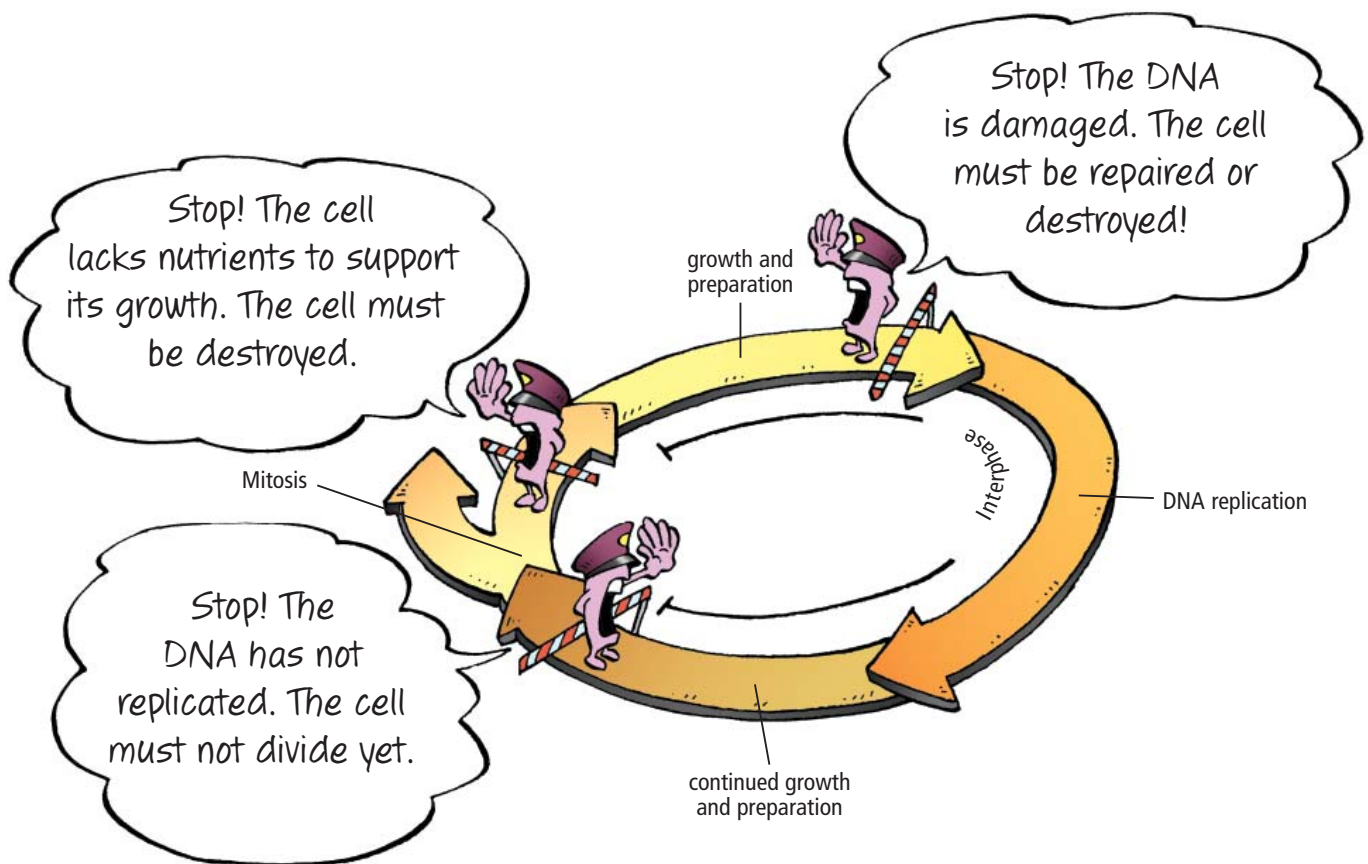


Figure 5.11 Checkpoints in the cell cycle

Reading Check

1. What are the phases of mitosis?
2. What do the nucleus and chromosomes look like during prophase?
3. How does cytokinesis differ in plant and animal cells?
4. What is the importance of checkpoints in the cell cycle?
5. What may happen when checkpoint proteins no longer function?

The Cell Cycle and Cancer

You have seen that checkpoints in the cell cycle can stop the cell from growing or dividing. Such precise control of the cell cycle is important to the survival of an organism. In section 4.2, you learned that mutagens can cause mutations in a cell and may harm the organism. These mutagens can include viruses, X rays, ultraviolet light, and chemicals such as acetone in cigarettes. Figure 5.12 shows the effect of radiation on a cell during mitosis. Skin cancer may eventually result from a single lengthy exposure to the Sun (Figure 5.13).



Figure 5.12 The effect of radiation on cells in mitosis. Here, some chromosomes fail to move to opposite poles of a cell during anaphase.

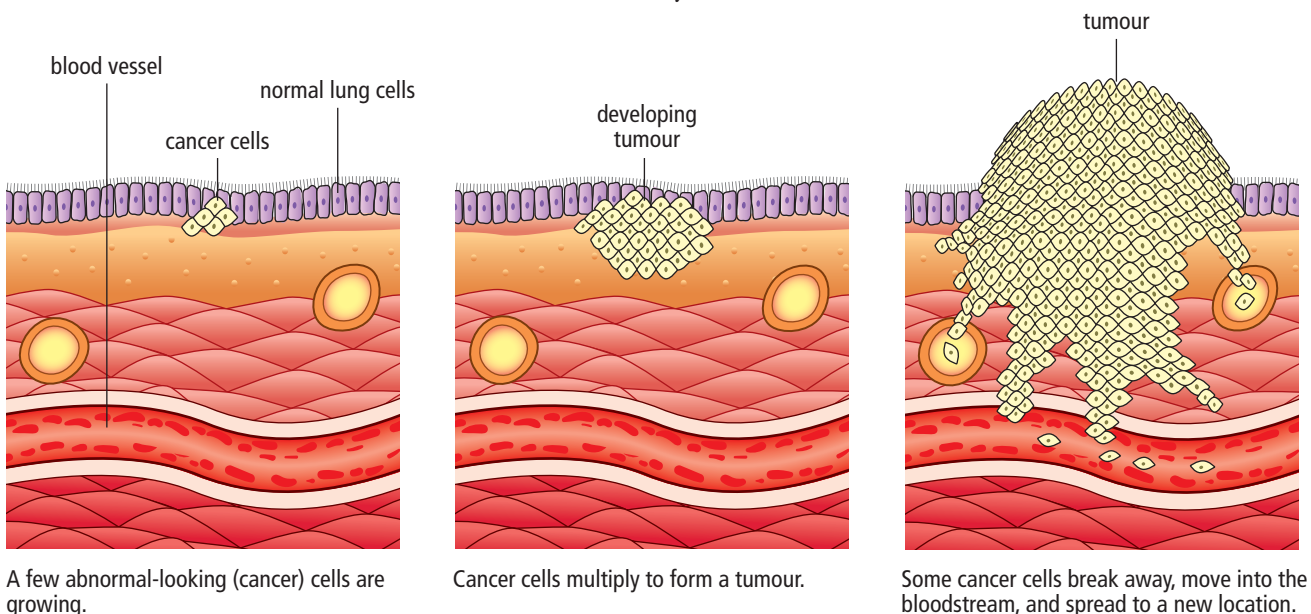


Figure 5.13 A severe sunburn is a risk factor for developing skin cancer.

If a mutation occurs in a gene producing the instructions for a checkpoint protein, cell cycle control will be lost. As a result, a damaged cell like the one in Figure 5.12 may divide uncontrollably. Cancer is the name given to certain diseases that result from uncontrolled cell division. Researchers have linked certain types of inherited colon cancer and breast cancer with gene mutations in checkpoint proteins.

Healthy, normal cells grow in a single layer and stop dividing when they receive messages from neighbouring cells. Cancer cells, however, do not respond to messages from nearby cells, so they begin to grow in multiple layers. These multiple layers form a tumour as shown in Figure 5.14 below.

When viewed with a microscope, cancer cells also show large, abnormal nuclei. These large nuclei result because cell division checkpoints no longer function and the chromosomes do not divide correctly.



A few abnormal-looking (cancer) cells are growing.

Cancer cells multiply to form a tumour.

Some cancer cells break away, move into the bloodstream, and spread to a new location.

Figure 5.14 A cancer cell divides uncontrollably and becomes a tumour. Nearby blood vessels provide nutrients to the tumour and carry cancer cells to new locations.

Cancer cells are not specialized, so they do not function as part of your body. A cancer cell formed in your lungs does not function as a lung cell because the cancer cell does not make the proteins for a lung cell. However, cancer cells can release chemicals to attract small nearby blood vessels. The blood vessels branch into the tumour and deliver nutrients to it. Nutrients feed the growing tumour, and tumour cells divide even more rapidly. Cancer can spread to other areas of the body if some tumour cells break away and are carried by the blood vessels to a new location where they may begin to divide and form a new tumour.

Cancer researchers strive to understand how cancer can disrupt the cell cycle, especially by looking for mutated genes that produce non-functioning checkpoint proteins. Cancer researchers also work to identify potential treatments, such as drugs that work by blocking cell division in a cancer cell and preventing the formation of a tumour.

Explore More

Scientists have found that for a cell to become cancerous it must have several mutations in its checkpoint proteins. This explains why the risk of cancer increases as you grow older. Find out more about the relationship between age and cancer. Begin your search at www.discoveringscience9.ca.

SkillCheck

- Observing
- Modelling
- Working co-operatively
- Graphing

Science Skills

Go to Science Skill 6 for information about using a microscope and Science Skill 5 for information on making scale drawings.

Safety

- Microscopes and slides can break, especially when using the high-power objective lens. Handle with care.

Materials

- ruler
- pencil
- microscope
- prepared slide of an onion root tip

The cells in the tips of onion roots constantly divide as the tip grows. In this activity, you will work in groups to observe the cells of onion root tips to determine the frequency of the events of the cell cycle.

Question

What is the frequency of the events of the cell cycle in an onion root tip?

Procedure

1. In your notebook, draw six boxes that are 30 mm high by 20 mm wide. Use a ruler to draw the boxes.
2. Label the boxes: prophase, metaphase, anaphase, telophase, cytokinesis, and interphase.
3. Place the onion root tip slide on the stage of the microscope, and focus on the tip of the root at low power.
4. Change the objective lens to medium power, refocus, and then move to high power. Review the diagrams and photographs on pages 142 to 143. Find a cell in prophase and draw it in the prophase box. Let the lines of the box represent the walls of the cell. Label the chromosomes.
5. Find a cell in metaphase, anaphase, telophase, and cytokinesis and draw your observations in the appropriate boxes.
6. After you have observed and drawn each of the above events, copy the chart below into your notebook. In your group, you will determine the number of cells in each event of the cell cycle. This is called the frequency. Follow steps 7 to 11 to complete the chart.
7. Count the number of cells across your field of view. Then count the number of rows of cells in the field. Multiply these two numbers together. This will give you an estimate of the total number of cells in your field of view. Record this estimate in the last box of the first column of the chart.

Cell Cycle Event	Group Data		Class Data	
	Frequency (number of cells)	Percentage	Frequency (number of cells)	Percentage
Prophase				
Metaphase				
Anaphase				
Telophase				

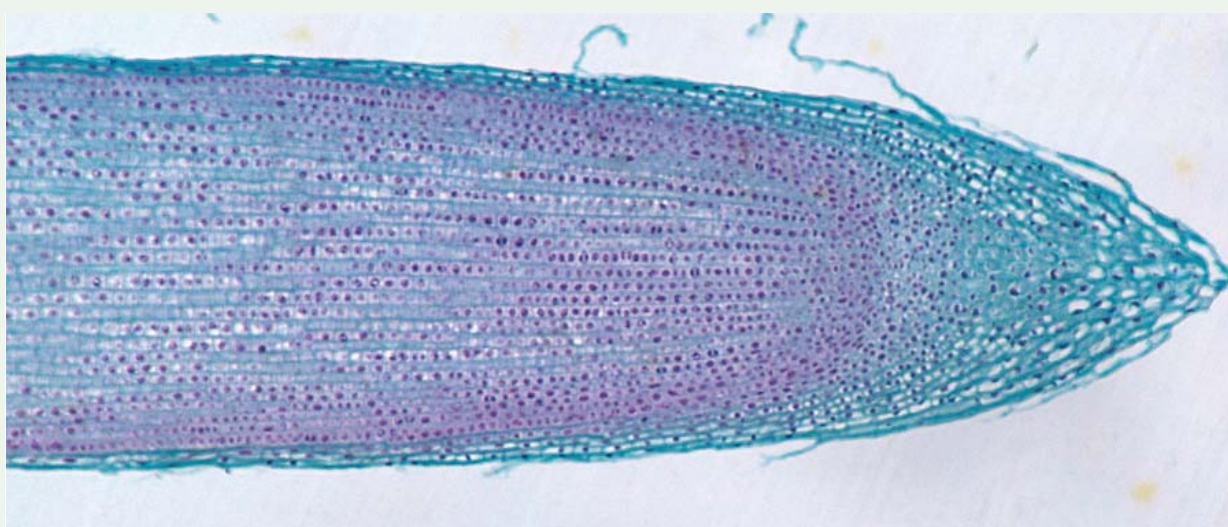
8. Have the person viewing the cells under high power call out the number of cells he or she can see in prophase. Have another person record this number in the prophase box in the table.
9. Repeat step 8 for each of the other events except interphase. Try not to count the same cell showing the same event twice. (You will determine the number of cells in interphase in step 10.)
10. Add together the number of cells seen in each event. Subtract this total from the number you estimated in step 7. This will give you the number of cells in interphase. Record this number in the chart.
11. Calculate the percentage for each event.
12. Share your results with the rest of the class and calculate total class frequencies.
13. Calculate class percentages for each event.
14. Plot a bar graph using the class data percentages.
15. Clean up and put away the equipment you have used.

Analyze

1. Which event of the cell cycle occurs most frequently?
2. How can you tell that the cell cycle is a continuous process?
3. (a) Which event of the cell cycle takes the longest period of time?
(b) Explain how you made your decision.
4. Are your group's results in this investigation different from the rest of the class? If so, how could you explain this?

Conclude and Apply

1. Suppose that you were told that the cell cycle lasts 16 h. Use your class data percentages to estimate the length of each of the six events in this 16 h cycle.
2. Many scientific and medical careers involve examining cells in great detail. Find out about and summarize what a technician in a medical laboratory does. Begin your research at www.discoveringscience9.ca.



The growing tip of an onion root

Science Watch

Stopping the Cell Cycle Clock

A cell cannot live forever, and eventually its cell cycle stops. On average, a human cell can divide only about 50 times. Embryonic stem cells are different. They are the early stage cells of a developing embryo. (An embryo is the early stage of development of a multicellular organism.) Scientists have discovered that embryonic stem cells have the potential to live indefinitely. However, once a cell becomes specialized, this fountain of youth is lost. One of the secret elixirs of stem cells is the enzyme telomerase [teh-loh-MEH-raze], which is found in egg, sperm, and embryonic cells.

Think of your chromosomes as pairs of shoelaces. As shoelaces become worn, the plastic end caps break and the shoelaces begin to fray. At the tips of your chromosomes are telomeres. These telomeres act like plastic shoelace caps to stop chromosomes from fraying and becoming tangled with other chromosomes. Each time your cells divide, your chromosomes shorten by about 50 base pairs. Eventually, the telomere cap disappears and the chromosomes are unable to divide correctly. When this happens, the cell dies.

Telomerase maintains the telomere caps so that the chromosomes do not become frayed. Since almost all cells in your body no longer make telomerase, each of your cells will age and eventually die.

Have researchers found the fountain of youth? Probably not, since there are other factors involved in cell aging. However, scientists have recently found that 90 percent of human cancer cells do not turn off the telomerase gene. Therefore, the telomere caps of these chromosomes do not shorten when the cells divide. As a result, these cells divide for longer than regular cells. Researchers believe that, if they can block the action of telomerase in cancer cells, they will be able to treat the disease and stop the clock of the cancer cell cycle.



Telomeres glow at the end of these chromosomes.

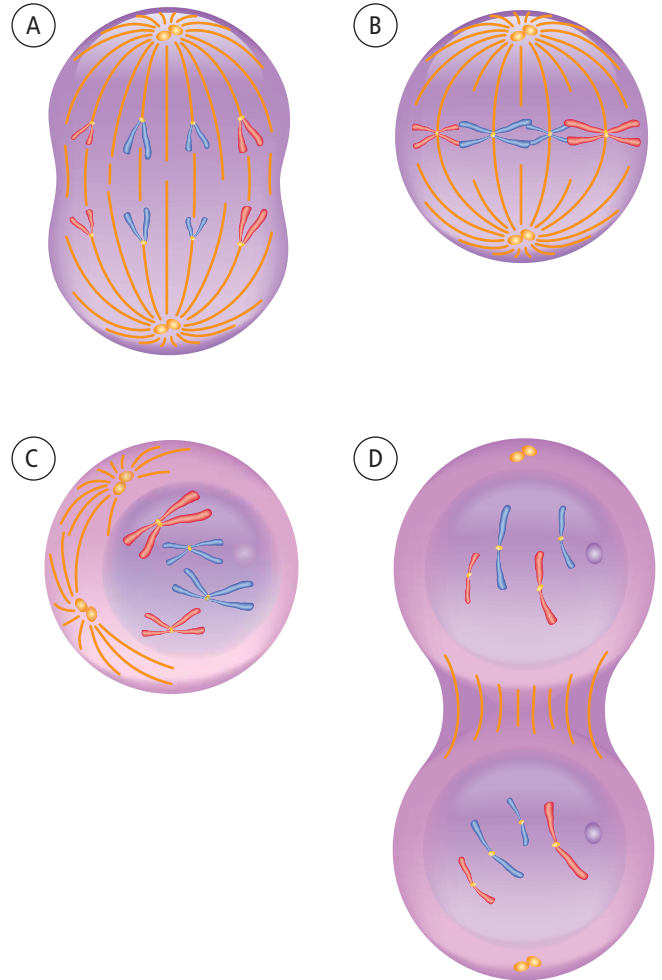
Questions

1. What causes cells to stop dividing?
2. Why is telomerase important to a rapidly dividing cell such as an embryonic cell?
3. How do cancer cells escape programmed cell death?

Check Your Understanding

Checking Concepts

- Outline the activities in the cell at each of the following phases of interphase:
 - growth and preparation
 - replication
 - continued growth and preparation
- Why is it important for replication of DNA to occur?
- What is the function of mitosis?
- Is mitosis constantly occurring in your cells? Explain.
- How many daughter cells are formed during mitosis?
- Use the diagrams on the right to answer questions (a) to (e).
 - Which diagram shows a cell at the beginning of anaphase?
 - Which diagram shows a cell with single-stranded chromosomes moving to opposite poles?
 - Which diagram illustrates a cell where a new nuclear membrane is forming?
 - Write down the correct sequence of letters to show the phases of mitosis from beginning to end.
 - Using the diagrams, explain how you could tell whether a cell has just completed mitosis or is entering mitosis.
- wrong in the cell cycle to cause a mutation?
- As you grow, mitosis occurs in your body to create new cells. Describe an example of why mitosis continues to occur even after you have stopped growing.



Understanding Key Ideas

- If you wanted to study mitosis in humans, what type of cells would you choose to study? Why?
- How is plant cell division different from animal cell division?
- In interphase, the DNA is loosely coiled. Why do you think it is important that the DNA be compact and tightly coiled during mitosis? (**Hint:** Think of an unravelled spool of thread.)
- What might happen if DNA replication and mitosis were not highly controlled?
- Mutations do occasionally occur during mitosis. What are some things that might go

Pause and Reflect

Interphase was previously called the resting stage of the cell cycle. Explain why "resting stage" is not an appropriate description.

5.2 Asexual Reproduction

In asexual reproduction, only one parent is required. Most sexually produced offspring, or clones, have identical genetic information to each other and to the parent. Asexually reproducing unicellular organisms reproduce quickly and in large numbers. Knowledge of asexual reproduction enables biotechnologists to clone both organisms and cells.

Key Terms

asexual reproduction
binary fission
budding
fragmentation
spore
vegetative reproduction

If you have heard anything about clones then you already know something about asexual reproduction. A clone is an identical genetic copy of its parent. You encounter clones every day. Bread mould is a group of clones that come from a single mould spore. A new duplicate tree growing up from the bottom of another tree is also a clone (Figure 5.15). A clone is produced through the process of **asexual reproduction**. In asexual reproduction, only one parent is required to produce offspring. The offspring look identical to the parent and to each other.

Figure 5.15 The aspen is one of the most widely distributed trees in North America. Many of these trees grow in multistemmed groups of clones.



Bread mould and tree shoots are examples of clones that occur naturally. Other types of clones are artificially made in agricultural or horticultural industries and in biomedical laboratories. The cloning of animals such as sheep, pigs, cattle, and horses and of plants such as ornamental shrubs and trees has become more frequent as bioengineers seek to improve livestock breeds and increase plant production. Bioengineers also clone individual skin cells to grow new tissue for burn victims. Geneticists clone healthy genes to replace mutated ones.

In 1999, scientists successfully extracted DNA from an unborn Tasmanian tiger pup, which had been preserved in ethanol for 150 years (Figure 5.16 on the next page). Two years later, scientists extracted more DNA from the bone, teeth, and dried muscle of two other pups. They successfully duplicated individual genes of the Tasmanian tiger and hope to use cloning technology to reproduce all of the genes and gene sequences of this extinct animal.



Did You Know?

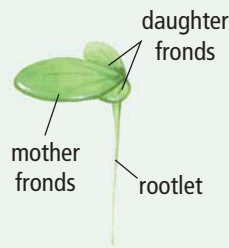
A clone bank is a collection of clones that make up the genome of a species. Clone banks enable biologists to preserve genetic information and to conduct research.

Figure 5.16 Scientists have succeeded in cloning the genes from an extinct Tasmanian tiger.

5-2A Asexual Reproduction in Duckweed

Find Out ACTIVITY

Duckweed is a very small aquatic plant with leaf-like structures called fronds. Duckweed reproduces asexually by producing two or three daughter fronds from each parent plant. As the daughter fronds grow larger, they break away from the parent frond. Under suitable conditions, a new plant may form within 24 h.



Safety



Materials

- 2 small jars or culture dishes
- 100 mL distilled water
- 100 mL Knop's solution
- 8 duckweed plants
- wax pencil

Science Skills

Go to Science Skill 11 for information about constructing data tables.

What to Do

1. Examine a duckweed plant. Identify the fronds, rootlet, and daughter fronds. Sketch the duckweed in your notebook.
2. Label two jars or culture dishes: A. Knop's solution and B. distilled water. Place 50 mL of the appropriate liquid into each container.
3. Place four duckweed plants into each container and place them in a well-lit area. Wash your hands when you are finished.
4. Over the next two weeks, count and record the number of separate plants in each container. Construct a table to show your results.
5. At the end of two weeks, construct a line graph showing the number of plants that were growing each day. Use two separate lines to compare the numbers of plants growing in the two containers.

What Did You Find Out

1. Describe the difference between the parent and offspring plants.
2. How do you think the genetic material in the offspring compares with that of the parent?
3. What was the purpose of setting up one container with distilled water?
4. Which container showed the greater number of new plants? Why?

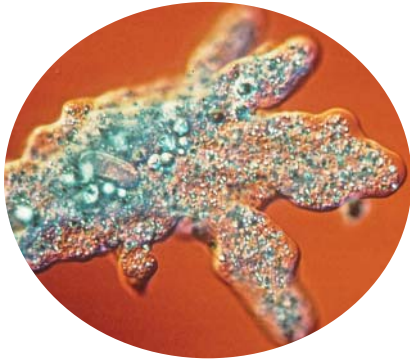


Figure 5.17 To survive, the amoeba must reproduce in great numbers.

Types of Asexual Reproduction

One-celled (unicellular) organisms, such as the amoeba (Figure 5.17), depend on asexual reproduction to reproduce themselves in great numbers. The amoeba and many other one-celled organisms are part of the food chain for more complex, multicellular organisms. Because of this role, it is important for their survival that they reproduce in large numbers.

Many species reproduce by asexual reproduction. Asexual reproduction occurs naturally in living things through a variety of methods, which include binary fission, budding, fragmentation, vegetative reproduction, and spore formation.

Binary fission

Small, one-celled eukaryotic organisms like the amoeba reproduce by **binary fission** (Figure 5.18). In binary fission, a single parent cell replicates its genetic material and divides into two equal parts. Amoebas have between 30 and 40 chromosomes depending on the species. *Amoeba dubia* has several hundred chromosomes! The chromosomes must be replicated and attached to the protein fibres in mitosis to ensure that the exact number of chromosomes ends up in each daughter cell.

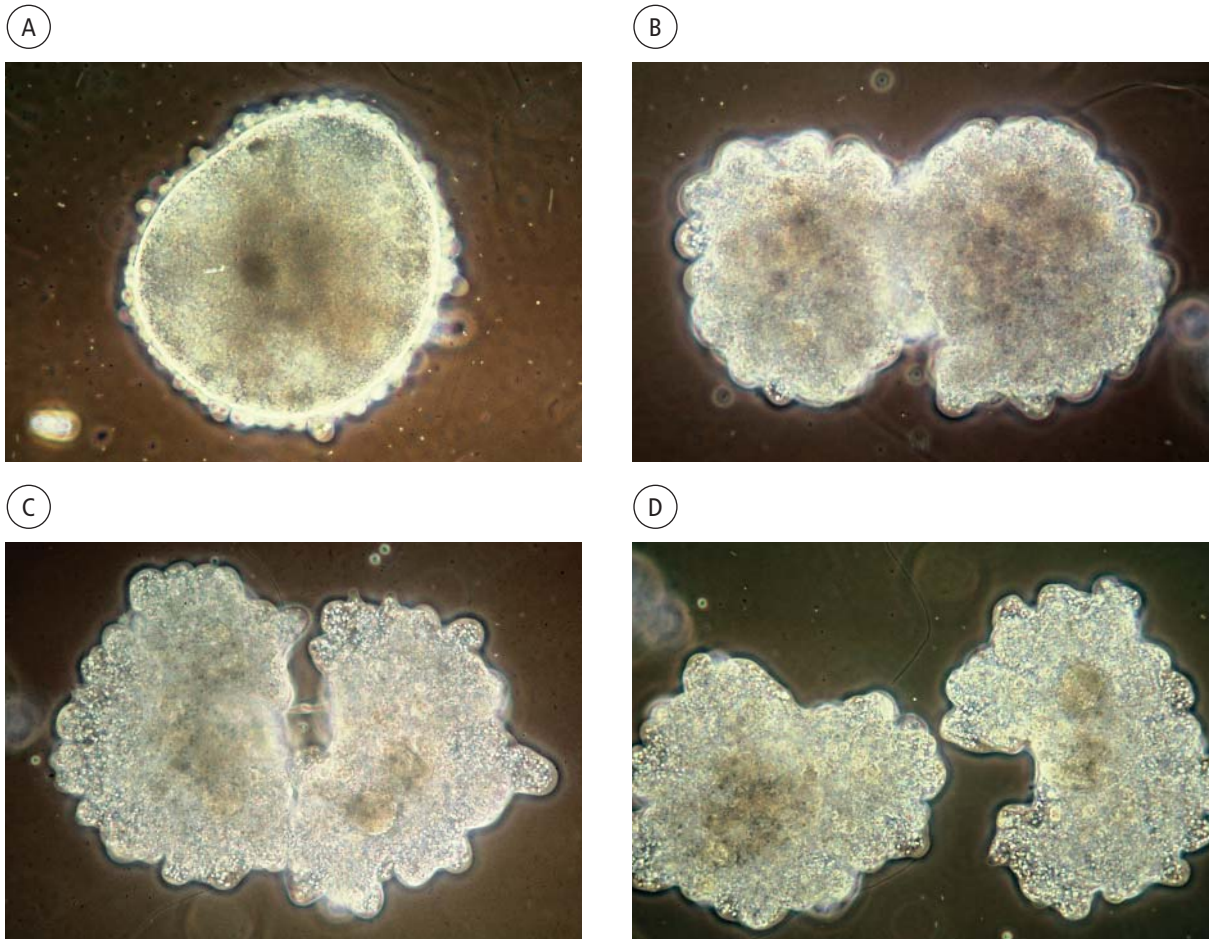


Figure 5.18 Binary fission in an amoeba

Binary fission is the only method of reproduction for some types of bacteria. Since bacteria do not have a nucleus (they are prokaryotic), they do not undergo mitosis. However, the one ring of DNA does replicate (Figure 5.19). If the environmental conditions are favourable, a bacterium can reproduce every 20 min by this method. You may have had an experience where you became ill very quickly. Within two days of *Streptococcus* bacteria entering your body, you may get a very sore throat and fever because the bacteria multiply into millions very quickly.

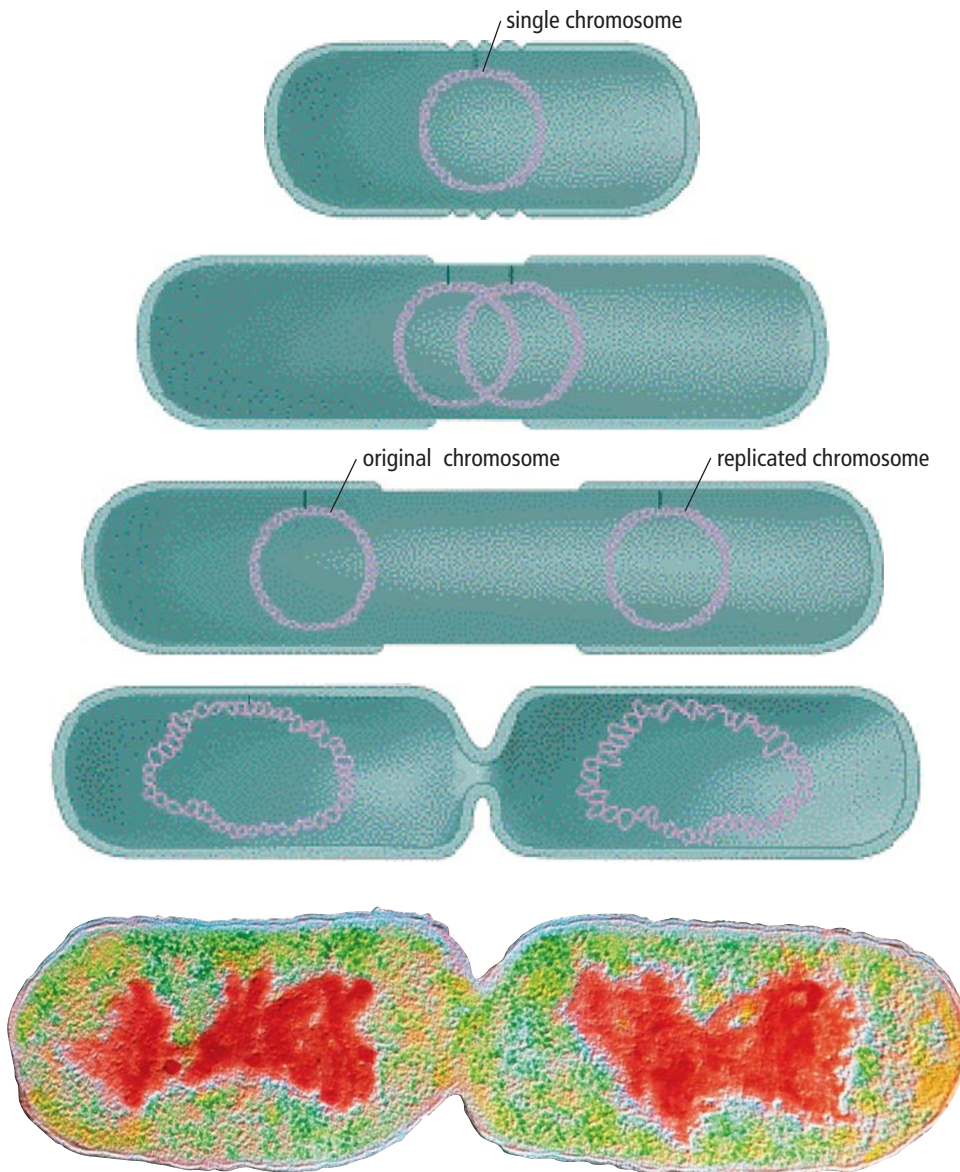


Figure 5.19 Binary fission in a bacterium

Word Connect

The term "binary fission" comes from the Latin words *binarius*, meaning two together, and *fissio*, meaning to split.



Figure 5.20 These marine algae can cause red tide.

The dinoflagellate *Alexandrium catenella*, which is one species of marine algae that causes paralytic shellfish poisoning, also reproduces by binary fission (Figure 5.20).

Mutation can happen during binary fission when errors occur during DNA replication or when chromosomes fail to move into the two new cells. The DNA in bacteria, for example, can mutate rapidly, which can make bacteria very resistant to antibiotics.

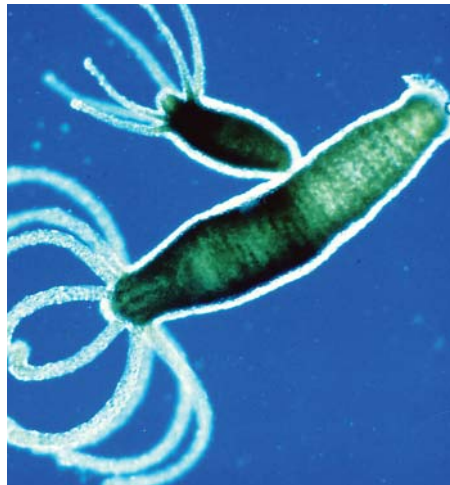
Budding

Unicellular yeasts reproduce asexually by a method called budding, as shown in Figure 5.21A. **Budding** occurs when part of the yeast cell pushes outward to form an outgrowth or bud. This bud then pinches off from the parent cell to become a yeast cell, identical to the parent cell. Since some multicellular organisms, such as hydras and sponges, have only a few different cell types, they are also able to reproduce by budding (Figures 5.21B and 5.21C). Like the yeast, hydra and sponges develop a bud; however, it may not always detach from the parent.

(A)



(B)



(C)



Figure 5.21 Budding can occur in some unicellular organisms such as yeast (A) and in some multicellular organisms such as the hydra (B) and the sponge (C).

Suggested Activity

Core Lab Conduct an Investigation 5-2B on page 162

Budding is advantageous for animals such as sponges, which attach to rock and move very little. Colonies can be maintained in the same place, or new colonies can be established when buds break away from their parents and are carried to new locations.

Fragmentation

Some animals and many plants can reproduce by a method called **fragmentation**. If an organism breaks apart as a result of injury, each fragment then develops into a clone of its parent.

Some animals, such as certain species of sea star, can reproduce asexually from fragments (Figure 5.22). In these species, if one of the arms detaches from the parent's body, it can develop into another sea star if it contains enough of the parent sea star's genetic information. The success of sea stars has had an impact on the shellfish industry. Most sea stars are carnivorous (meat eaters) and feed on oysters and clams, but they will also eat any type of animal tissue.



Figure 5.22 The northern sea star, found off the coast of Newfoundland and Labrador, is able to reproduce asexually by fragmentation.

Plants can also reproduce by fragmentation provided that there are enough nutrients available. Japanese knotweed is an example of such a plant. Japanese knotweed, also known as “killer bamboo” because of its bamboo-like stems, was introduced to North America as an ornamental plant in the late 1800s. Now it is found across the continent, and is considered a weed due to its ability to crowd out native species, take over gardens and lawns, and even grow through asphalt. It spreads rapidly because of its ability to reproduce by fragmentation. When its underground stems, or rhizomes, are disturbed, each piece of the rhizome is able to sprout a new plant (Figure 5.23).



Figure 5.23 Japanese knotweed is commonly found throughout Newfoundland and Labrador along roadways, railway lines, and areas of disturbed soil.

Vegetative reproduction

Many plants can also reproduce by **vegetative reproduction**. Vegetative reproduction occurs when special cells, usually in plant stems and plant roots, divide repeatedly to form structures that will eventually develop into a plant identical to the parent. Tulip, daffodil, and hyacinth bulbs; strawberry stem runners; and potato sprouts or “eyes” produce new plants by this natural method of asexual reproduction (Figure 5.24).

The main disadvantage of vegetative reproduction is that the new plants will all grow very close to each other and to the parent. This can lead to a competition for soil, nutrients, and light and can cause the plants to be less healthy.

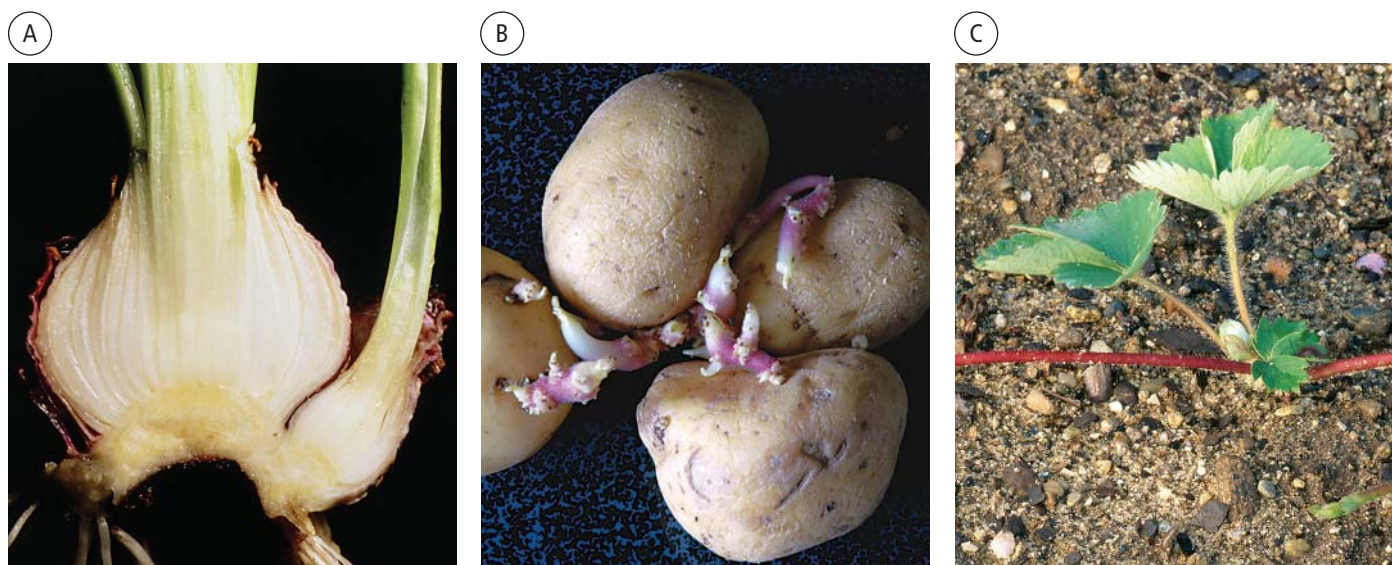


Figure 5.24 A new plant is forming from the bulb of this hyacinth (A). The sprouts or “eyes” growing from these potatoes can develop into separate plants (B). New strawberry plants form where strawberry runners develop roots (C).

Benefits to humans of vegetative reproduction

Asexual reproduction of plants has benefited humans for centuries. Potatoes, for example, are the number one tuber crop in the world. Originating in South America, potatoes were taken to Europe by explorers around the beginning of the 1500s. Since then, potatoes have become an important crop in many parts of the world. Edible bulbs such as onions and garlic have also become successful crops due to their ability to reproduce asexually.

The ability of crop plants to reproduce asexually allows farmers to grow exact copies of individual plants that have desirable traits, such as abundant yield. Farmers do not have this advantage with most common crop plants, including corn, wheat, and rice, since these plants are not able to reproduce asexually. Scientists are searching for genes that will allow them to “turn on” asexual reproduction in these plants.

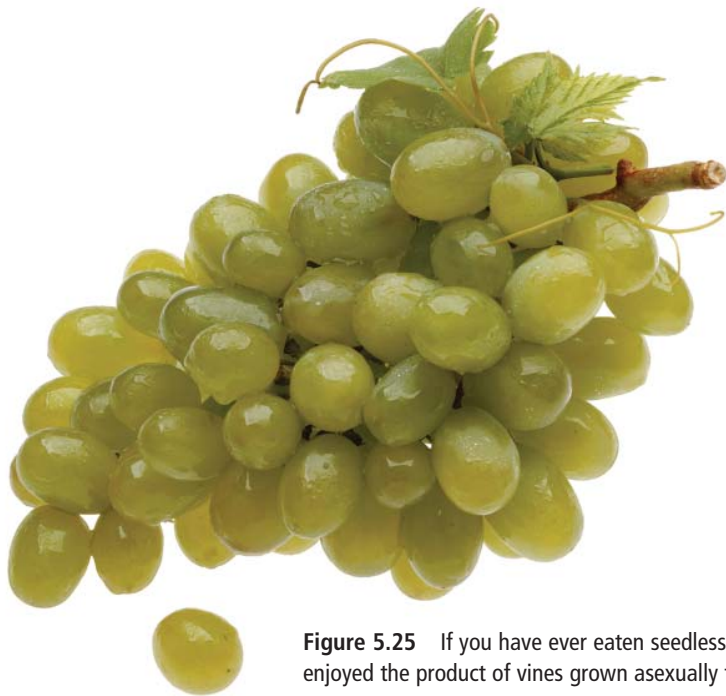


Figure 5.25 If you have ever eaten seedless grapes, you have enjoyed the product of vines grown asexually from cuttings.

Throughout history, humans have assisted nature in helping plants reproduce. Human-assisted methods of vegetative reproduction include methods such as cuttings and grafts (Figure 5.25). In the cutting method, a plant grower removes a section of stem (or leaf or root) and plants the cutting in a special growing medium. With increased technology, researchers have determined the correct amounts of nutrients necessary to help cuttings grow roots. More than 45 different kinds of house plants, such as the African violet, can reproduce by this method. Plant hormones, which are chemical messengers, are often applied to the cut stem (Figure 5.26). The hormones signal the nuclei in the cells of the cutting to stimulate cell division and growth, which causes some cells to develop into root tissue (Figure 5.27).

Did You Know?

The aspen, which can reproduce through vegetative reproduction, is dying in western North America from mysterious causes. The closeness of the trees and their genetic similarity may be factors in their decline.



Figure 5.26 Cuttings are often dipped into rooting powder containing plant hormones.



Figure 5.27 Root tissue has developed from the stem cutting of an African violet.

For plants that cannot grow roots from cuttings, growers use a method called grafting to produce new plants. In grafting, stems called scions are attached to the rooted stock (or “rootstock”) of a similar plant species (Figure 5.28A). This technique is often used to reproduce apple trees and rose plants. Grafting has several advantages. It can help the scion benefit from a more vigorous root system. Grafted trees produce fruit within two to three years because of the developed root system onto which they are attached. (Trees grown from seeds can take 5 to 10 years to produce apples.) Grafting can also control the eventual size of the plant. For example, apple scions are often grafted onto dwarfing rootstock so that they will develop into smaller trees. Another form of grafting is called budding, which is also used to grow apple trees (Figure 5.28B).

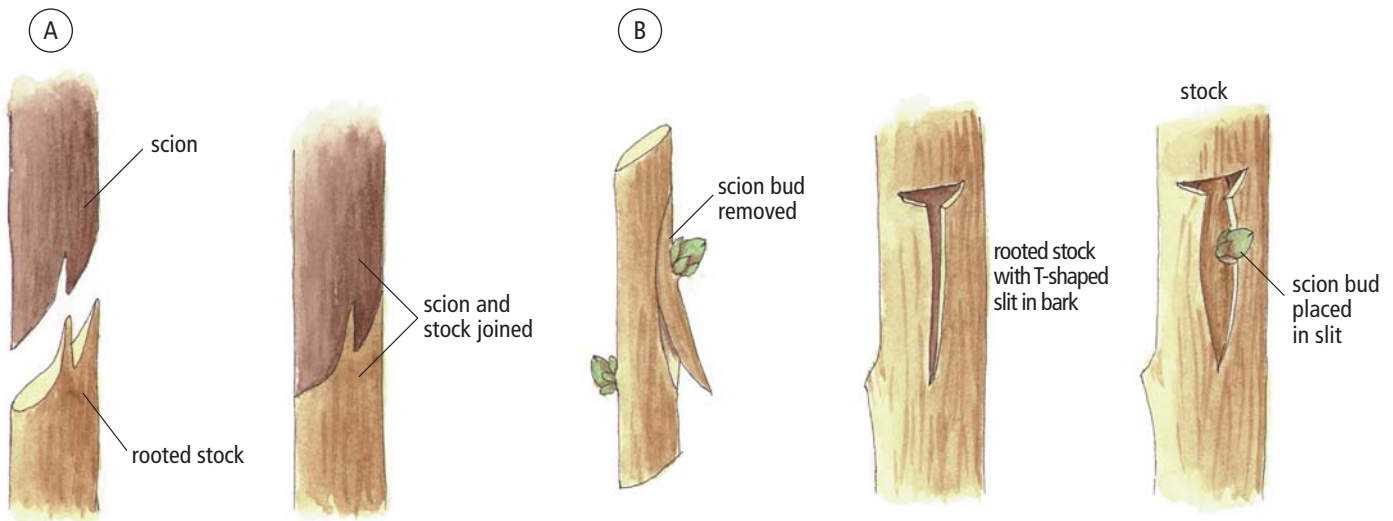


Figure 5.28 In grafting, parts of a desirable plant are removed and attached to the rooted stock of another plant. In Figure A, a stem called a scion is attached to the rooted stock of a plant. In Figure B, a plant bud is removed from the desired plant and attached to the rooted stock.

Spore formation

Some bacteria, micro-organisms, and fungi such as bread mould (Figure 5.29 on the next page) and puffballs (Figure 5.30 on the next page) can reproduce asexually by forming single-celled **spores**. A spore is a reproductive cell that grows into a new individual by mitosis. Some plants such as mosses and ferns can also form spores to reproduce. Spores are very light in weight, and spore producers rely on water or wind to carry the spores away from the parent. If conditions are suitable—there is enough moisture, the temperature is right, and there is a source of food—a new individual will begin to grow wherever it lands. Many spore types have a tough outer coating that allows them to survive in harsh conditions such as drought or extreme temperatures until conditions become favourable.



Figure 5.29 Each black dot on this bread mould is a spore. Millions of spores can be found on one piece of mouldy bread.



Figure 5.30 The cloud of spores rising up into the air will be carried away from the parent fungus by wind.

In this section, you have read about a variety of organisms that reproduce asexually. You have also learned that asexual reproduction has both advantages and disadvantages for the survival of these species. Table 5.1 presents a short summary of the advantages and disadvantages of asexual reproduction.

Table 5.1 Advantages and Disadvantages of Asexual Reproduction

Advantages	Disadvantages
<ul style="list-style-type: none"> Large numbers of offspring are reproduced very quickly from only one parent when conditions are favourable. 	<ul style="list-style-type: none"> Offspring are genetic clones. A negative mutation can make asexually produced organisms susceptible to disease and can destroy large numbers of offspring.
<ul style="list-style-type: none"> Large colonies can form that can out-compete other organisms for nutrients and water. 	<ul style="list-style-type: none"> Some methods of asexual reproduction produce offspring that are close together and compete for food and space.
<ul style="list-style-type: none"> Large numbers of organisms mean that species may survive when conditions or the number of predators change. 	<ul style="list-style-type: none"> Unfavourable conditions such as extreme temperatures can wipe out entire colonies.
<ul style="list-style-type: none"> Energy is not required to find a mate. 	

SkillCheck

- Observing
- Measuring
- Controlling variables
- Working co-operatively

Safety

- Be careful when handling acids (vinegar) and bases (ammonia).
- Wash your hands thoroughly after doing this investigation.

Materials**Part 1**

- petri dish
- 0.5 g yeast
- 1 g sucrose (table sugar)
- 5 mL warm tap water (24°C–27°C)
- thermometer
- medicine dropper or toothpick
- microscope slide
- cover slip
- microscope

Science Skills

Go to Science Skill 6 for information about how to use your microscope.

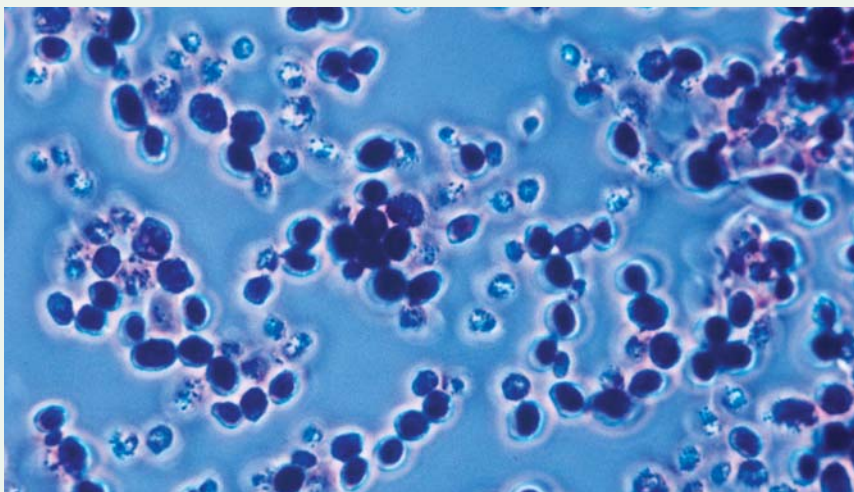
Yeast are small single-celled fungi. They obtain energy from sucrose in a process called fermentation. During this process, carbon dioxide and alcohol are produced. Yeast are used to make bread, beer, wine, and cheese. In this investigation, you will first observe yeast budding under the microscope, and then you will conduct two experiments to determine what the optimum conditions are for yeast reproduction. You will consider the effect of nutrients and pH level (acidity and alkalinity) on yeast reproduction. As more yeast are produced, more fermentation will occur. The amount of fermentation that occurs can be compared by collecting the carbon dioxide gas produced. You may conduct all three parts of this investigation, or your teacher may ask you to conduct only one part and report your findings to the rest of the class.

Question

What are the optimum conditions for yeast reproduction?

Procedure**Part 1 Observing Budding in Yeast**

1. Place 0.5 g of yeast and 1 g of sugar in a petri dish.
2. Confirm that the water temperature is correct using the thermometer, then add 5 mL warm water and let the dish sit covered on your lab bench for 10 min.
3. Smear a yeast sample on a slide with a toothpick or place a small drop on the slide using a medicine dropper. Cover with the cover slip.
4. Observe the yeast under the microscope using high power. You may need to reduce the light using the diaphragm below the stage.
5. You should see circle-shaped yeast cells. Look for cells that appear to have a little bump on them. Record your observation in a drawing.
6. Clean up and put away the equipment you have used.



Part 2 Observing the Effect of Nutrients

7. Label the flasks A through D with the wax pencil.
8. Confirm that the water temperature is correct using the thermometer, then add 80 mL of hot water to each flask.
9. Dissolve the following amounts of sucrose in each flask:
 Flask A: 0 g
 Flask B: 5 g
 Flask C: 30 g
 Flask D: 50 g
10. Add 4 g of yeast to each solution and stir.
11. Place a balloon on each flask, and seal it tightly with masking tape.
12. Every 2 min, stir the contents of each flask by swirling it slowly.
13. After 15 min, record your observations in a table (like the one below), and make additional observations every 10 min until no further changes occur. During your observations, describe the fermentation activity in each flask and measure the circumference of each balloon using the string or thread.

Flask	Conditions	Fermentation Observed	Carbon Dioxide Produced*
A	0 g sucrose		
B	5 g sucrose		
C	30 g sucrose		
D	50 g sucrose		

*Measured by the balloon circumference in centimetres

14. Remove the balloons very carefully as the foam may rise and spill all over you and the lab bench.
15. Clean up and put away the equipment you have used.

Part 3 Observing the Effect of pH

16. Label the flasks E through H with the wax pencil.
17. Confirm that the water temperature is correct using the thermometer, then add 80 mL of hot water to each flask.
18. Dissolve 5 g of sucrose in each flask.
19. Use pH paper to verify the level on the 14-point pH scale as you use the medicine dropper to add drops of vinegar or ammonia as follows:
 Flask E: add enough vinegar to adjust the pH to 3.
 Flask F: add enough vinegar to adjust the pH to 5.
 Flask G: add enough vinegar or ammonia to adjust the pH to 7.
 Flask H: add enough ammonia to adjust the pH to 10.

Materials

Part 2

- 4 Erlenmeyer flasks or small glass soft-drink bottles
- wax pencil or marker
- 320 mL hot tap water (40°C)
- thermometer
- 85 g sucrose (table sugar)
- stirring rods
- 16 g yeast
- four 7.8 cm balloons
- masking tape
- string or thread

Part 3

- 4 Erlenmeyer flasks or small glass soft-drink bottles
- wax pencil or marker
- 320 mL hot tap water (40°C)
- thermometer
- 20 g sucrose (table sugar)
- stirring rods
- medicine dropper
- 10 mL vinegar
- 10 mL ammonia
- pH paper
- 16 g yeast
- four 7.8 cm balloons
- masking tape
- thread or string

Inquiry Focus

20. Add 4 g of yeast to each solution and stir.
21. Place a balloon on each flask, and seal it tightly with masking tape.
22. Every 2 min, stir the contents of each flask by swirling it slowly.
23. After 15 min, record your observations in a table (like the one below), and make additional observations every 10 min until no further changes occur. During your observations, describe the fermentation activity in each flask and measure the circumference of each balloon using the string or thread.

Flask	Conditions	Fermentation Observed	Carbon Dioxide Produced*
E	40°C + pH 3		
F	40°C + pH 5		
G	40°C + pH 7		
H	40°C + pH 10		

*Measured by the balloon circumference in centimetres

24. Remove the balloons very carefully as the foam may rise and spill all over you and the lab bench.
25. Clean up as instructed by the teacher, and put away the equipment you have used.

Analyze

1. Describe what you saw that indicated yeast reproduction.
2. Which flasks showed the greatest rate of yeast reproduction?
3. Compare the contents of the flasks at the beginning of Part 2 and at the end of Part 2. Were they the same? Explain.
4. Compare the contents of the flasks at the beginning of Part 3 and at the end of Part 3. Were they the same? Explain.
5. What conditions were the least favourable for reproduction?
6. Describe the controls that were used in this investigation.

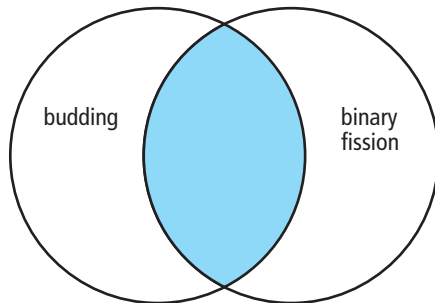
Conclude and Apply

1. Design an experiment to test the effect of temperature on yeast. Write out a list of materials and a procedure. If time permits, your teacher may allow you to carry out your experiment.
2. Draw bar graphs to compare the balloon circumference with changing nutrient concentration. On the same graph, using different colours, draw bar graphs comparing the balloon circumference with changes in pH.
3. If a baker wanted to maximize the rising of a batch of bread, what suggestions would you give the baker?

Check Your Understanding

Checking Concepts

- Match the following types of asexual reproduction with the examples in parts (a) to (e).
 - binary fission
 - budding
 - fragmentation
 - vegetative reproduction
 - spore
 - a cutting taken from a houseplant
 - bacteria
 - hydra
 - an animal that grows from a piece that has separated from the parent
 - a reproductive cell that may be able to survive extreme conditions
- Draw a Venn diagram like the one below to compare and contrast budding and binary fission.



- Give an example of a unicellular organism that reproduces by budding.
- List three ways plants can reproduce asexually.
- Explain why organisms that reproduce asexually often produce large numbers of offspring.
- How do some spores survive unfavourable conditions?

Understanding Key Ideas

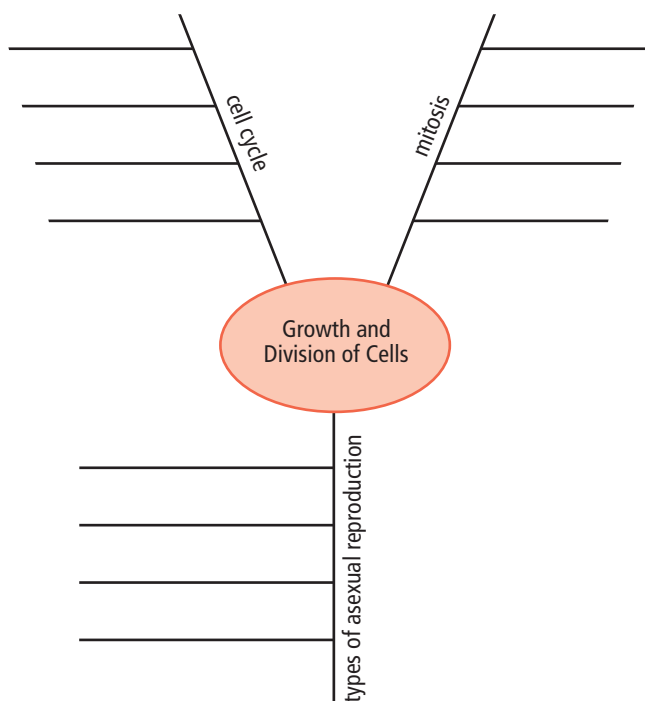
- There is a bacterium on the laboratory bench beside you. What do you think limits the number of times the bacterium will divide?
- Why are most multicellular organisms unable to reproduce by budding?
- Explain why bacteria do not undergo mitosis.
- How does binary fission in bacteria differ from binary fission in eukaryotic cells?
- Sea stars are able to attach to oysters, pry open their shells, and eat the insides. Oyster farmers once tried to destroy sea stars by cutting them into pieces and throwing them back into the ocean. Predict what happened.
- Describe how grafting can be used to produce an apple tree bearing four different varieties of apples.
- The number of plants, such as tulips, in a flower bed can increase without additional bulbs being planted. Explain how this can happen.
- What are the advantages and disadvantages of asexual reproduction?

Pause and Reflect

Some organisms, such as corals, have the ability to regrow parts that have been lost through injury. What cell process do you think scientists study to learn more about this regenerative ability?

Prepare Your Own Summary

In this chapter, you investigated the cell cycle, mitosis, and how cells and organisms reproduce asexually. Create your own summary of the key ideas in this chapter by making a spider map. Copy the following spider map into your notebook. Beside each idea, fill in as many words as you can related to that idea. When you have completed the map, go back through the chapter and look for other words you could include. Add these words to the map using a different colour of pen.



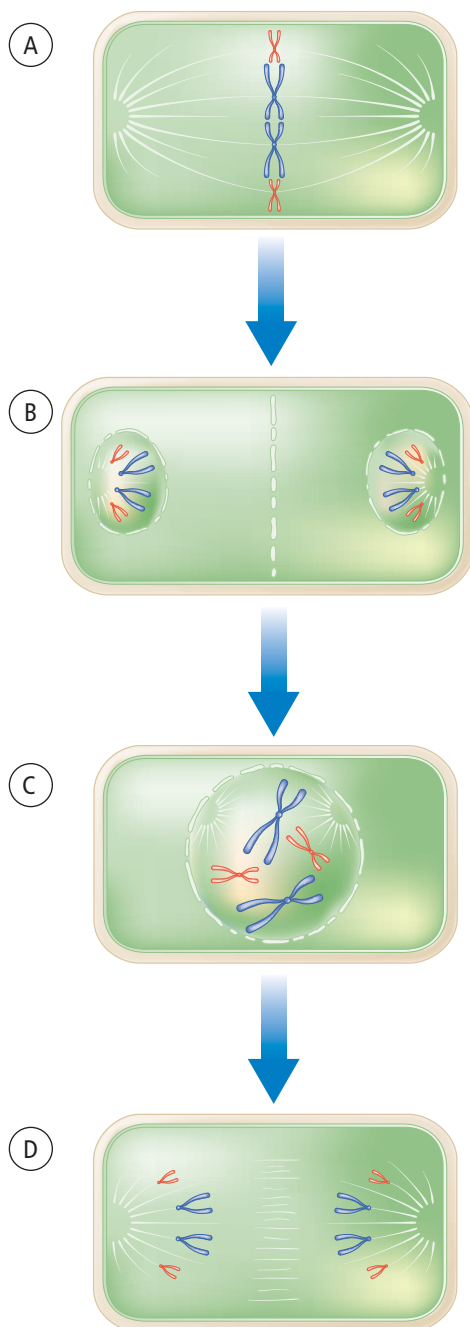
Checking Concepts

1. Why is cell division necessary in unicellular organisms?
2. Why is cell division necessary in multicellular organisms?
3. What are the three stages of the cell cycle?
4. Cells spend much of their time in interphase. What is occurring during this stage?
5. What would happen if a cell was unable to make protein to form fibres during mitosis?
6. How can binary fission lead to your becoming sick shortly after a few bacteria enter your body?
7. Design a chart listing the stages of the cell cycle. For each stage, describe one important event.
8. Design a chart listing the phases of mitosis. For each phase, describe one important event.
9. Make a sketch to illustrate how mitosis in plant cells differs from mitosis in animal cells.
10. What is the major disadvantage of asexual reproduction?
11. Give three examples of commercial uses of vegetative reproduction.
12. What unique advantage does spore production have over other asexual methods of reproduction?
13. How does budding in yeast differ from binary fission in amoebas?

Understanding Key Ideas

14. What are two characteristics of asexual reproduction?
15. Why must the nuclear membrane disintegrate during prophase?

16. Look at the following cells.
- What type of cells are they?
 - Explain how you know.
 - Write down the correct sequence of letters to show the phases of mitosis.
 - Write down the name and a brief description of each phase.



- Explain what might happen if the chromosomes did not separate correctly during anaphase.
- How has vegetative reproduction been helpful to farmers? Include examples in your explanation.
- What advantages do organisms that produce spores have over organisms that reproduce by budding or binary fission?
- Only less complex forms of animal life can reproduce by asexual reproduction without human assistance. Why?
- Asparagus dies back to the ground in the winter and regrows new shoots from its roots in the spring. How could this process be beneficial to farmers?

Pause and Reflect

An organism can produce an identical copy, or clone, of itself through asexual reproduction. Are offspring that are produced through asexual reproduction always identical to their parents?