1.2 The Cell Cycle and Mitosis

Here is a summary of what you will learn in this section:

- The life cycle of a cell has four phases.
- Growth and repair of cells is accomplished by mitosis.
- Cancer cells have an abnormal rate of cell division.

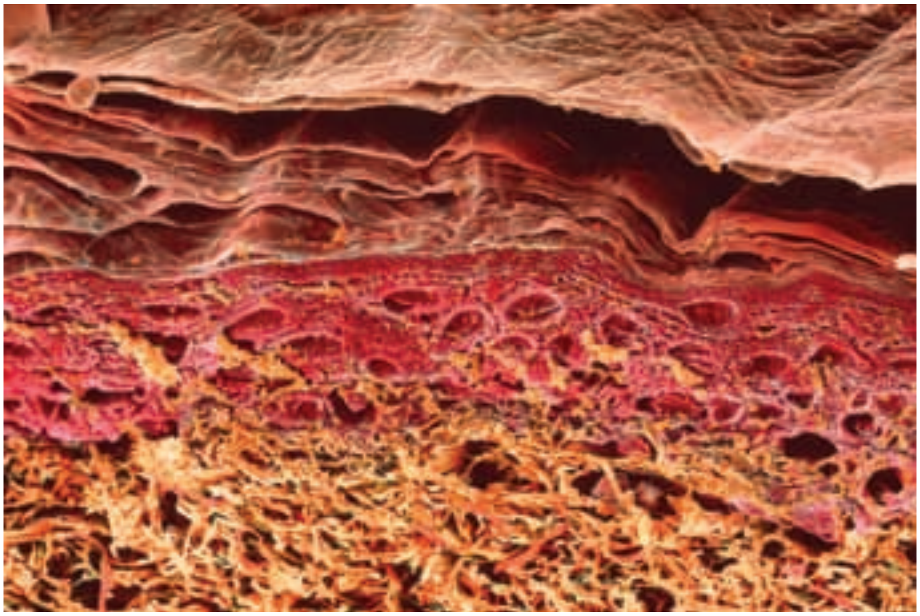


Figure 1.26 An electron micrograph of the skin shows the different layers of cells.

The Life and Death of Skin Cells

Stare at your face in the mirror. Your eyes are bright and alive, and your skin looks . . . dead? Actually, when we look at our skin, we are viewing dead cells. You lose about 30 000 to 40 000 skin cells every minute. If you collected all the dead cells that you shed over a day, you would collect 0.5 g of dead cells. If you collected those cells over a year, you would have about 3 kg of skin cells.

Since we lose so many skin cells every day, it is surprising that our skin does not simply wear away. However, our skin is made of different layers of cells (Figure 1.26). Skin cells are produced in the deeper layers of the skin and, in young people, mature over a period of about four weeks. During this time, the cells travel to the surface, where they are eventually sloughed off, leaving younger cells behind.

The cells on the surface are old, dead cells that have become toughened and flattened. This change in structure enables them to form a good protective layer for your body. These surface cells are continuously being replaced by cells from the layer below.

The time taken for the process of cell renewal changes as individuals age, or with changes in hormone or vitamin levels. For example, in older people, surface cells are held in the skin for up to 75 days, resulting in skin that is thicker and duller in appearance.

People apply products to their skin to keep it healthy, attractive, and young looking (Figure 1.27). The best way to keep skin healthy is to stay out of the Sun. Exposure to the Sun is responsible for damaging skin cells. Much of the damage is associated with premature skin aging, including the appearance of wrinkles and discoloured areas. Excessive exposure to the ultraviolet (UV) radiation in sunlight can also cause skin cancer: each year, about 30 000 Ontarians are diagnosed with skin cancer. The UV radiation changes the genetic information that is coded in the skin cells' DNA. This affects the functions of the cell, including the ability to reproduce and to repair itself. You can protect your skin from UV damage by wearing protective clothing (long-sleeved shirts and hats) and sunglasses, limiting your time in the Sun, and applying sunscreen to exposed skin.

Figure 1.27 People use skin creams to keep their skin looking healthy.

A7 **STSE** *Quick Lab*

Taking Protective Actions

The Sun is necessary for all life on Earth, but it is also the source of ultraviolet (UV) radiation, which is harmful to skin cells. There are things that you can do to protect your skin.

Purpose

To survey your class about Sun protection behaviours and to compare the class data with national data

Procedure

1. Think about your typical Sun protection behaviours during the summer.
2. Create a table in your notebook in which to record the results of your survey. Your table should indicate the total number of students responding to the survey and the total number of "yes" and "no" responses.
3. Participate in a survey of three questions of your class members.
   - Do you regularly practise Sun protection behaviours in the summer?
   - Have you suffered at least one major sunburn in the summer?
   - How many hours per day do you spend in the Sun during the summer?
4. Use the number of positive responses and the total number of students surveyed to calculate the percentage of students who practise Sun protection behaviours during the summertime.

Questions

5. Do your data suggest that youth are practising Sun protection behaviours?
6. How do your class data compare with the data in Table 1.3?

Table 1.3 National Sun Survey 2006

Percent of Canadians who:	16–24 years old	
	Male	Female
• spent at least 2 h in the Sun daily	47%	32%
• practised Sun protection behaviours	42%	58%
• acquired a tan from the Sun	28%	49%

7. What is one action that you could take to encourage your friends and family to practise Sun protection behaviours?
8. What Sun protection behaviours should people who work outside every day practise?

The Cell Cycle

Every hour, about one billion (10^9) cells die and one billion cells are made in your body. Through careful observation, scientists have identified a repeating cycle of events in the life of a cell. This cycle of events is called the **cell cycle**. During much of the cell cycle, the cell grows and prepares for cell division. In fact, although the main goal of the cell cycle is division, the cell spends most of its time preparing for division. The cell is in **interphase** when it is preparing for cell division. Cell division involves packaging the genetic information in the nucleus into two equal portions; this process is called **mitosis**. Then, the cytoplasm is split into two portions so that the original parent cell divides to form two new "daughter cells." Cells use mitosis in the processes of growth and repair.

We can visualize the cell cycle by considering Figure 1.28. There are four phases in the cell cycle: first growth phase (G_1), synthesis phase (S), second growth phase (G_2), and mitosis (M).

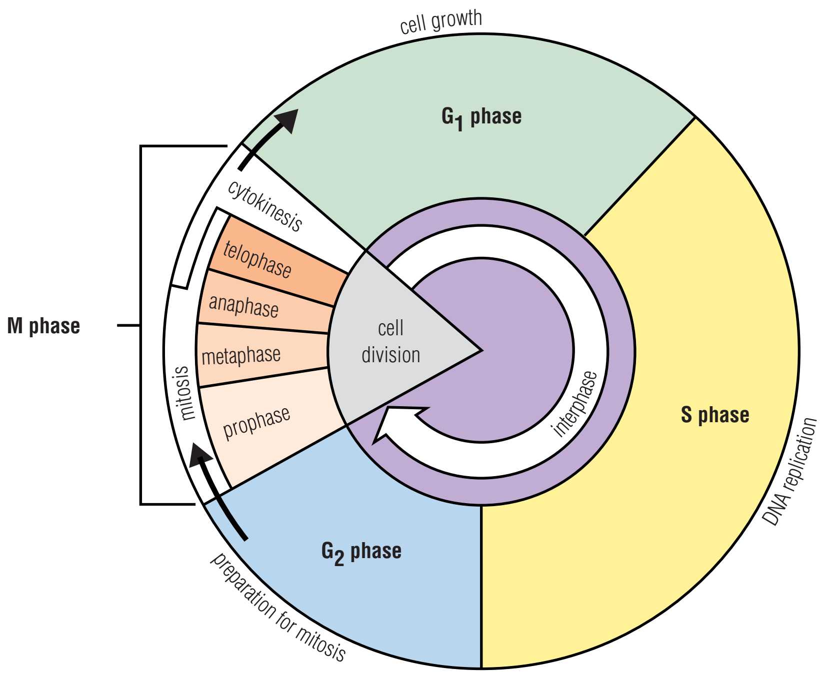


Figure 1.28 The cell cycle has four phases. During most of the cell cycle, the cell is growing, replicating its DNA, and preparing for cell division.

Chromosomes

Every cell contains chromosomes. Each **chromosome** is a long piece of coiled DNA and proteins. The number of chromosomes in each cell differs between organisms. For example, a horse has 64 chromosomes, while a hermit crab has 254 chromosomes. The typical human cell has 46 chromosomes — 23 matching pairs of chromosomes.

Chromosomes are visible only when the cell is dividing. When the cell is not dividing, the DNA and proteins that make up the chromosomes are spread throughout the cell in the form of chromatin. At the beginning of cell division, the chromosomes condense into visible structures. Before cell division can occur, each chromosome is copied. As shown in Figure 1.29, the chromosome consists of two identical copies, called **sister chromatids**. When the cell divides, one chromatid goes to each of the new cells.

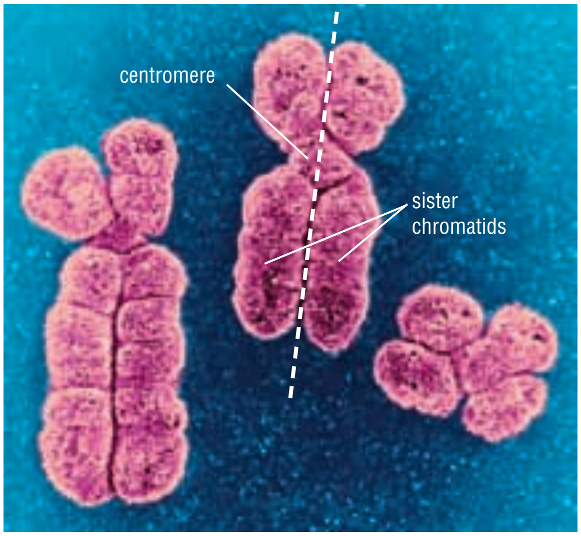


Figure 1.29 Each chromosome consists of two identical sister chromatids (shown magnified 8,300×).

A Closer Look at Interphase

A cell spends about 90 percent of its time in interphase. During interphase, the cell is growing. However, there is a limit to how big a cell can become. As a cell increases in size, the relationship of the surface area of the cell membrane to the amount of volume of cytoplasm changes. The volume of a cell's cytoplasm increases faster than the surface area of a cell's membrane. This affects how well a cell can absorb substances from its environment or expel wastes into its environment. When a cell reaches a certain size, it is healthier for the cell to undergo division. On average, the cells of an adult human are the same size as the cells in a child — however, there are more cells in an adult.

During interphase, the cell takes in nutrients, grows, and conducts other normal cell functions. There are three phases of interphase.

First Growth Phase (G_1)

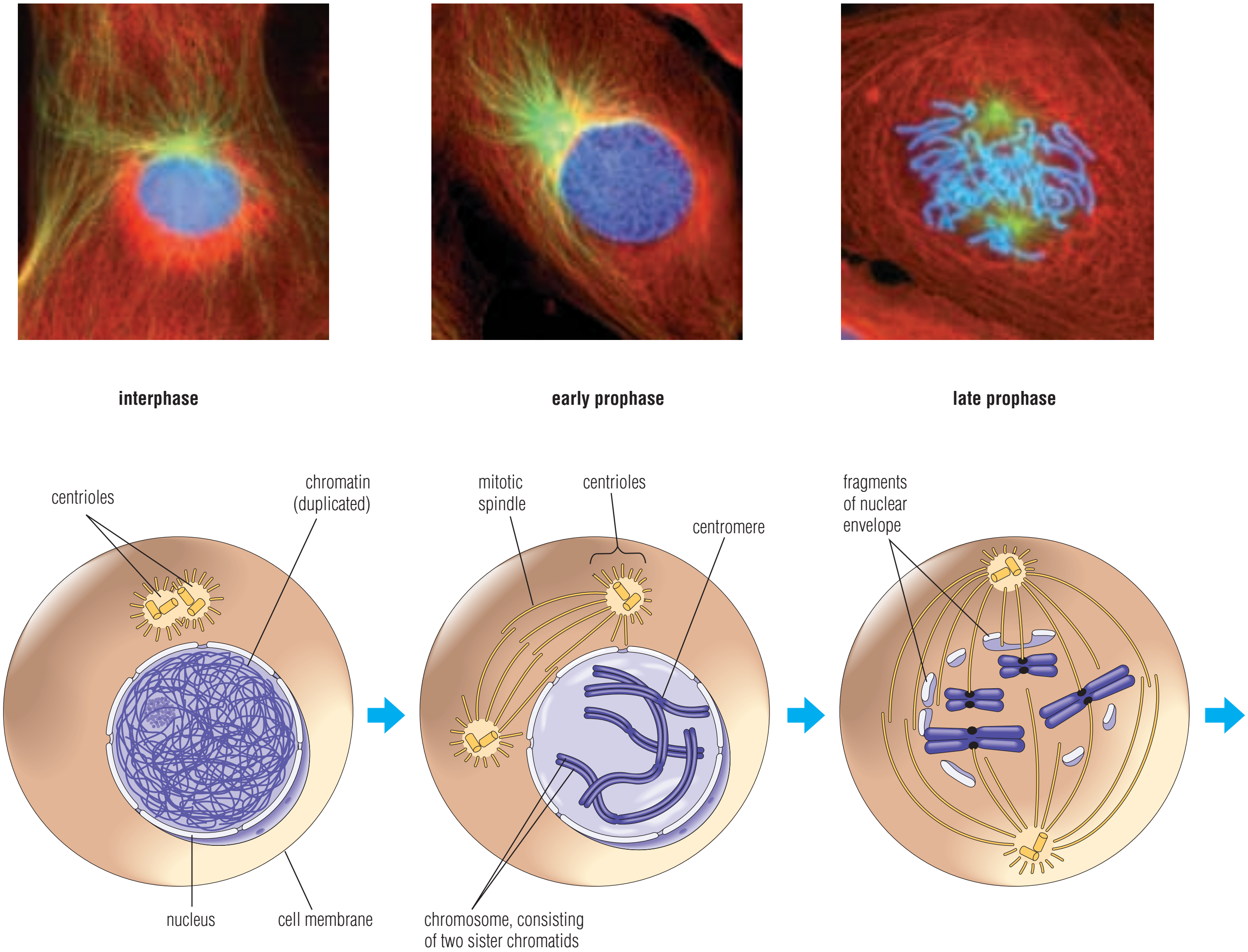
This phase is a period of growth for the cell. During this phase, the cell also produces new proteins and organelles. If the cell is healthy and conditions are favourable, the cell moves into the next phase.

Synthesis Phase (S)

During this phase, the cell makes (synthesizes) an entire copy of the DNA of the cell. Key proteins that are associated with chromosomes are also produced during this phase.

Second Growth Phase (G_2)

Once the DNA has been copied, the cell moves into the second growth phase. During this phase, the cell produces the organelles and structures needed for cell division. This phase is the shortest of the phases of interphase.



DNA has been duplicated in the S phase and appears as threads in the nucleus.

The chromatin condenses to form chromosomes. The centrioles move toward the poles. Spindle fibres form.

The nuclear envelope breaks down. Each chromosome is connected to a spindle fibre at its centromere.

WORDS MATTER

Many of the words associated with cells come from Greek words. "Mitosis" comes from the Greek word *mitos*, meaning thread. The words "meta," "ana," and "telo" come from the Greek words for between, renewal, and end.

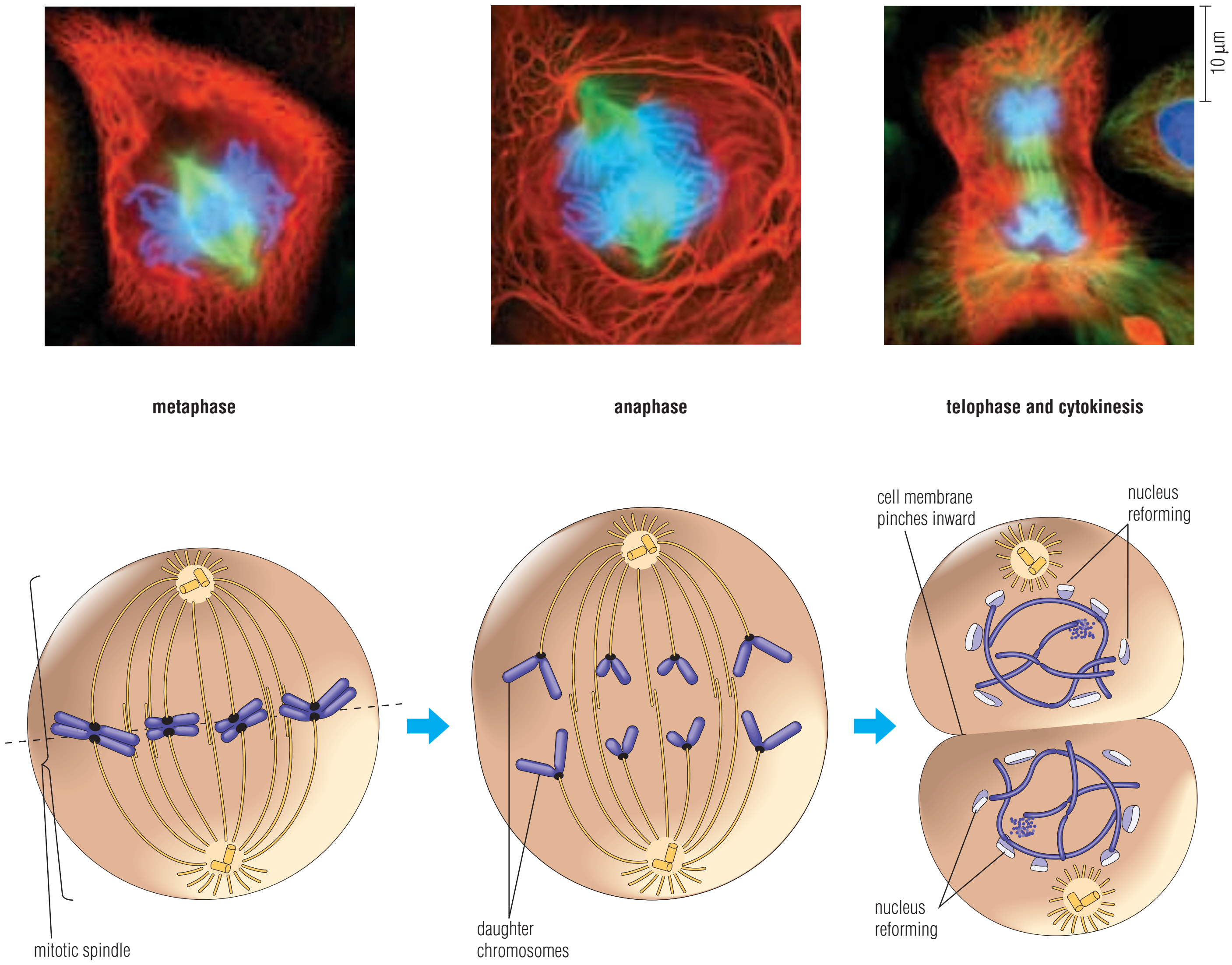
Suggested Activity •

A8 Inquiry Activity on page 35

A Closer Look at Mitosis

During most of the cell cycle, the cell is in interphase — it is growing, synthesizing DNA, and repairing itself. Once the cell is ready to divide and make two new identical cells, it enters mitosis (M phase). Before cell division can be accomplished, the cell must undergo great change. Therefore, during the M phase, the cell's energy must be entirely devoted to the process of cell division.

There are four phases in mitosis: prophase, metaphase, anaphase, and telophase. At the end of telophase, two daughter cells, each containing identical genetic information, are formed.



The chromosomes line up at the centre of the cell.

The sister chromatids separate into individual chromosomes and move to opposite poles.

The mitotic spindle breaks down, and two new nuclei form. The chromosomes lose their distinct shape. The cytoplasm and the cell membrane pinch in half to form two new daughter cells.

Prophase

During the first phase of mitosis, called **prophase**, the chromatin (DNA and proteins) that makes up the chromosomes condenses. At this stage, the chromosome is actually two identical copies called sister chromatids attached together at a centromere. These sister chromatids will eventually separate and move to opposite sides of the cell. To enable the movement of the chromatids within the cell, the nuclear structures and nuclear envelope disintegrate. In addition, a framework called the mitotic spindle forms to move the chromatids around in the cell. Chromatids are attached to the spindle at their centromeres. In animal cells, a pair of organelles called centrioles moves to each end of the cell, forming the poles of the mitotic spindle.

Metaphase

As the cell moves into the second stage of mitosis, called **metaphase**, each chromosome becomes completely condensed. The chromosomes move toward the centre of the cell and line up at the middle of the cell. The mitotic spindle is complete and is made of tiny tubes that extend from each pole to the middle of the cell. These tubes connect the centromere of each chromosome to the two poles.

> ***During Reading*** — Thinking Literacy
>
> **Match the Story to the Picture**
>
> You may read paragraphs where there are so many new terms that you cannot understand all of them. Do not forget to check the diagrams and other pictures included in the text. Reread the text, matching the words you are reading to the pictures to get a better understanding of the ideas.

Anaphase

During **anaphase**, the sister chromatids separate at the centromere. Each chromatid is now a complete chromosome. The separated chromosomes are pulled to opposite ends of the cell.

Telophase and Cytokinesis

During the last phase of mitosis, known as **telophase**, the cell divides the cytoplasm into two portions. The process of splitting the cytoplasm is known as **cytokinesis.** In animal cells, the cell membrane pinches inward, eventually splitting the one cell into two cells. In plant cells, the cell plate forms the cell wall and inner plasma membrane in each of the new cells. At the end of cytokinesis, the two new cells return to interphase conditions. Two nuclei form where each pole of the parent cell was. The mitotic spindle disappears. Each of the new cells enters the G_1 phase of the cell cycle, and the cell cycle is repeated.

Learning Checkpoint

1. What is the purpose of the cell cycle?
2. Define the term "interphase" and describe its purpose.
3. (a) What is mitosis?

   (b) Why is mitosis important to the cell?
4. Define and distinguish between the following terms: chromosome, centromere, and sister chromatids.
5. Explain the meaning and importance of the term "cytokinesis."

Cell Growth and Repair

Multicellular organisms are made up of many different cells. These different cells all undergo cell growth and cell division at different rates. For example, in the human body, nerve cells do not undergo mitosis once they mature. Other cells, such as skin cells and cells in the digestive tract, undergo cell division regularly. Cell division provides new cells to replace cells that wear out or break down. After observing rates of cell division, scientists concluded that differences in rates of cell division reflect the internal control systems of the cell cycle.

In a growing organism, there is rapid mitosis of cells in areas of growth. Cells that are likely to be damaged or injured as they function also have high rates of mitosis. For example, your intestinal cells divide every three days and are then broken down by the digestive process, whereas your red blood cells may last for four months. In plants, growth occurs in the meristem region (Figure 1.30). The cells in the meristem region of a root tip appear to divide every 12 to 36 h.

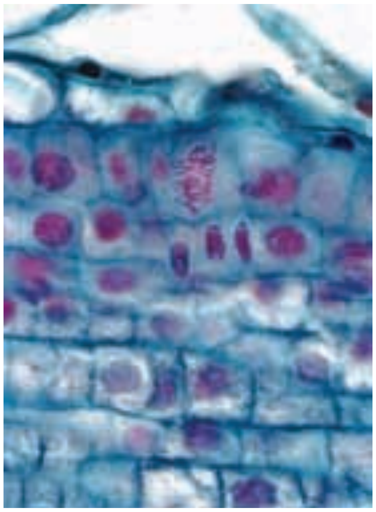


Figure 1.30 Cells in the meristem region in an onion root tip undergoing mitosis (magnification 350×)

Factors That Affect Mitosis

The environment impacts the rate of mitosis. For example, if you travelled to a part of the world where you were exposed to a change in environmental conditions, such as a change in altitude, the rate of mitosis in your blood cells would increase. Plants may also respond to environmental changes by altering their rates of mitosis: a plant will bend toward the light because the cells in the stem opposite the light grow more rapidly than those facing the light (Figure 1.31).

Antibiotics can also affect the rate of mitosis of a cell. Antibiotics are drugs given to combat bacterial infections. Some antibiotics, called bacteriostatic drugs, temporarily stop bacteria from growing by interfering with mitosis. Some bacteriostatic drugs inhibit the replication of DNA. Other drugs, called cytostatic drugs, also interfere with mitosis and are used in chemotherapy.

Figure 1.31 A field of sunflowers in Ontario

Will Cells Live Forever?

The cell cycle regulates how long a cell lives. Sometimes, cells die because they have suffered injury or damage that cannot be repaired. For example, cells that are exposed to a poison may absorb the poison and die. This type of death is known as cell necrosis.

A cell also dies as a normal part of the functioning of healthy multicellular organisms. This regulated, or controlled, cell death is known as **apoptosis**. Apoptosis is the death of cells that are no longer useful (Figure 1.32). For example, when your body fights a viral infection, your body produces many cells to fight that infection. When the virus has been removed from your body, these cells are no longer needed and they are removed by apoptosis. Apoptosis also removes cells that have lost their ability to perform efficiently.

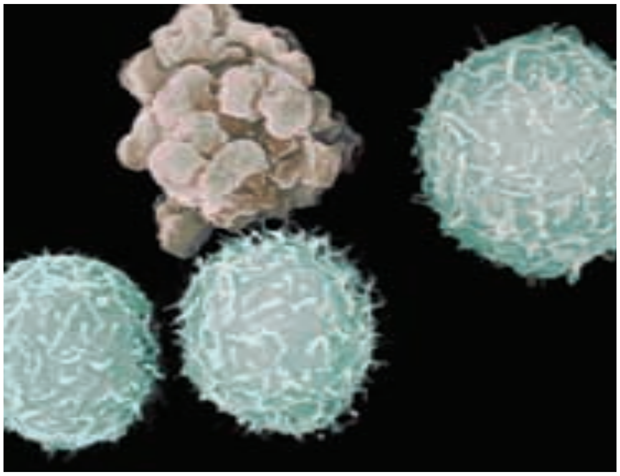


Figure 1.32 Scanning electron micrograph showing normal cells surrounding a cell undergoing apoptosis (magnification 3000×)

Cancer Cells

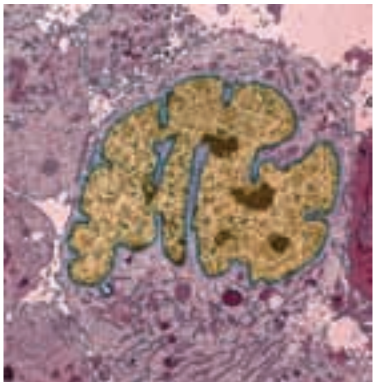


Figure 1.33 A transmission electron micrograph of a lung cancer cell. The nucleus (beige) is enlarged and irregularly shaped (magnification 1000×).

A cell that divides uncontrollably is called a **cancer cell** (Figure 1.33). Cancer cells develop when a change occurs in the cell that affects how that cell divides. When a cell's DNA is changed, it is known as a mutation. Some viruses and environmental agents, such as ultraviolet radiation or cigarette smoke, can cause cell mutations. Some cancer-causing mutations are inherited.

A cancer cell divides differently from a normal cell. For example, while normal cells usually live for about 50 to 60 cell divisions, cancer cells can seem to be "immortal" because they do not stop dividing. A normal cell will undergo apoptosis if it is damaged genetically, whereas a cancer cell will continue to divide (Figure 1.34). Table 1.4 compares the characteristics of a normal cell with a cancer cell.

Suggested Activity •
A9 Quick Lab on page 36

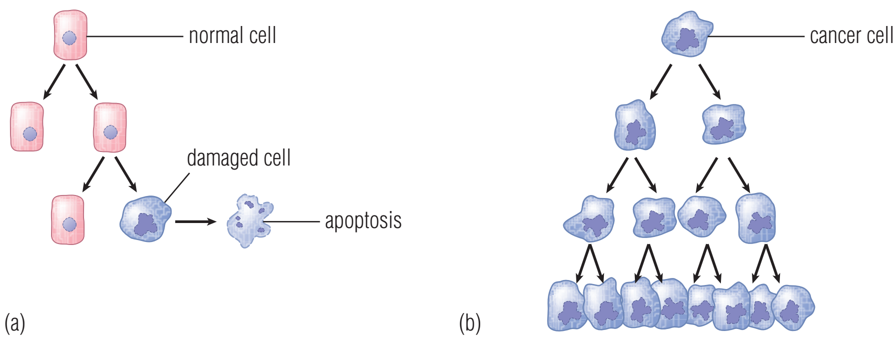


Figure 1.34 (a) Cell division and cell death in normal cells. (b) Cell division in cancer cells

Take It Further

HeLa cells have been used in cancer research for over 50 years. Research the history of HeLa cells. Be prepared to report on your findings. Begin your research at ***ScienceSource***.

Table 1.4 Comparing Normal Cells with Cancer Cells

Normal Cells	Cancer Cells
• make exact copies of themselves through mitosis	• make exact copies of themselves through mitosis
• reproduce for about 50–60 cell divisions	• do not stop reproducing
• stick together to form masses of cells as appropriate	• do not stick to other cells • behave independently
• self-destruct when too old or too damaged	• may move to another location of the body

A8 *Inquiry Activity* Skills References 2, 6, 10

SKILLS YOU WILL USE
- Observing, and recording observations
- Interpreting data/information to identify patterns or relationships

Identifying the Stages of Mitosis in Plant and Animal Cells

To understand and identify the different stages of mitosis, you need to examine plant and animal cells undergoing mitosis.

Question

What similarities and differences between plant and animal cell mitosis can you see using a microscope?

Materials & Equipment

- compound light microscope
- pen and/or pencil
- paper
- prepared slides of plant and animal cells in mitosis

CAUTION: Practise proper techniques in handling the microscope and slides.

Procedure

Part 1 — Examining Plant Cell Mitosis

1. Review the proper handling and use of the microscope in Skills Reference 10. Set up your microscope.
2. Place a prepared slide of plant cells on your microscope.
3. View this slide and scan to see its contents using low power. Adjust the light so that you can see the cell contents clearly.
4. Find the section of small cells near the top of the root cap. Move the slide so that these cells are in the centre of your field of view.
5. Look at the cells using the low-, medium-, and high-power lenses. Identify cells that are in each phase of mitosis.
6. Make sketches of cells in each phase of mitosis. Count the number of cells that are in each phase in one field of view.
7. Remove the plant cell microscope slide, and return the microscope to low power.

Part 2 — Examining Animal Cell Mitosis

8. Place a prepared slide of animal cells on your microscope.
9. View this slide and scan to see its contents using low power. Adjust the light so that you can see the cell contents clearly.
10. Find a section of cells that appear to be in mitosis. Look at the cells using the low-, medium-, and high-power lenses. Identify cells that are in each phase of mitosis.
11. Make sketches of cells in each phase of mitosis. Count the number of cells that are in each phase in one field of view.
12. Clean up your work area. Make sure to follow your teacher's directions for safe disposal of materials. Wash your hands thoroughly.

Analyzing and Interpreting

13. Was there a difference in the frequency of cells in the various stages of mitosis? If so, what stage of mitosis did you find most frequently?
14. Based on your observations, which phase do you think takes the longest? Why?

Skill Practice

15. Explain how the use of contrast (light levels and use of stain) improved your understanding of the cells that you were viewing.

Forming Conclusions

16. What similarities and differences did you observe between the plant cells and the animal cells undergoing mitosis?

A9 Quick Lab

Comparing Cancer Cells and Normal Cells

The main difficulty in detecting cancer is that the appearance of symptoms depends on how fast the cancer cells are dividing. The rate of cancer growth is measured in doubling times. One doubling time is the length of time it takes for the cancer cells to double in number. Doubling times for different types of cancer cells vary from 10 days to several years. The average doubling time for a cancer cell is four months.

Purpose

To compare the rate of cell division in cancerous cells and non-cancerous cells

Procedure

1. Identify which diagram in Figure 1.35 represents cancerous cells.
2. It takes about 30 doubling times for a cancer cell to form a tumour that is large enough to be felt through the skin with hands. Calculate how many months it would take for the cells in Figure 1.36 to form a tumour that could be felt if the doubling rate is two months.

Questions

3. Explain how you know which diagram in Figure 1.35 shows cancerous cells.
4. What do you think is happening in Figure 1.36?
5. If the cancerous cells were left untreated, what do you predict would happen?
6. What are the limitations of visual inspection as a diagnostic tool for cancer?

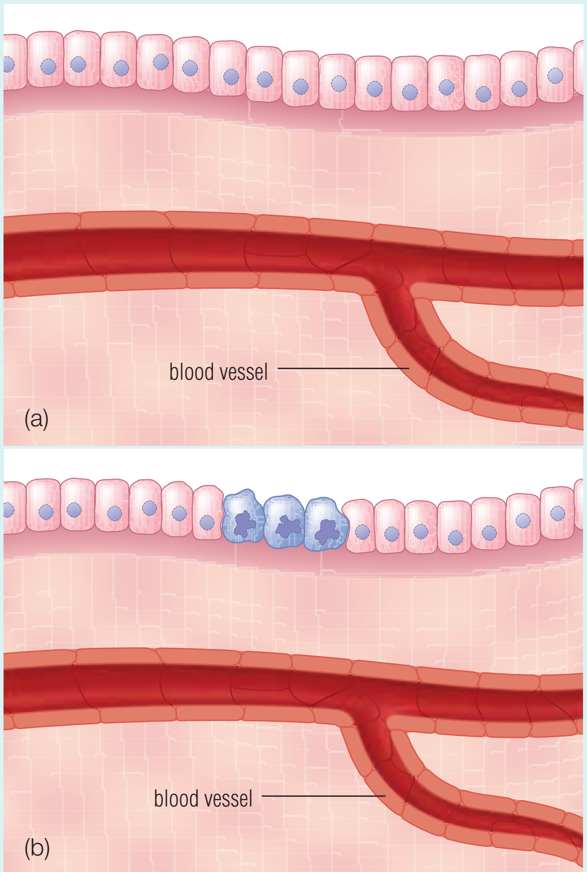


Figure 1.35

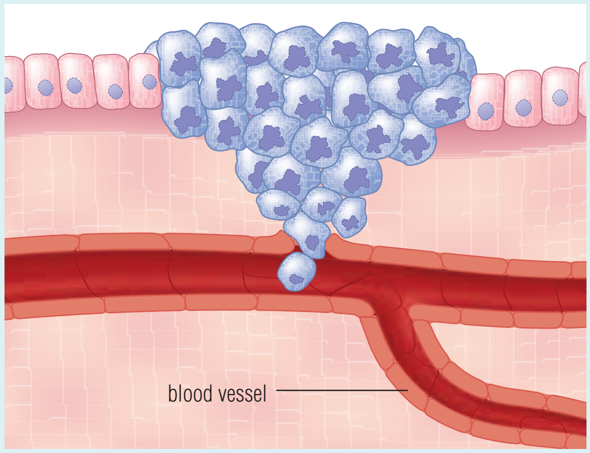


Figure 1.36

1.2 CHECK and REFLECT

Key Concept Review

1. Describe the events in the cell cycle.

2. Compare mitosis in plant and animal cells.

3. Describe the meaning of the term “apoptosis,” and state its importance.

4. State one similarity and one difference between plant and animal mitosis.

5. What is a cancer cell?

6. Explain how mitosis ensures genetic continuity.

7. How does mitosis make the growth and repair of cells possible in an organism?

8. Why would you expect cells to spend the greatest percentage of their cycle in interphase?

9. What happens to the chromosomes as a cell prepares to divide?

10. How is a cancer cell different from a normal cell? Give three differences.

Connect Your Understanding

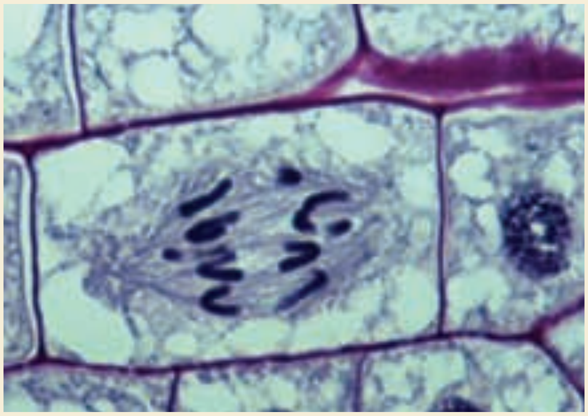
11. Describe the differences between mitosis in an animal cell and a plant cell.

12. Why must cell division be controlled or regulated for cells to remain healthy? Explain your answer.

13. A certain antibiotic affects cells by preventing the formation of spindle fibres. Explain how this drug would affect mitosis in cells.

14. A drug used in chemotherapy causes chromosomes to move incorrectly during mitosis. As a result, the daughter cells that are produced have either too much or too little genetic information. Predict why this treatment causes the cancer cells to die.

15. Identify the stage of mitosis shown in the photo below. Explain your thinking.



Question 15

16. The nerve cells in our bodies rarely undergo mitosis. Use this information to explain why complete recovery from injuries to our nervous system may not occur.

17. Sunscreens protect your skin by blocking types of ultraviolet radiation. Explain why the Canadian Cancer Society advises Canadians to apply sunscreen.

18. Suggest reasons why cancer researchers may be interested in using their learning about the processes of cell division to develop new forms of cancer prevention and treatment.

19. Three samples of cells from three different patients were unlabelled. One sample was from an 85-year-old man, one was from a 5-year-old boy, and one was from a person with skin cancer. How could you determine to which patient they belonged?

Reflection

20. How did your understanding of cell division change after you viewed cells under a compound light microscope?

For more questions, go to ***ScienceSource***.