

Topic 1.2

Why do animal cells divide and what happens when they do?

Key Concepts

- Cells must divide for an organism to survive.
- Hereditary material is passed on during cell division.
- Animal cells have a life cycle that includes both growth and division.
- New animal cells are created during the cell cycle.
- Uncontrolled, rapid division of animal cells can be cancer.

Key Skills

Inquiry
Literacy
Numeracy

Key Terms

cell cycle
interphase
mitosis
cytokinesis
regeneration
prophase
metaphase
anaphase
telophase

In the world of science fiction movies, a creature may lose its head—literally—and then grow it right back again. Of course, nothing like that happens in real life—unless you happen to look in a pond! If a pond-dwelling planarian flatworm loses its head or tail to one of its many predators, it can grow an entirely new one. It can even regenerate an entirely new body from just a small fragment of tissue. Other organisms such as starfish and earthworms have a similar ability. They can re-grow a missing limb or tail. Scientists are studying cell division in these organisms in an attempt to understand how such complex healing is possible. If this knowledge could be applied to cell division in the human body, medical breakthroughs such as regenerating an amputated limb could become a reality for humans.

Starting Point Activity

1. As a class, brainstorm as many situations as you can in which the following organisms might need to produce new cells: starfish, snake, human.
2. With your classmates, try to explain why a planarian flatworm can grow a new head but you cannot.



A HORROR HORDE OF CRAWL-AND-CRUSH GIANTS

CLAWING OUT OF THE EARTH

FROM MILE-DEEP

CATACOMBS!



"This city is under martial law until we annihilate THEM!"

Kill one and two take its place!

THE AMAZING NEW WARNER BROS. SENSATION!

Cells must divide for an organism to survive.

Cells divide because there is a limit to how large they can grow. For a cell to survive, it must take in a constant supply of materials such as nutrients, oxygen, and water. It must get rid of waste products it produces. And materials must travel within the cell's cytoplasm to reach the cell membrane and other organelles. If a cell grows too large, it cannot carry out these processes efficiently. Read the information below to find out why.

Cell size is limited because the amount of material in a cell increases faster than the cell membrane grows.

The only way for nutrients and wastes to get in and out of a cell is to pass through the cell membrane. As a cell gets larger, the amount of material inside the cell increases more than the cell membrane can grow to contain it. After a while, nutrients and wastes can no longer pass through the cell membrane in the amounts required. As a result, the cell dies.

Cell size is limited because the amount of material in a cell increases, but the speed of diffusion does not.

As the cell grows, the amount of material inside it increases. As a result, it takes longer for nutrients and wastes to diffuse between the cell membrane and all parts of the cell. Use [Figure 1.5](#) to help you understand this idea. To keep this model cell alive, you need to swim from the edge of the pool to the centre carrying a pool noodle. Then you must swim back to the edge carrying a beach ball. If the pool is small, you can keep up with moving these materials in and out. As the pool gets bigger, however, it takes longer to make these trips. Over time, you can't supply nutrients or remove wastes from all parts of the cell fast enough to meet its needs. Eventually, it will either starve to death or be poisoned from a build-up of waste products.

► **Figure 1.5** A pool can be used to model a cell. As the size of the pool increases, it takes longer to transport pool noodles and beach balls between the edge of the pool and the centre. Similarly, as the size of a cell increases, it takes longer to transport nutrients and wastes between the cell membrane and the rest of the cell.



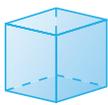
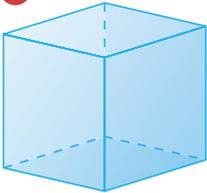
Activity 1.5

CELL NUMBER CRUNCH

The *cell surface* is the area of the cell over which all nutrients must enter and all wastes must leave. The *cell volume* determines how much the cell holds. It also determines how far nutrients and waste must diffuse to be used or removed.

If a cell has a larger surface, it means that more nutrients can get in and more wastes can get out. But when the cell surface increases, the volume increases even more. Refer to the table below to see why this is the case. A larger volume means that the amounts of nutrients that must travel in or out of the cell increase even more. As well, the distance that nutrients must diffuse also gets longer. In the case of a growing cell, there will be a point at which the surface area is not large enough to meet the demands of the cell's volume.

- If Cube B, with sides that are 2 mm, grows to have sides that are 3 mm
 - what is the new surface area?
 - what is the new volume?
- Which has increased more: surface area or volume?
 - Why would this be a problem if the cube were a cell?

| Cube | Side Length | Surface Area (length × width × number of sides) | Volume (length × width × height) |
|---|--|---|--|
| A  | 1 mm | $1 \text{ mm} \times 1 \text{ mm} \times 6 = 6 \text{ mm}^2$ | $1 \text{ mm} \times 1 \text{ mm} \times 1 \text{ mm} = 1 \text{ mm}^3$ |
| B  | 2 mm The length of any side on Cube B is two times larger than on Cube A. | $2 \text{ mm} \times 2 \text{ mm} \times 6 = 24 \text{ mm}^2$ The surface area of Cube B is four times larger than the surface area of Cube A. | $2 \text{ mm} \times 2 \text{ mm} \times 2 \text{ mm} = 8 \text{ mm}^3$ The volume of Cube B is eight times larger than the volume of Cube A. |

LEARNING CHECK

- Why do cells divide instead of simply growing larger and larger?
- Use **Figure 1.5** to explain why a cell may die if it becomes too large.
- As a cell grows, which increases in size faster: the cell membrane or the cell contents?

Hereditary material is passed on during cell division.

When a cell divides, two new cells are created. Each new cell is identical to the original cell. Each new cell inherits a set of instructions from the original cell. These instructions determine all the details of the organism's life. They determine its characteristics, its functions, and even how long it will live. These instructions are found in the nucleus of the cell. They are stored in a unique molecule called DNA. DNA is short for **deoxyribonucleic acid**.

DNA: The Cell's Hereditary Material

The nucleus of almost every cell in an organism carries all the DNA needed to create an identical twin of itself. How does so much information fit into the nucleus of each cell? DNA molecules are shaped like long strands of a very thin, twisted ladder (**Figure 1.6**). To fit into a small space, they coil and compact to form threads called *chromatin* (**Figure 1.7**). The chromatin are packed together tightly within the nucleus. If you were to uncoil the DNA in one of your cells, it would be 2 m long—taller than most grade 10 students. Amazingly, the diameter of a nucleus is only about 5 μm (0.000 005 m). (In comparison, imagine stuffing a piece of string that is 100 km long into a lunch box, as in **Figure 1.8**.)

When a cell divides, the DNA is packed together even more tightly. A super-condensed form of chromatin called *chromosomes* is formed at this time. Because chromosomes are so compact, they are a convenient way to pass on hereditary information when a cell divides.

▲ **Figure 1.6** DNA is arranged in two long strands that look like a twisted ladder.

Activity 1.6

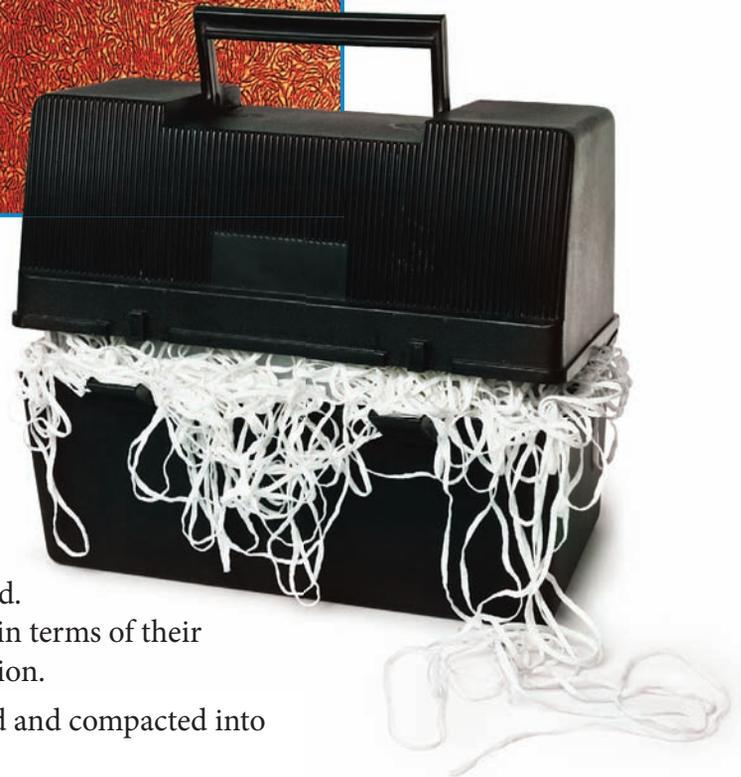
MODELLING THE COILING AND CONDENSING OF DNA

To get an idea of how much DNA is packed into a nucleus, see how much string you can stuff into a small box such as the box from a deck of cards. *Much* more DNA fits into the nucleus than string fits into a small box.



◀ **Figure 1.7** DNA is further condensed into coiled threads called chromatin.

▶ **Figure 1.8** About 2 m of DNA are coiled and condensed to fit into the nucleus. This is like stuffing 100 km of string into a lunch box.



LEARNING CHECK

1. When a cell divides, two new cells are created. Compare these new cells to the original cell in terms of their appearance, their organelles, and their function.
2. What is the benefit of DNA being condensed and compacted into coiled threads of chromatin?
3. Why do you think DNA is packed together even more tightly into chromosomes when a cell divides?

Animal cells have a life cycle that includes both growth and division.

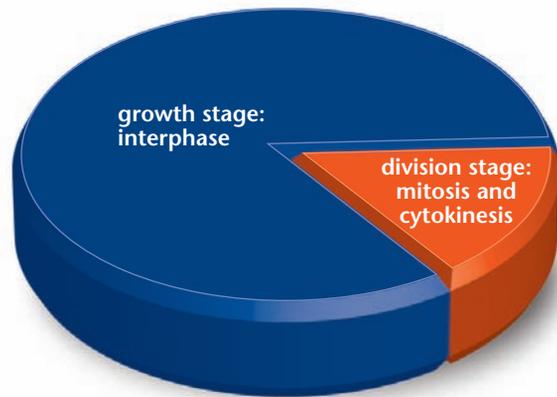
cell cycle: the continuous series of events in the life of a cell in which it is born, grows, reproduces, and dies

All organisms must be able to produce new cells. Many-celled organisms have a special set of cells, called stem cells, that can divide to produce new cells. The series of events that occur when they are dividing is called the **cell cycle**.

Stages of the Cell Cycle

As shown in **Figure 1.9**, the cell cycle is made up of two main stages: a growth stage called interphase and a division stage that consists of mitosis and cytokinesis. Each of these stages includes a series of distinct events.

► **Figure 1.9** The cell cycle is divided into a growth stage and a division stage.



interphase: the stage in the cell cycle when a cell grows and carries out its usual functions, as well as making a copy of its DNA and organelles to prepare for cell division

mitosis: the stage in the cell cycle when the contents of the nucleus separate into two identical copies

cytokinesis: the stage in the cell cycle when the cytoplasm and organelles divide into two identical, separate cells

The Growth Stage: Interphase

Most of a cell's life cycle is spent in a growth stage called **interphase**. During interphase, the cell grows and carries out its usual functions. The cell also makes a copy of its organelles and the DNA in its nucleus to prepare for division. The majority of cells spend most of their lives in interphase. Interphase ends when a cell begins its division stage.

The Division Stage: Mitosis and Cytokinesis

Cell division is a process in which one cell produces two new cells that are exact copies of the original cell. There are two main phases of cell division:

1. **Mitosis:** During mitosis, the contents of the nucleus separate into two identical copies.
2. **Cytokinesis:** During cytokinesis, the cytoplasm and organelles divide into two identical, separate cells. Each of these cells will now go on to complete its own cell cycle.

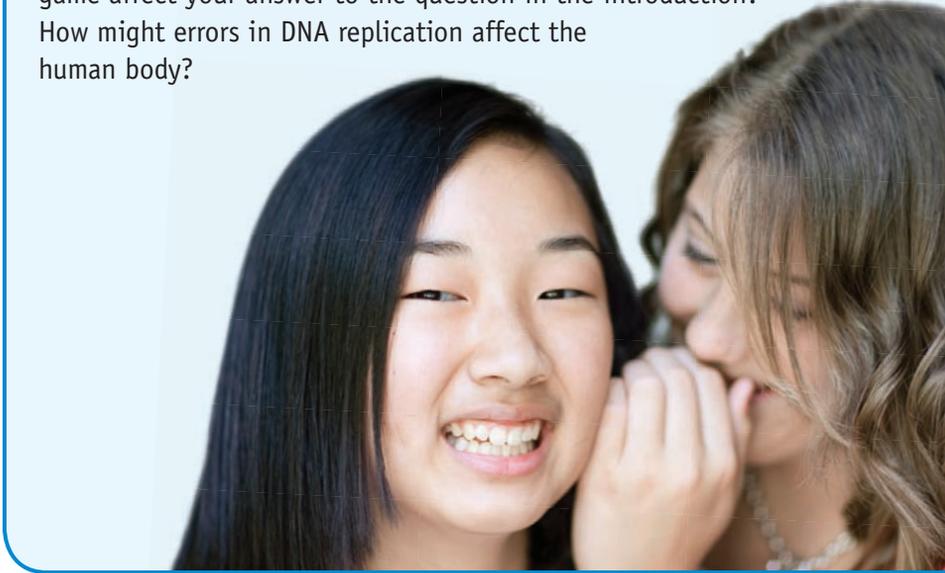
Activity 1.7

HOW IS DNA REPLICATION LIKE A GAME OF “TELEPHONE?”

Imagine how many times DNA replicates during a person’s life. How likely do you think it is that mistakes are made during replication?

Form a group of at least eight students. Whisper a message to your neighbour. Pass the message from one person to the next. Has the message changed by the time it reaches the last person? How do the results of this game affect your answer to the question in the introduction?

How might errors in DNA replication affect the human body?



Why Cell Division Is Important

Cell division enables organisms to carry out three important functions:

- **Growth:** Cell division enables organisms to grow from a single cell into a multi-celled organism that can contain trillions of cells.
- **Maintenance:** Cell division produces new cells to replace worn-out or dead cells.
- **Repair:** Cell division regenerates damaged tissues. **Regeneration** is the ability to grow new cells to replace damaged or lost body components. If you cut your finger, skin cells reproduce so that skin is regenerated over the injured area. Some organisms, such as the starfish in the topic opener, can even regenerate entire body parts.

regeneration: the ability to grow new cells to replace damaged or lost body components

LEARNING CHECK

1. State two reasons why cells reproduce.
2. Make a flowchart to outline what happens during cell division.
3. Do you think cell division occurs more often in a 4-year-old or a 40-year-old? Explain your thinking.

ACTIVITY LINK

Activity 1.10, on page 34

New animal cells are created during the cell cycle.

prophase: the first phase of mitosis when the nucleus and nuclear membrane disappear and chromosomes form

metaphase: the second phase of mitosis when the chromosomes align in the centre of the cell

anaphase: the third phase of mitosis when the chromosomes separate and move to opposite ends of the cell

telophase: the fourth phase of mitosis when the membrane surrounding the nucleus re-forms, creating two new nuclei

In the cell cycle of dividing cells, a precise sequence of events leads to the creation of new cells. Those events are:

- **interphase;**
- the four phases of mitosis (**prophase**, **metaphase**, **anaphase**, and **telophase**);
- **cytokinesis.**

Figure 1.10 shows and describes these events of the cell cycle.

Literacy Focus

Activity 1.8

CELL CYCLE MNEMONICS

You can use a mnemonic (a memory aid) to help you remember the order of events of the cell cycle. For example, look at this statement:

“I Prefer Mice And Talking Cats.”

See that each word starts with the same letter as an event from the cell cycle: **I**nterphase, **P**rophase, **M**etaphase, **A**naphase, **T**elophase, **C**ytokinesis.

Make up your own mnemonic for the events in the cell cycle.

LEARNING CHECK

1. Name the three main events in the life cycle of a cell.
2. Use a main idea web to summarize the phases of mitosis.
3. Describe how **Figure 1.10** on page 29 and **Figure 1.9** on page 26 are related.
4. Explain what you think could happen if a cell makes an error copying its DNA during interphase.

INVESTIGATION LINK

Investigation 1A, on page 32

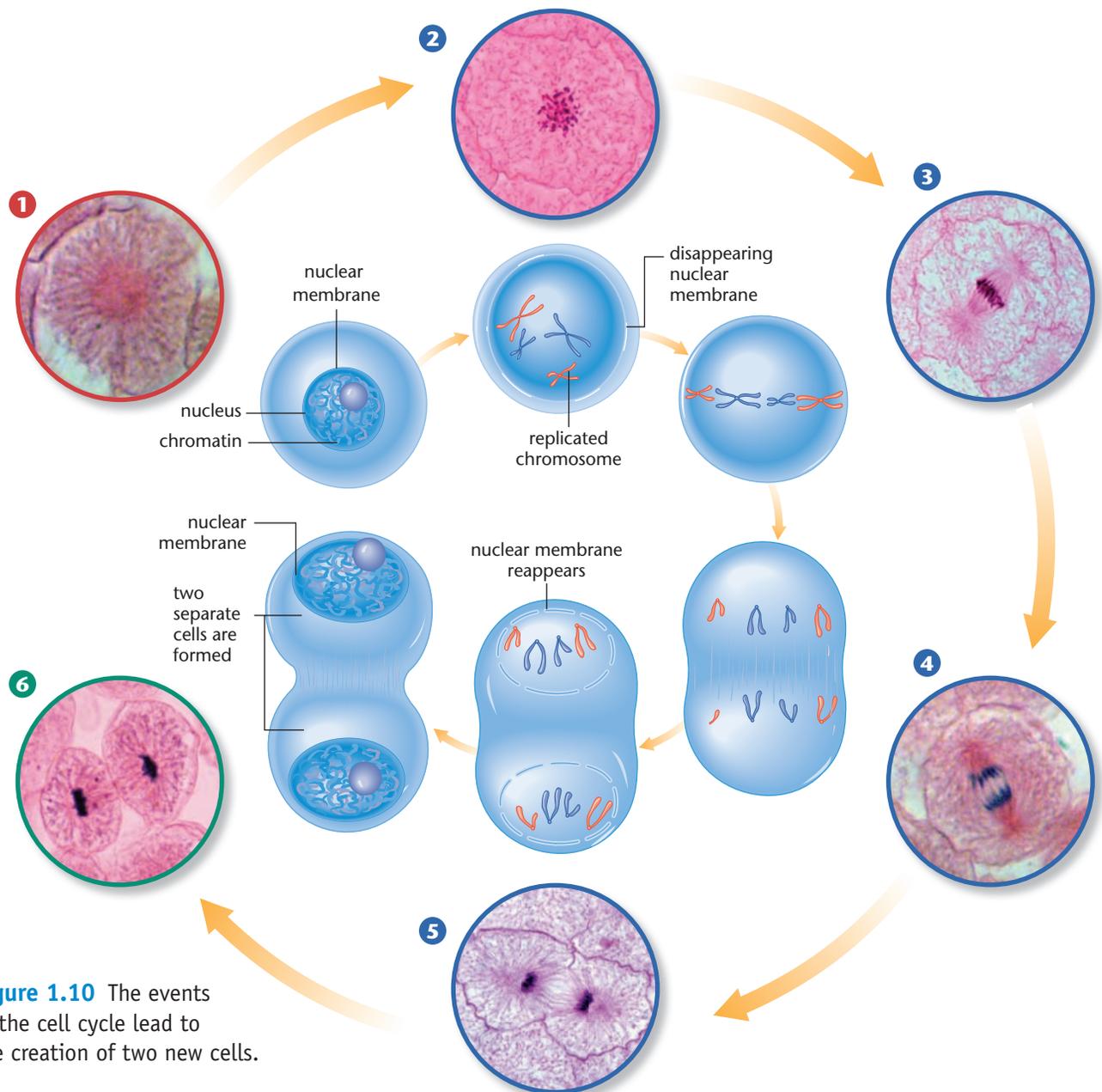


Figure 1.10 The events in the cell cycle lead to the creation of two new cells.

1. Interphase

- The cell grows to nearly twice its original size.
- The number of organelles in the cytoplasm increases.
- The DNA in the nucleus duplicates into two identical copies.

2. Prophase (Mitosis Phase 1)

- The nuclear membrane begins to disappear.
- The duplicated DNA condenses into chromosomes that are visible under the microscope. Each chromosome is made up of two identical copies of DNA that are joined at one point.

3. Metaphase (Mitosis Phase 2)

- Fibres in the cytoplasm push the chromosomes together, lining them up in the middle of the cell.

4. Anaphase (Mitosis Phase 3)

- The points where the two copies of DNA were attached in each chromosome split apart, separating the identical copies of DNA. Each part is now called a chromosome.
- The new chromosomes are pulled apart and drawn to each end of the cell.

5. Telophase (Mitosis Phase 4)

- Membranes begin to form around the two new nuclei. Each nucleus has a complete set of chromosomes that contain a complete copy of the cell's DNA.
- The chromosomes begin to uncoil.

6. Cytokinesis

- The elongated cell begins to pinch apart at the centre, dividing the cytoplasm into two parts.
- Cytokinesis ends when there are two identical, separate cells.

Uncontrolled, rapid division of animal cells can be cancer.

What determines when a cell starts and stops dividing? The cell cycle is controlled by a communication system that involves chemical signals. Consider a cell that is dividing to heal a wound. At a certain point, it receives a chemical signal that the wound has healed and it adjusts its rate of division accordingly.

Unchecked Cell Growth Results in Tumours

If a cell ignores a signal to stop dividing, unchecked cell growth can result. Over time, the newly divided cells form a mass called a *tumour*. Why do some cells ignore signals to stop dividing? The answer lies in mutations. A *mutation* is a permanent change in a cell's DNA. All tumours start with a mutation that affects a cell's response to division signals. This mutation is passed on to other cells during mitosis.

Some mutations are inherited. Some simply occur randomly. And others result from exposure to environmental factors. Environmental factors that result in mutations include ultraviolet light and radiation. Many chemicals, such as those in cigarettes, alcohol, and other drugs, also cause mutations.

Some Tumours are Cancerous

Different mutations can result in different types of tumours. Some mutations can cause benign tumours, while others cause cancerous tumours. Several factors distinguish cancer from a benign tumour, as shown in **Table 1.1**.

Table 1.1 Comparing Cancer and Benign Tumours

| Tumour | Characteristics |
|---------------------------|---|
| Benign | <ul style="list-style-type: none">• Cell division is unchecked and proceeds at a moderate rate.• Does not invade surrounding cells, but may push nearby cells out of the way.• Does not spread to other parts of the body• Relatively harmless unless found in a part of the body, such as the brain, where it may press on other cells |
| Cancer (malignant tumour) | <ul style="list-style-type: none">• Cell division is unchecked and occurs very quickly. Cells spend little time in interphase.• Damages and destroys surrounding cells by invading them• Can spread to other parts of the body• May interfere with the function of other cells, sometimes resulting in death if the tumour is not destroyed or removed |

Go to **scienceontario**
to find out more

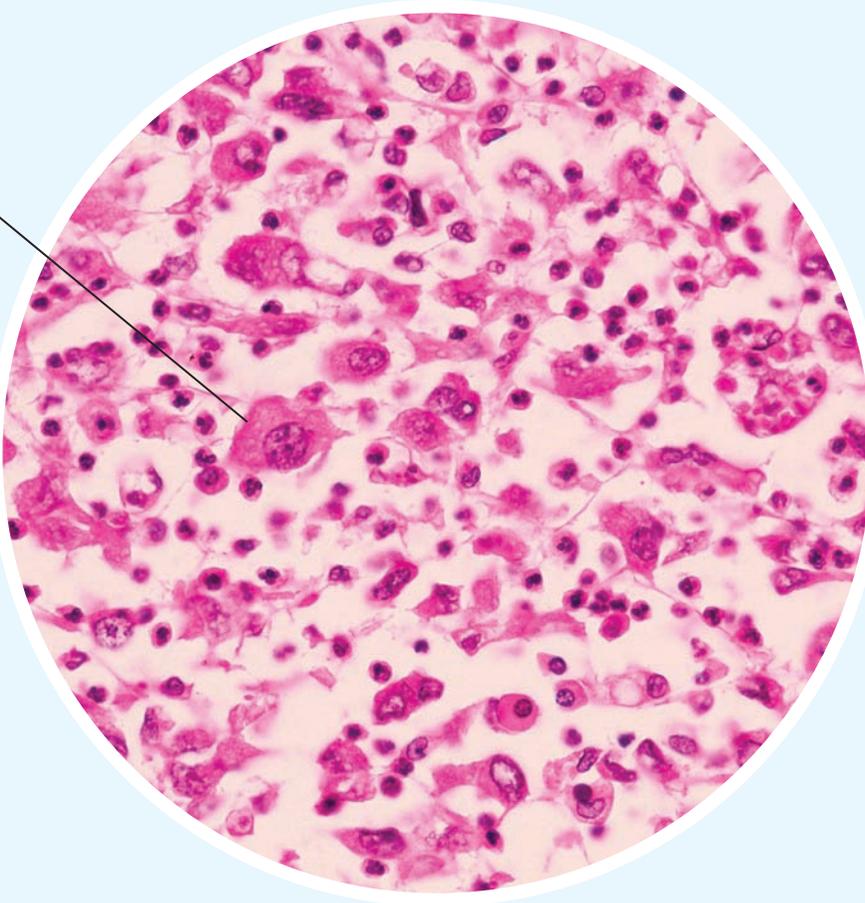


Activity 1.9

COMPARING CELLS

Benign tumour cells tend to look normal. It can be hard to distinguish them from the cells they originated from. Cancer cells, however, look much more “unusual.” The image below shows normal cells and a cancer cell.

cancer cell



1. Use a graphic organizer to record the similarities and differences you see between the normal cells and cancer cells shown in this photo.
2. Compare organizers with another student. Add any similarities and differences you may have missed.

Hint: Note how cancer cells differ from normal cells in shape, size, and content.

LEARNING CHECK

1. How is the cell cycle regulated?
2. What is cancer?
3. Is cancer (a malignant tumour) always more life threatening than a benign tumour? Explain.

ACTIVITY LINK

Activity 1.11, on page 35, and Activity 1.12, on page 36

Skill Check

initiating and planning

- ✓ performing and recording
- ✓ analyzing and interpreting
- ✓ communicating

Safety



- Microscope slides are made of glass. If they break, put them in the container for broken glass.
- Make sure that the microscope is turned off and your hands are dry when you plug or unplug the cord.
- To unplug a microscope, pull on the plug not the cord.

What You Need

- microscope
- prepared slides of whitefish embryo cells

Observing the Cell Cycle in Animal Cells

Observe and compare the stages of the cell cycle using prepared slides of whitefish embryo cells. Whitefish embryos are in a period of rapid growth.



What To Do

1. Obtain a microscope and a whitefish embryo slide. Use the following checklist to help you set up your microscope:
 - ✓ Plug in the microscope and turn on the light.
 - ✓ Turn the nosepiece until the low-power lens faces the stage.
 - ✓ Put the slide on the stage so that you will be able to see what is on the slide.
 - ✓ Secure the slide using the stage clips.
 - ✓ Looking from the side of the microscope, use the coarse-adjustment knob to bring the lens as close as it will go to the stage.
 - ✓ Look in the eyepiece. Slowly turn the coarse-adjustment knob to get the slide in focus.
 - ✓ Find an area of dividing cells. Make sure that the cells you want to observe are in the centre of the circle.
 - ✓ Turn the fine-adjustment knob to get the best possible focus.
 - ✓ Looking from the side of the microscope, turn the nosepiece until the medium-power lens faces the stage. Look through the eyepiece again. Focus using only the fine-adjustment knob.
 - ✓ Looking from the side of the microscope, turn the nosepiece until the high-power lens faces the stage. Look through the eyepiece again. Focus using only the fine-adjustment knob.
 - ✓ Determine the stage of the cell cycle you are viewing.

2. Identify one cell in each of the following stages of cell division.

- interphase
- prophase
- metaphase
- anaphase
- telophase
- cytokinesis

Draw each cell. Use **Figure 1.10** on page 29 to help you label as many parts as you can. Refer to the Science Skills Toolkit for instructions for drawing scientific diagrams.

3. Look again for an area of dividing cells on your slide. Move the slide until you are viewing about 100 cells. Record how many cells are dividing and how many are not dividing within your field of view.

What Did You Find Out?

1. Explain how you determined whether or not a cell was dividing.
2. What were the easiest parts of the cell to identify and label?
3. Were most of the cells you examined in step 3 dividing or not dividing? Explain your result.
4. Would you expect most of the cells on a slide of an adult whitefish bone to be dividing or not dividing? Explain your thinking.

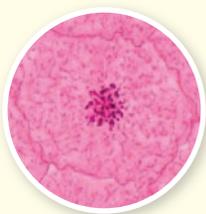
Inquire Further

Repeat this investigation using prepared slides of human skin cells. Would you expect to see as many cells dividing? Use your prediction to create a hypothesis.

Stages of the cell cycle in whitefish embryo cells.



interphase



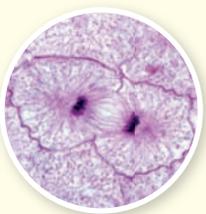
prophase



metaphase



anaphase



telophase



cytokinesis

Activity 1.10

HOW MANY TIMES HAVE YOU SHED YOUR SKIN?

Unlike a snake, which sheds all its skin at once, you are always shedding cells from the outer layer of your skin. This happens because older cells are constantly being pushed to the surface by new cells that are growing below. In fact, your entire outer layer of skin is replaced by new cells every 28 days.

What You Need

- calendar
- calculator

What To Do

1. Determine the number of times you have changed your skin in your lifetime. Use a calendar and the hints below to complete the following equation:

number of days in a year

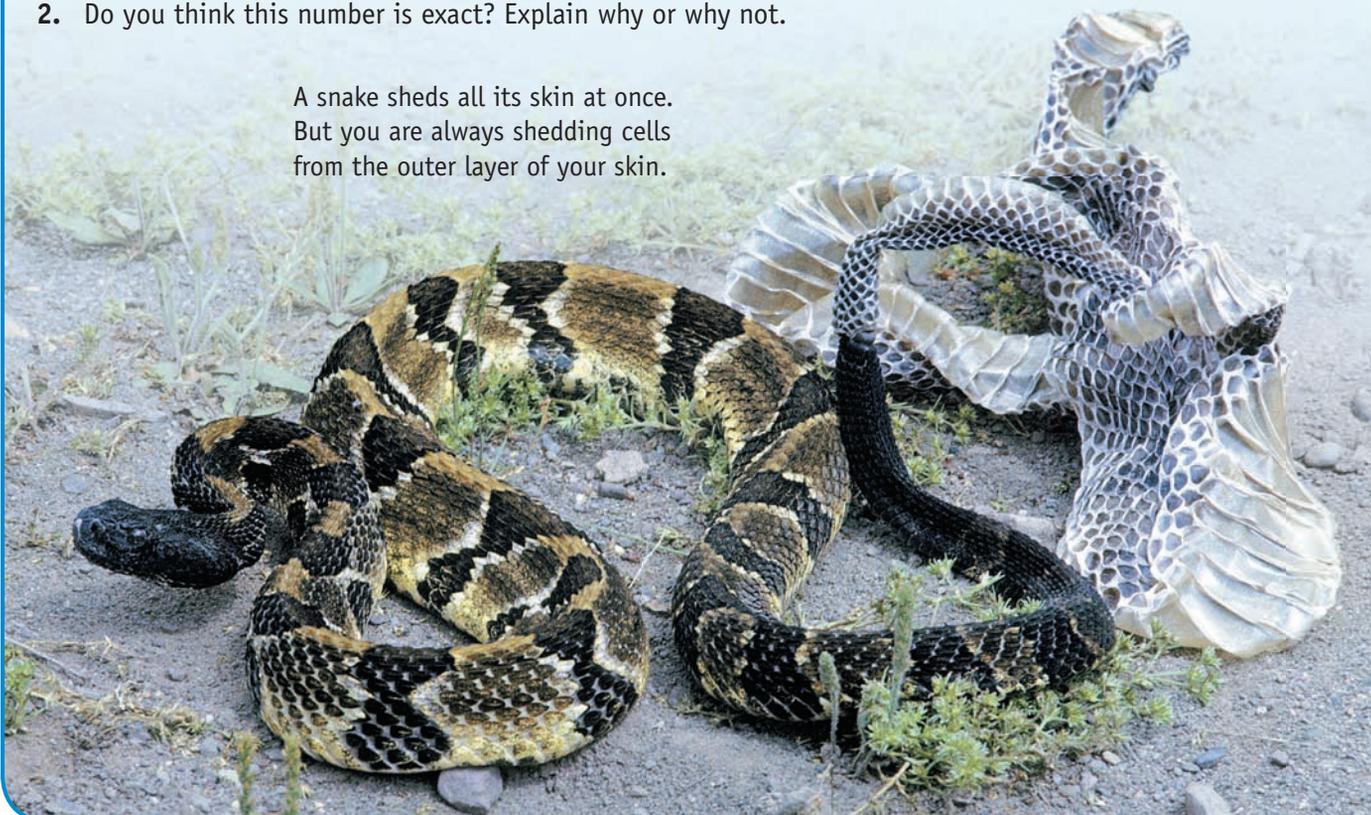
$$\text{Number of times you have changed your skin} = \frac{\text{your age} \times 365 + \text{number of days since your last birthday}}{28}$$

number of days your skin takes to replace itself completely

What Did You Find Out?

1. How many times in your lifetime have you changed your skin?
2. Do you think this number is exact? Explain why or why not.

A snake sheds all its skin at once. But you are always shedding cells from the outer layer of your skin.



Activity 1.11

CELLS CYCLING OUT OF CONTROL

Mutations can occur in all types of cells. Some mutations cause a cell to ignore a signal to stop dividing. Such a mutation can result in out-of-control cell division unless the mutated cell dies. In this activity, you will explore how such a mutation affects cell division in cancerous and non-cancerous cells.

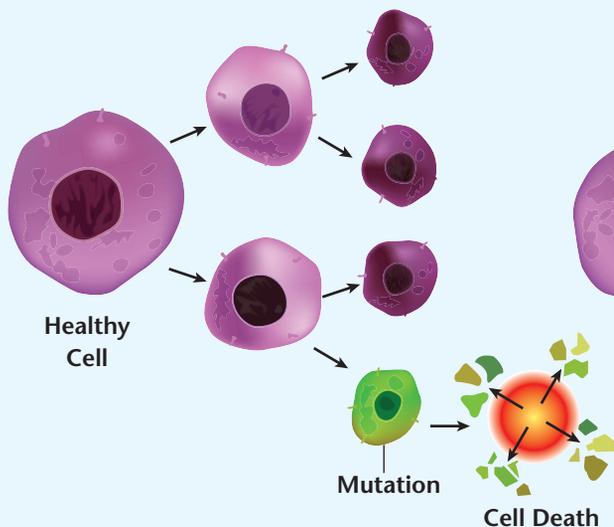
What To Do

1. Examine illustrations A and B. Both illustrations begin with a normal cell in the process of dividing.
2. Use the Internet to find and view animations of cell division in normal cells and cancerous cells. Write a paragraph that compares the division of both types of cells.

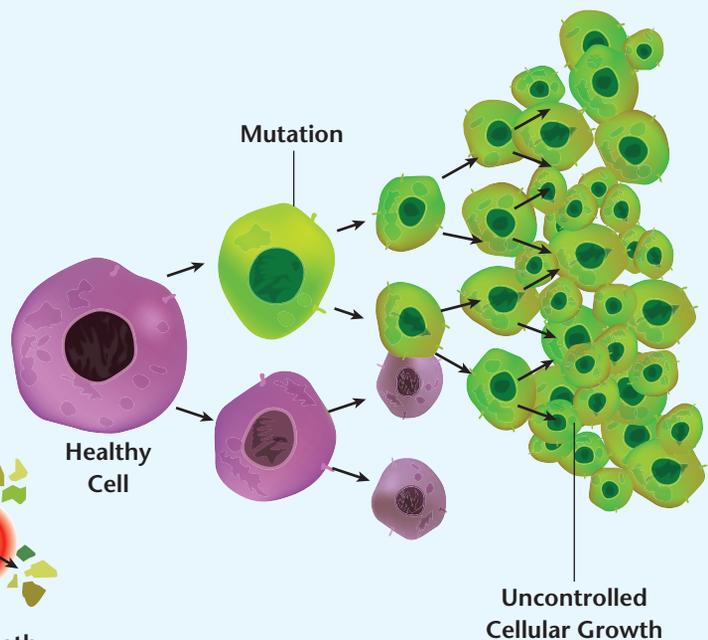
What Did You Find Out?

1. At what stage of the cell cycle are the cells in A and B?
2. Explain what happens during normal cell division when a cell mutation causes the cell to ignore a signal to stop dividing.

A Normal Cell Division



B Cancer Cell Division



Activity 1.12

ELEPHANTS AND CELLS RUN AMOK

What could elephants and cancer cells possibly have in common? Imagine what would happen if the birth rate of elephants skyrocketed and their death rate decreased to zero. The elephant population would grow unchecked. The elephants would devastate the environment, knocking down trees and trampling over fields and cities. They would eat all the food so nothing else could survive. Eventually the elephants would destroy life on Earth!

What To Do

1. Create a graphic organizer that compares the effects of unchecked elephant population growth with cancer cell division.

What Did You Find Out?

1. a) How would the growth of the elephant population affect other animals and plants on Earth?
b) How is this similar to how cancer affects cells around it?
2. Describe two other ways in which the uncontrolled growth of an elephant population is similar to the uncontrolled growth of cancer cells.
3. The idea of out-of-control elephant population growth is an analogy, which is a comparison that helps us understand the effects of cancer better. With a partner or as a class, come up with another analogy to help explain the effects of cancer to someone who is not in your class.



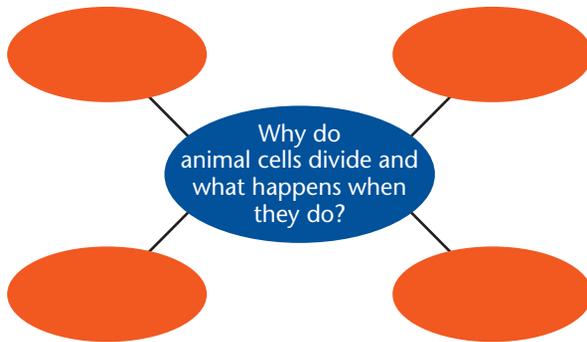
Topic 1.2 Review

Key Concept Summary

- Cells must divide for an organism to survive.
- Hereditary material is passed on during cell division.
- Animal cells have a life cycle that includes both growth and division.
- New animal cells are created during the cell cycle.
- Uncontrolled, rapid division of animal cells can be cancer.

Review the Key Concepts

1. **K/U** Answer the question that is the title of this topic. Copy and complete the graphic organizer below in your notebook. Fill in four examples from the topic using key terms as well as your own words.



2. **A** After you are fully grown, why do your cells continue to divide?
3. **A** Imagine you are made of one giant cell instead of billions of small ones. Describe two problems you would encounter. Explain why you would have these problems.
4. **K/U** Explain the role DNA plays in cell division.
5. **K/U** In which stage of the cell cycle is DNA replicated?

6. **K/U** Describe what happens during the following phases of mitosis: prophase, metaphase, anaphase, and telophase.
7. **T/I** **A** What evidence do you have that some cells in your body are dividing?
8. **T/I** The dark spot on this photo turns out to be skin cancer. What might have been the cause? How was cell division involved?



9. **C** Cigarettes are known to cause cell mutations. Write a letter to the editor of the school paper that explains mutations and why it is important to avoid smoking and limit exposure to cigarette smoke.