

# Reproduction

## **CHAPTER 5**

### Cell Growth and Reproduction

## **CHAPTER 6**

### A Closer Look at Cell Division

## **CHAPTER 7**

### Sexual Reproduction and the Diversity of Life

## **CHAPTER 8**

### Zygotes and Development

# Unit 2 Overview

**D**uring the 1800s scientists constructed what has come to be known as the cell theory. The theory is based on three important principles.

- All living things are composed of one or more cells.
- The cell is the functional unit of life.
- All cells come from pre-existing cells.

How do single cells make duplicate cells? How do multicellular organisms produce offspring by combining genetic information from two parents? What are the impacts of scientific research and technological innovations within a social context?

## 5. Cell Growth and Reproduction

All living things undergo cell division. Cell division is essential for the perpetuation of life.

**In this chapter, you will be able to:**

- Explain the importance of the cell theory in developing a modern understanding of cell biology.
- Describe the processes and explain the importance of cell division.
- Examine how different organisms use various types of asexual reproduction for propagation.
- Use a microscope and mathematical computations to determine the rates of cell division, and the growth rates of plants and animals.



## 6. A Closer Look at Cell Division

The way in which a cell functions and divides is determined by genetic information contained in its nucleus.

**In this chapter, you will be able to:**

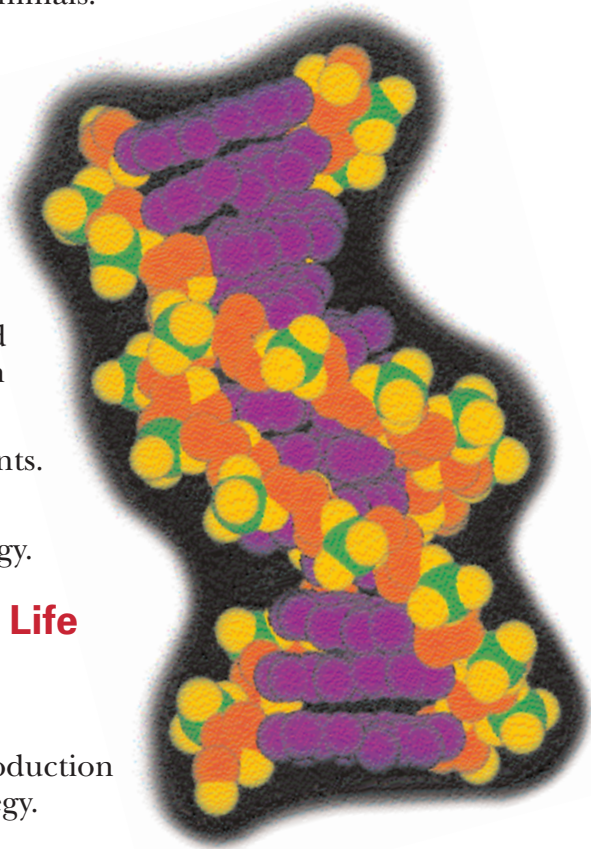
- Explain the importance of DNA replication to the survival of an organism.
- Identify factors that can alter the genetic information and explain how changes in the DNA structure can change an organism.
- Describe and carry out experiments on the cloning of plants.
- Explain technological innovations for regeneration and cloning and evaluate social issues related to this technology.

## 7. Sexual Reproduction and the Diversity of Life

Sexual reproduction creates a diversity of species.

**In this chapter, you will be able to:**

- Describe the difference between asexual and sexual reproduction and indicate advantages and disadvantages for each strategy.



- Identify and describe adaptive advantages for different strategies of sexual reproduction such as: conjugation, hermaphroditic reproduction, and separate sexes.
- Identify reproductive structures within flowers and humans.
- Describe the process by which sex cells are formed within multicellular organisms and explain why sex cells have half as many chromosomes as other cells.
- Describe, in general terms, the roles of hormones in the formation and maturation of sex cells and the role of hormones in pregnancy and birth of humans.

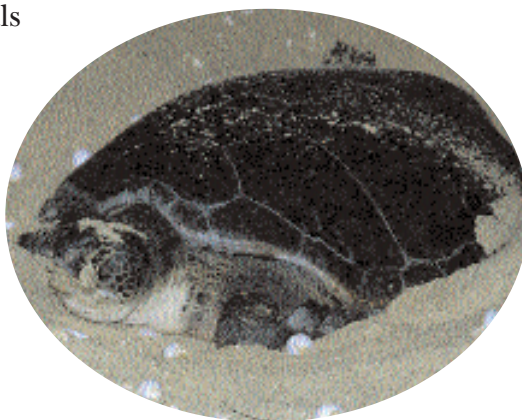


## 8. Zygotes and Development

Different organisms use very different strategies, and combinations of strategies, to ensure the survival of their offspring.

### In this chapter, you will be able to:

- Identify and describe adaptive advantages for different developmental strategies such as: spores, seeds, eggs, and development within the uterus.
- Explore seed formation and germination of plant embryos within a laboratory setting.
- Examine the events of zygote formation, embryo growth, and fetal development of humans within the uterus.
- Examine and evaluate the social implications of various reproductive technologies designed to assist couples who want to have children.
- Explain how materials pass across the placenta between mother and child, and examine the moral implications of drug use by parents during pregnancy.



## Challenge

**In this unit you will be able to...**  
demonstrate your learning by completing a Challenge.

### Society and Reproductive Technology

As you learn more about reproduction and related technologies, think about how you would accomplish these challenges.

#### 1 Survey on Reproductive Technology

Conduct a survey to determine public opinion about various scientific breakthroughs in reproductive technology.

#### 2 Public Information Display

Prepare a display for the general public that presents the issues about one type of reproductive technology.

#### 3 Futuristic Short Story or Play

Write a futuristic short story or a play that focuses on issues involving reproductive technologies and how they can affect our society.

To start your own Challenge, see page 258.

Record your ideas for the Challenge when you see

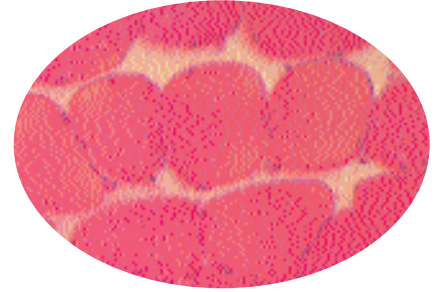
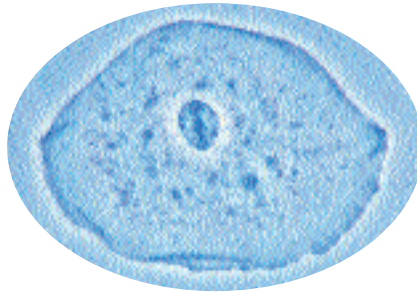
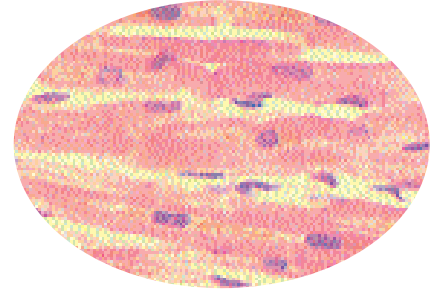
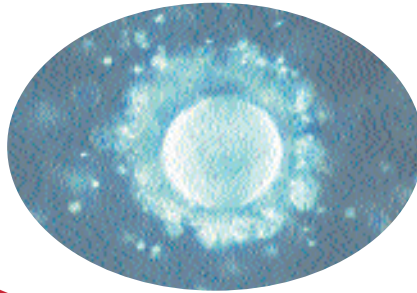
## Challenge



# Cell Growth and Reproduction

## Getting Started

**1** The 100 trillion cells of your body are truly awe-inspiring, when you think that they all started from a single fertilized egg. They stand as proof of the ability of human cells to grow and reproduce. How does one cell grow into a multicellular organism? If all the cells in your body came from the same egg cell, why don't they all look alike? Why are there more of some cell types than others?



**2** The 35-m blue whale is about 18 times longer than the average human. A look at the giants on this planet also reveals the sequoia tree, three times longer than the massive blue whale but also hundreds of years older. Do larger organisms have larger cells? Is cell division in plants similar to that in animals? Do all cells divide at the same rate?

**3** The largest known living organism is a quaking aspen plant. In the photograph, all of what appear to be individual aspen trees are actually one organism with a common root system. This single organism covers 43 ha or over 80 football fields! The trees develop from runners: horizontal roots that grow above or below the ground. All the trees have the same genetic information: they are one organism. What are the advantages of reproducing by runners?



### Reflecting

Think about the questions in **1**, **2**, **3**. What ideas do you already have? What other questions do you have about how cells grow and reproduce? Think about your answers and questions as you read the chapter.

### Try This

#### Monitoring Cell Replacement

Using a permanent marker, place a small drop of ink on the palm and back of your hand. Because the marker ink is not water soluble, the cells that absorb the dye are permanently stained.

Predict in which area the stain will first disappear. Observe the stained areas daily and record your observations. Explain your observations.



# The Microscope and Cell Theory

Scientific discovery often depends upon technological innovation. Nowhere is that more evident than in cell biology. Advances in lens grinding led to the development of microscopes, which in turn opened a window to a microscopic world.

Cells were first described in 1665, when the English scientist, Robert Hooke, noticed many repeating honeycomb-shaped structures while viewing a thin slice of cork under his primitive microscope. In his book, *Micrographia*, Hooke used the word “cell” to describe these structures. However, cork, the inner bark from oak trees, has few living cells. What Hooke observed were the rigid cell walls that surrounded the once-living plant cells.

A few years later, Anton van Leeuwenhoek observed living blood cells, bacteria, and even tiny single-cell organisms in a drop of water, using a simple microscope (a microscope with a single lens). As microscopes improved, cells could be observed and described more closely, but it wasn't until 1820 that a scientist, Robert Brown, examined plant cells and described the tiny sphere called the nucleus (plural: nuclei). Nuclei were soon discovered in animal cells as well. In the mid-1800s, a zoologist, Theodor Schwann, and a botanist, Matthias Schleiden, concluded that plant and animal tissues are composed of cells. This discovery provided the foundation for the first part of the cell theory. The first two parts of the cell theory state

- All living things are composed of one or more cells.
- The cell is the functional unit of life.

## Technological Advances in Microscopy

Microscopes provided scientists with a new window into cells. Greater magnification not only allowed them to discover smaller cells, but it allowed them to gain a better understanding about how cells worked. **Table 1** shows the magnification required to view different objects.

### Viewing with the Compound Light Microscope

An important advance in the development of the microscope came when scientists added a second lens to the simple microscope. An image magnified 10× by the first lens and 10× by the second lens could be viewed as if it were 100× larger (**Figure 1**).

Even the most sophisticated techniques limit the light microscope to about 2000× magnification. But in order to see very tiny viruses or the detail within a human cell, greater magnification is required. The electron microscope provides this window.

**Table 1**

#### Magnification Needed to Create a 1-mm Image

Object	Magnification
fish egg	none
human egg	10×
plant cell	20×
animal cell	50×
bacterium	1000×
mitochondrion	1000×
large virus	10 000×
ribosome	40 000×
cell membrane	100 000×
hydrogen atom	10 000 000×



**Figure 1**

Algae cells seen through a light microscope

## Viewing with the Transmission Electron Microscope

A very crude electron microscope was invented in Germany in 1932. It provided an image of  $400\times$  magnification, but the image was grainy. The electron microscope's true value became apparent in 1937 when James Hillier and Albert Prebus unveiled their electron microscope at the University of Toronto. Their instrument was capable of  $7000\times$  magnification. Today, transmission electron microscopes are capable of  $2\,000\,000\times$  magnification (**Figure 2**).

Instead of light, the electron microscope uses beams of electrons. Electrons are tiny subatomic particles that travel around the nucleus of an atom. However, electron microscopes have two limitations. First, specimens that contain many layers of cells, such as blood vessels, cannot be examined. A thick specimen would absorb all the electrons and produce a blackened image. Because the electrons pass best through single layers of cells, only thin sections of cells can be used. These thin sections are produced by encasing a specimen in plastic and shaving off thin layers. But mounting cells in plastic kills them, which means that only dead cells can be observed—the second limitation. Although ideal for examining the structures within a cell, the transmission electron microscope does not allow you to examine a living cell as it divides.

## Viewing with the Scanning Electron Microscope

The scanning electron microscope provides a new method for investigating thicker specimens by reflecting electrons from their surface. This scanning electron microscope produces a three-dimensional image (**Figure 3**). Electrons are passed through a series of magnetic lenses to a fine point. This fine point of electrons scans the surface of the specimen. The electrons are reflected and magnified onto a TV screen where they produce an image. The scanning electron microscope lacks the magnification and the high resolution of the transmission electron microscope, however, it provides greater depth of field.



**Figure 3**

Algae cell seen through a scanning electron microscope



**Figure 2**

Algae cell seen through a transmission electron microscope

### Understanding Concepts

1. Explain how the evolution of the microscope made it possible to develop a cell theory.
2. Give one advantage of using a compound light microscope over a single lens microscope.
3. Give one advantage of using the light microscope over a transmission electron microscope.

### Making Connections

4. Which microscope do you think would be best for viewing each of the following? Give reasons for your choice.
  - (a) a virus
  - (b) a hair mite
  - (c) the detailed structure of a cell's nucleus
  - (d) a living microorganism

### Challenge

As you have seen, all microscopes have limits. When you are creating your display, how could you present the limits on what scientists can know?



# Cells: The Basic Unit of Life

## Animal-Cell Structures

After many hours spent looking through microscopes, scientists have determined that even though there is no one, common cell, all plant and animal cells have many common factors.

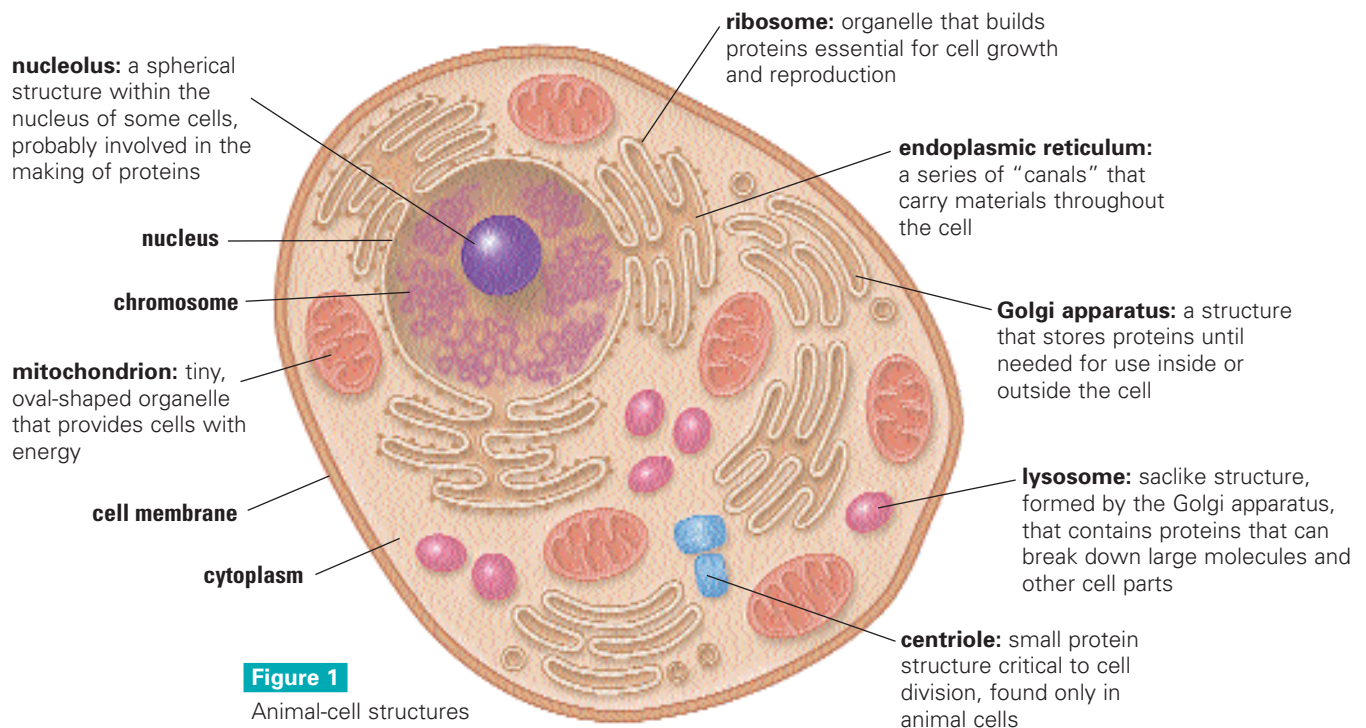
Many of the cell structures shown in **Figure 1** can be seen with a light microscope. You should be able to see the nucleus and possibly some of these other structures.

The entire cell is covered by a **cell membrane**. The membrane acts like a gatekeeper, controlling the movement of materials into and out of the cell.

The **nucleus** of the cell acts as the control centre, directing all of the cell's activities. Genetic (hereditary) information is organized into threadlike structures called **chromosomes**. Each chromosome contains many different genes. **Genes** are units of genetic information that determine the specific characteristics of an individual.

The **cytoplasm** is the area of the cell where the work is done. Nutrients are absorbed, transported, and processed within the cytoplasm.

The cytoplasm contains a number of different organelles that each have a specific form and function. An **organelle** is a specialized structure inside a cell.



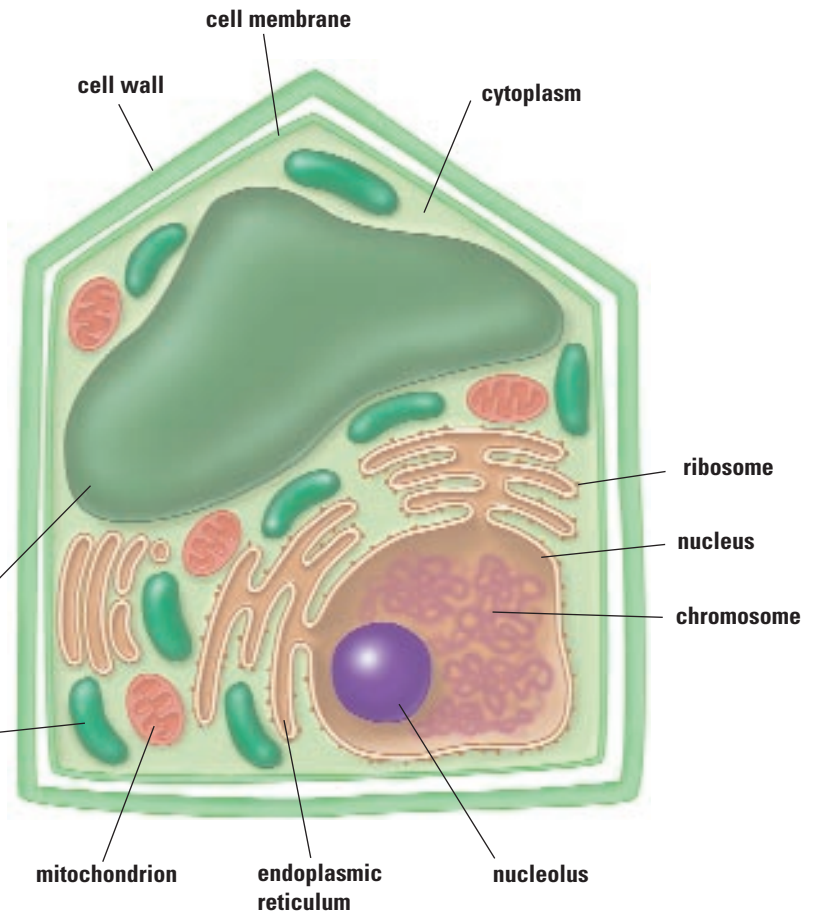
## Plant-Cell Structures

Plant cells, as shown in **Figure 2**, contain all the organelles found in animal cells plus a few other structures. For example, the cell membrane of a plant cell is surrounded by a **cell wall**. Composed of a rigid material called cellulose, cell walls protect and support plant cells. Gases, water, and some minerals can pass through small pores (openings) in the cell wall. Immediately inside the cell wall is the cell membrane; however, you usually cannot see it when you examine plant cells with a light microscope.

Both animal and plant cells contain a vacuole, but in plant cells they are much larger. Plant cells also contain chloroplasts.

**vacuole:** fluid-filled space containing water, sugar, minerals, and proteins

**chloroplast:** organelle containing chlorophyll used in photosynthesis



**Figure 2**

Plant-cell structures

## Movement

Outside the cell membrane, some cells have a **flagellum** (plural: flagella), a whiplike tail that helps the cell move. Some cells have many tiny hairs, called **cilia**, that either move the cell or the environment surrounding the cell. The cilia usually work together.

### Understanding Concepts

1. What is the function of
  - (a) the cell membrane of a cell?
  - (b) the cytoplasm?
2. Where in a cell is genetic information found?
3. How does the structure of plant cells differ from that of animal cells?
4. What can a plant cell do that no animal cell can? What plant-cell structure enables it to carry out this function?

### Challenge

In the future, new forms of microscopes may be invented. Could a new microscope play a role in your story or play? What would it reveal?

# Discovering the Origin of Cells

Which came first, the chicken or the egg? Where did the first cell come from? People have always had theories about the origins of living things. But everyone believed that cells came from non-living things.

## Life from the Heavens

Thousands of years ago, scientists (or natural philosophers as they were called then) noticed that when a pond dried up during a long period of drought, no living frogs or fish were found in the mud. When rain finally began to fall, the pond filled with water and was soon teeming with frogs and fish. Some philosophers concluded that the frogs and fish must have fallen to Earth during the rainstorm.

- (a) What observations can you make to support or refute the hypothesis that fish and frogs fall to Earth during rainstorms?

## Aristotle's Proposal

Aristotle, a great philosopher who lived in Greece in the 4th century B.C., rejected the hypothesis that life came from rain. He proposed that the fish and frogs came from the mud, a non-living thing. Aristotle also believed that flies came from rotting meat, because he had always observed flies on rotting meat. Aristotle's theory, known as spontaneous generation, persisted for nearly 2000 years. Spontaneous generation is a theory that suggests that non-living things can be transformed into living things without any external causes.

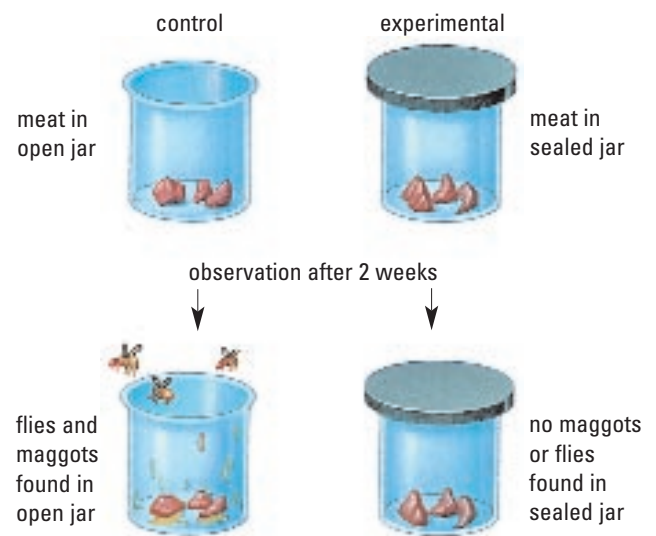
- (b) What observations can you make to support Aristotle's theory?
- (c) What observations can you make to challenge Aristotle's theory?

## Testing the Theory of Spontaneous Generation

In 1668, Francesco Redi designed an experiment to test the hypothesis that rotting meat is transformed into flies. Redi placed bits of meat in two jars and sealed one of the jars, as shown in **Figure 1**. The open jar was designated the control, while the closed jar was designated the experimental.

- (d) Before you read on, predict what happened in both jars. Provide your reasons.

Apparently, flies were attracted to the meat in the open jar and began laying eggs on this food supply. The eggs hatched into maggots, which then began feeding on the meat. The maggots became flies, and the cycle continued. Redi concluded that flies come from other flies, not from rotting meat!



**Figure 1**

Redi's experiment



## Spontaneous Generation and Single-Cell Organisms

Although Francesco Redi helped defeat the theory of spontaneous generation for relatively complex organisms, like flies, many scientists continued to accept the theory for microorganisms (organisms that can only be seen with the aid of a microscope). John Needham (1713–1781) was one of these scientists. Needham noticed that meat broth left unsealed would soon change colour and give off a putrid smell. Microorganisms, sometimes called microbes, were found growing in the broth, but where did they come from?

### Needham's Experiment

Needham boiled meat broth in flasks for a few minutes in order to kill the microbes. The broth appeared clear after boiling. The flasks were then tightly sealed and left for a few days, and the murky contents were examined under a microscope. As shown in **Figure 2**, the broth was teeming with microorganisms.

- (e) Does this mean that the broth had spontaneously created microorganisms? Give your reasons.
- (f) What changes would you make to Needham's experimental procedure before accepting his data?

Needham rushed to retest the experiment. This time he checked for microbes before sealing the flasks completely (**Figure 3**).



**Figure 2**

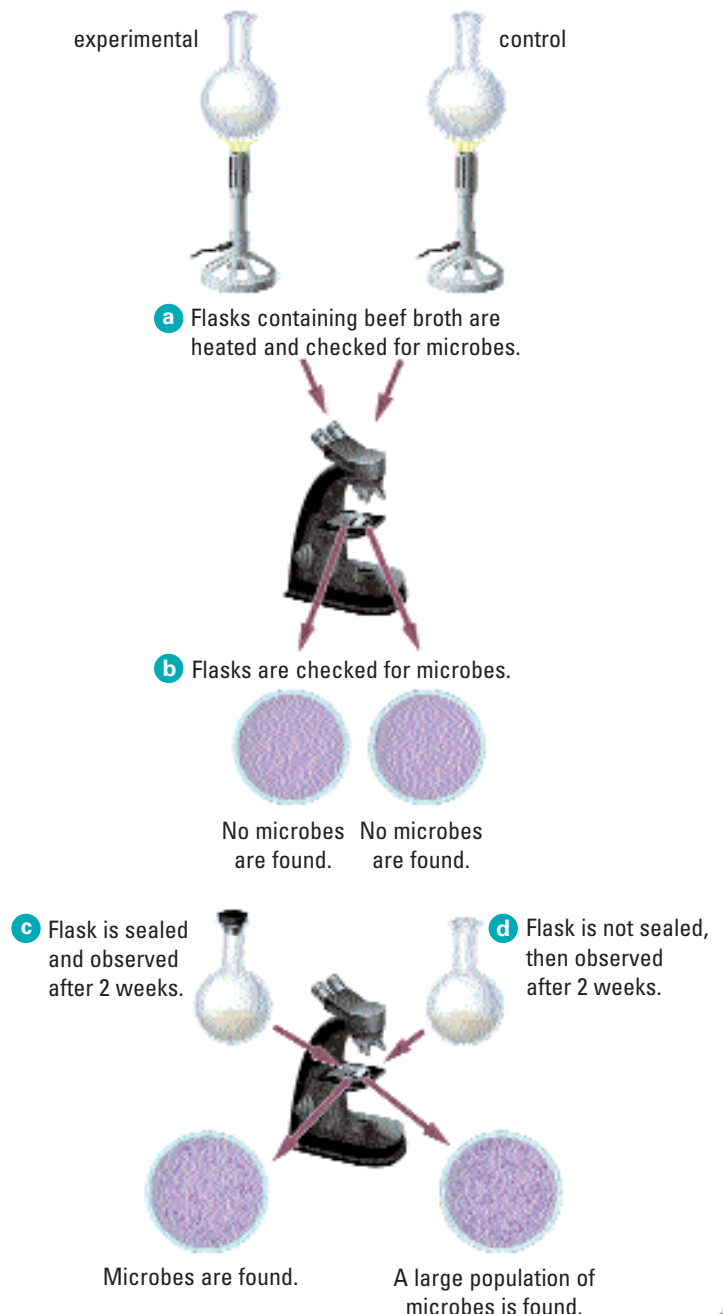
Needham's experiment

When he observed sample drops of broth through his microscope, he found no microbes after boiling. Needham reasoned that the boiling had destroyed the microbes. However, when the flasks were checked a few weeks later, many microbes had reappeared. Needham concluded that microbes came from non-living things in the nutrient broth!

- (g) How is it possible to check for microbes immediately after boiling and not find any, but find so many two weeks later?

**Figure 3**

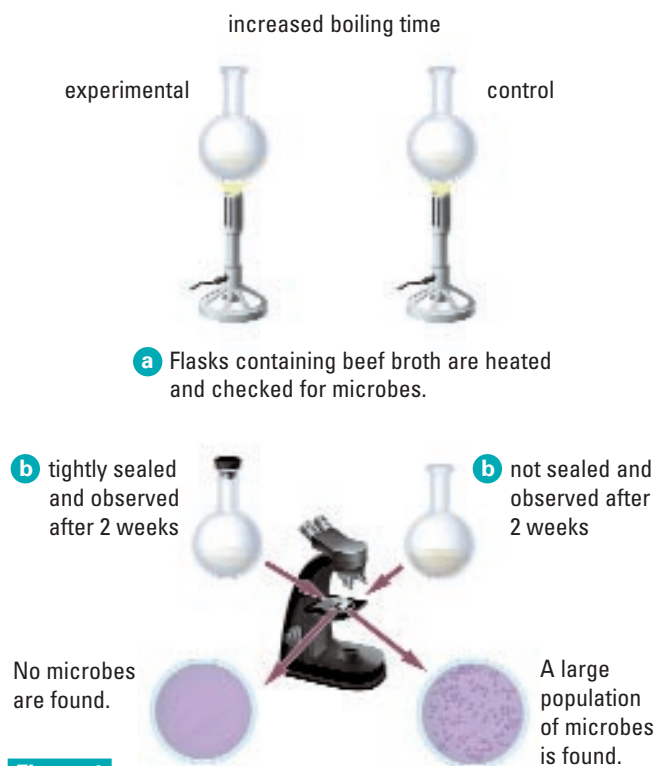
Needham's second experiment



## Changing or Replacing a Theory

Scientific theories are accepted as long as they can explain observed events. Once evidence is collected that challenges the theory, the scientific theory must either be modified or abandoned.

Needham's conclusions were not challenged until 25 years later. Then, Lazzaro Spallanzani (1729–1799) repeated Needham's experiment, but he boiled the flasks longer and sealed some of them tighter, as shown in **Figure 4**.



**Figure 4**  
Spallanzani's Experiment

- (h) How might a longer boiling time affect the experimental results?
- (i) How might making the seal on the flasks tighter affect the results?
- (j) Predict the results of Spallanzani's experiment and justify your prediction.

Spallanzani found no microorganisms in the tightly sealed flask of broth. The longer heating time with the tight seals employed by Spallanzani must have killed the few remaining microbes.

- (k) What conclusion would you draw from Spallanzani's experiment?

## The Source of Needham's Error

Because Needham only examined a few drops from the beef broth immediately after boiling, he missed the few microbes that were not killed. Imagine finding just a few cells in a 500-mL flask of beef broth.

- (l) If only a few microbes remained in the flasks after Needham heated them, how could you explain that the flasks were filled with microbes a few weeks later?

## Accepting a New Theory

Like many people, scientists do not accept change easily. New theories are often opposed, even if they are supported by experimental evidence. So, some scientists constructed arguments to dismiss Spallanzani's experiment. These critics suggested that sealing the flasks prevented the "active principle" in the air from reaching the broth so microorganisms could be created.

- (m) What problem is created when fresh air gets into the flask?

## Louis Pasteur and the End of the Spontaneous Generation Theory

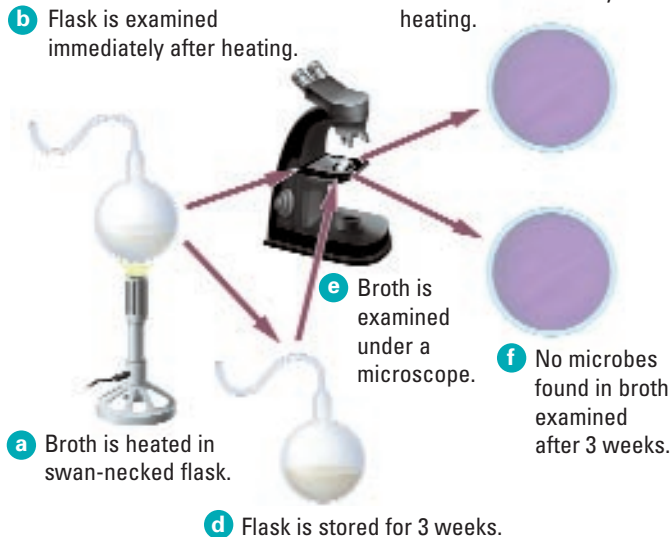
The final blow that demolished the theory of spontaneous generation was delivered by the great French scientist, Louis Pasteur (1822–1895). In 1864, Pasteur had a glass-worker make special flasks called swan-necked flasks, as shown in **Figure 5**. Broth was placed in a flask and boiled to destroy the microbes. Fresh air entered the flask as the flask cooled; however, microbes were not carried into the broth from the surrounding air. The microbes were trapped in the curve of the swan-necked flask.

- (n) What conclusion can be drawn from the observation that the flask appeared clear both immediately after heating and three weeks later?
- (o) Is this conclusion supported by the rest of the observations of the experiment?

As a finale, Pasteur tipped the broth in one of the flasks, allowing it to run into the

**Figure 5**

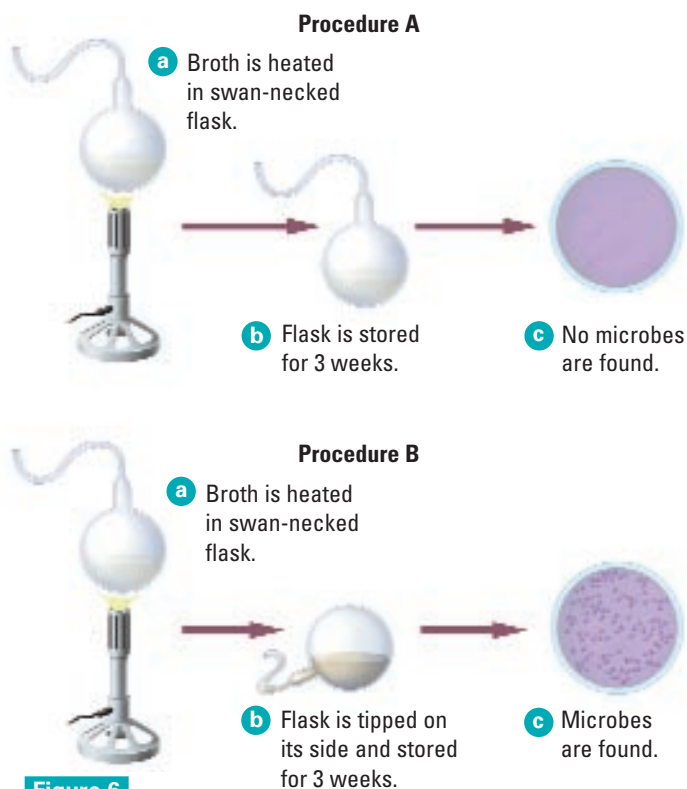
Pasteur's experiment



curve of the swan-necked flask (see **Figure 6**). The broth here quickly became cloudy.

(p) Compare the colour of the two flasks, for procedure A and procedure B, in **Figure 6**.

(q) Why are microbes found in a sample of the broth from procedure B but not from procedure A in **Figure 6**?

**Figure 6**

Pasteur's second experiment

## The Cell Theory

The theory of spontaneous generation was thus replaced by the third, and last, part of the modern cell theory, which states that all cells come from preexisting cells. This explains how life perpetuates itself.

The complete cell theory is

- All living things are composed of one or more cells.
- The cell is the functional unit of life.
- All cells come from preexisting cells.

### Understanding Concepts

1. What is spontaneous generation?
2. What variable was Redi attempting to control in his experiment?
3. Identify one variable in Needham's **2A** experiment.
4. What were two major differences between Needham's and Spallanzani's experiments?
5. Examine Needham's experiment. After two weeks of storage, why were more microbes found in the unsealed flask than in the sealed flask?
6. Use Pasteur's experiments to explain why controls are important.
7. The modern cell theory states that all cells come from preexisting cells. What evidence have you seen to support this theory?

### Exploring

8. Suggest what evidence would have to be collected to prove that cells come from other cells. How would you gather that evidence?
9. Repeat Needham's experiment to determine **4B** the minimum boiling time required to kill all the microbes in the beef broth. Have your teacher check your written procedure for safety before beginning.

### Challenge

For centuries, people believed in spontaneous generation. People still have misconceptions about reproduction. How could you identify those misconceptions for your display?



# The Importance of Cell Division

Have you ever peeled the skin from your shoulder after a sunburn? Imagine your terror if new cells had not replaced the dead skin cells you pulled off. Imagine what you would look like if every scratch or blemish on your skin remained. Cells come from preexisting cells through the process of cell division. Throughout your entire life, you will rely on cell division to replace dead or damaged cells in your body (**Figure 1**).

## Functions of Cell Division

### Healing and Tissue Repair

Healing and tissue repair are important functions of cell division. A related function is the replacement of dead cells (**Figure 2** and **Figure 3**). You don't go through life with all the same cells you had at birth. Every second, millions of your body cells are injured or die. If the remaining cells did not reproduce, your body would gradually shrink in size and eventually die.

### Growth

A more obvious function of cell division is to increase the number of cells. As the number of cells in an organism increases, so does the size of the organism. Growth of all living organisms depends on cell division. Human growth begins with the division of a fertilized egg cell. All multicellular organisms also rely on cell division to grow.

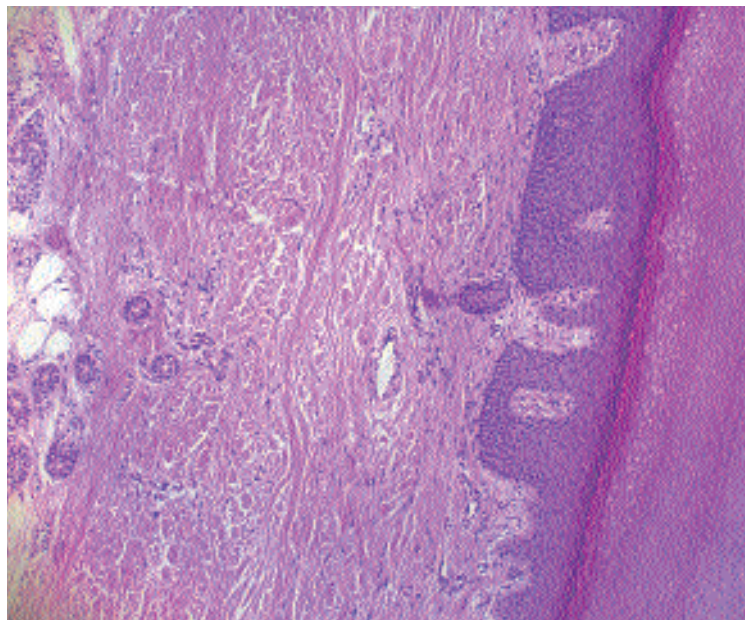
Most cells are small and of a relatively constant size. Instead of dividing, why don't cells simply continue to increase in size? The reason is that the relationship of the surface area of the cell membrane to the volume of cytoplasm is very important. As a cell grows, the volume of cytoplasm increases faster than the surface area of the cell. All essential substances enter and exit the cell through the cell membrane. If a cell became too large, there would not be enough exchange of materials through the cell membrane to sustain it.

Also, the distance of the nucleus, which controls all of the cell's activities, from all parts of the cytoplasm must be kept small so that messages can be relayed efficiently. In short, cell division allows an organism to grow, while still maintaining a cell size that keeps the organism healthy.



**Figure 1**

Normal activities remove millions of skin cells that must be replaced daily. It has been estimated that approximately 50% of the dust in a furnace filter is dead human skin cells.



**Figure 2**

The outer layer of skin is made up of dead cells that become twisted and bent out of shape as they dry. Replacing these dead cells is an important function of cell division.



## Reproduction of Organisms

Another very important function of cell division is that it perpetuates life. This is most obvious in the case of unicellular organisms, like bacteria. Cell division in unicellular organisms creates two new organisms. Cell division is also fundamental to reproduction of multicellular organisms.

## Unanswered Questions

Cell division is one of the most studied, yet least understood areas of biology. Through painstaking hours of observation, scientists have collected a great deal of information about cell division. Yet despite all they have observed, many questions remain unanswered. How do cells know when to divide? The formation of calluses on your hands after a few days of working in the garden provides evidence that the rate of cell division can be altered. How and why is it altered? Why does a fertilized egg cell divide so rapidly after fertilization? Why do the cells that give rise to red blood cells divide at enormous rates, but brain cells rarely divide in adults? These are some of the questions that still need to be answered as the science of cell division continues to evolve.

### Did You Know ?

In the human body, red blood cells live a mere 120 days; white blood cells anywhere from 1 day to 10 years; and platelets, the cells that help blood clot, only about 6 days.



## Understanding Concepts

1. Why is cell division important?
2. Provide evidence that suggests that not all cells in your body divide at the same rate.
3. Imagine two cubic cells, one with sides of 1 mm, and one with sides of 2 mm. For each cell, calculate
  - (a) the total surface area
  - (b) the volume
  - (c) the surface area/volume ratio

Using these calculations, explain why cells have to divide as an organism grows.

## Making Connections

4. At one time, doctors transfused blood from younger individuals to the elderly. They believed that the younger blood would provide the elderly with more energy. Do older people actually have older blood? Support your answer.
5. Why might scientists want to get mature nerve cells to divide?

## Exploring

6. Research reasons for the different rates of replacement of red blood cells, white blood cells, and platelets.

## Challenge

In your display, should you present the questions scientists are still investigating that may affect decisions about reproductive technology?

Figure 3

Cell division is not limited to animals. The oldest living cells in a 300-year-old redwood tree are no more than 30 years old. The inner portion of a tree trunk is composed mainly of dead cells. Although dead, these cells still function to transport water up the tree.

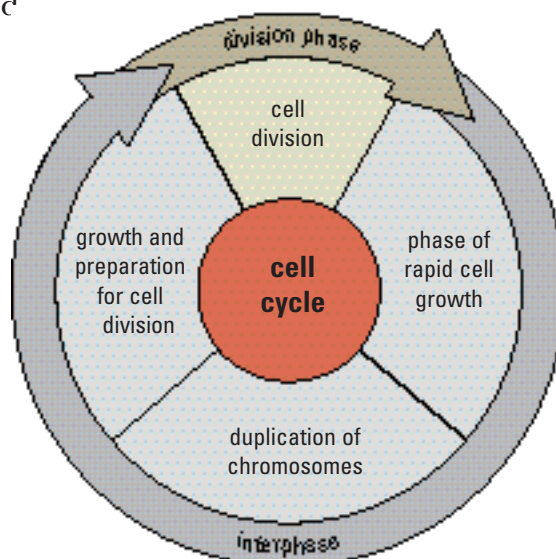


# Cell Division

All cells come from preexisting cells through cell division. Cell division, then, is how life is perpetuated (**Figure 1**). The approximately 100 trillion cells in your body began as a single, fertilized egg cell. This cell divided into two cells. Then each of these divided into two cells, and so on, until they formed the complete, functioning, multicellular organism that is you.

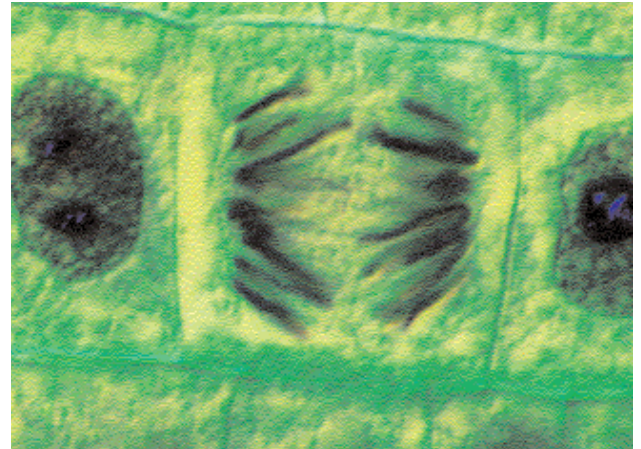
## The Cell Cycle

Cells alternate between stages (phases) of dividing and not dividing. The sequence of events from one division to another is called the **cell cycle**, shown in **Figure 2**. For most cells, the cell division phase is a small part of this cycle. The stage between cell divisions is called interphase. During interphase, the cell takes in nutrients, such as sugars, and produces building materials, such as proteins. These materials are used by the cell for energy, growth, and repair of damaged parts. After a period of rapid growth, the cell prepares for division by duplicating its chromosomes within the nucleus. It is critical that the genetic material is duplicated before cell division. The chromosomes contain all the necessary information for all cell functions—including cell division! Each new cell will need a copy. After the genetic material is copied, there is another period of growth and preparation for cell division.

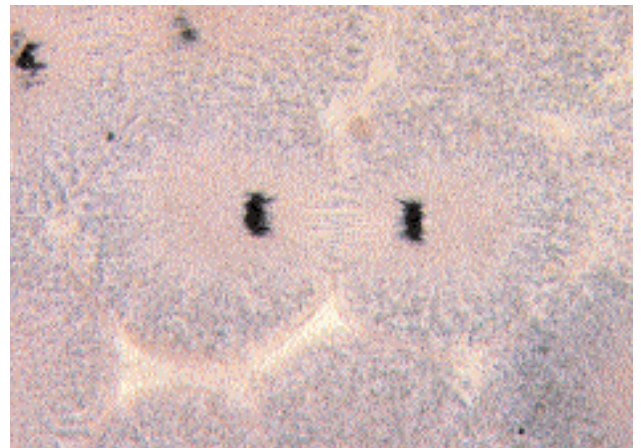


**Figure 1**

On a cellular level, reproduction is one cell becoming two.



**a** A plant cell dividing



**b** Cell division in a whitefish embryo

**Figure 2**

The cell cycle. The circle represents the entire life of a cell, which can be divided into two major phases: interphase and the cell division phase.



## Mitosis and Cytokinesis

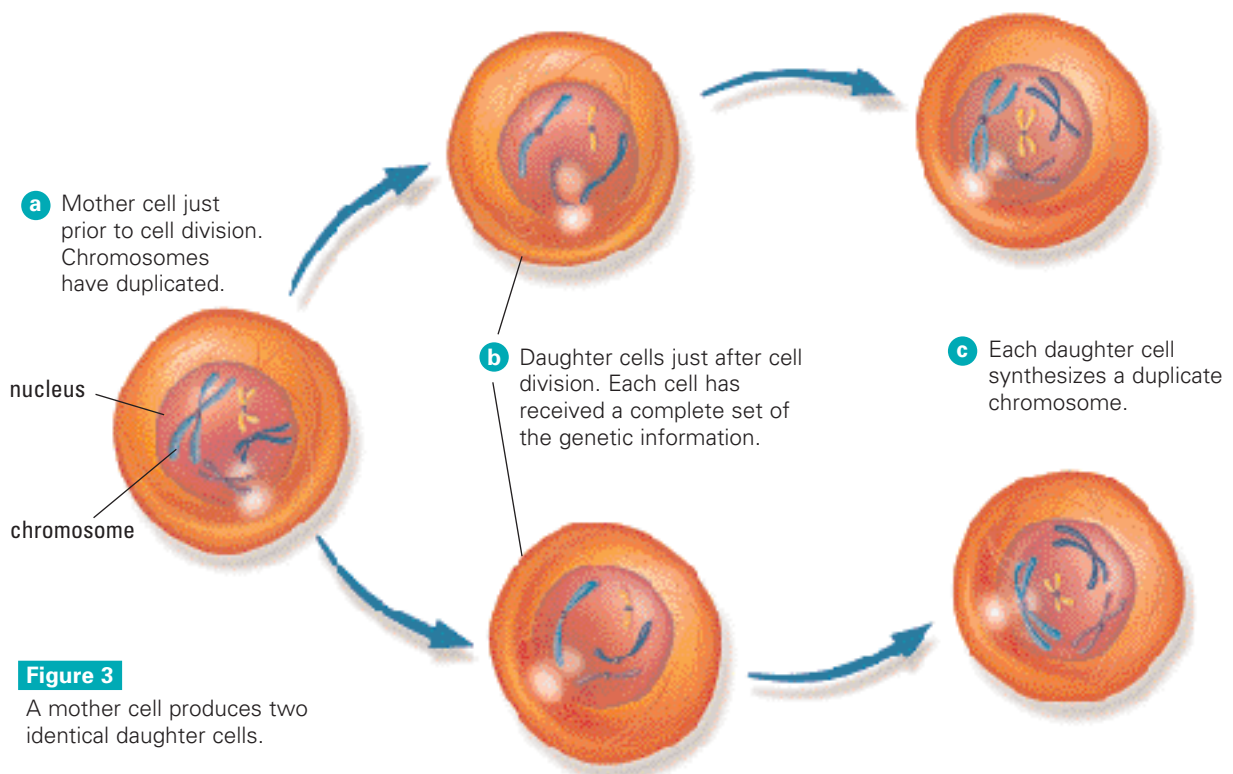
Despite great differences among living things, most cells show remarkable similarities in the way they divide. Cell division occurs in very simple, unicellular forms of life, such as the bacteria, as well as in complex, multicellular organisms, such as humans. In all cases, the initial mother cell divides into two identical daughter cells, as shown in **Figure 3**.

Cell division involves the division of nuclear materials and the sharing of the cytoplasm, which includes the organelles. During cell division, the duplicated chromosomes, copied during interphase, divide and move to opposite ends of the cell. This process of dividing nuclear material is called **mitosis**.

Cell division continues with the separation of the cytoplasm and its contents into equal parts. This process is called **cytokinesis**. This process begins before mitosis is complete. About half of the cytoplasm, containing about half of the organelles, goes to each daughter cell.

Cytokinesis differs in animal and plant cells. In animal cells, the cell membrane pinches together in the middle, separating the cytoplasm into equal parts and creating two new cells. In plant cells, a new cell wall forms along the middle, creating two new cells.

Together, mitosis and cytokinesis result in cell division, or the production of two new daughter cells. As the daughter cells grow during interphase, they make additional cytoplasm and organelles and eventually reach the size of the parent. The daughter cells will also use the single chromosomes to synthesize a duplicate set of genetic material.



## The Phases of Mitosis

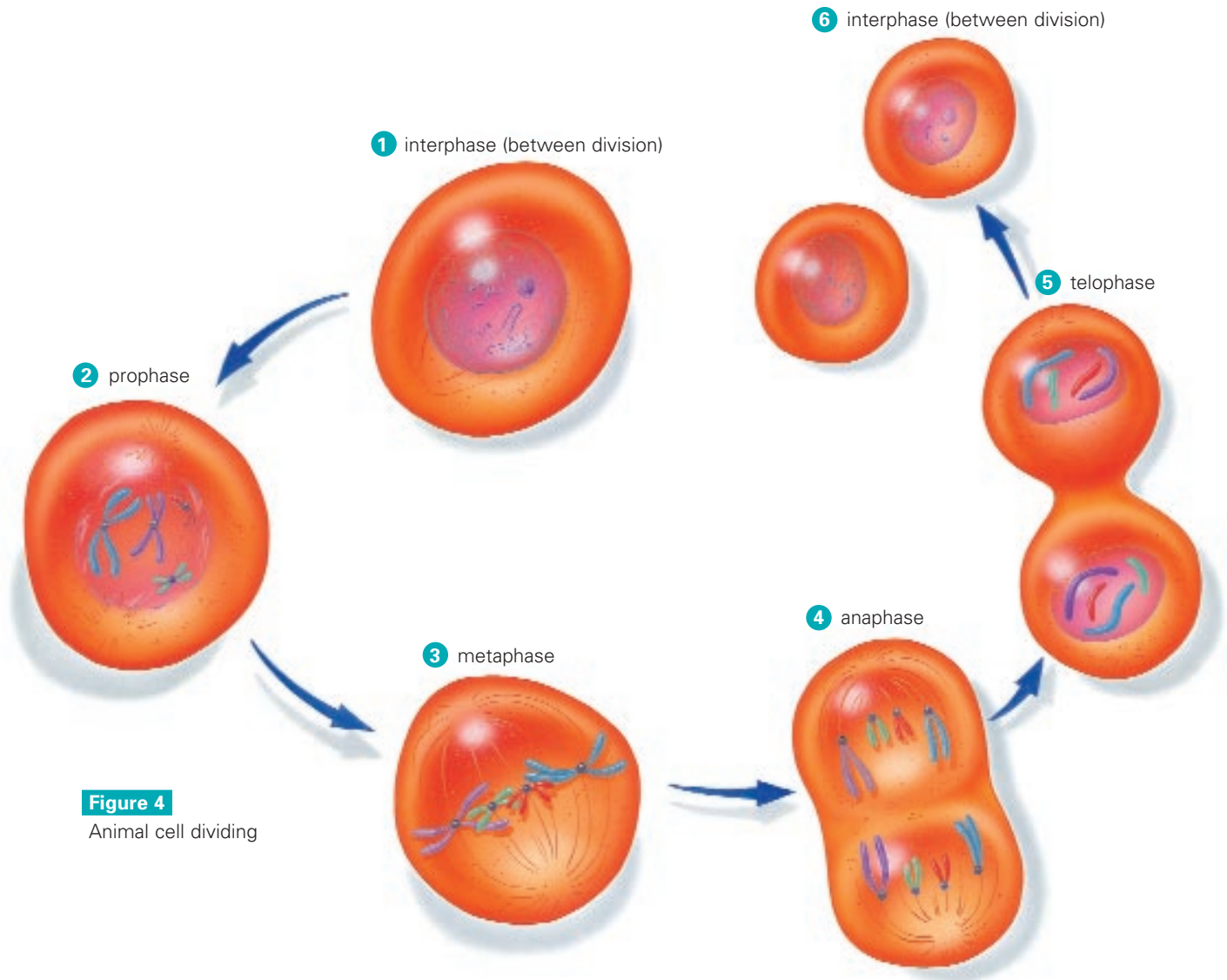
**Figure 4** shows an animal cell dividing. To help describe the events of mitosis, scientists have divided the process into several phases. However, you must remember that the process is a continuous one. Think of each phase as a snapshot taken at a particular moment during cell division.

### 1. Interphase

During **interphase** the cell grows then prepares for cell division by duplicating its genetic material. Another growth phase readies the cell for division.

### 2. Prophase

In **prophase**, the individual chromosomes, now made up of two identical strands of genetic information, shorten and thicken. They become visible with the use of a light microscope. The nuclear membrane appears to fade when viewed under the microscope; in effect, it is dissolving.



**Figure 4**

Animal cell dividing

### 3. Metaphase

In **metaphase**, the double-stranded chromosomes line up in the middle of the cell.

### 4. Anaphase

During **anaphase**, each chromosome splits. The two halves move to opposite poles of the cell. If anaphase proceeds correctly, each of the daughter cells will have a complete set of genetic information.

### 5. Telophase

During **telophase**, the chromosomes reach the opposite poles of the cell and a nuclear membrane begins to form around each set. Cytokinesis begins. The cytoplasm and organelles separate into roughly equal parts, and the two daughter cells are formed.

### 6. Interphase

The daughter cells begin growth and duplication of genetic material.

#### Try This

#### A Dynamic Model of Mitosis

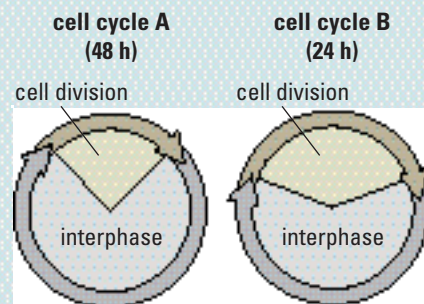
Although mitosis is described in stages, the process of cell division is continuous. To help you understand this process, work with a partner to build a dynamic model in which chromosomes can be moved to show the events of cell division. To keep your model simple, use only two to four chromosomes. In your model be sure that you are able to line up the chromosomes in the centre of the cell, and that the single strands are able to move to opposite ends of the cell as they do during anaphase.

#### Challenge

One way to analyze and present data is to use graphs, such as a pie graph. How will you design the questions in your survey so the data are easy to analyze and present?

### Understanding Concepts

1. Describe the cell cycle. What happens during interphase?
2. Why is the duplication of the nuclear material necessary during the cell cycle?
3. How do the new cells formed during cell division compare with the initial cell?
4. List and describe four phases of mitosis.
5. A normal human cell has 46 chromosomes. After the cell has undergone mitosis, how many chromosomes would you expect to find in each cell?
6. Cells alternate between phases of dividing and not dividing. The sequence of events from one interphase to the next is called the cell cycle.
  - (a) Describe the differences between the two cell cycles in **Figure 5**.
  - (b) Which cell cycle represents a cell of an embryo or fetus and which a cell in an adult? Give your reasons.



**Figure 5**  
Cell cycles

### Making Connections

7. Speculate about how modern advances in microscopes would also have advanced our understanding of cell division.
8. X rays and other forms of high-energy radiation can break chromosomes apart. Physicians and dentists ask women if they are pregnant before taking X rays. Why don't they want to X ray pregnant women?

### Reflecting

9. Draw a sketch of your body. Under the sketch, list areas of the body where you think cell division is most rapid. Why do you think cells from these areas divide most rapidly? Check your answer once again at the end of the chapter.



## 5.6 Activity



# Observing Cell Division

In the previous sections you learned why and how cells divide. In this activity you will have an opportunity to view and compare plant and animal cells during mitosis. You will examine prepared slides of the onion root tip and the whitefish embryo to identify cells that are dividing. Because prepared slides are used, these cell divisions have been “frozen in time.” You will not be able to watch a single cell divide from prophase to telophase.

### Materials

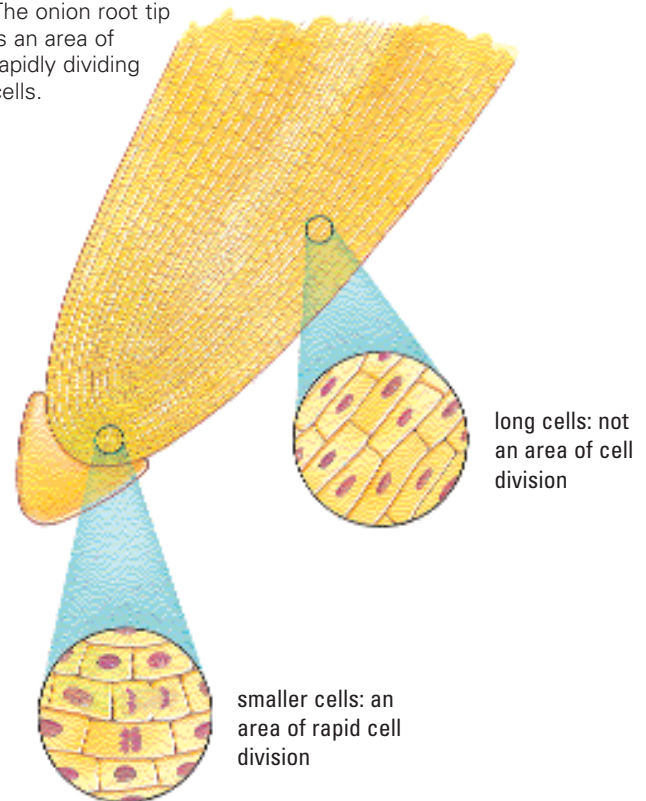
- microscope
- lens paper
- prepared microscope slide of an onion root tip
- prepared microscope slide of a whitefish embryo

### Procedure

- 1 Obtain an onion root tip slide and place  it on the stage of your microscope.
  - 2 View the slide under low-power magnification. Focus using the coarse-adjustment knob. Find the cells near the root cap (**Figure 1**). This is the area of greatest cell division for the root.
  - 3 Centre the root tip and then rotate the nosepiece to the medium-power objective lens. Focus the image using the fine-adjustment knob only. Identify a few dividing cells.
-  (a) How can you tell if the cells are dividing?
- 4 Rotate the nosepiece to the high-power objective lens. Use only the fine-adjustment knob to focus the image. Locate and observe cells in each phase of mitosis. Use the photographs of cells dividing, shown in **Figure 2**, to help you. Don't worry if what you see does not look exactly like the photographs.

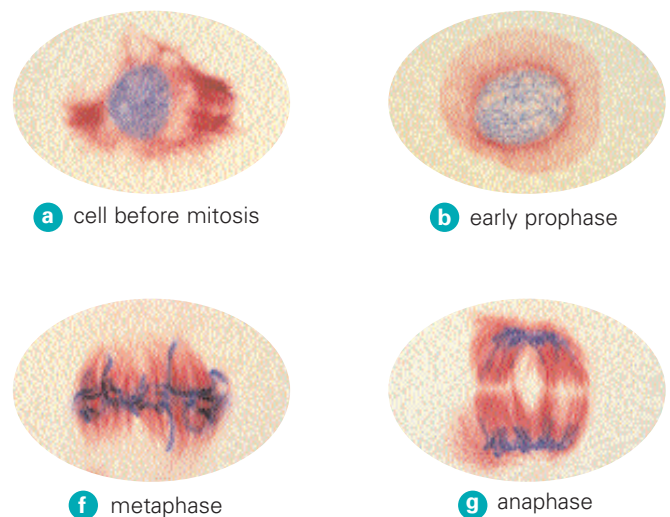
**Figure 1**


The onion root tip is an area of rapidly dividing cells.



**Figure 2**

Onion cells in mitosis




-  (a) Draw and title each of the phases that you see. Label chromosomes if they are visible. It is important to draw and label only the structures that you see under the microscope.

**5** Return your microscope to the low-power objective lens and remove the slide of the onion.

**6** Place the slide of the whitefish embryo on the stage. (An embryo is an animal in the very early stages of its development.) Focus the slide using the coarse-adjustment knob.

**7** Repeat steps 3 and 4 for the whitefish cells.

-  (a) Draw and title each of the phases that you see. Label the chromosomes if they are visible.

**8** Compare your diagrams with those of other students in your class. Assist each other in locating phases or cell structures.

**9** Return your microscope to the low-power objective and remove the slide of the whitefish embryo. Put away your microscope and return the slides to your teacher.

### Understanding Concepts

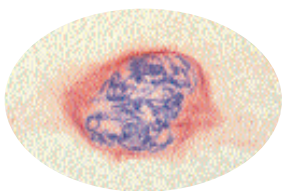
1. Why were plant root tip cells and animal embryo cells used for viewing cell division?
2. Explain why the cells that you viewed under the microscope do not continue to divide.
3. Compare the appearance of the dividing animal cells with that of the dividing plant cells. You may wish to use a table to list the differences and similarities.
4. If a cell has 10 chromosomes, how many chromosomes will each cell have following cell division by mitosis?
5. Predict what might happen to each daughter cell if all of the chromosomes moved to only one side of the cell during anaphase.

### Exploring

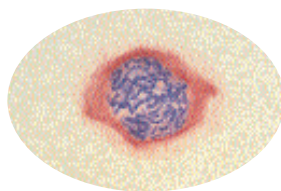
- 6.** Search the Internet for pictures of cells that are dividing. What additional information about cell division can be gained by studying these pictures?

### Challenge

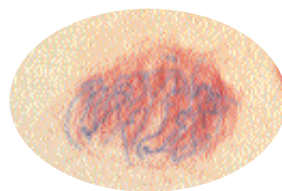
Modern microscopes are linked to computers that can measure and count cells much faster than humans. Will this technology improve? What place could it take in your story or play?



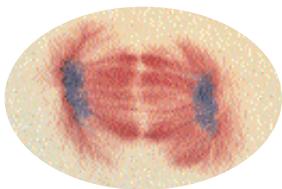
**c** prophase



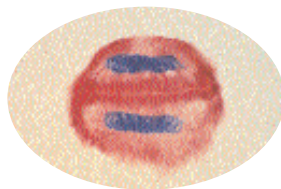
**d** late prophase



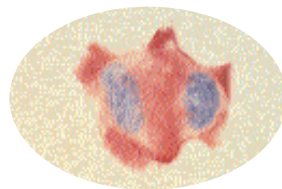
**e** transition to metaphase



**h** telophase



**i** late telophase



**j** cells after mitosis

## 5.7 Investigation

### SKILLS MENU

- Questioning
- Conducting
- Analyzing
- Hypothesizing
- Recording
- Communicating
- Planning

# Determining the Rate of Cell Division

A great deal of money is spent on agricultural chemicals used to increase plant growth. To find out if this is an efficient use of money, scientists must be able to analyze the effectiveness of these chemicals. One way to do this is by studying the rate of cell division. In this investigation, using prepared slides, you will be able to observe and determine the rate of cell division yourself.

### Question

Can you tell how fast an organism is growing?

### Hypothesis

- 1** Write a hypothesis for this experiment. **4A**


### Materials


- microscope
- lens paper
- prepared microscope slide of an onion root tip
- prepared microscope slide of a whitefish embryo

### Procedure

#### Part 1: Onion Root Cells

- 2** Obtain an onion root tip slide and place it **5B** on the stage of your microscope.
- 3** View the slide under low-power magnification. Focus using the coarse-adjustment knob. Locate the area of cell division, immediately above the root cap.
- 4** Centre the root tip and then rotate the nosepiece to the medium-power objective lens. Focus the image using the fine-adjustment knob.
- 5** Count 20 cells that are next to one another in the onion root tip. Determine which of those cells are dividing.

-  (a) In your notebook, record the number of cells dividing.

-  (b) Of the 20 cells, calculate the percentage that is dividing. For example, if you found 8 cells dividing:

$$\text{Percentage of cells in prophase} = \frac{8}{20} \times 100\% = 40\%$$

- 6** Examine two other areas of the onion root tip to determine if the division rate is the same in those areas.
- (a) Construct and title a table to record the division rate of the three areas of the root tip.
- (b) Draw a small diagram of the onion root **6C** tip and show the approximate location of each area you selected.
- 7** Return your microscope to the low-power objective lens and remove the slide of the onion root tip.

#### Part 2: Whitefish Embryo Cells


- 8** Place the slide of the whitefish embryo on the stage. Focus the slide using the coarse-adjustment knob.
- (a) Predict whether the onion root tip or the whitefish embryo will have a greater percentage of actively dividing cells. Give reasons for your prediction.
- 9** Centre the whitefish embryo and then rotate the nosepiece to the medium-power objective lens. Focus the image using the fine-adjustment knob. Under medium-power magnification, repeat steps 5 and 6 for the whitefish cells.
- 10** Return the nosepiece to the low-power objective lens and remove the slide of the whitefish embryo.



### Part 3: Making a Cell Division Clock

- 11** Replace the slide of the onion root tip under your microscope, and focus using the coarse-adjustment knob.
- 12** Under high-power magnification, locate 20 cells that are dividing. Identify the phase each cell is in. (Do not count cells in interphase.) You may have to search for enough dividing cells by moving the slide.
- (a) Make a chart like the one below and enter the number of cells you found in each phase.

Phase	Number of cells	Percentage of total in phase
prophase	?	?
metaphase	?	?
anaphase	?	?
telophase	?	?

-  (b) Calculate the percentage of cells that are in each phase of division and include that number in your table.

- 13** With your data, you can now construct a clock for cell division. It actually takes between 12 h and 16 h to complete one mitosis, but for the sake of simplicity, assume it takes 12 h.

**7B**

- (a) Calculate the number of hours spent in each phase by multiplying the percentage of cells in each phase by 12 h. If you found 40% of the 20 cells in prophase, for example:

$$\text{Time spent in prophase} = 40\% \times 12 \text{ h} = 4.8 \text{ h}$$

- (b) Draw a clock and indicate the amount of time spent in each phase of cell division.

### Analysis and Communication

- 14** Analyze your observations by answering the following questions:

- (a) Which areas of the onion root tip have the fastest cell division rate?
- (b) Were there any differences in the cell division rates of the three areas of the whitefish embryo? What do you conclude from this?
- (c) Which has the greater percentage of dividing cells, the whitefish embryo or the onion root tip? What does this indicate about the cell division rates of the plant root tip and the animal embryo?

### Making Connections

- Why might someone be interested in determining the cell division rate of a plant or animal?
- Herbicides are chemicals designed to kill weeds. Some herbicides, such as 2,4,D and 2,4,5,T, make plant cells divide faster than normal. Why would these herbicides kill weeds? (Hint: Think about what cells do when they are not dividing.)
- What important part of the cell cycle is missing from your cell clock?

### Exploring

- 4.** Choose one of the cell division rates you **7B** calculated in this investigation. Draw a pie graph showing the percentage of cells involved in cell division and those not involved.

### Reflecting

- 5.** Mitosis is described in phases because this makes it easier to talk about. But the cells do not stop between each of the phases. What observations have you made that suggest that mitosis is a continuing process?



## Using Law in Science

**H**arriet Simand was 20 years old, a healthy student just back from a summer in Europe, when she went for a routine medical checkup. That is, routine until she found she had a rare kind of vaginal cancer known as clear-cell adenocarcinoma. The cancer was so advanced she needed an immediate hysterectomy.

Simand's cancer had been caused by a drug known as DES: diethylstilbestrol. She had never taken it herself; it had been prescribed to her mother, and to thousands of other pregnant women, to prevent miscarriage.

With little background in science, Simand soon learned a great deal about chemistry, especially about pharmaceuticals and their effect on people. She found that between 200 000 and 400 000 women took DES in Canada before the drug was banned in 1971. Side effects include breast cancer among mothers who took the drug, and premature births and fertility problems in their daughters. There may be problems with their sons as well, but this area has not been studied fully.

Simand decided to obtain a law degree so that she could work to change the laws concerning pharmaceuticals. Since getting it, she has worked to publicize the dangers of DES. The first job is to find women who were exposed, a difficult job because "drug companies have never invested any money in tracking people down. We are still finding people who didn't know they were exposed, who don't even know what DES is... [But] when the cancer is caught early it has a higher cure rate."

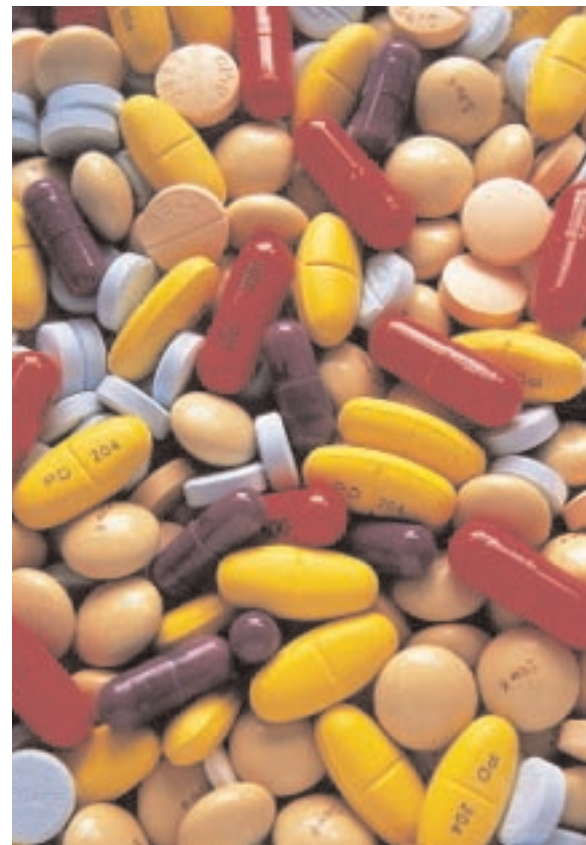
### Exploring

1. In what other areas could a knowledge of law and science be used side by side?
2. There are other pharmaceuticals that have caused harm to fetuses. Choose one to research. Present your findings to your class.

### Challenge

In your story or play, one of your characters will face a decision. Could the decision have some negative results? What might they be?

“Even without a medical degree you can become an expert in your own health. You still need to inform yourself enough to know what questions to ask the doctor, because doctors can't read every single journal.”



# Reproduction and Cell Division

Reconsider the modern cell theory.

- All living things are made up of one or more cells.
- The cell is the functional unit of life.
- All cells come from preexisting cells.

Cell division, the process by which cells come from preexisting cells, is the process that perpetuates life and allows species to continue. Just as cells reproduce as part of the cell cycle, living organisms reproduce as part of their life cycle.

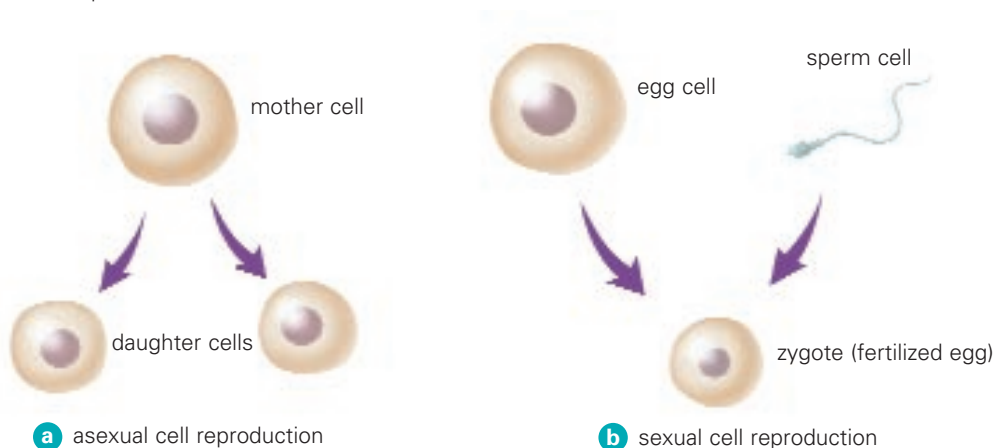
Organisms of all species reproduce. They may reproduce sexually or asexually. In **asexual reproduction** a single organism gives rise to offspring with identical genetic information. The cells of the human body, other than those found in female ovaries and male testes, reproduce asexually by mitosis. Most single-cell organisms, such as bacteria, and some multicellular organisms use asexual reproduction to produce offspring.

In **sexual reproduction**, genetic information from two cells is combined to produce a new organism. Usually, sexual reproduction occurs when two specialized sex cells unite to form a fertilized egg called a **zygote**. **Figure 1** compares asexual and sexual reproduction at the cell level.

Note that some organisms use both methods of reproduction. For example, bacteria reproduce mostly in an asexual process called binary fission, which is basically cell division as you have learned it. However, bacteria are also able to exchange genetic information in a form of sexual reproduction. Similarly, most plants reproduce sexually, in the process that results in seeds, but many also reproduce asexually in various other ways, which are shown in **Figure 2**.

**Figure 1**

Asexual and sexual reproduction of cells. Notice that when a cell reproduces asexually, the parent cell becomes two identical daughter cells. In sexual reproduction two specialized cells fuse.



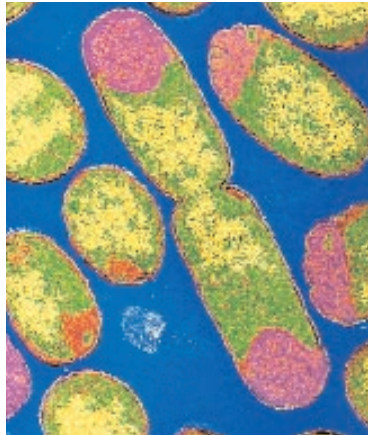


**Figure 2**

Various types of asexual reproduction

**a** binary fission

In **binary fission**, the organism splits directly into two equal-sized offspring, each with a copy of the parent's genetic material. Binary fission is a common type of reproduction in single-celled organisms, such as these intestinal bacteria.



**b** budding

In **budding**, the offspring begins as a small outgrowth from the parent. Eventually, the bud breaks off from the parent, becoming an organism on its own. Budding occurs in some single-cell organisms, such as yeast, and in some multicellular organisms, such as the hydra shown here.



**Try This**

**How many divisions will it take?**

Many single-cell organisms reproduce by binary fission. How many organisms would there be after five divisions? Copy and complete the chart to help you answer this question.

Number of divisions	Number of organisms
0	1
1	2
2	4
3	?
4	?
5	?

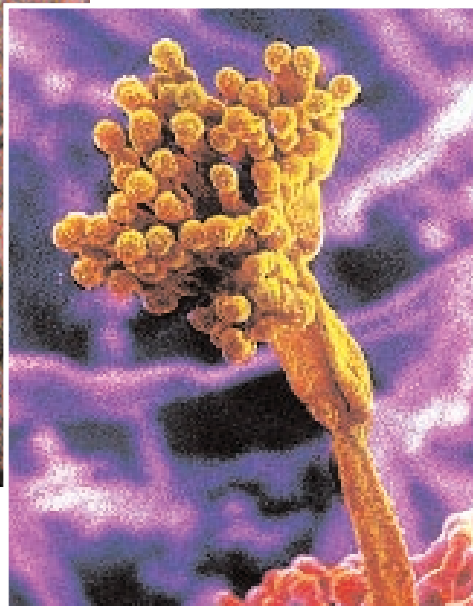
1. What pattern relates the number of divisions to the number of resulting organisms?
2. Use the pattern to predict how many organisms are produced after 10 divisions.
3. How many divisions are required to produce over a million organisms?
4. The single, fertilized cell from which you began divided to produce the many cells that make up your body. Estimate how many cell divisions it took.





**c** fragmentation

In **fragmentation**, a new organism is formed from a part that breaks off from the parent. Many types of algae and some plants and animals can reproduce this way. If a starfish is cut through its central disk, each section will develop into a new starfish that contains identical genetic information.



**d** spore formation

In **spore formation**, the organism undergoes frequent cell division to produce many smaller, identical cells called spores. The spores are usually housed within the parent cell. Many spores have a tough, resistant coating that allows them to survive after the parent cell dies. The penicillium mould shown here reproduces by forming spores. Each spore can develop into a mature organism.



**e** vegetative reproduction

Many plants, such as spider plants, strawberries, and the quaking aspen shown on page 139, make use of **vegetative reproduction**. They produce runners that can develop into another plant. Each runner from this spider plant can develop into another plant with identical genetic information.

## Understanding Concepts

1. How is asexual reproduction different from sexual reproduction?
2. Why must the genetic material of the cell be duplicated before cell division begins?
3. How is the zygote, produced by sexual reproduction, different from daughter cells, produced by asexual reproduction?
4. (a) Describe briefly five types of asexual reproduction.  
(b) Choose one type of asexual reproduction. Explain how a plant nursery could make use of it.

## Making Connections

5. Identify the type of asexual reproduction in each of the following situations:
  - (a) A multicellular algae is struck by a wave. The algae breaks up and each new piece grows into a new organism.
  - (b) A new tree begins to grow from the root of a nearby tree.
  - (c) A small cell begins to grow on the outside of another cell. Eventually, it breaks away from the larger cell and continues to grow.

## Reflecting

6. What advantages might an organism have that can reproduce asexually? Make a list of the advantages. Add to your list or modify it as you progress through this unit.

## Challenge

Could humans attempt to reap the benefits of asexual reproduction? Could an asexual reproduction technology play a role in your play or story?

## 5.9 Investigation

### SKILLS MENU

- Questioning
- Conducting
- Analyzing
- Hypothesizing
- Recording
- Communicating
- Planning

# Calculating Population Growth Rates

You've created a clock to measure how long cells in an onion root tip spend in each stage of reproduction. Because those cells were dead when you observed them, you couldn't measure their rate of reproduction. Also, the cells in the onion tip reproduce asexually, but they also work together with other cells in a multicellular organism—their rate of reproduction varies according to where they are in the root tip. What about unicellular organisms? What is their rate of reproduction? What factors affect that rate?

In this investigation you will be observing paramecia, unicellular organisms that live in fresh water. Under most conditions, they reproduce asexually by binary fission. You will learn to estimate the population of paramecia in a culture using a sampling technique. In addition, you will change the environment of the organisms. After several days of observation, you will be able to calculate the rate at which their population grows.

### Question

How do populations of paramecia change over time?

### Hypothesis

- 1 Write a hypothesis to predict how a population of paramecia will change under different conditions

### Materials

- apron
- light microscope
- transparent ruler (mm marks)
- paramecium culture
- microscope slide
- cover slip
- rice grains
- medicine dropper

### Procedure

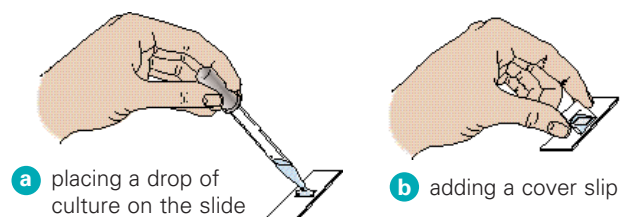
#### Part 1: Determining the Field of View

- 2 Measure the field of view with the low-  
5B power objective lens in place.
  - (a) Record the field diameter under the low-power objective lens in millimetres.
- 3 Measure the field of view for the medium-power objective.
  - (a) Record the field diameter under medium-power objective lens in millimetres.
- 4 Determine the field of view under high-power magnification.
  - Calculate the ratio of the magnification of the high-power objective lens to that of the low-power objective lens.
  - Use the ratio to determine the field diameter under high-power magnification.
$$\text{Field diameter (high power)} = \frac{\text{field diameter (low power)}}{\text{ratio}}$$
  - (a) Calculate the field diameter of the high-power lens. Show your calculations.

#### Part 2: Determining the Number of Paramecia

- 5 Using a medicine dropper, place a drop from the paramecium culture on a microscope slide and add a cover slip. Using a ruler, measure the diameter of the wet mount preparation.
  - (a) Record the diameter. Calculate and record the area of the wet mount.

#### Step 5






- 6** Place the slide on the microscope stage and examine for paramecia first under low-power and then medium-power magnification.

- (a) Describe the appearance of the paramecia.
- (b) Do any of the paramecia appear to be dividing?
- (c) Draw any cells that you believe are **6C** undergoing cell division.

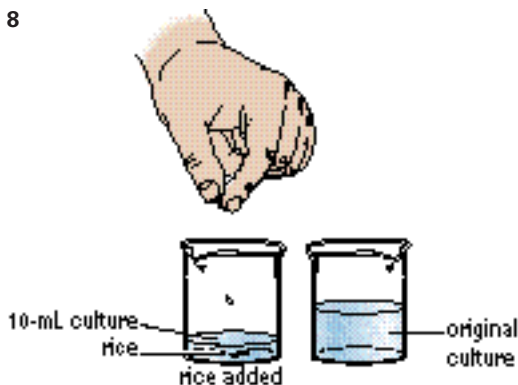
- 7** Using medium-power magnification, estimate the number of paramecia in three different fields of view.

-  (a) Record the number of paramecia seen in each field.
- (b) Calculate the average number of paramecia in a field of view.


### Part 3: Environmental Factors Affect Growth Rate

- 8** Measure 10 mL of the culture and pour it into a glass or plastic container. Add a few grains of rice to the container. The rice will serve as a food source.

#### Step 8



- 9** Check the paramecia cultures over the next 10 days and determine the population by the sampling technique described in Part 2. Compare the two cultures: with rice and without.

- (a) Construct a data table to show populations every day.
-  (b) Record your daily observations in the data table.

## Analysis and Communication

- 10** Analyze and summarize your results by completing the following:
- (a) Identify the control used in Part 3.
  - (b) Graph the changes in the population **7B** of the paramecia in both the control and experimental groups. Plot time along the  $x$ -axis and population along the  $y$ -axis.
  - (c) Does the population grow at a constant rate? Give reasons for your answer.
  - (d) Extrapolate from your graph the estimated number of paramecia that would be found if the experiment were extended to 20 days.
  - (e) Calculate the number of paramecia in 1 mL (20 drops from the medicine dropper = 1 mL). Use the following formula to help you:

$$\frac{\text{Number of paramecia in one drop} = \text{area of the wet mount} \times \text{no. of paramecia per field of view}}{\text{area of field of view (medium power)}}$$

- (f) Calculate the population growth by using the following formula:
- $$\frac{(\text{final population/mL}) - (\text{original population/mL})}{\text{Time}}$$

### Making Connections

1. Did the populations change? If so, why?
2. From your investigation, what do you think paramecia need to live and reproduce?

### Exploring

3. Different groups in your class could test different numbers of rice grains. Is there an "optimum" nutrient level?
4. Design and conduct an investigation to test **2A** another environmental factor that might increase the rate of population growth.

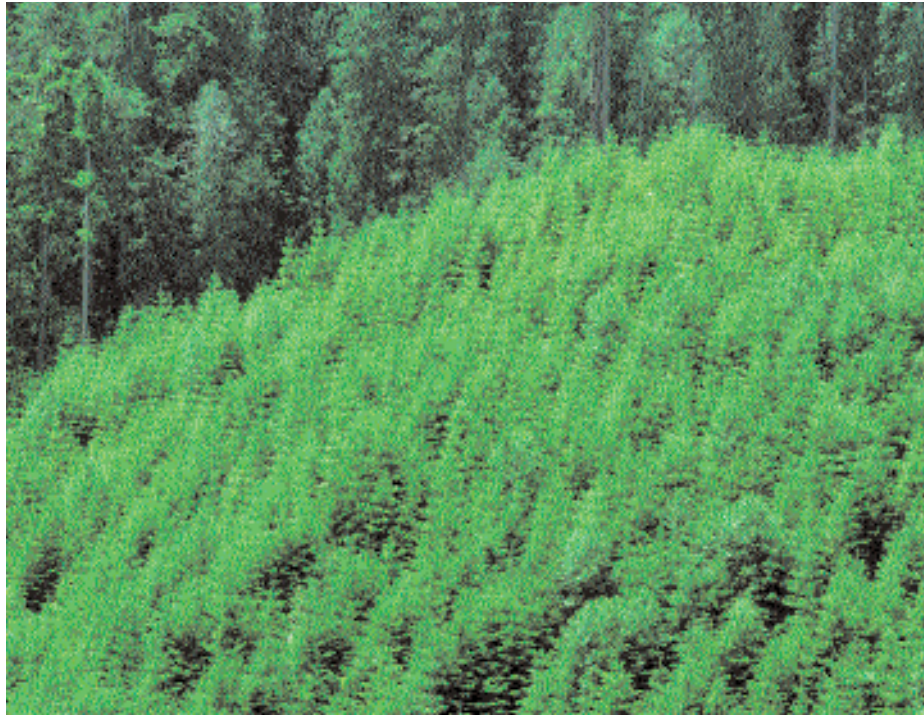
## Challenge

In both the survey and the display, you must present data. How could you use graphs to improve your presentation?

# Hormones for Cell Growth and Division

What causes some plants, like the ones in **Figure 1**, to grow full and bushy while others grow tall and thin? Why do some animals grow faster and larger than others? Understanding the factors that either promote or inhibit cell growth and cell division is important for scientists who are working to increase food production.

Scientists don't really know why some cells divide more frequently than others. However, they do know that cells communicate with one another using chemical messengers. These messengers, called **hormones**, are produced in cells in one part of the body and can affect cells in other parts. Some hormones trigger cells to grow or divide.



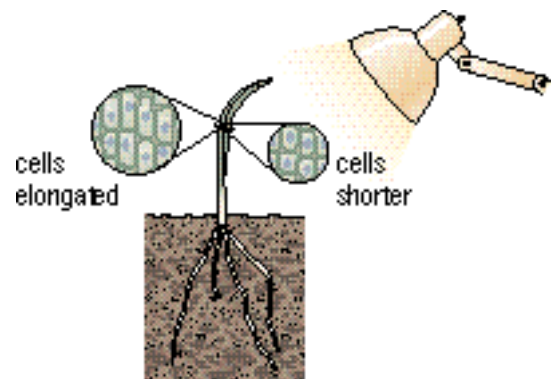
**Figure 1**

## Plant Growth Hormones

Plants produce a variety of growth hormones. For example, when one side of a plant is not exposed to light, hormones called auxins collect on the dark side. These hormones signal the cells to grow so they become longer. As the cells grow in length, the plant bends toward the light, as shown in **Figure 2**.

As the name suggests, cytokinins are plant hormones that stimulate cell division. Cytokinins released from the roots promote cell growth and division in the buds on the side of a plant. This causes the plant to grow wider.

Often, cytokinins and auxins work in opposite ways. For example, auxins produced at the top of a plant inhibit the growth of the buds on the side. This causes the plant to grow up. Horticulturists have known about the interaction of auxins and cytokinins for years. By removing the top buds from a plant, auxin production is reduced, and the plant slows its upward growth and becomes bushier. Apple growers prune the tops of their trees, making them bushier. Low, bushy apple trees mean more fruit, easier picking, and less bruising of mechanically picked apples.



**Figure 2**

Grass seedlings bend toward the light.



## Animal Growth Hormones

Animals also have hormones that affect the growth and division of their cells. Growth hormone (GH) is produced in the pituitary gland and carried by the blood to all areas of the body. However, GH affects some cells, such as bone, muscle, and cartilage cells, more than others. Stimulated by GH, they divide rapidly to produce more cells, which then grow and make a bigger organism.

The effects of human growth hormone are particularly noticeable when it is produced in abnormal amounts. Low production of GH during childhood can result in dwarfism, while high secretions can result in gigantism, as shown in **Figure 3**.



**Figure 3**

Abnormally low or high secretions of growth hormone can result in dwarfism and gigantism.

### Understanding Concepts

1. What are hormones and why are they important to the survival of multicellular organisms?
2. What environmental stimulus could cause the release of a hormone?
3. Identify two hormones of plants and explain what each does.
4. What is animal growth hormone? What does it do?
5. Calluses form when cells in the skin layer divide and grow rapidly to protect cells below. How does this indicate that chemical signals stimulate cell division?

### Making Connections

6. What do you think might happen if you added cytokinins to the soil of your houseplants?
7. What could a plant nursery worker do to make young plants bushier?

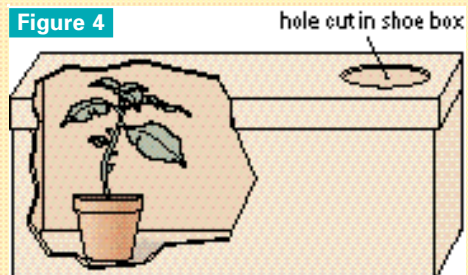
### Exploring

8. Some farmers give “growth enhancers” to some of their **3A** livestock, particularly beef cattle. **3B** Many consumers are concerned that this practice could cause health problems in humans. Research both sides of this topic. Use the Internet and talk to people in the agriculture industry to find out what growth enhancers are and how they work.

### Try This

### Response to Sunlight

Set up an experiment, as shown in **Figure 4**, to study a plant's response to sunlight. Predict what you think will happen to the plant as you observe it for several days. Record your observations. In which parts of the plant do the cells elongate? **2A**





## 5.11 Investigation

### SKILLS MENU

- Questioning
- Hypothesizing
- Planning
- Conducting
- Recording
- Analyzing
- Communicating

# Measuring Plant Growth

Selecting the plants best suited for a particular environment, whether it's a field, an orchard, or a garden, requires an effective way of measuring growth rates. In this investigation, you will mark a growing root and then measure it to determine the area of the root where cell division took place at the most rapid rate.

### Question

- 1 Write a question for this experiment. 4A

### Hypothesis

If a plant grows, then its cells must be undergoing cell division and cell growth.

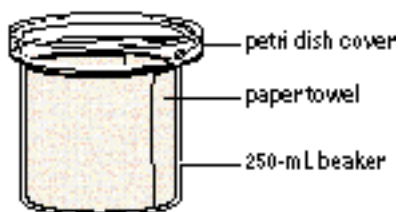
### Materials

- germinating seedlings, approximately 4 cm long
- 250-mL beaker
- elastic band
- ruler (mm)
- paper towel
- petri dish
- permanent marker
- nylon thread
- glass plate or cardboard sheet
- cross section of tree
- prepared microscope slide of a woody stem

### Procedure

- 2 Prepare a growth chamber by lining a 250-mL beaker with damp paper towel. Add approximately 20 mL of water to the beaker. Place a petri dish cover over the beaker.

Step 2



- 3 Select 5 seedlings that are reasonably straight. Place them on a dry paper towel to remove excess water.

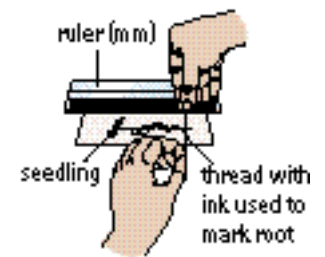
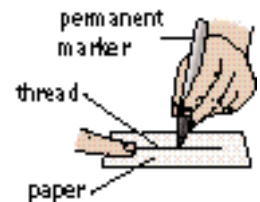
Step 3



select germinating seedlings

- 4 Place a piece of nylon thread on a sheet of paper. Run a permanent marker pen along the thread until the thread has picked up the ink. Use the thread and a ruler to lightly place a mark every 1 mm along the root of each seedling.

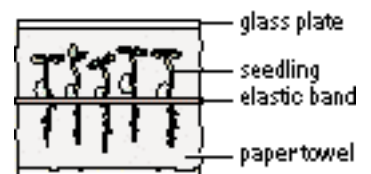
Step 4



- (a) Why is it important to use permanent ink rather than water-soluble ink?

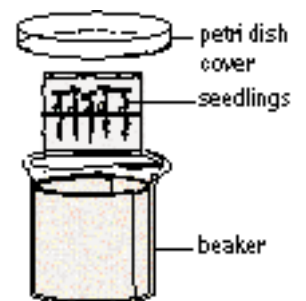
- 5 Cover a glass plate or small piece of cardboard with a paper towel. Use an elastic band to gently hold the 5 seedlings in place on the paper towel.

Step 5



- 6 Stand the plate with the seedlings in the growth chamber, cover the chamber, and leave it in a dark place for 48 h.

Step 6



- 7** Make a data table such as **Table 1** to record your observations. Section 1 is the section closest to the root tip.

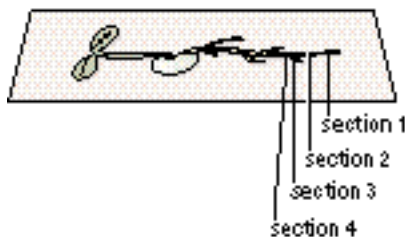
**Table 1** Root Growth in Seedlings

Section number	Distance (mm) after 48 h				
	Seedling 1	Seedling 2	Seedling 3	Seedling 4	Seedling 5
1	?	?	?	?	?
2	?	?	?	?	?

- 8** After 48 h, gently take one of the seedlings and measure the distance between each pair of ink marks on the root. Remember that your original marks were 1 mm apart. Replace the seedling on the plate.

- 6B** (a) Record your measurements in your table.

Step 8 After 48 h



- 9** Repeat step 8 for the remaining seedlings. Return the seedlings to the growth chamber.

- 6B** (a) Record all measurements in your table.

- 10** Repeat steps 8 and 9 after 72 h, and again after 96 h.

- 6B** (a) Record all measurements in your table. Note any changes in the root sections that show the most growth.

- 11** In addition to increasing in length, roots and stems also grow thicker. This type of growth is referred to as secondary growth. Because little growth occurs during the winter months, the secondary growth can be identified as bands of cells, called annual rings. Examine the cross section of a tree.

- 6B** (a) Estimate the age of the tree in **Figure 1**.

## Analysis and Communication

- 12** Analyze your results by completing the following:
- Which section of the root showed the most growth?
  - Make a graph to show which section of the roots grew the most after 48 h. Plot the average length of each section on the y-axis and the section number along the x-axis. **7B**
  - Construct a graph that shows the change in growth rate over time.
  - Why was most of the growth located in one area?
  - Summarize in a paragraph why you used 5 seedlings in this experiment instead of only one.
  - What can you conclude about the relationship between organism growth, cell growth, and cell division?
  - Write a hypothesis that explains why some annual rings are thicker than others.

### Exploring

- Repeat the experiment after removing different lengths of root tip from a number of seedlings. Compare the growth rate of these seedlings with normal seedlings.
- Design a method for determining the growth rate of leaves and stems. Plant some of the remaining seedlings used in this activity in vermiculite and test your procedure. **4B**



**Figure 1**

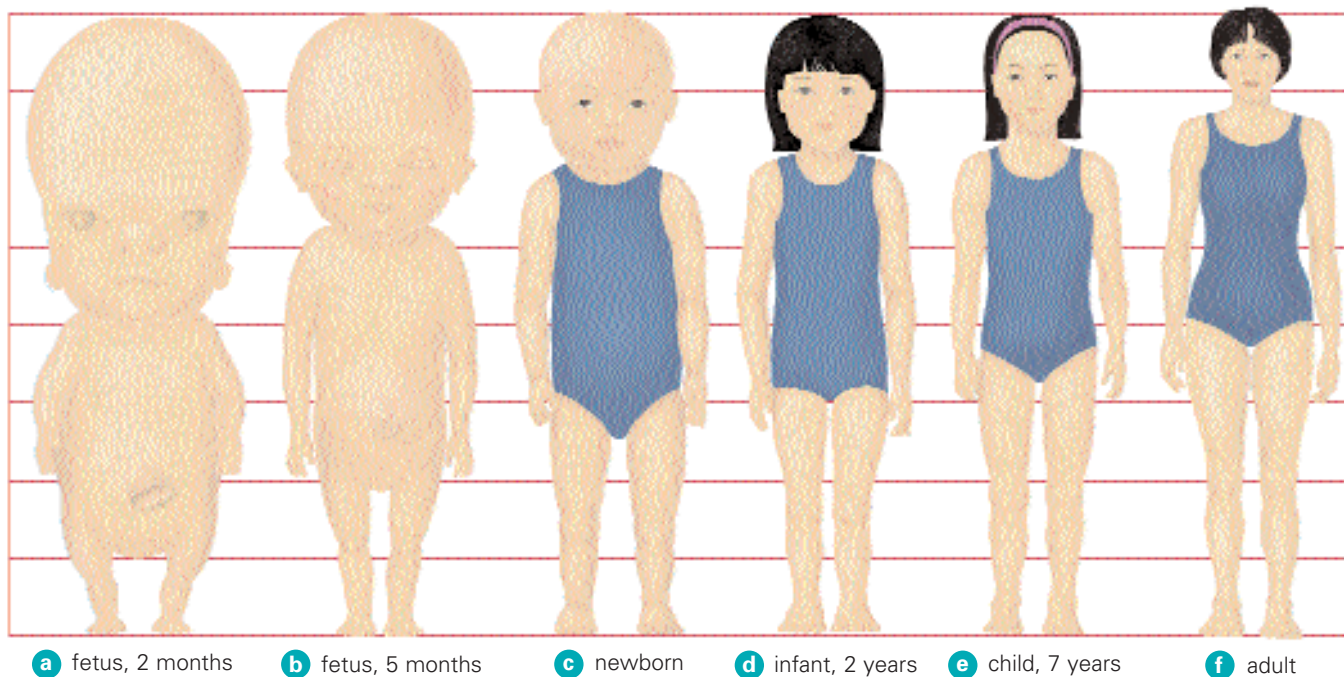
# Cell Division and Patterns of Growth

Humans grow most quickly during the nine months before and the first three months after their birth. However, not all of their body parts grow at the same rate. In this case study, you will investigate some of the differences in growth rate as a human body matures.

## Growth of the Body

Examine **Figure 1** showing changes in body proportions from the fetus to the adult. The individual diagrams are not drawn to the same scale. However, proportions are indicated by eight different segments, each of which represents one-eighth of the total body size.

Figure 1



- (a) Which parts of the body appear to grow the most between a two-month-old fetus and an infant?
- (b) Which parts of the body appear to grow the most between infancy and adulthood?
- (c) Which parts of the body grow the least during each time?
- (d) Speculate about why an infant's head is so large in comparison to the rest of its body.



## Growth of Organs

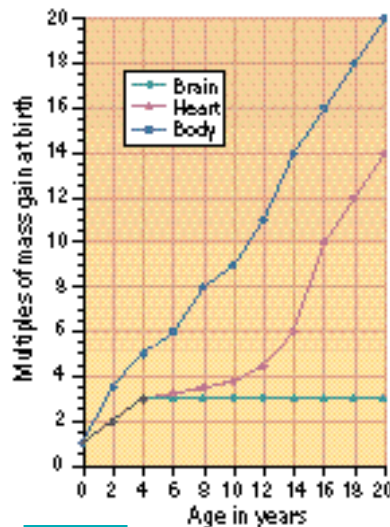
Examine the graph in **Figure 2** showing the rates of growth of the brain, heart, and body. The graph shows that at the age of two, the masses of the brain and heart have doubled, whereas the mass of the body is almost four times the mass at birth.

(e) By how many times has the body mass increased by **7A** age 19? By how many times has the heart increased in mass?

(f) At what approximate age does the brain reach its maximum mass?

(g) How does the growth of the heart compare with that of the brain?

(h) Would you expect the change of mass of the heart and body to continue at the same pace after 19 years of age? Explain your answer.



**Figure 2**

Growth rates of the brain, heart, and body

## Growth of Bones

**Figure 3** shows changes in the growth rate of the foot and shin bone (tibia).

- (i) Which body part (foot or shin bone) grows faster?
- (j) Plot a graph that shows the difference between the **7B** growth rate of the foot and that of the shin bone (tibia).



**Figure 3**

The bones of the foot and tibia do not grow at the same rate.

## Understanding Concepts

1. Where in your body would you expect to see the highest rate of cell division? Explain your answer.
2. Based on the information in this activity, what can you conclude about the growth of your brain?

## Making Connections

3. The graph of the growth rates of the brain, heart, and body is taken from data collected from a large group of people. Why do scientists compile data from many people rather than just record the information from a single individual?

## Exploring

4. How large would the picture of the adult be if it were drawn to the same scale as the infant? Assume that the size of the adult's head is approximately twice that of the infant's head. The following steps may help your calculations:
  - Use a ruler to take a horizontal measurement of the infant's head and the adult's head.
  - Calculate the size of the adult's head, if drawn to same scale as the infant's head.
  - Calculate the size of the adult, if drawn to same scale as the infant.

## Reflecting

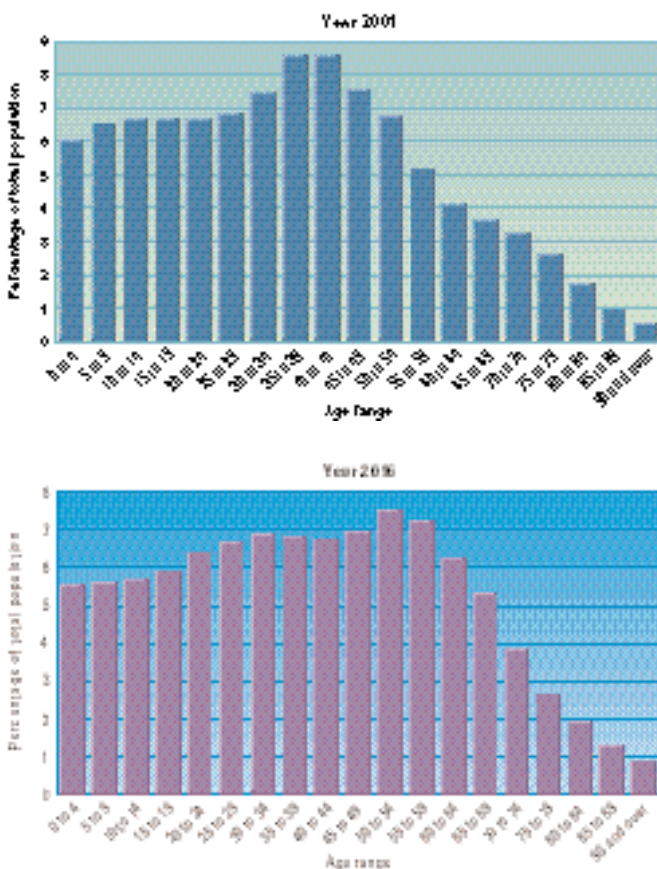
5. What evidence can you draw from your own growth patterns to suggest that all parts of your body do not grow at the same rate? If possible, use photographs of yourself at different ages as evidence.

# Slowing Down Aging

People are living longer. The life expectancy (the average lifespan) for Canadians born in 1991 was 75 years for men and 81 years for women. In 1951, the life expectancy was only 66 years for men and 71 years for women. According to Statistics Canada projections (**Figure 1**), the percentage of the population that is older than 65 years is going to grow every year for decades (**Figure 2**). People have always aged, but there was little that could be done about it. In the near future, that may change. The question “Why do cells age?” is central to a growing field of research.

**Figure 1**

Population projections for the years 2001 and 2036 show that the number of older people will increase.



## Aging and Cell Division

The answer to the question of aging seems to have a lot to do with cell division. The oldest organisms on Earth, trees such as the giant redwood trees on the west coast of North America, started growing around the same time people figured out how to use iron to make axes—about 3000 years ago. Yet even in these incredibly ancient trees, the oldest living cells are only 30 years old. The same is true of the cells in your body—very few of the cells you were born with are still around. They have died and been replaced by their descendants. Red blood cells live only about 120 days; your skin cells are replaced by the hundreds of thousands daily. Few cells exist for the entire life of most plants and animals.

**Figure 2**





To stay alive, you rely on cell division. But research on chicken heart cells grown in tissue culture indicates that there's a limit to the number of times cells can divide. For those immature heart cells, the maximum was 50 times. Other types of cells have different limits, but once they have reached their maximum, they can no longer divide. If a neighbouring cell dies or is injured, they cannot reproduce to replace it. This may be at the core of aging. Cells die and are not replaced. Injuries are not repaired. Because of accumulating damage, the function of organs slows. Eventually the damage becomes so serious that an organ or an organ system can no longer function, and the person dies.

## Fighting Age

Is there a way around the biological clock? Scientists are exploring this question. A 1990 study indicated that injections of growth hormone (GH) could slow aging. According to the research, the injections in older people increased muscle development and caused fat to disappear. In many ways, GH seemed to reverse decades of aging.

There may be a cost. Researchers warn that the long-term effects of GH injections have not been studied, and the hormone may not be for everyone. Scientists and non-scientists remain doubtful about the potential of GH. Since 1990, many scientists have begun research on other substances that may reverse the aging process.

### Issue

## Should we be fighting nature? 8B

### Statement

Hormones or drugs should not be used to reverse or even slow the processes of aging.

### Point

- The idea of reversing aging presents many difficulties. First, the cost would be immense. GH is expensive. At current prices, injections of GH for a 70-kg man would cost about \$14 000 per year. Only the richest in society would be able to pay for such treatments.

### Counterpoint

- Expense has no bearing on the issue. Cosmetics are a billion-dollar business. The money spent on hormone or other treatments for aging would also produce economic benefits. People would work longer and generally experience a better quality of life.

### What do you think?

- In your group, discuss the statement and the point and counterpoint above. Write down additional points and counterpoints that your group considered.
- Decide whether your group agrees or disagrees with the statement.
- Search newspapers, a library periodical index, a CD-ROM directory, 3A and, if available, the Internet for information on drugs or hormones used to slow aging.
- Prepare to defend your group's position in a class discussion. 3B





# Chapter 5 Review

## Key Expectations

Throughout this chapter, you have had opportunities to do the following things:

- Explain the cell theory and illustrate its contributions to the concept of cell division. (5.1, 5.3, 5.5, 5.8)
- Explain mitosis and its significance. (5.4, 5.5, 5.6)
- Describe representative types of asexual reproduction. (5.8, 5.9)
- List the advantages of asexual reproduction. (5.8)
- Investigate the processes of cell division, and organize, record, analyze, and communicate results. (5.6, 5.7, 5.9, 5.11)
- Formulate and research questions related to cell division and communicate results. (5.4, 5.6, 5.8)
- Use a microscope to identify cells undergoing division. (5.6, 5.7, 5.9)
- Use a microscope to observe an organism undergoing fission, and design and conduct an investigation into cell division. (5.9)
- Predict the number of cells produced in a given amount of time. (5.8)
- Describe the historical development of reproductive biology, including the role of the microscope. (5.1, 5.3)

- Provide examples of how advances in cell biology will affect human populations. (5.10, 5.13)
- Describe Canadian contributions to research and technological developments in genetics and reproductive biology. (5.1)
- Explore careers that require an understanding of reproductive biology. (Career Profile)

### KEY TERMS

anaphase	Golgi apparatus
asexual reproduction	lysosome
binary fission	metaphase
budding	mitochondrion
cell cycle	mitosis
cell membrane	nucleolus
cell wall	nucleus
centriole	organelle
chloroplast	prophase
chromosome	ribosome
cilia	sexual reproduction
cytokinesis	spore formation
cytoplasm	telophase
endoplasmic reticulum	vacuole
flagellum	vegetative reproduction
fragmentation	
gene	

## Reflecting

- “All living things undergo cell division. Cell division is essential for the perpetuation of life.” Reflect on this idea. How does it connect with what you’ve done in this chapter? (To review, check the sections indicated above.)
- Revise your answers to the questions raised in Getting Started. How has your thinking changed?
- What new questions do you have? How will you answer them?

## Understanding Concepts

1. Make a concept map to summarize the material that you have studied in this chapter. Start with the words “cell division.”

2. Use the diagram in **Figure 1** of plant and animal cells during cell division.
  - (a) Identify each of the cells as either plant or animal cells.
  - (b) Identify the phases of cell division.

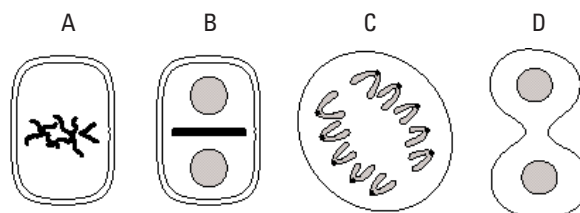


Figure 1

3. What is the cell cycle?
4. What is interphase and why is it important for the process of cell division?

- Compare mitosis in plant and animal cells.
- What evidence can you provide that suggests that not all cells divide at the same rate?
- Why is the duplication of genetic material important for cell division?
- How did the experiments performed by Spallanzani and Pasteur support the cell theory postulate that states: "All cells come from preexisting cells"?

## Applying Skills

- Three groups of seedlings were placed in growth chambers. Each growth chamber received 10 mL of a different nutrient solution. The root lengths of the seedlings were measured over a five-day period. The data in **Table 1** were obtained:

**Table 1**

Time (days)	Root Length (mm)		
	Solution X	Solution Y	Solution Z
0	2	2	2
1	2	4	4
2	3	6	9
3	4	10	14
4	4	12	18
5	5	15	28

- Graph the results obtained by plotting days on the  $x$ -axis and root length on the  $y$ -axis.
  - Provide a conclusion from the data given.
- The data in **Table 2** were collected from two different fields of view of hamster embryo cells. The number of cells found in each phase of cell division was recorded. It took 660 min to complete one cell cycle from the beginning of one interphase to the beginning of the next.

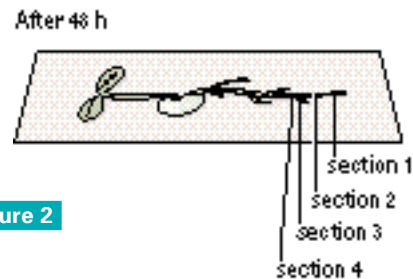
**Table 2**

Cell phase	Area 1	Area 2	Total cell count	Time for each phase
interphase	91	70	?	?
prophase	10	14	?	?
metaphase	2	1	?	?
anaphase	2	1	?	?
telophase	4	4	?	?

- Copy the table in your notes and complete the calculations.

- Using the data provided, draw a circle graph of the cell cycle.

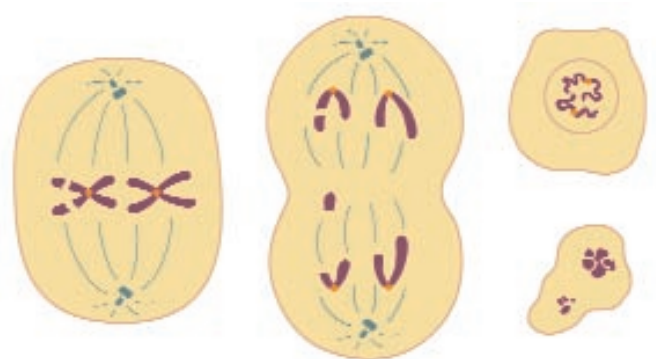
- An experiment measured the rate of growth of a seedling root. Lines were marked on the root 1 mm apart. After 48 h, the root appeared as shown in **Figure 2**. Examine the results and draw a conclusion.



**Figure 2**

## Making Connections

- Many times science is presented as a compilation of facts; however, there are a great many things that are not known about cell division. Make a list of unanswered questions that have been introduced in the chapter. What things don't we know about cell division?
- Irradiation can break apart chromosomes. The diagram in **Figure 3** shows the effects of irradiation on cells undergoing metaphase. Food companies sometimes irradiate fruit and vegetables to improve shelf life. How does irradiation help preserve food?



**Figure 3**

- No nucleus is found in the outermost layer of skin cells that covers your body. A moisturizer claims to restore and rejuvenate these cells.
  - Would these skin cells be capable of producing other skin cells?
  - How would you go about testing the claim?