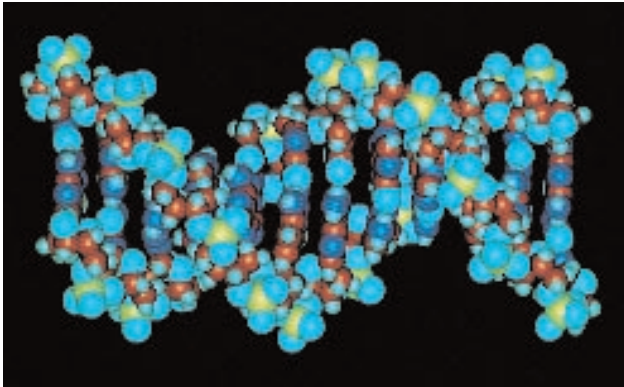


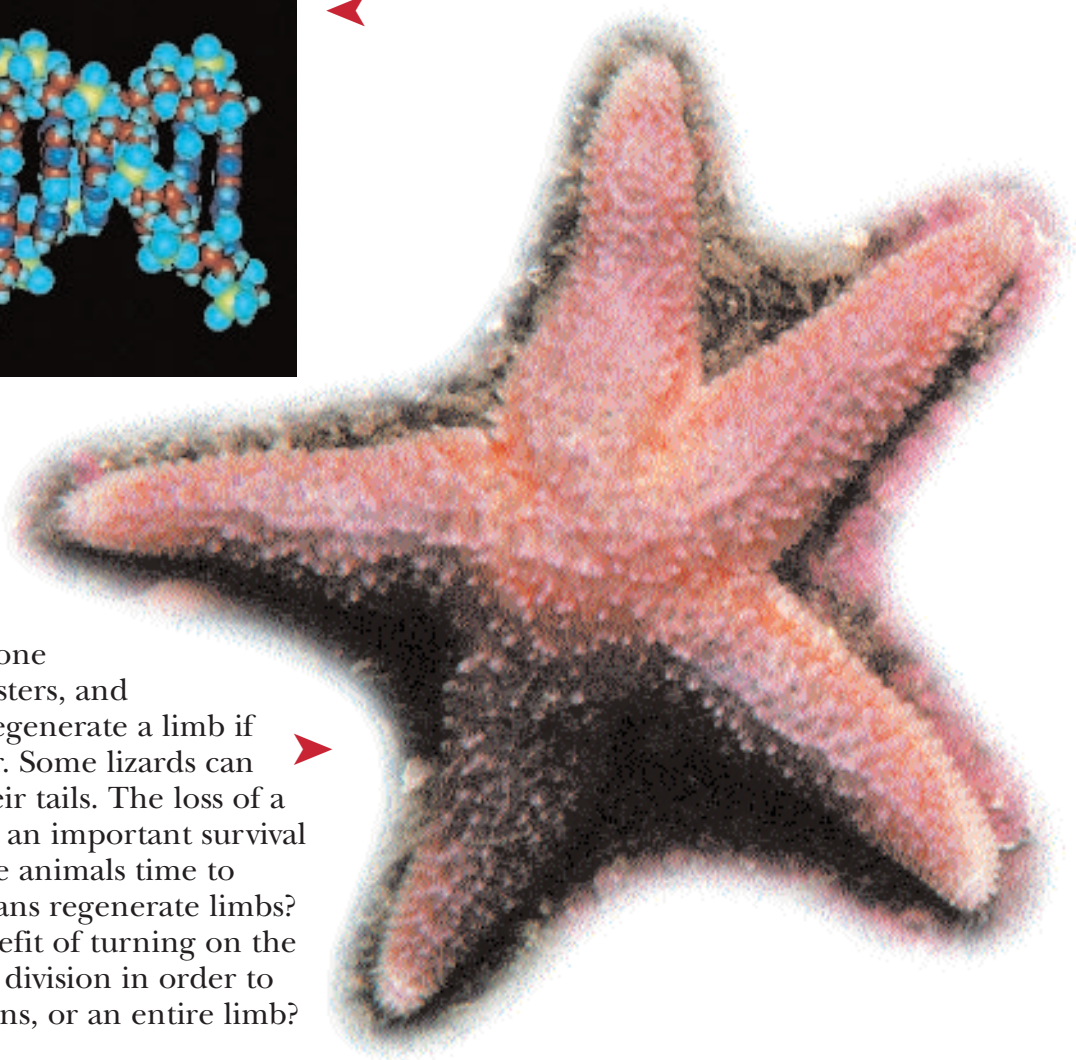
A Closer Look at Cell Division

Getting Started

- 1 DNA is the amazing, dynamic, genetic material found in the chromosomes of a cell. It contains all of the information that determines how cells function and respond to their environment. DNA is one of the very few molecules capable of duplicating itself. But DNA is still just a chemical. How does your hereditary material differ from that of a tree or a frog?



- 2 Peering into a tank of lobsters at a grocery store, you may see one that has one large and one small claw. Starfish, lobsters, and most amphibians can regenerate a limb if one is lost to a predator. Some lizards can regenerate a part of their tails. The loss of a limb or a tail-tip can be an important survival technique—it allows the animals time to escape. Why can't humans regenerate limbs? What would be the benefit of turning on the genes that regulate cell division in order to regenerate tissues, organs, or an entire limb?



- 3 The plot of the 1997 movie, *Multiplicity*, was based on cloning. The busy hero enlisted the help of scientists to make duplicates of himself so that he would be able to spend more time with friends and family. Does cloning actually work the way it was depicted in the movie? Have people ever been cloned? What ethical issues surround the cloning of humans, plants, and other animals?



Reflecting

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

Try This Cloning a Potato

Locate a potato that has many “eyes.” Using a knife, cut the potato into several pieces. Some of the potato chunks should contain eyes, others should have none. Plant each piece in potting soil in the school laboratory. Label each piece. (You could also plant them in your garden or a school garden.)

1. Do any of the pieces of the potato grow? If so, which ones?
2. What is an “eye” of a potato tuber?



DNA: The Genetic Material

What makes you different from a mouse or a dog? Why don't you have whiskers and walk on four legs? The answer is that your body was shaped by the genetic information in each of your cells. Based on that, you might expect that your genetic information would be obviously different from that of a mouse or a dog.

The packaging is certainly different. A look into one of your cells as it divided would reveal 46 chromosomes.

A dog has 78 chromosomes, and a mouse has 40.

However, a closer look at the chromosomes

reveals something very surprising. All chromosomes, whether in mice, dogs, eagles, fish, toads, or humans, are composed of the same chemical.

This genetic chemical is called **deoxyribonucleic acid (DNA)** for short).

DNA provides the directions that guide the repair of worn cell parts and the construction of new ones. It describes how cells will respond to changes in their environment and to messages from other cells. This information is sent from DNA in the nucleus to the organelles in the cytoplasm using chemical messengers.

The Code Inside the Chromosome

The surprise that the genetic material is the same chemical in all living things is explained by a closer look at DNA. The molecule has an interesting structure. It is made up of a series of chemicals called nitrogen bases, held in a long, winding helix (**Figure 1**). These nitrogen bases are used like letters or characters in a simple code. Computers use a two-character code (1 and 0) to store information. English uses a 26-character code called the alphabet. Other languages may use many more or fewer characters.

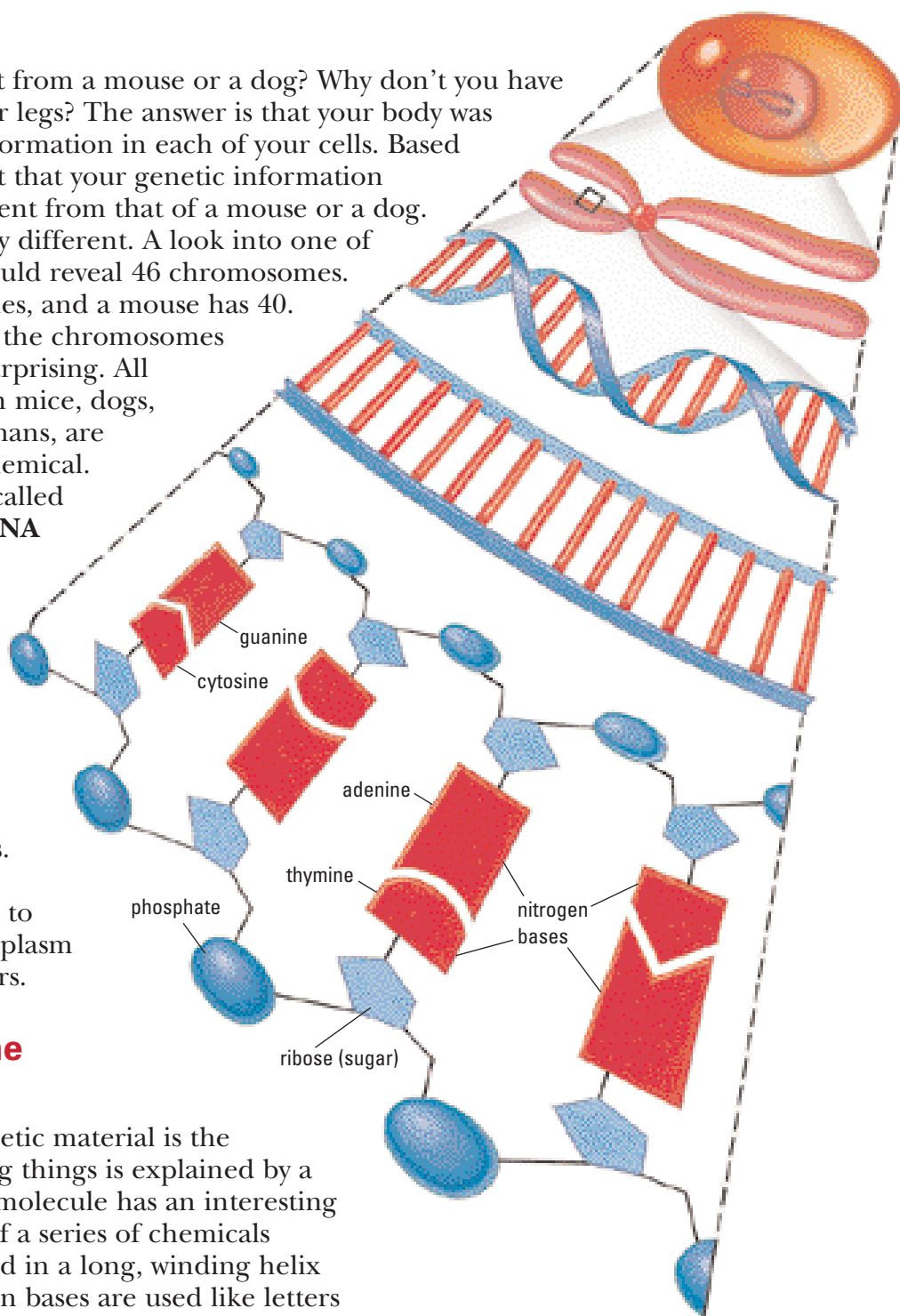


Figure 1

DNA molecules are shaped like a twisted ladder. Sugar and phosphate molecules make up the sides of the "ladder," while nitrogen bases form the "rungs." The nitrogen bases form pairs—adenine always pairs with thymine and cytosine always pairs with guanine. The sequence of the bases makes each DNA molecule different from any other DNA molecule.

DNA uses a four-character code made up of the nitrogen bases adenine (A), thymine (T), cytosine (C), and guanine (G). The order that the bases appear in is the code. This genetic code is arranged in what might be described as “words”—three-character sequences of nitrogen bases—and those words combine to form “stories”—a complete description of a molecule that can be read by the cell and used as a blueprint to make that molecule.

The DNA “stories” are genes, which you encountered earlier. A gene is a long section of DNA that determines a characteristic. Your hair colour, skin colour, and nose length, all the instructions that make you a unique individual, are coded as genes within the chemical structure of your DNA. This “language of life,” the genetic code, is stored in the 6 billion nitrogen bases of DNA, arranged in about 100 000 genes on the 46 human chromosomes.

Did You Know ?

If the DNA from a single cell were stretched into a line, its length would be greater than your height. In each cell of your body, your DNA codes for enough information to fill the pages of more than 100 books the size of this text.

DNA Replication

This remarkable molecule can make perfect copies of itself in a process called replication (**Figure 2**). Without this unusual ability of DNA, cell division would not be possible. Recall that before a cell divides, each strand of genetic information makes a duplicate. During cell division the duplicates separate, so each cell has a complete set of genetic information.

DNA, Genes, and Variation

Mice and humans are different because of the genes they carry in their DNA. Mice have genes that make them mice, and humans have genes that make them human. But why are humans different from each other?

You have 46 chromosomes arranged in 23 pairs. One chromosome in each pair comes from your mother, the other comes from your father. The chromosome from each parent carries the same genes, so you have two copies of each gene, but within each copy there may be small differences in the code. For example, all humans carry a set of genes that allows follicle cells in our scalp to build hair. One gene determines the structure of the hair. There are different versions of this gene. One version results in hair that is straight; another version produces curly hair. You may have two genes for straight hair (one from each parent), or two genes for curly hair, or one of each. How curly your hair is depends on which versions of the gene are on your chromosomes, and how the genes interact with each other.

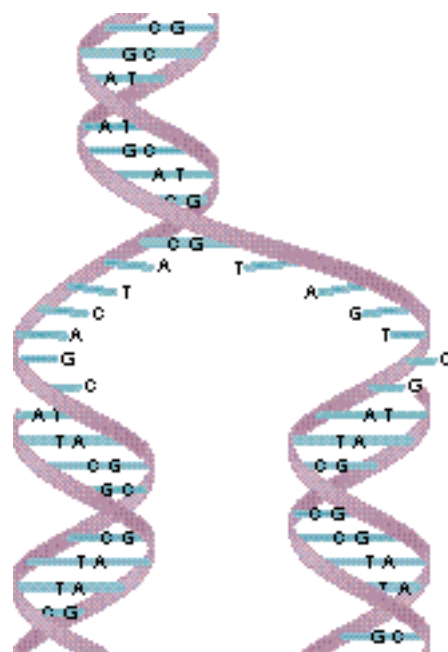


Figure 2

When replicating, the DNA molecule “unzips,” and each side serves as a template. On each half of the molecule, a new complementary half is built. Because adenine (A) always pairs with thymine (T), and cytosine (C) always pairs with guanine (G), when the DNA unzips, any As attract only Ts, and Cs attract only Gs. By the end of the process, two helixes have been formed. The two new DNA molecules are identical to each other!

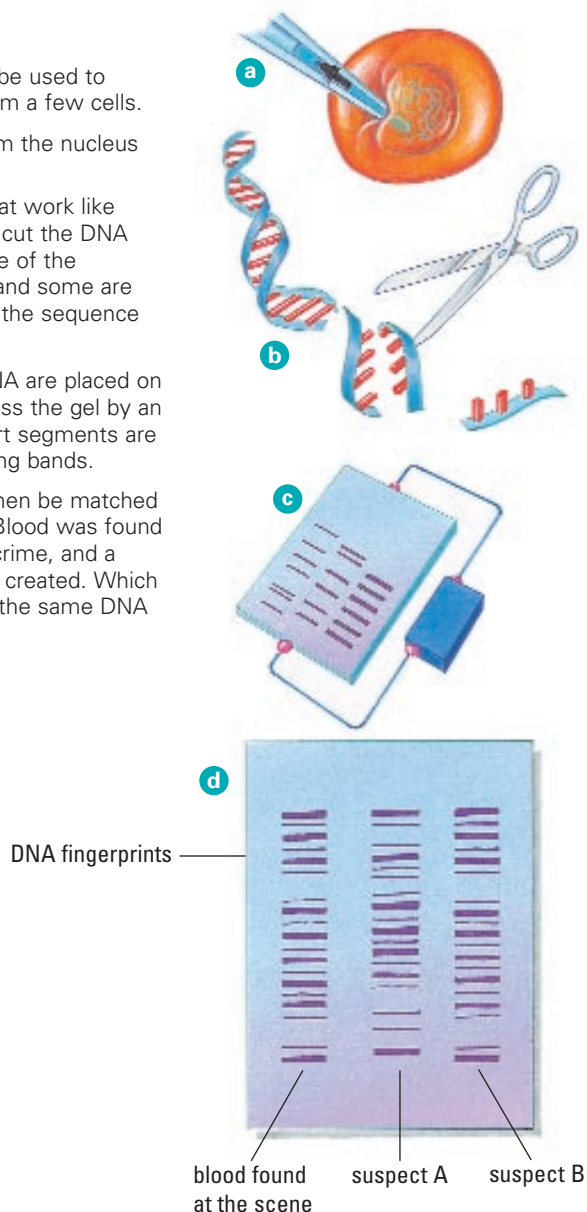
DNA Fingerprints

The DNA contained in your chromosomes is unique to you. No one else, except an identical twin if you have one, has exactly the same DNA. Therefore, one way to identify a person is by his or her DNA. You may be able to alter your physical appearance, but your DNA will always give you away! That is one of the reasons why DNA has found its way into the courtroom—a good example of how research to learn more about cell reproduction is now also important in other areas. In a simplified form, **Figure 3** shows the technique used in DNA fingerprinting.

Figure 3

DNA fingerprinting can be used to identify an individual from a few cells.

- a** DNA is removed from the nucleus of a cell.
- b** Special chemicals that work like scissors are used to cut the DNA into segments. Some of the segments are long, and some are short, depending on the sequence in the DNA.
- c** The segments of DNA are placed on a gel and pulled across the gel by an electric current. Short segments are drawn farther, creating bands.
- d** Bands of DNA can then be matched to known samples. Blood was found at the scene of the crime, and a DNA fingerprint was created. Which of the suspects has the same DNA fingerprint, A or B?



Understanding Concepts

1. What molecule makes up the genetic material?
2. There are only four different nitrogen bases found in DNA, so why are organisms so different?
3. How does a DNA molecule make an identical copy of itself? Why is this important to each individual organism?
4. Why are humans different from each other?

Making Connections

5. Describe another practical application for DNA fingerprinting. What benefits might it have for society? What are some of the problems it may create?

Exploring

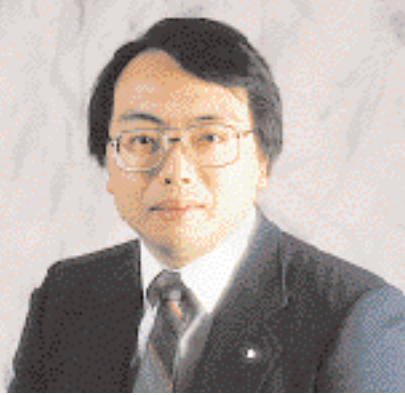
6. What is the relationship between DNA in the nucleus and the synthesis (manufacture) of proteins in the cytoplasm?
7. You may have heard about a recent use of DNA fingerprinting. Write down the circumstances under which it was used.

Reflecting

8. Explain the importance of DNA replication to your own survival.

Challenge

Technology exists that can pinpoint which versions of some genes an individual carries. Soon it will be possible to create genetic profiles of all genes. In your survey, you may want to explore how people would feel about making their profiles public.



Cystic Fibrosis Researcher

Lap-Chi Tsui exchanged a tiny, crowded island for a tiny, crowded lab, but the journey from Hong Kong to Toronto's Hospital for Sick Children has been a very rewarding one for the soft-spoken doctor. He is an

internationally-renowned researcher in the field of medical genetics: the study of the genes that can cause illness. His primary focus is the cystic fibrosis gene.

Cystic fibrosis is a disease that affects about one in 2500 Canadians, usually causing death before the age of 25. One of the symptoms is the production of extremely thick, gluey mucus. This may not sound life-threatening, but in fact can result in damaged lungs, blocked respiratory passages, and digestive disorders. For years researchers, suspecting that the disorder was caused by a harmful gene received from both parents, studied the DNA of young people with cystic fibrosis.

Lap-Chi Tsui arrived in Canada after earning both bachelor's and master's degrees in biology at the Chinese University of Hong Kong and a Ph.D. at the University of Pittsburgh. He joined a group of scientists in the Department of Genetics at the Research Institute at the Hospital for Sick Children in Toronto in 1981, and joined the search for the cystic fibrosis gene.

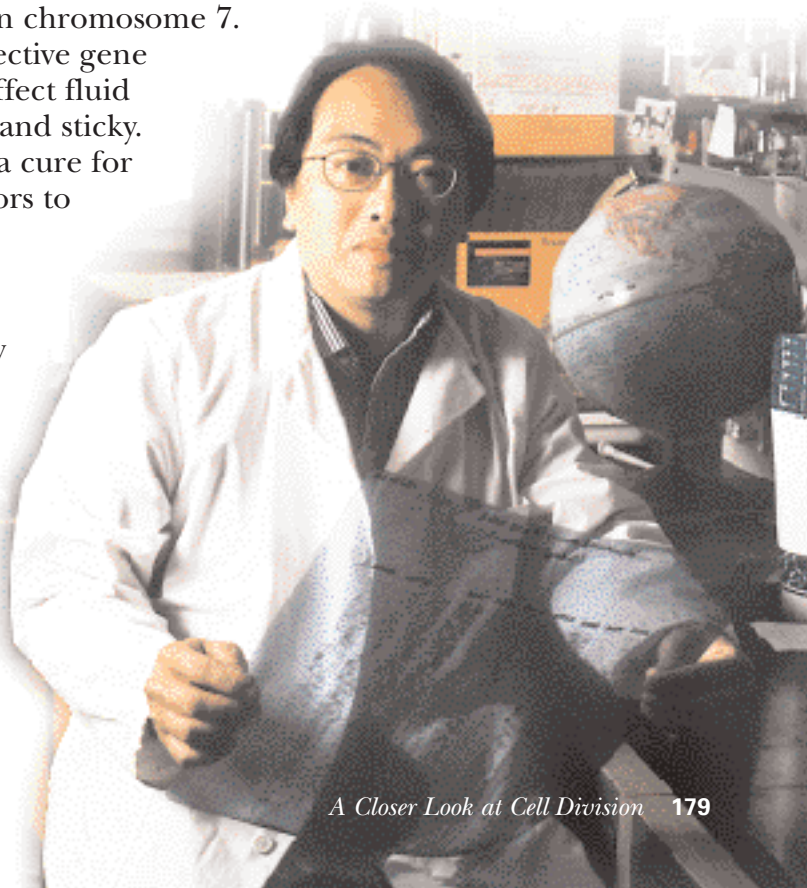
In 1989, after years of painstaking research, Tsui and his research team discovered the culprit section of DNA on chromosome 7. In a person who carries two copies of the defective gene (one from each parent), this gene seems to affect fluid secretion, which in turn makes mucus thick and sticky.

Dr. Tsui's research has not yet resulted in a cure for cystic fibrosis, but it certainly opened new doors to further research.

Exploring

1. Investigate the story of Dr. Tsui's discovery of the cystic fibrosis gene. How does this research illustrate the scientific method?
2. Brothers and sisters of children with cystic fibrosis do not necessarily have the disease. Propose an explanation for this.
3. Lap-Chi Tsui chose the field of genetics only after completing two degrees in biology. With these two degrees, what alternative careers might he have chosen?

The process of scientific discovery is not a simple thing. It takes months of repetitive testing....



DNA, Mutations, and Cancer

When computer programmers write code to make a piece of software, they have to get it exactly right. One misplaced symbol can make the software malfunction. A similar situation can occur with the genetic code. It can also become “buggy.” DNA is floating in a solution that contains many chemicals, some of which come from outside the cell and may be harmful. DNA may be exposed to radiation from the Sun or to viruses, both of which can cause changes in the sequence of the nitrogen bases.

Changes in the genetic code are called **mutations** (Figure 1). Mutations may be beneficial to the cell, but most are either neutral or damaging. One set of damaging mutations are those that cause cancer.

Cancer

When cell division goes out of control, it is called **cancer**. Cancer is actually a group of diseases, each associated with uncontrolled, unregulated cell division. Unlike many diseases that cause the death of cells, cancer can be described as too much life. Cancer cells divide more quickly than they should.

All cancers are caused by mutations in the genes that regulate cell division. Any substance or energy that causes such a mutation is called a **carcinogen**. Figure 2 shows the three types of known carcinogens: viruses (some of which cause leukemia, cancers of white blood cells); radiation (ultraviolet radiation from the Sun has been linked to skin cancer); and hazardous chemicals, such as those found in cigarette smoke, which cause lung and other cancers.



Figure 2

Carcinogens are known to cause cancer.

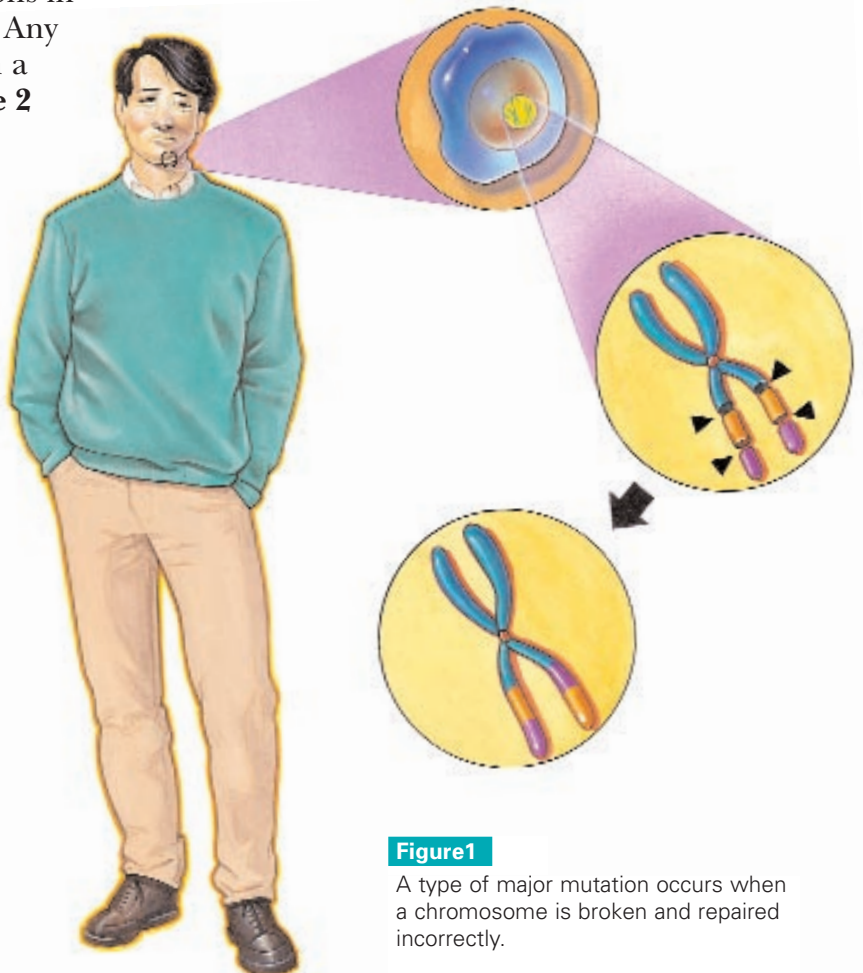


Figure 1

A type of major mutation occurs when a chromosome is broken and repaired incorrectly.

Did You Know ?

Cancer is not found only in humans. Many plants and animals also develop cancers. Sunflowers and tomatoes often display a form of cancer called a gall. These plant tumours are caused by invading viruses, bacteria, fungi, or insects. Evidence of cancerous tumours has been found in dinosaur bones and even in the cells found in the linen wrapped around ancient mummies.

Cancer Cells

Normal cells in multicellular organisms cannot divide when isolated from one another. Cell to cell “communication” is essential for normal cell division. Cancer cells, by comparison, are capable of dividing in isolation. Some cancer cells, grown in an artificial culture, have divided once every 24 h. At this rate of division, a single cancer cell would generate over 1 billion descendants in a month. Fortunately, cancer cells do not reproduce that quickly in the body of an organism. However, their growth can crowd (and damage) other cells.

The human body has many different types of cells. Each cell type has a unique shape that enables it to carry out a specialized function. As the organism grows from the fertilized egg, different clumps of cells “specialize,” forming nerve cells or liver cells or bone cells—whatever is needed.

Unlike normal cells, cancer cells do not change shape and specialize as they mature (Figure 3). Therefore, they pose another threat. Because the cancer cells cannot carry out some of the functions of the normal cells, they are inefficient. They use up the energy and resources of the other cells of the body to reproduce, but they do not do the same work as the normal cells.

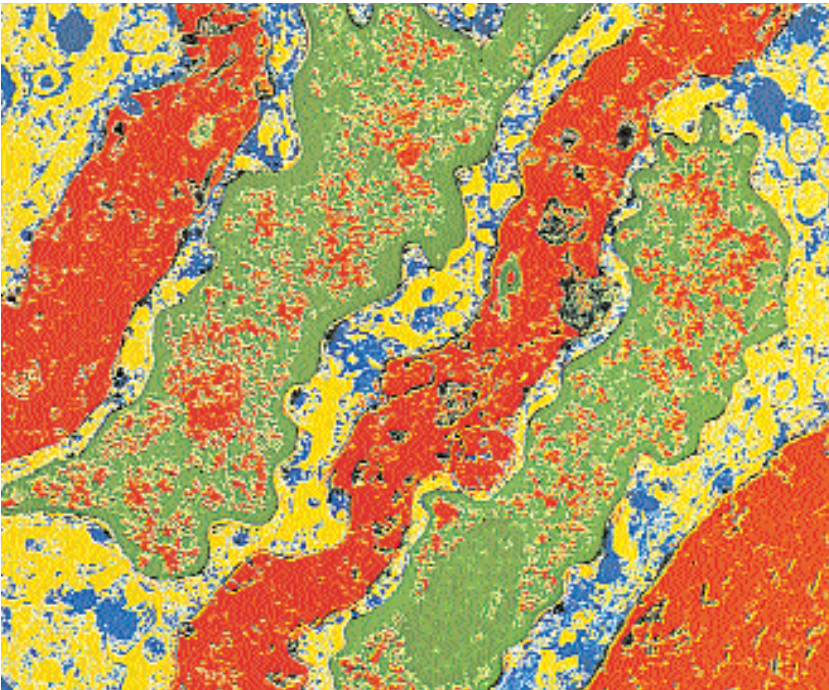


Figure 3
A cancer cell can often be identified by an enlarged nucleus and reduced cytoplasm. Why do you think a cancer cell might have a large nucleus?

Understanding Concepts

- 1. What is cancer?
- 2. What is a mutation?
- 3. In what ways do cancer cells differ from other cells?

Making Connections

- 4. Not all rapid cell growth is cancerous. A certain virus causes skin cells to divide quickly, producing a wart. Imagine what would happen if a cell and its descendants divided every hour. How large would the growth become? Make a table similar to the one below and fill in the blanks. What pattern do you see in the number of cells?

Time (h)	Number of cells	Size of cell mass
0	1	20
1	2	40
2	4	80
3	?	?
4	?	?
5	?	?

Exploring

- 5. Choose one type of cancer and 3A prepare a report that considers the following points:
 - (a) What causes this type of cancer (i.e., virus, chemicals, radiation, unknown)?
 - (b) What treatments are available?
 - (c) How dangerous is the cancer?
- 6. Research a study that relates a 2B certain type of cancer with a particular behaviour or environmental condition. Summarize and present the results.

6.3 Activity

Lifestyle and Cancer

Rapid cell growth can result in a mass of cells called a **tumour**. Harmless tumours are said to be **benign**. These tumours remain in a confined area, causing little damage to the organism. In contrast, dangerous tumours spawn cells that can break away and move to other areas of the body. These tumours are **malignant**, and can move from a tissue where they cause little harm to a vital organ.

Most experts believe that cancer rates can be reduced dramatically with changes in lifestyle. In this activity you will interpret data about cancer in order to predict trends.

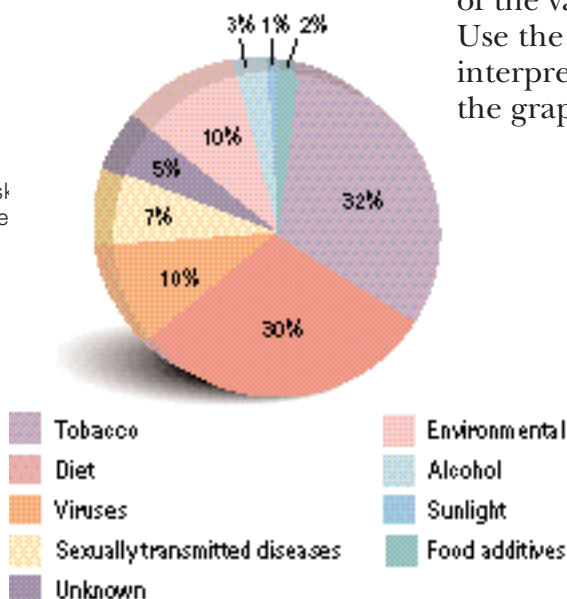
Materials

- graph paper
- pencil

Procedure

- Study the pie chart in **Figure 1** that shows the risk factors associated with cancer.
 - Which factor is responsible for the most cancer cases?
 - Which of the cancer causes could be reduced by changes in lifestyle?
 - List at least three lifestyle changes that could reduce cancer rates.

Figure 1
Estimates of risk factors calculate percentages



- Copy a table similar to the one below in your notebook and complete the calculations for survival rates.

Type of cancer	New cases	After five years	
		Deaths	Survival rate
lung	19 600	16 600	15%
breast	17 000	5400	?
colon	16 300	6300	?
prostate	14 300	4100	?
bladder	4800	1350	?
kidney	3700	1350	?
leukemia	3200	1110	?

Source: Statistics Canada, 1994, based on latest available data from British Columbia, Saskatchewan, and Ontario.

- Present this data in graph format. **7B**
- Based on the data, which type of cancer is most deadly?

- Lung cancer is the second leading cause of death in both men and women in Canada. It is also a disease that can be largely prevented. Over a period of time, controllable environmental factors may cause lung cells to develop one or more of the various forms of lung cancer. Use the following questions to help you interpret the information presented in the graph in **Figure 2**:
 -

- (a) In the early 1920s, shortly after World War I, smoking became fashionable for men. Hypothesize about why lung cancer rates did not increase until the 1950s.
- (b) Suggest a reason why no comparable increase in lung cancer in women occurred during the same period. Explain.
- (c) Using what you know or can find out about the current smoking habits of Canadians, predict trends in lung cancer over the next 10 to 20 years.
- (d) Compare the trends for males and females between 1980 and 1995.

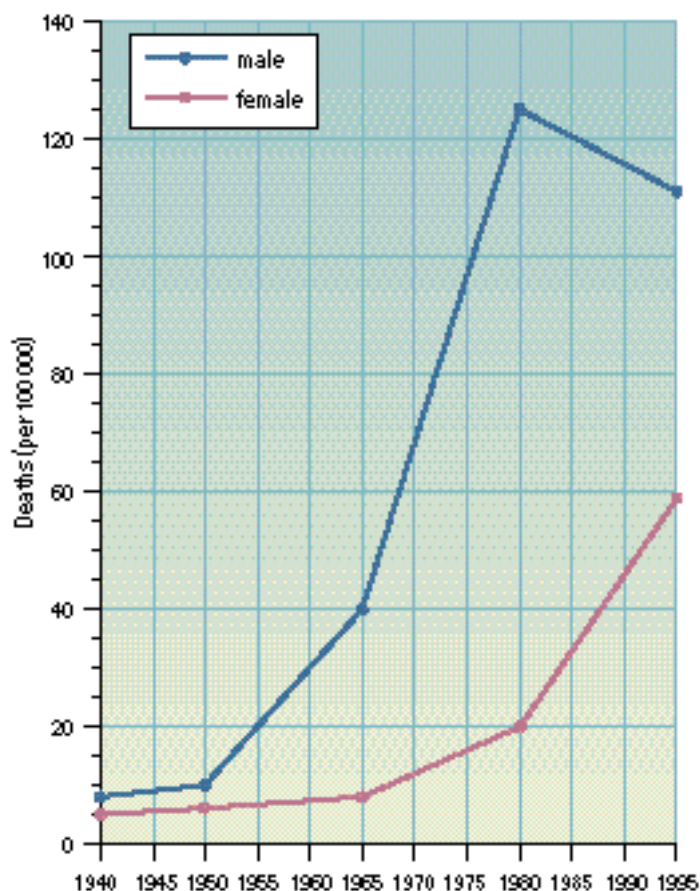


Figure 2

Lung cancer deaths in Canada

Understanding Concepts

1. What is a tumour?
2. Describe the difference between benign and malignant tumours.
3. Calculate the amount of carcinogenic tar absorbed by a smoker in one week. The following data will help you with your calculations:
 - Assume that the smoker smokes 10 cigarettes a day.
 - There are 20 mg of tar in most cigarettes (1000 mg = 1 g).
 - Approximately 25% of the tar is released in the form of smoke or is exhaled. The remaining 75% is absorbed by the smoker.

Making Connections

4. The money spent on cancer treatment continues to grow every year. One politician has suggested that cancers caused by inappropriate lifestyle choices should be given a lower priority for treatment.
 - (a) Identify cancers that could be reduced by changing lifestyles.
 - (b) Comment on the politician's statement. Should health care money be used first to treat people who have not contributed to their problem?
 - (c) Who would decide who gets treatment and who doesn't?

Challenge

Statistics is a set of mathematical tools that can be used to compare data that have been organized into categories. How will you use statistics in your survey report or your display?

6.4 Investigation

SKILLS MENU

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

Inhibiting Cell Division

Have you ever noticed that very little will grow under a pine tree? Pine trees, like many species of plants, produce chemicals that inhibit the growth of plants that would otherwise compete with them for available nutrients.

Researchers looking for a cancer cure are very interested in these chemicals because they selectively destroy only the most rapidly dividing cells, and cancer cells divide continually and rapidly. Treating cancer with such chemicals is called chemotherapy.

In this investigation, plants are chopped up in a blender to obtain an extract. The extract is poured on germinating seedlings, and root growth is monitored. The root tip is the area of most rapid cell division.

Question


- 4A **1** Write a question for this investigation.

Hypothesis

If plants produce chemicals that inhibit cells that divide rapidly, then they should affect cells near the root tip.

Materials

- scissors
- pine needles (or ragweed or bitter vetch leaves)
- blender
- elastic band
- cheesecloth
- 250-mL beaker
- various germinating seeds, such as canola, tomato, carrot, lettuce, and radish
- 2 petri dishes
- wax pencil
- forceps
- 8 filter papers
- distilled water
- 10-mL graduated cylinder
- clear tape
- hand lens or dissecting microscope

 **Caution:** Scissors are sharp; handle with care. Students who are sensitive to pollen should breathe through a disposable mask.

Procedure

- 2** Using scissors, cut the needles from a small pine branch and place the needles in a blender. Add 50 mL of distilled water. Do not put the stem in the blender. Ragweed leaves or bitter vetch leaves may be substituted for the pine needles. Place the top on the blender and turn the blender on for approximately 2 min.

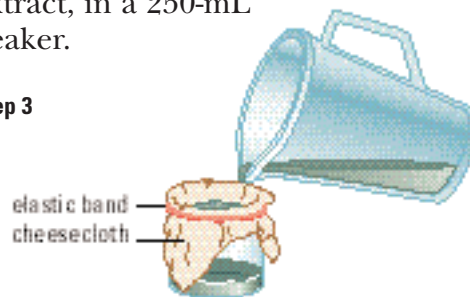


Step 2



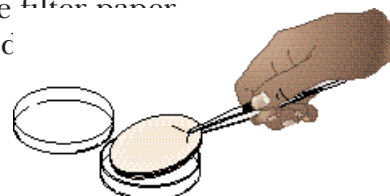
- 3** Pour the blender contents through a cheesecloth filter. Store the solution, or extract, in a 250-mL beaker.

Step 3



- 4** Using a wax pencil, label the bottoms (the smaller pieces) of two petri dishes: one C for control; the other E for experimental. Label both petri dishes with the name of the seeds used by the group.

- 5** Using forceps, place 4 filter papers into each of the petri dishes. Add just enough distilled water to the petri dishes to moisten the filter papers. Replace the lid.

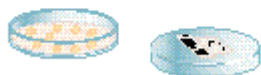


Step 5

- 6** Count 20 seeds and, using forceps, transfer 10 to each petri dish. Spread the seeds out in each of the petri dishes.



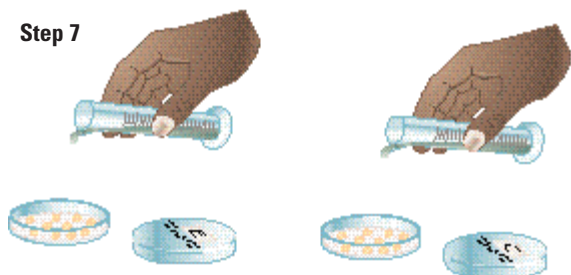
Step 6



- 7** Using a 10-mL graduated cylinder, add 4 mL of distilled water to the seeds marked C, the control. Make sure the water covers the seeds. Measure 4 mL of pine or other plant extract. Transfer it to the petri dish labelled E, experimental.

- (a) Why is it necessary to add 4 mL of distilled water to the control?
- (b) Why do you add the distilled water to the control first?

Step 7




- 8** Keeping each petri dish flat, seal the edge with clear tape and place the dishes in a dark area.

- (a) Speculate about why the petri dishes are sealed.

- 9** After 24 h examine the seeds with a hand lens.

- (a) Select 3 or 4 seedlings from each petri dish and draw diagrams of the developing roots.

-  (b) Prepare a data table and record your observations.

6D

- 10** Repeat step 9 and question (a) after 48 h and 72 h.

- 11** After 72 h, select 5 seeds from each petri dish and measure the length of the shoots and roots.



- (a) Record your observations in your data table.

- (b) Calculate the mean length of growth for both the root and the shoot.

Analysis and Communication

- 12** Analyze your results by answering the following questions:

- (a) Which seeds are most affected by the extract?

- (b) Why were 10 seeds used for each test rather than one seed?

- (c) Why was a control used for the experiment?

- (d) Write a summary paragraph to explain how the pine extract could be used as a herbicide to kill weeds.

Making Connections

1. How could a growth-inhibiting substance found in the needles affect root growth?
2. What advantage might natural herbicides have over herbicides created in a laboratory?
3. Explain why scientists involved in cancer research might be interested in chemicals that affect cell division.
4. Ideally, chemotherapy should affect only cancer cells, without injuring normal cells. Why is this difficult to accomplish? (Hint: Remember that cell division is a normal process taking place in the body.)
5. Chemotherapy often causes hair loss. What reason can you suggest for this?

Exploring 4B

6. How does pine extract affect pine seedlings? Design an experiment to find the answer.
7. Design and carry out an investigation to test a variety of plants to determine which produces the best growth-inhibiting extracts.

Regeneration

On a construction site, a saw jumps while cutting a board, severing the finger of a worker. The worker, along with the finger wrapped in ice, is taken to the hospital. In the operating room, blood vessels, bones, muscles, nerves, and skin are reattached. With some luck, the finger will regain most of its original function.

Now imagine a very different scenario: the wound is cleaned and sealed, and a tiny finger begins to regrow. Months later, the tiny finger has grown to almost the same size as the other fingers on the hand. Today this scenario is science fiction. Humans are unable to regenerate fingers. **Regeneration** is the ability to regrow a tissue, an organ, or a part of the body. Tissue regeneration in humans is limited to tissues such as the blood, bone (to repair a fracture), and the outer layer of the skin (to heal a wound). Your liver and kidneys also have a limited ability for regeneration. What factors allow human skin cells, but not nerve cells, to divide and repair themselves?

Regeneration and Specialized Cells

Pass a living sponge through a cheesecloth and the cells that remain alive can join together again as a new sponge. Cut a sponge in two, and two sponges grow. Planarian flatworms can be cut in two, and each piece makes a new, identical flatworm (**Figure 1**). Through cell division, both sponges and planarians can reproduce an entire organism asexually through **fragmentation**.

Animals with little cell specialization, such as sponges and planarians, are capable of regeneration. Cells in the body of a sponge resemble each other. The planarian's cells are only slightly more specialized, and it has almost the same ability to regenerate.

As animals become more complex, greater cell specialization is needed. Cells assume specific tasks, but with greater cell differentiation comes a loss of regenerative capacity. Earthworms cannot reproduce by fragmentation and can only regenerate certain parts of the body.

Did You Know ?

Tales of regeneration are found throughout mythology. Hercules fought Hydra, the many-headed monster. Each time one of the heads was lopped off, two grew back in its place.

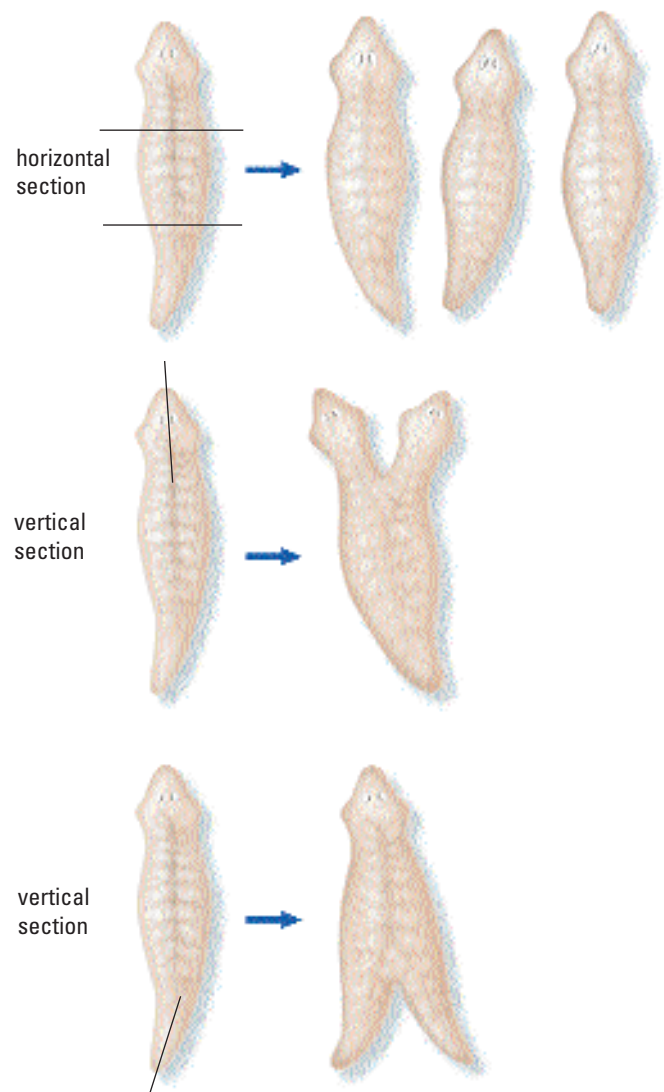


Figure 1

When cut across, a single planarian can become multiple copies by fragmentation. After an incomplete longitudinal cut through the body, the animal can regenerate an extra head or tail.

Increasingly more complex animals follow the same trend. As more cells become specialized, the ability to grow “replacement parts” is decreased. Salamanders regenerate limbs, and lizards grow severed tails, but neither can be sliced in half and have both parts survive. Why do more complex animals lose their ability to regenerate?

A clue can be found by looking at the wound of a severed limb of a starfish (**Figure 2**). Cells in the area where the limb was severed appear as an irregularly shaped ball. Microscopic examination shows little cell specialization. These cells closely resemble cells of an embryo. They are called stem cells and are able to divide many times and then specialize into cells of bone, cartilage, muscle, or nerve.



Figure 2

This starfish has lost one of its arms. The new arm will grow where the mass of unspecialized cells (white) has started to divide.

Specialization and DNA

The nucleus of every cell in your body contains a complete code for all of your characteristics and all cellular functions. In other words, every cell contains identical DNA. Why, then, are a skin cell and a nerve cell different? Each of these cells uses different parts of their DNA: they are directed by different genes. Specialized cells use only small amounts of their genetic information. For example, a nerve cell no longer needs the instructions to make muscle protein or to produce skin pigment. The genes that are not needed in a specialized cell are “turned off.” Most specialized cells also turn off the genes that would allow them to reproduce.

Salamanders overcome the problem of cell specialization by “turning back the clock.” Mature, specialized cells become like immature stem cells. As rapid cell division produces a new limb, the new cells specialize into cells of bone, nerve, and so on.

Stem Cells in Humans

Human skin, bone marrow, and some other tissues contain stem cells. That helps explain how we can easily grow new skin cells, but not new nerve cells. If specialized cells could “turn on” the segments of genetic information that allow them to divide, they could work like stem cells and once again begin dividing. This would mean that nerve cells could be restored following a stroke or spinal cord injury. Recent research suggests this may soon be possible.

Understanding Concepts

1. How does fragmentation differ from regeneration?
2. Why are less complex animals better able to regenerate than more complex animals?
3. What are stem cells?
4. What advantage is gained by changing specialized cells to act like stem cells?

Exploring 3A

5. Some hospitals are giving new parents the option of saving some of the cells of their baby’s umbilical cord. These are relatively unspecialized cells. Research this development and prepare a brief report on its possible benefits and drawbacks.
6. Research neurophysiologist Dr. Albert Aguayo and his work on the regenerative capacity of nerve cells.

Transplant Farms

Some people require an organ transplant—a kidney, eye cornea, liver, heart—to replace an organ that isn't functioning well. In 1996, approximately 25 000 North Americans received such a transplant. However, more than twice that number remained on waiting lists. One estimate from the United States indicates that 4000 people died that year waiting for an organ.

Organs are taken from donors after accidental death, as long as the organs are still healthy. However, the supply of organs has never come close to meeting demand.

To solve the problems created by the shortage of organ donors, scientists

researched two different options. One option is to harvest genetically altered organs from farm animals such as pigs (**Figure 1**). Transplanting a normal pig kidney or liver into a human is almost impossible. The human immune system recognizes the pig cells as foreign invaders and responds by “rejecting” them. White blood cells attack the foreign tissue, and its blood supply is cut off—the organ starves and dies.

This is where the understanding of DNA is vital. Scientists believe that the rejection problem can be solved by transferring human genes into the nuclei of pig embryo cells. As the cells of the pig divide, they copy the

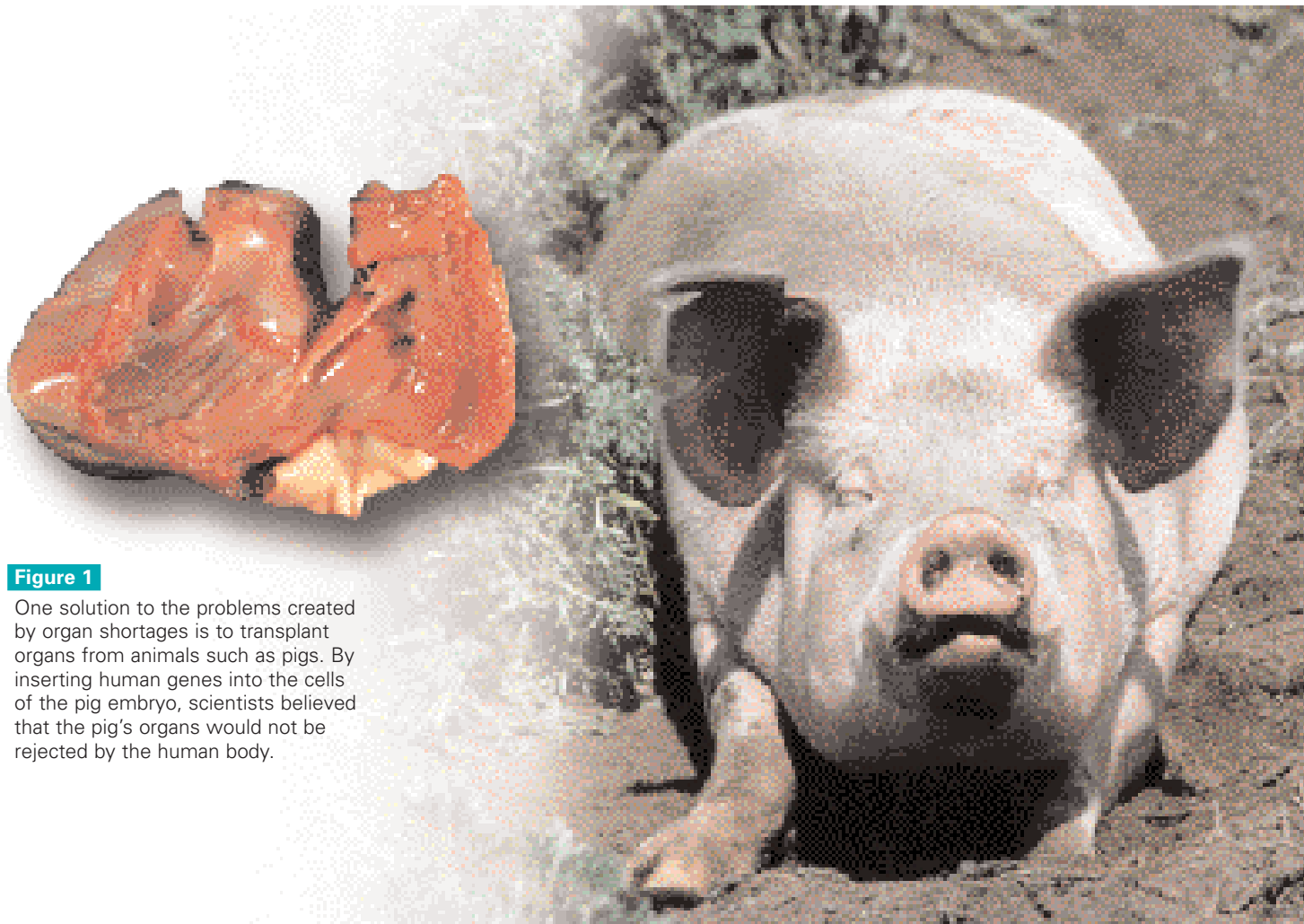


Figure 1

One solution to the problems created by organ shortages is to transplant organs from animals such as pigs. By inserting human genes into the cells of the pig embryo, scientists believed that the pig's organs would not be rejected by the human body.

human DNA as if it were their own. Amazingly, the human genes work in the pig's cells. The cells use the transplanted human genes to provide the information to make proteins, the structural components of cells. And the human genes cause the production of human proteins, not pig proteins, within the pig's cell. The combination (hybrid) cell,

containing pig and human genes, has both pig and human cell characteristics.

Once transplanted, the human's immune system no longer identifies these pig cells as "foreign." The human proteins produced by the hybrid cell fool the human's immune system into believing that the organ or tissue is from a human and not a pig.

Issue

The Ethics of Transplant Farming 8B

Statement

Pig farms should be used to grow organs and tissues for transplants.

Point

In some parts of the world, the shortage of healthy organs has created a thriving business opportunity. The illegal purchase of organs, such as kidneys, from the poor of India and South America is well documented. It has been estimated that in 1998, more than 2000 poor people in India sold one of their kidneys. In February 1998, the *New York Times* reported that the FBI had arrested two men in New York City who were selling organs taken from Chinese prisoners who had been executed.

Regulated transplant farms would reduce the demand for illegal human organs.

Counterpoint

Transplanting organs from pigs sounds like a good solution, but by making pig cells "somewhat human" another problem is introduced. What happens if a virus, now found only in pigs, enters the human body because it contains hereditary material from pigs? These new hybrid cells could create a gateway through which harmful viruses would move from pigs to humans.

What do you think?

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

Producing Plants Without Seeds

Often, a home gardener forgets to remove an onion or a potato from the garden in autumn. The food plant pushes up through the soil. Examples of plants that store food in underground storage organs are potatoes, onions, and garlic. When the temperature cools and the sunlight decreases, these plants become less active. In the fall, the plant dies, leaving behind one or more food-containing organs. As spring approaches, the soil warms, and new shoots grow from the food-storage organs (**Figure 1**). These plants are growing without seeds through vegetative reproduction.

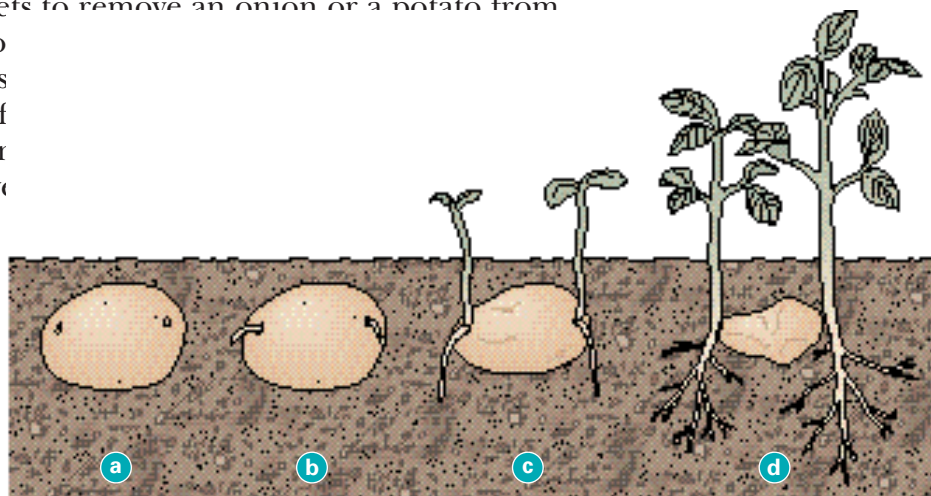


Figure 1

The potato plant dies in the fall, leaving the potato tubers (not roots) in the ground. The tubers sprout again in the spring, producing more plants. This is vegetative reproduction.

The new plant, like all products of asexual reproduction, is genetically identical to its parent. If the parent grew well in the shade or in dry conditions, so will the new plant. For this reason, people who grow plants often prefer to use asexual reproduction instead of seeds to produce new plants. They can be confident that the new cloned plants will have the same desirable characteristics as the parent.

Figure 2 shows several methods to produce plants asexually. Although the diagrams illustrate houseplants, the same methods can also be used to propagate a variety of food-producing plants such as potatoes, herbs, and fruit trees.

Did You Know?

The word "clone" comes from the Greek word *klon*, meaning a plant cutting or twig.

Try This

Examining a Potato Tuber

Examine a new potato and one that has been left in a dark cupboard for one month. Identify the eyes of the potato. Describe the differences between the two potatoes. Examine the old potato. Where are the new shoots getting their food?

Caution: Exercise care when using a knife.

Using a knife, cut the potato open and scrape some of the inside cells with a toothpick. Smear the collected cells across a microscope slide.

Put on gloves and safety goggles.

Caution: Iodine irritates eyes and skin and may stain.

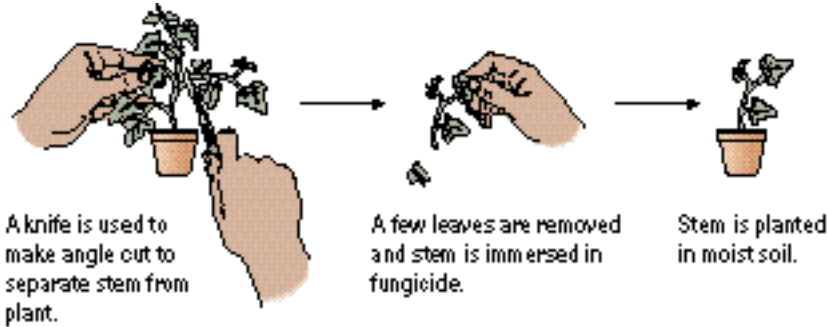
Prepare a wet mount by adding a drop of iodine and then a cover slip. Starch turns a blue-black colour in the presence of iodine. Examine the slide under low- and medium-power of a light microscope. **5B**

1. Draw diagrams of a few cells, as seen under medium-power magnification. **6C**
2. Describe the appearance of the starch granules found in the cells.

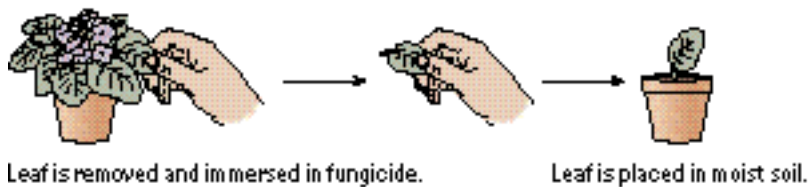
Figure 2

Summary of asexual reproduction techniques

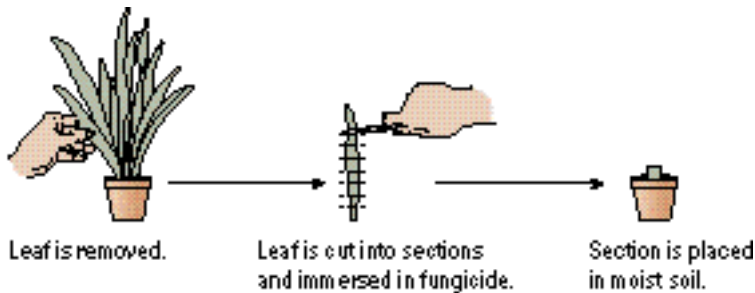
- a** Stem cuttings
Recommended for: geraniums, coleus, begonias, dieffenbachia, impatiens, philodendrons, holly, ivy, jade, most vines.



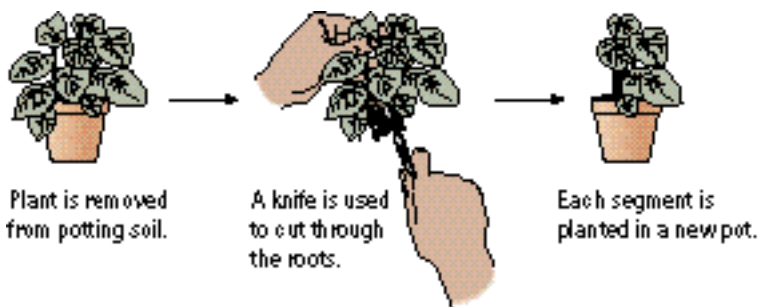
- b** Leaf cuttings
Recommended for: African violets, peperomia, and some begonias.



- c** Leaf section cuttings
Recommended for: most begonias, sansevieria.



- d** Root division
Recommended for: most plants with fibrous roots, such as ferns, spider plants, peperomia.



- e** Runners
Recommended for: strawberries, geraniums, raspberry, ivy, spider plants, philodendron.



Making Connections

1. What advantages does asexual reproduction of plants have for a farmer? Imagine that there is a dramatic climate shift during the growing season. What disadvantage would asexual reproduction have?

Exploring

2. A single apple tree can produce several varieties of apples if twigs from different varieties of trees are grafted onto one root stock (**Figure 3**).
- (a) What types of plants are commercially produced by asexual reproductive techniques?
- (b) How long have these techniques been used?
- (c) Outline some of the economic benefits associated with this technology.



Figure 3

3. Investigate the greenhouse industry in Ontario. What kinds of plants are produced, and how are they propagated?

Reflecting

4. Speculate about how seedless grapes or oranges reproduce.

Challenge

Figure 2 presents information through the use of graphics. How could you use graphics in your display?

6.8 Investigation

SKILLS MENU

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

Cloning from Plant Cuttings

Some plants naturally reproduce asexually when a portion of the plant, such as a stem or leaf, breaks off and drops to the ground. Roots develop on the broken part and penetrate the soil. The broken part becomes a new plant. Willow trees spread along streams when ice storms break fragments from the original tree.

Cuttings from the seedless-grape vine have been grafted to grape vines all over the world. You wouldn't be able to eat seedless grapes if it were not for cloning. Because no seeds are produced, conventional methods of reproduction are not possible.

In this investigation, you will grow a plant from a cutting, thereby making a clone of the original plant.

Question

- 1 Write a question that this investigation **4A** answers.

Hypothesis

If plants can be cloned, then offspring can be produced by cuttings.

Materials

- lab apron
- knife
- coleus plant (or alternative)
- small beaker or jar
- potting soil
- flower pot (or alternative)
- root stock
- appropriate twig (for grafting)
- grafting tar
- string

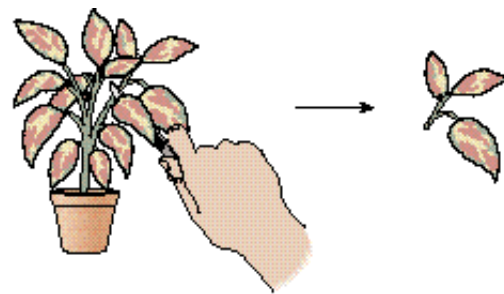
 **Caution:** Exercise care when using a knife.

Procedure

Part 1: Stem Cuttings

- 2 Using a knife, carefully cut off the tips of three coleus stems. Include two or three leaves on each stem.

Step 2



- 3 Place each piece into a small beaker containing water. Water must cover as much of the stem as possible without covering any of the leaves. You may need to support the stems to keep them upright.

Step 3



- 4 Place the beaker in a sunny place and check daily to maintain the water level.



(a) Make and record observations.

- 5 After the roots appear on the stem, allow an additional week's growth and then transplant the cutting into a flower pot filled with moist potting soil.

Step 5

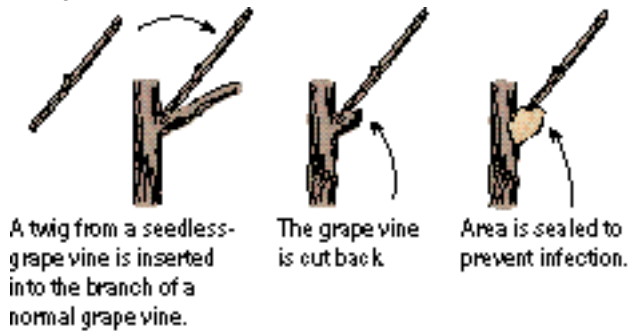


(a) Record the growth rate of the plant.

Part 2: Grafting


- 6** Use the illustration below as a guide for tree grafting. Grafts must be from a similar species. For example, different varieties of apple trees can be grafted together. Do not attempt to graft the branch of a pear tree with that of an apple tree.

Step 6



 **Caution:** Exercise care if using pruning shears.

- 7** Using string, tie the graft in place. Encase the graft with grafting tar to prevent the entry of bacteria or fungi.

 (a) Record your observations over several weeks.

Analysis and Communication

- 8** Analyze your results by answering the following questions:
- What evidence suggests that coleus has the ability to regenerate parts of the plant lost to injury?
 - In what ways would the new coleus resemble the parent plant?
 - Suggest two simple ways you can prove that the roots from the cutting are growing.
 - If the grafts did not “take,” the grafted branch will die. If your graft took, when did you know the graft was successful? If it did not, suggest what you could do differently that would make success more likely.
- 9** Summarize your evidence to support or disprove the hypothesis.

Making Connections

- A hailstorm can shred most plants. After a hailstorm, what advantage would a coleus plant have over plants that cannot reproduce vegetatively?
- If a McIntosh branch is grafted onto a red delicious apple tree, would the branch continue to produce McIntosh apples?
- Seedless grapes are genetic mutations. Unlike other grapes, they do not reproduce by seeds. Explain why grafting is used to establish new vineyards of seedless grapes.
- Explain why someone might want to graft a number of different varieties of pears onto one tree.

Exploring

- 5.** Grow a pineapple clone using the method shown in **Figure 1**.

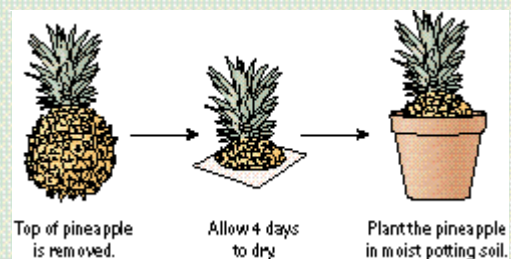


Figure 1

- 6.** Research the use of clones for food production. Outline the positive and negative outcomes of this practice.

Challenge

Cloning of food plants is a technology that you could present in your display. What would the issue be? Do you think most people realize that the apples, grapes, and oranges they eat come from clones? What other misconceptions might be common?

The information that is included in a question can affect the answers to that question and following questions. How will you factor this into the design of the questions in your survey?

Cloning

When people think of cloning, they often imagine a sinister scientist working in a dungeonlike laboratory, far from the peering eyes of the public. Human clones are often portrayed as robots that are exact duplicates of the original. A person aged 25 years meets his or her 25-year-old clone. Even the scars acquired during childhood are found on the clone. Such images distort science and are actually impossible. Why?

You may be surprised to know that clones have always been with us. **Cloning** is a natural process, repeated daily in nature. The vast majority of organisms on our planet produce exact duplicates of themselves by asexual reproduction, using the process of binary fission. The mother cell divides into two identical daughter cells, or clones, as shown in **Figure 1**.

The parent organism does not always split in two to produce offspring. Some organisms reproduce by budding (**Figure 2**), and others by producing runners (**Figure 3**).

Only One Parent

Cloning is the process of forming identical offspring from a single cell or tissue. Because the clone originates from a single parent, it is genetically identical to that parent. Therefore, cloning is referred to as asexual reproduction.

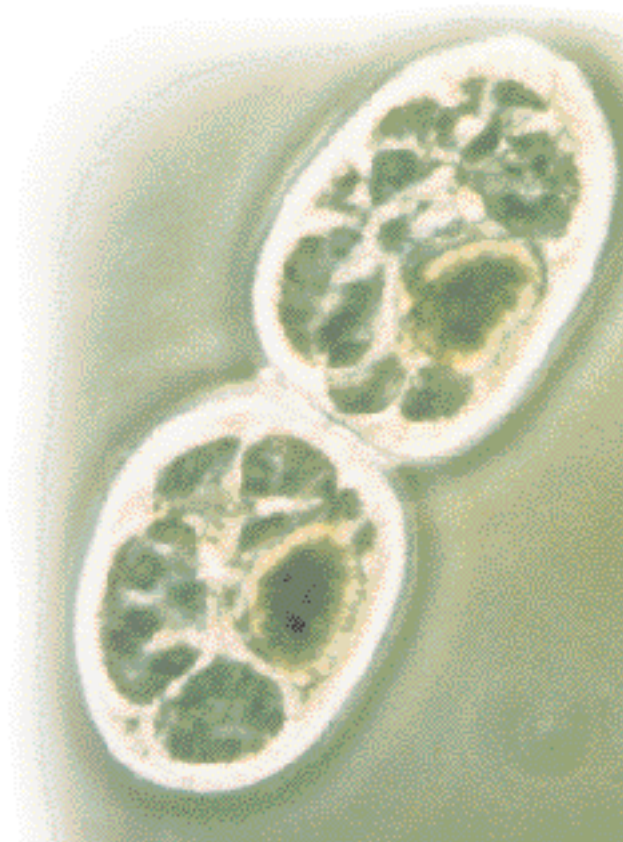


Figure 1

Paramecia reproduce by means of binary fission. One cell divides to form two identical cells.



Figure 2

The small outgrowth from the parent hydra's body is called a bud. Eventually the bud will break off and form a separate, but identical, organism.



Figure 3

Strawberry plants produce runners that produce new plant clones. Unlike plants that grow from seeds, these plants have the advantage of relying on the parent for nutrients. This gives the clone a head start.

Cloning a Plant from a Single Cell

Frederick Stewart caused great excitement when he revealed a plant he grew from a single carrot cell in 1958 (**Figure 4**). He isolated a group of cells from the area of rapid cell growth near the root tip and placed them in a culture medium with a plant growth hormone that promoted cell division. A mass of cells began to grow. After a few days, parts of the cell mass were transferred into another culture medium that did not contain the growth hormone. Cell division within the new culture slowed, and the cells had time to change shape and start to specialize before their next cell division. Once the cell mass began to specialize into cells that form the root, stem, and leaves, the plant was transferred into soil.

Carrots, ferns, tobacco, petunias, and lettuce respond well to cloning, but grass and legume families do not. No one really knows why. The secret seems to be hidden somewhere in the genetic makeup of the plant. Each cell contains the complete complement of DNA from the parent. Yet some cells specialize, becoming roots, stems, or leaves. Leaf cells use only certain parts of their genetic material, while root cells use other segments. Huge sections of the genetic information remain “turned off” in specialized cells. The trick in cloning plant cells appears to be in delaying specialization.

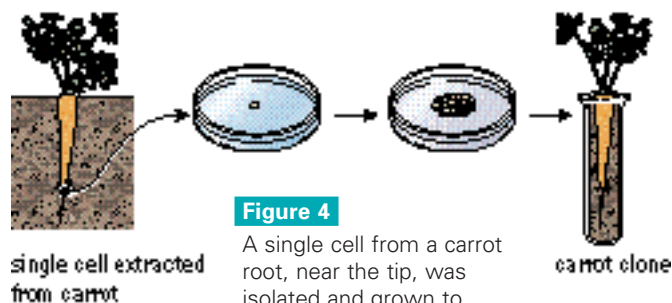


Figure 4

A single cell from a carrot root, near the tip, was isolated and grown to produce an entire carrot plant.

Cloning Animals

Animal cloning experiments were also being conducted. Working with the common grass frog, Robert Briggs and Thomas King extracted the nucleus from an unfertilized egg cell by inserting a fine glass tube into the cytoplasm (**Figure 5**). The cell without the nucleus is called an “enucleated” cell.

Next, a nucleus from a frog embryo in the early stages of development was extracted and then inserted into the enucleated cell (**Figure 6**). The egg cell with the transplanted nucleus began to divide, much like any normal fertilized egg cell, and grew into an adult frog. Not surprisingly, the adult frog displayed the characteristics of the frog that donated the transplanted nucleus, not those of the frog that donated the unfertilized egg cell. Analysis proved that the adults were clones of the frog that donated the nucleus.

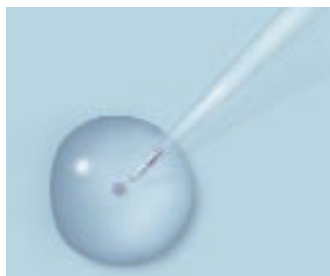


Figure 5

A small glass tube, called a micropipette, is used to remove the nucleus from a cell.

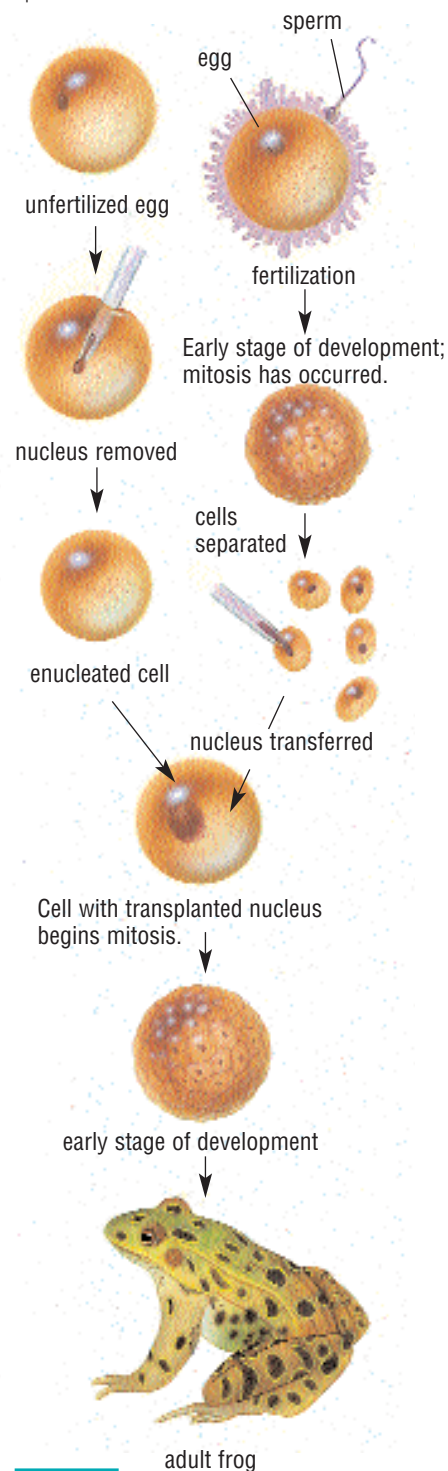


Figure 6

The nucleus is transferred from one embryo cell into an egg cell.

However, different results were obtained when the researchers took a nucleus from a cell in a later stage of development. With this nucleus, the cell did not grow and divide. The scientists concluded that something was missing from the nucleus used. The nucleus of a cell in the later stages of development, unlike those of cells of an earlier stage, had begun to specialize. Some regulatory mechanism must have “turned off” some of the genes as the cell began to specialize.

Mammal Clones by Embryo Splitting

Mammalian cells have been cloned using a similar technique to that of frogs. Scientists were successful only when they took the nuclei from embryo cells up to the eight-cell stage of development (**Figure 7**). After the eight-cell stage, the cells began to specialize.

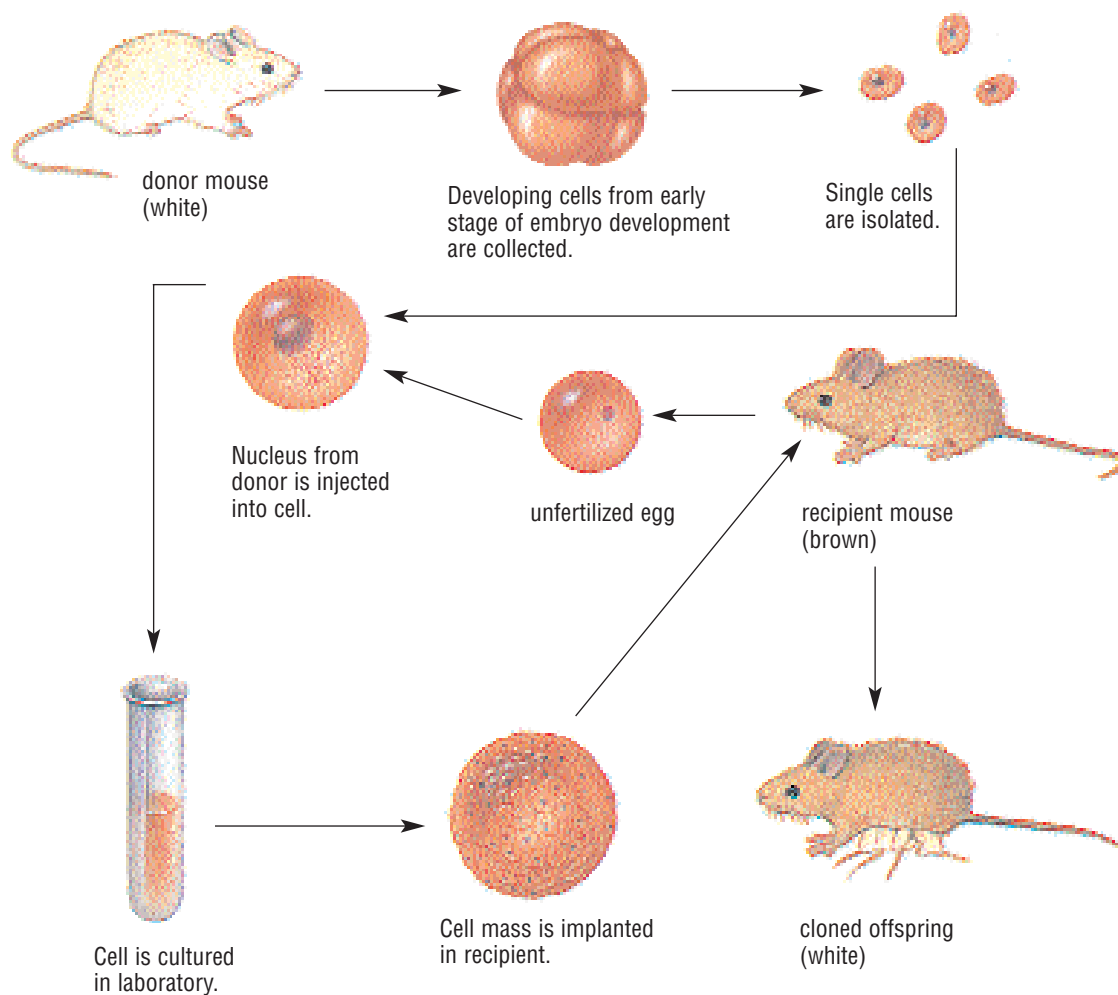


Figure 7
The cloned offspring appear identical to the donor parent.

The Dolly Revolution

The scientific world was rocked with the appearance of a sheep named Dolly. Prior to Dolly, scientists believed that cells that had specialized had lost their ability to give rise to new organisms. Dr. Ian Wilmut, of the Rosalind Institute in Scotland, proved the accepted rule wrong by using the genetic material from an adult cell. Some cells from the udder of an adult Finn Dorset sheep were grown in a cell culture and starved for a few days. Then a nucleus was extracted and placed into an enucleated egg cell from a Poll Dorset sheep. Finally, the dividing embryo was placed into the womb of a third sheep. The offspring, named Dolly, looked nothing like the birth mother. She carried the genetic information identical to the Finn Dorset adult—Dolly was a clone (**Figure 8**).

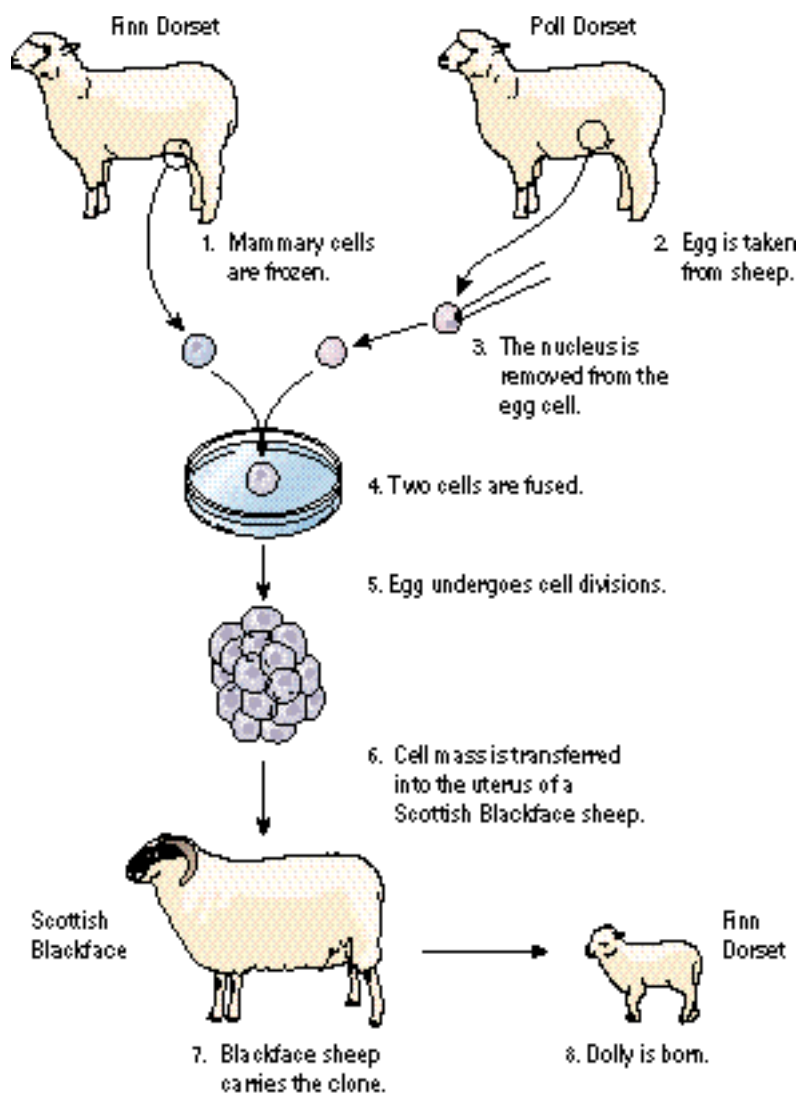


Figure 8

Dolly could claim three different sheep as mothers. In fact, her genetic mother died before Dolly was born.

Understanding Concepts

1. What is binary fission?
2. How are plants cloned?
3. What is an enucleated cell?
4. Describe how nuclear transplants are used to clone animals, such as frogs.
5. If the nucleus were extracted from a human adult cell and placed into an enucleated egg, how could you distinguish the cloned individual from the original?
6. Dolly was not the first cloned animal, nor was she the first mammal clone. What made her cloning so special?

Making Connections

7. Imagine that farmers were able to easily clone any animal in their herd or flock. What might be the benefits for food production? Would there be any disadvantages? Explain.
8. What ethical issues can you list that relate to cloning? Write a paragraph sharing your own perspective on one of these issues.

Challenge

For a while, Dolly was “hot” in the media. What is hot now? Newspapers, TV news, and magazines may be good sources of ideas for your Challenge.

Movies, TV shows, comic books, and novels may also be sources of misconceptions about reproductive technologies. How do these misconceptions affect how people think about cloning? How would you address this in your display?

Chapter 6 Review

Key Expectations

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

- Explain the importance of DNA replication for cell division and for the survival of an organism. (6.1, 6.5, 6.9)
- Describe representative types of asexual reproduction (6.5, 6.7, 6.8, 6.9)
- Explain cloning in plant and animals as examples of asexual reproduction. (6.7, 6.8, 6.9)
- Identify factors that may lead to cancer-causing mutations, and define cancer as abnormal cell division. (6.2, 6.3)
- Investigate how plants are able to reproduce without seeds, and organize, record, analyze, and communicate results. (6.8)
- Investigate questions related to the causes and treatments of cancer, and organize, record, analyze, and communicate results. (6.3, 6.4)
- Formulate and research questions related to DNA and its role in cell division, and communicate results. (6.1, 6.2, 6.5, 6.6, 6.7, 6.8)
- Provide examples of how developments in reproductive biology have affected plant and animal populations. (6.6, 6.7, 6.9)
- Describe Canadian contributions to research and technological developments in genetics and reproductive biology. (Career Profile)

KEY TERMS

benign	fragmentation
cancer	malignant
carcinogen	mutation
cloning	regeneration
deoxyribonucleic acid (DNA)	tumour

Reflecting

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

- (b) Indicate why the process is essential to all living things.

Figure 1



Understanding Concepts

1. Make a concept map to summarize the material you have studied in this chapter. Start with the words “deoxyribonucleic acid.”
2. Why is DNA replication important for the survival of life on Earth?
3. Use **Figure 1** to answer the following questions:
 - (a) Describe the process shown.
 4. Describe a DNA molecule and identify its three chemical components.
 5. How does DNA replicate?
 6. Briefly describe the process of DNA fingerprinting.
 7. Describe two methods that permit the cloning of plants.

8. Describe the process of nuclear transplants during animal cloning.
9. What evidence can you provide that suggests that not all cells divide at the same rate?
10. Explain why a salamander can regenerate a limb but a human can not.
11. What are stem cells?
12. In what ways does a cancerous cell differ from a normal cell?
13. List three factors that cause or contribute to the development of cancer.
14. What changes in lifestyle could reduce the incidence of cancer?
15. Why was the birth of Dolly considered to be such ground-breaking research?
16. Why might a gardener want to graft branches from different trees to a single stem?
17. Extracts from plants, such as pine needles, prevent the growth and division of cells in the root tip of a germinating seed. Explain how plant extracts serve as a model for understanding how chemotherapy drugs work to destroy cancer cells.

Applying Skills

18. The spinal cords of various mice were severed. All of the mice lost control over the lower limbs of their bodies. Researchers transplanted cells from the spinal cord of a mouse embryo into the severed spinal cord of each adult mouse. They noticed that the embryonic nerve cells began to grow in the adult mouse. After a while, some of the muscle control to the lower limbs had returned.
 - (a) What was the purpose of the experiment?
 - (b) How would you set up a control for the experiment?
 - (c) Identify the independent and dependent variables.
 - (d) Provide an explanation for the results obtained in the experiment.
 - (e) Do you think the experiment was justified? What practical application might this procedure present for society?
19. A scientist treats cells that produce cartilage with a drug that reduces their activity. The cells become less specialized and begin to act

like stem cells. The cartilage-producing cells begin to divide at a rapid rate.

- (a) Why would the scientist want to make mature cells behave like cells that aren't specialized?
- (b) What practical application would this experiment have?
20. A manufacturer claims that its sunblock has a rating greater than 15, and therefore provides added protection from skin cancer. How would you set up a controlled experiment to check this claim?
21. A research team studied the growth rate of a type of cancer cell in mice. Every 2 days for 60 days, they counted the number of cells in an area of 1 mm^2 . Which of the following graphs represents their data? Explain your answer.



Making Connections

22. In 2105, politicians decide that all food plants will be reproduced by tissue cloning. Predict some of the potential problems.
23. In the movie *Multiplicity*, genetic engineers make many duplicate models of the movie's hero, played by Michael Keaton. A number of comedic situations are created because his wife is unable to distinguish him from the clones. Explain the scientific flaw in the plot.
24. How does society react to the research about cloning? What legal and ethical issues are raised by this research?
25. A project called the human genome project is one of the largest research initiatives ever undertaken. The object of the project is to identify the position of every human gene along each of our 46 chromosomes. Make a list of some possible benefits of this project. How might the research be used?