UNIT

2 Reproduction

Salmon in the wild lay big eggs stored with energy, and the offspring have a high survival rate after they hatch. Studies have shown that female chinook salmon raised in captive breeding programs lay many more eggs than wild chinook salmon. The eggs of captive females, however, are 25 percent smaller. Smaller eggs are less likely to survive in the wild and may eventually harm the survival of wild salmon populations into which captive females are reintroduced. Scientists are continuing to research the impact of human-controlled reproduction to ensure the survival of wild salmon populations.

Key Ideas

4 **The nucleus controls the functions of life.**

4.1 The Function of the Nucleus within the Cell

4.2 Mutation

5 **Mitosis is the basis of asexual reproduction.**

5.1 The Cell Cycle and Mitosis

5.2 Asexual Reproduction

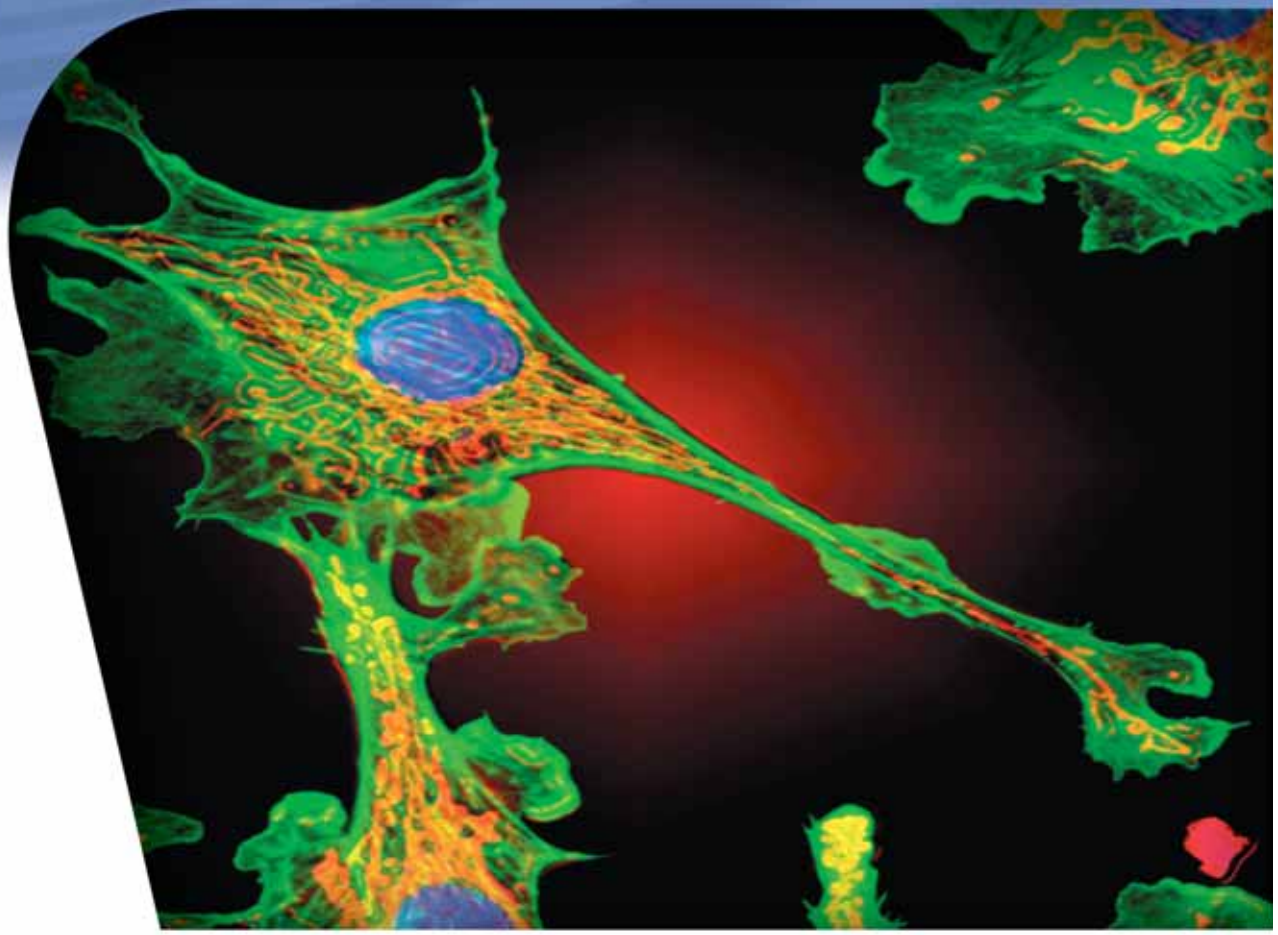
6 **Meiosis is the basis of sexual reproduction.**

6.1 Meiosis

6.2 Sexual Reproduction

6.3 Assisted Reproductive Technologies

Getting Started



internet connect

Nanotechnology is unlocking many mysteries of science. Find out how nanotechnology is playing a larger part in our everyday lives and in the world. Begin your search at **www.bcscience9.ca**.

Dr. Gill has just awoken from a restless night's sleep. This is the day she has dreamed about for months. In a few hours, she will take a new look inside the **nucleus**, the control centre of a living cell. As a cell biologist, she has used all types of microscopy to obtain images and information about what happens inside a cell's nucleus. Today is different, because Dr. Gill will be using nanotechnology to make her observations, and she will be able to see these processes in three dimensions.

Nanotechnology is the development and use of extra-small tools to study materials and living things on an extra-small, or nano, scale. Nanoscale objects are a billionth of a metre in size, or smaller. This is like comparing the size of a marble to the size of Earth.

Using nanoprobes, Dr. Gill will observe living cells carrying out their day-to-day activities during a one-week period. The nanoprobes are like nano-sized flashlights made of cadmium, selenium, and zinc. Getting them inside the nucleus is a challenge. The nucleus has a strong, protective barrier called the **nuclear membrane**. The nuclear membrane separates the nucleus from the rest of the cell. To get through this barrier, Dr. Gill and her team have disguised the nanoprobes so that they can pass through pores in the nuclear membrane.

Once inside the nucleus, the nanoprobes will allow Dr. Gill to observe the kind of detail that no one has seen before. The nanoprobes produce a much brighter light than other microscopy techniques, and the light does not fade away quickly. There is a good chance Dr. Gill will witness a rare event happening in the nucleus.

This story may sound like science fiction, but scientists today are already taking advantage of technology such as nanoprobes. Research using nanotechnology will confirm or change our current understanding of the cell and the activities of the nucleus. Nanotechnology will also help researchers find new ways to treat and cure diseases.

The Nucleus as a Black Box

Find Out ACTIVITY

In the early 1830s, a Scottish naturalist named Robert Brown first discovered the nucleus. He described it as a dark spot within the plant cell he was studying. Since then, scientists have learned much about the nucleus, especially during the last 20 years. However, many of the activities occurring within a cell's nucleus remain a mystery. Nanotechnology will allow scientists to gain more knowledge by posing new questions and making new predictions based on their observations.

Scientists use the term "black box" to describe something in which the inner workings cannot be seen. A cell's nucleus is a black box, because the activities within the nucleus are not always visible or understood.

In this activity, you will consider the limitations and challenges that a scientist must face when exploring the unknown. Using two different tools, you will investigate the inside of a sealed box. Then, from the information you gain, you will make inferences about the contents of the box.

Materials

- 1 black box
- 1 cotton ball
- 1 drinking straw
- clear adhesive tape
- 1 wooden skewer

What to Do

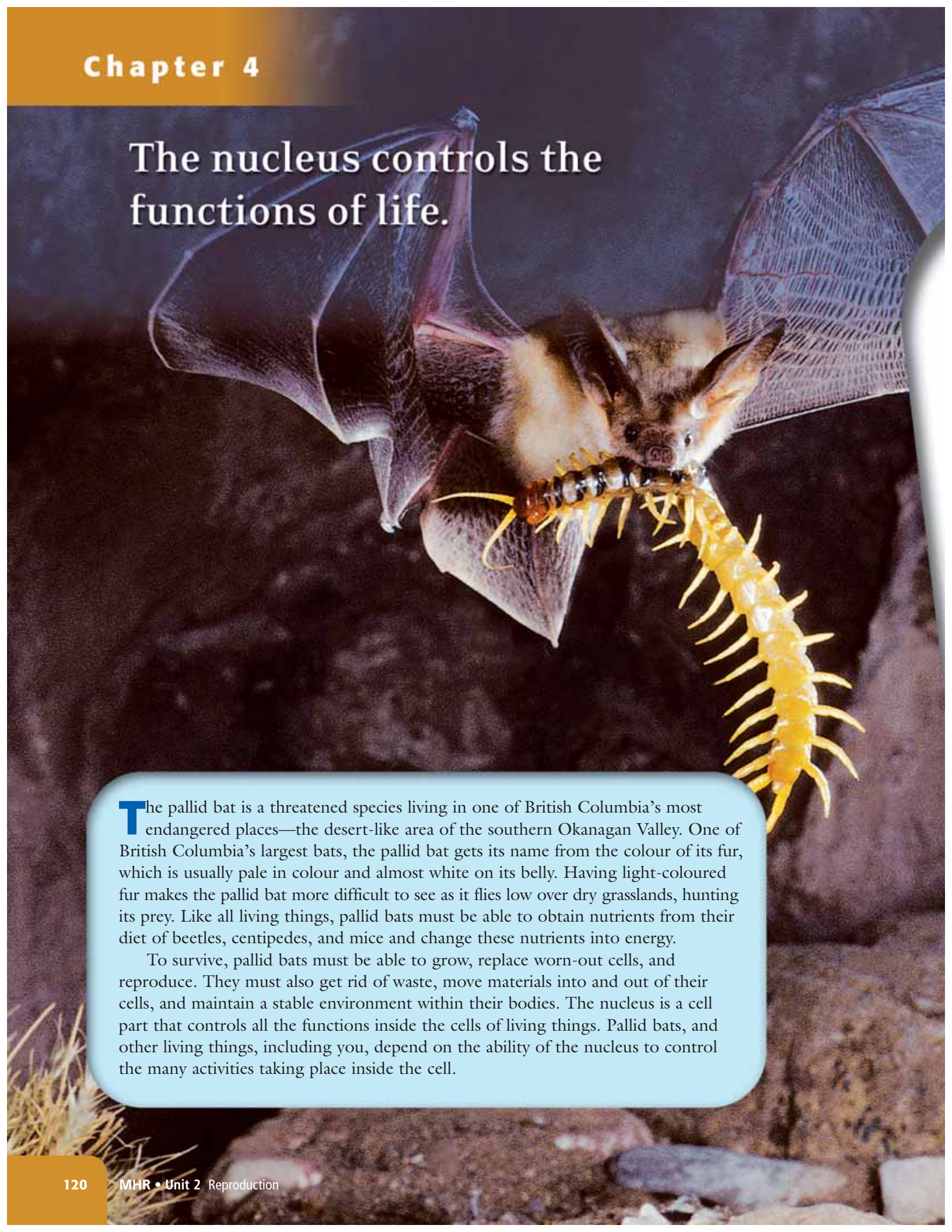
1. Your teacher will give you a closed box with a hole in the top. Do not open the box or look through the hole.
2. Attach the cotton ball to the drinking straw with adhesive tape.
3. Put the straw probe through the hole in the box. By feeling around with the straw, determine what is in the box. Draw a sketch of your observations in your notebook.
4. Repeat step 3 with the wooden skewer, using the sharp end. (Do not attach a cotton ball.) Draw a new sketch and add any new information.

What Did You Find Out?

1. List as many inferences as you can about the contents of the box.
2. What difficulties did you encounter when you probed the inside of the black box?
3. Explain how you were able to overcome these difficulties.
4. Compare the information you gained using the straw probe with the information you gained using the wooden skewer.
5. How confident are you that your drawing accurately represents the contents of the box? Explain.
6. Without opening the box, how could you gain further information?

Chapter 4

The nucleus controls the functions of life.



The pallid bat is a threatened species living in one of British Columbia's most endangered places—the desert-like area of the southern Okanagan Valley. One of British Columbia's largest bats, the pallid bat gets its name from the colour of its fur, which is usually pale in colour and almost white on its belly. Having light-coloured fur makes the pallid bat more difficult to see as it flies low over dry grasslands, hunting its prey. Like all living things, pallid bats must be able to obtain nutrients from their diet of beetles, centipedes, and mice and change these nutrients into energy.

To survive, pallid bats must be able to grow, replace worn-out cells, and reproduce. They must also get rid of waste, move materials into and out of their cells, and maintain a stable environment within their bodies. The nucleus is a cell part that controls all the functions inside the cells of living things. Pallid bats, and other living things, including you, depend on the ability of the nucleus to control the many activities taking place inside the cell.

What You Will Learn

In this chapter, you will

- **describe** the nucleus and the relationship of the nucleus with other cell parts
- **describe** the role of genes in the production of proteins
- **explain** how proteins function in a cell
- **describe** factors that may lead to changes in a cell's genetic information
- **demonstrate** an understanding of how mutations occur

Why It Is Important

Understanding the structure of DNA and how the nucleus controls cell activities provides us with knowledge about how cells function and how mutations occur. As scientists learn more about the nucleus, they will continue to develop technologies such as gene therapy to correct mutations and treat people with genetic disorders.

Skills You Will Use

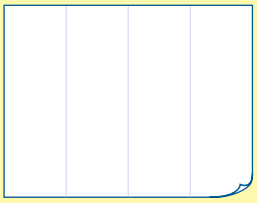
In this chapter, you will

- **observe** DNA from living things
- **construct** a model of DNA
- **work** co-operatively
- **communicate** your understanding of how the nucleus controls a cell's activities

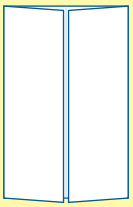
FOLDABLES™
Reading & Study Skills

Make the following Foldable and use it to take notes on what you learn in Chapter 4.

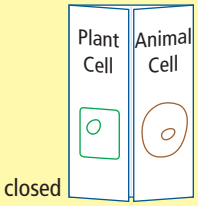
STEP 1 **Fold** a sheet of paper into fourths.



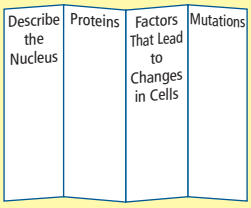
STEP 2 **Refold** to form a shutterfold as pictured.



STEP 3 **Draw** a plant cell on one side of the shutterfold and an animal cell on the other side.



STEP 4 Inside the shutterfold, **label** the four columns with the following titles: Describe the Nucleus, Proteins, Factors That Lead to Changes in Cells, Mutations.



Compare and Contrast Diagram, label, and explain the parts of a plant cell and an animal cell on the front of the Foldable, then compare and contrast the two. What part does the nucleus play in both types of cells?

4.1 The Function of the Nucleus within the Cell

The nucleus controls the functions of a living cell. Chromosomes within the nucleus are composed of deoxyribonucleic acid, or DNA. DNA carries the master set of instructions for cell function. Genes are small segments of DNA. Genes contain the information to produce proteins that control a cell's activities.

Words to Know

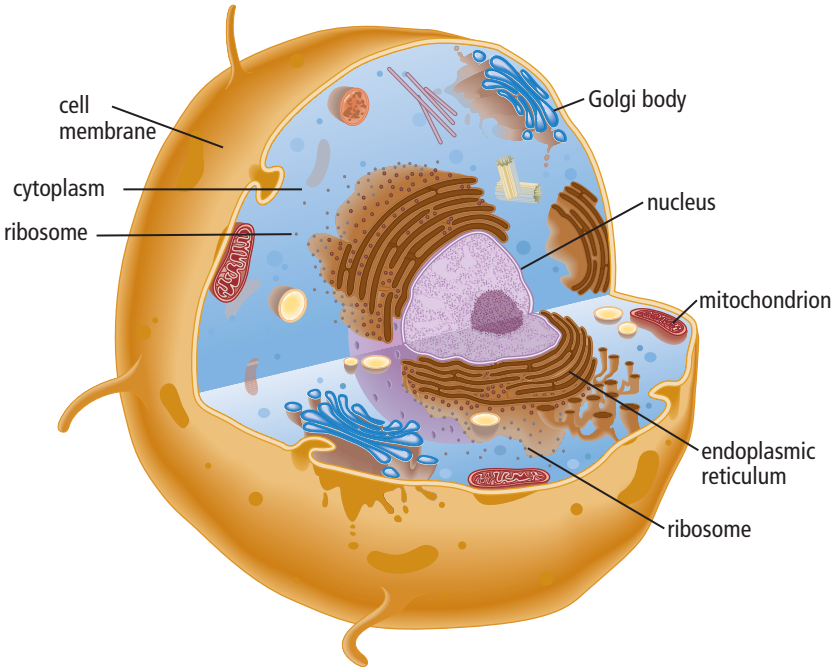
chromosome
DNA
gene
nucleolus
nucleus
protein

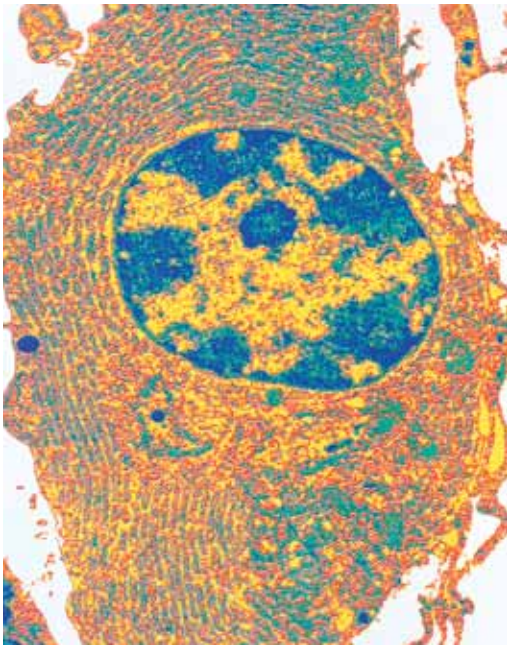
Life processes within cells occur very quickly. Using technologies such as nanoprobes, scientists are seeing these processes more clearly and learning more about how cell parts function and transmit messages to the nucleus. So far, the journey into animal and plant cells has helped scientists determine the structure and function of the cell parts shown in Figure 4.1A and Figure 4.1B on the next page.

A Survey of Animal and Plant Cells

All cells are surrounded by a thin covering called the **cell membrane** that separates the inside of a cell from its external environment. The cell membrane controls the flow of materials into and out of the cell. In addition to a cell membrane, plant cells also have a **cell wall**. The cell wall is a tough, rigid structure that surrounds the cell membrane. The cell wall provides support for the plant cell and prevents the cell from bursting when a plant is in a very moist environment.

Figure 4.1A An animal cell





The **cytoplasm** is a jelly-like substance that contains the organelles and other life-supporting materials, such as water and sugar. An **organelle** is a specialized cell part that carries out specific functions to ensure a cell's survival. Remember from previous science courses that in eukaryotic cells, such as animal cells, most organelles are surrounded by a membrane. Prokaryotes, such as bacterial cells, do not have membrane-bound organelles.

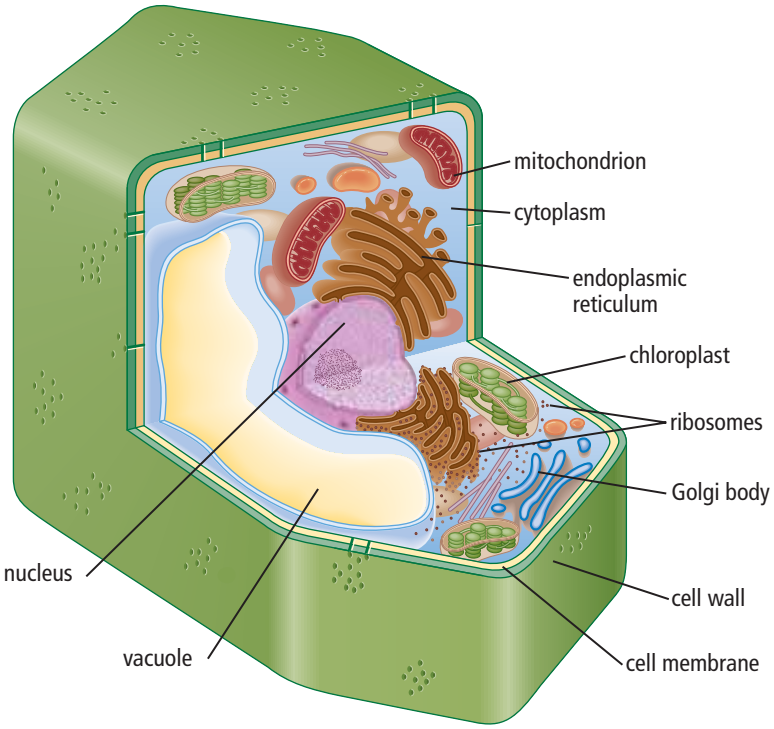
The **mitochondria** (singular: mitochondrion) are organelles that are specialized to provide energy for cells by changing sugar called glucose into usable energy. The chemical reactions that occur on the many folds of the inner membrane of a mitochondrion provide energy for the cell.

Plant cells have specialized organelles called **chloroplasts** that trap the energy from the Sun and make glucose. The production of glucose takes place on the stacks of membranes within a chloroplast.

Ribosomes are small organelles that do not have a membrane. Some ribosomes float in the cytoplasm. Other ribosomes are attached to the endoplasmic reticulum. Each ribosome is like a manufacturing plant that makes proteins. **Proteins** are essential materials required for the cell to carry out the activities necessary for its survival.

The **endoplasmic reticulum** is a network of membrane-covered channels within a cell. This organelle acts as a transport system for materials made in the cell. Proteins made on ribosomes that are attached to the endoplasmic reticulum travel through these channels and are often processed further in the Golgi body.

Figure 4.1B A plant cell



Vesicles are membrane-covered sacs that form off the ends of the endoplasmic reticulum. Vesicles transport new proteins to the Golgi body for further processing and export out of the cell.

The **Golgi body** is a specialized organelle that sorts and packages proteins for transport. If a protein is to be transported out of the cell, a vesicle will form off the end of the Golgi body. The vesicle is then carried to the cell membrane.

Vacuoles are membrane-covered storage containers within cells. Plant cells often contain small vacuoles to store starch and a large vacuole to store water. Some animal cells have small vacuoles.

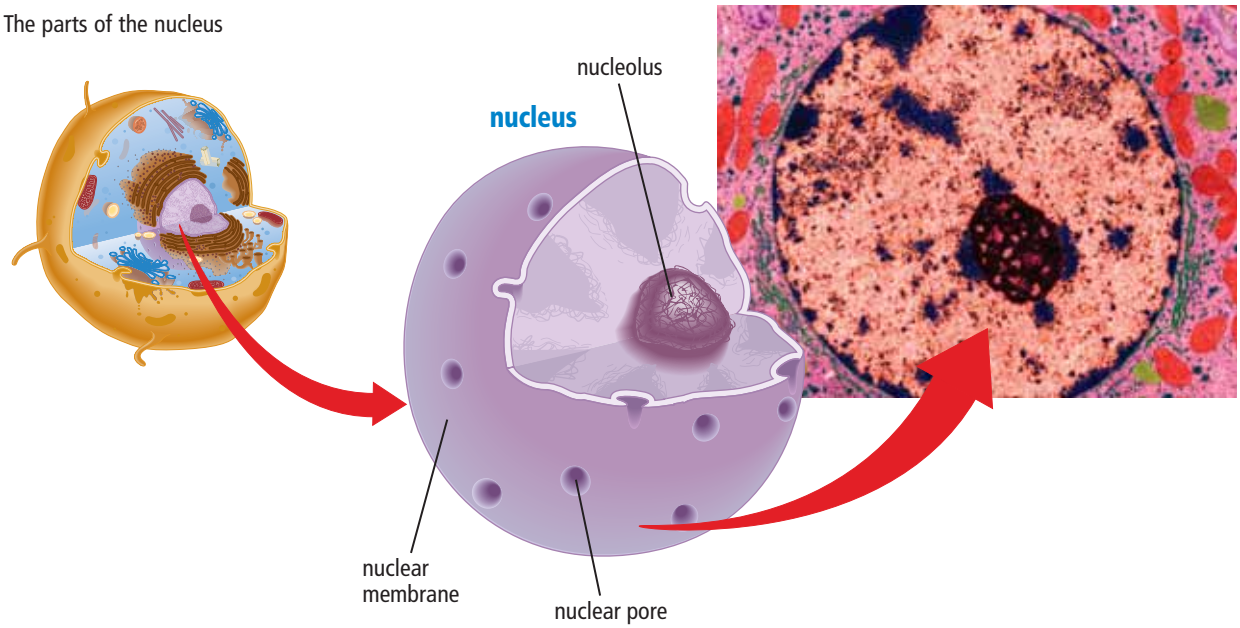
The **nucleus** (plural: nuclei) is the organelle that controls all the activities of the cell parts described above. The nucleus is surrounded by the **nuclear membrane**, which is similar in structure to the cell membrane. The nuclear membrane protects the contents of the nucleus (Figure 4.2).

The **nucleolus** is a membrane-free organelle that floats in the interior of the nucleus. The function of the nucleolus is to make ribosomes. **Nuclear pores** are openings in the nuclear membrane that allow only certain materials into and out of the nucleus. Ribosomes made in the nucleolus will leave through the pores and go to the cytoplasm or the endoplasmic reticulum.

internet connect

To find out more about cell parts and organelles, go to **www.bcscience9.ca**.

Figure 4.2 The parts of the nucleus



Reading Check

1. What is the function of a cell membrane?
2. Describe the structure of a cell wall.
3. What is an organelle?
4. What is the function of mitochondria?
5. What is the function of a ribosome?
6. Where do proteins go after they are made on the endoplasmic reticulum?
7. What is the function of the nucleolus?

4-1A Help Wanted: Apply Within

Find Out ACTIVITY

A cell is often compared to a factory or a business office. Companies write help-wanted advertisements to find employees with particular qualifications for a specific job. In this activity, your group will form a hiring committee for a company called Know Your Cells, Inc. Your group will create a help-wanted advertisement for the job of a specific cell part. Then you will ask your classmates to guess which cell part is described in your advertisement.

Materials

- sample newspaper help-wanted advertisements

What to Do

1. Study a few help-wanted advertisements to determine what information they have in common. You may want to share your findings with another group.
2. Choose a cell part and write a help-wanted advertisement for the cell part you have chosen. Be sure to include all the information required in a help-wanted advertisement. Do not name the cell part in your advertisement.
3. Share your advertisement with the rest of the class to see if they are able to guess your cell part.

What Did You Find Out?

1. How many cell parts were you able to recognize from the help-wanted advertisements written by your classmates?
2. How could you improve your help-wanted advertisement?
3. Which help-wanted advertisement did you enjoy the most, and why?

The Nucleus: Control Centre of the Cell

Studying the picture on this page and looking up at your teacher require the activity of different cells in the retinas of your eyes. Every cell in your body has a specific function, yet you have seen that every body cell contains the same cell parts and organelles. So how do retina cells become retina cells and not toenail cells? The answer lies in the nucleus. The nucleus contains the master set of instructions that determines what each cell will become, how it will function, when it will grow and divide, and when it will die (Figure 4.3).

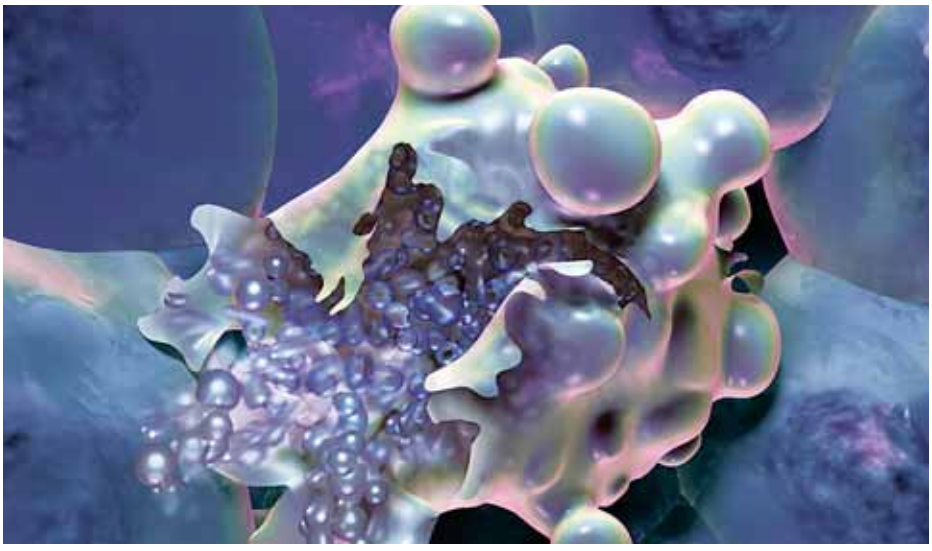


Figure 4.3 A cell in the process of dying. Cell death is important to an organism's growth and life cycle. For example, during your development as an embryo, your fingers started to form when the nuclei in the cells between your fingers instructed these cells to die.

Figure 4.4 A model of the DNA molecule

DNA carries the master set of instructions for cell function

The instructions in the nucleus are carried in long, two-stranded molecules called **deoxyribonucleic acid**, or **DNA**. The DNA molecule looks like a twisted ladder (Figure 4.4). The two strands, or sides, of the DNA ladder wrap around each other in a spiral shape that scientists call a double helix. The word "helix" comes from a Greek word meaning to wrap.

The sides of the DNA ladder are made of sugar and phosphate. The steps of the ladder are made of four nitrogen bases, which are represented by the letters A (adenine), G (guanine), C (cytosine), and T (thymine). Figure 4.5 shows the structure of the DNA molecule.

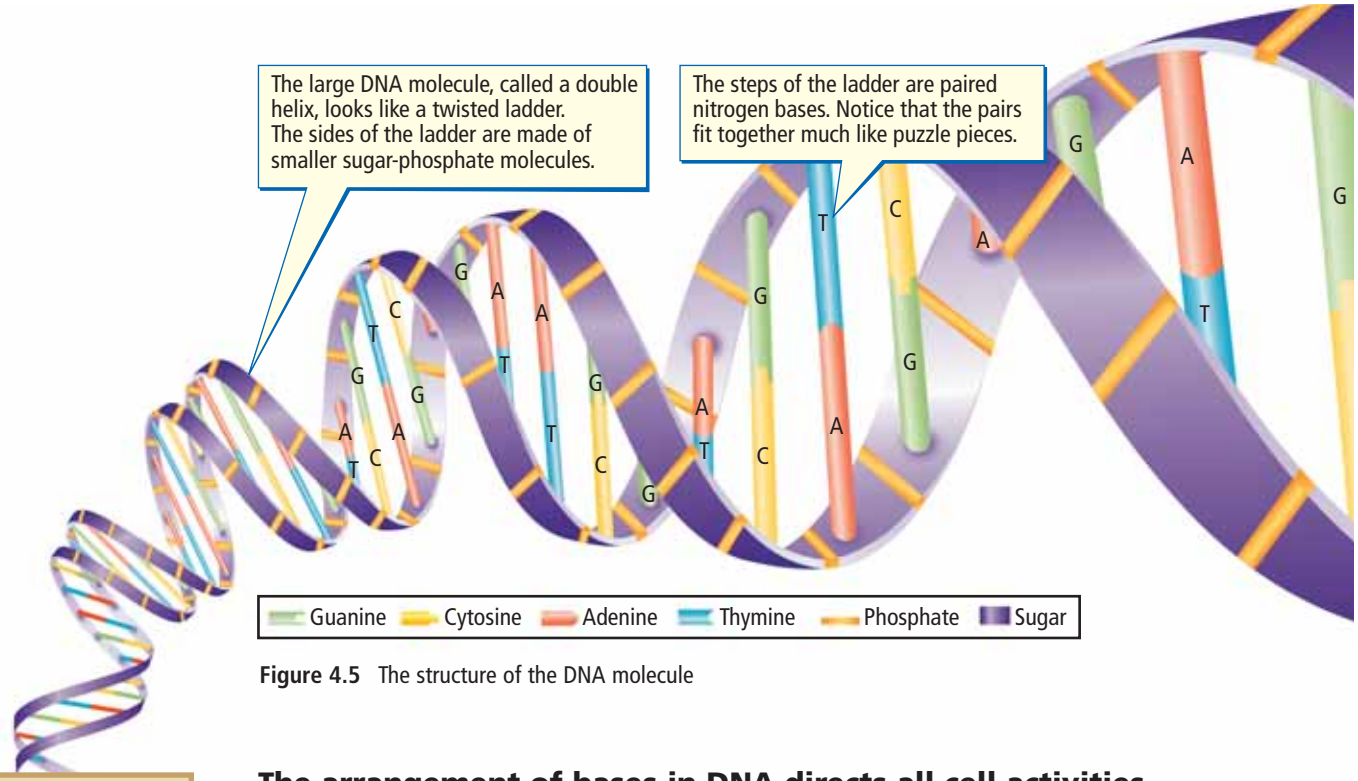


Figure 4.5 The structure of the DNA molecule

Connection

Section 3.1 has more information about phosphate.

The arrangement of bases in DNA directs all cell activities

Everything that occurs within a cell is the result of how the bases on the DNA molecule are arranged. This arrangement is known as the DNA message. As you can see in Figure 4.5, bases in a DNA molecule always join in a specific way:

- A always joins with T
- G always joins with C

However, the order and number of these bases can vary greatly within the DNA molecule. In humans, a single DNA molecule can be several million base pairs in length.

4-1B Creating DNA Messages

Find Out ACTIVITY

The number and order of the A, G, C, and T bases determine the message carried by a DNA molecule. In this activity, you will work in groups to come up with as many combinations of A, G, C, and T as possible to create as many DNA messages as you can. Each DNA message must be 12 bases long, and you will be given 3 min to complete this activity.

Materials

- paper and pencil

What to Do

1. Use the letters of the four bases, A, G, C, and T, to create a list of different DNA messages. Remember that each message must be 12 letters in length.
2. After 3 min, count how many different DNA messages your group created. Write this number at the top of your paper.
3. Compare your DNA messages with those of two other groups. Put a red checkmark beside any of your messages that are identical to the messages of another group.
4. Post your list on the classroom wall.
5. After all the lists are posted, visit each list and count the number of red checkmarks. Total the number from all groups.

What Did You Find Out?

1. How many identical DNA messages did you find when you compared your list with another group's list?
2. If you had compared your list with all groups in the class, do you think you would have found more identical messages? Explain.
3. A single DNA molecule can be several million base pairs in length. Knowing that, what can you say about the number of messages in a DNA molecule?

DNA is stored in chromatin

Most of the time, DNA exists in the nucleus in the form of **chromatin** (Figure 4.6). Chromatin is a substance that contains DNA and proteins. Within each strand of chromatin is one molecule of DNA. When a cell is growing, the DNA is uncoiled and aids in the manufacture of proteins the cell requires.

Word Connect

The word "chromatin" comes from the Greek word *chroma*, meaning colour. Chromatin was given its name because of the way it becomes coloured and is visible when a cell is stained.

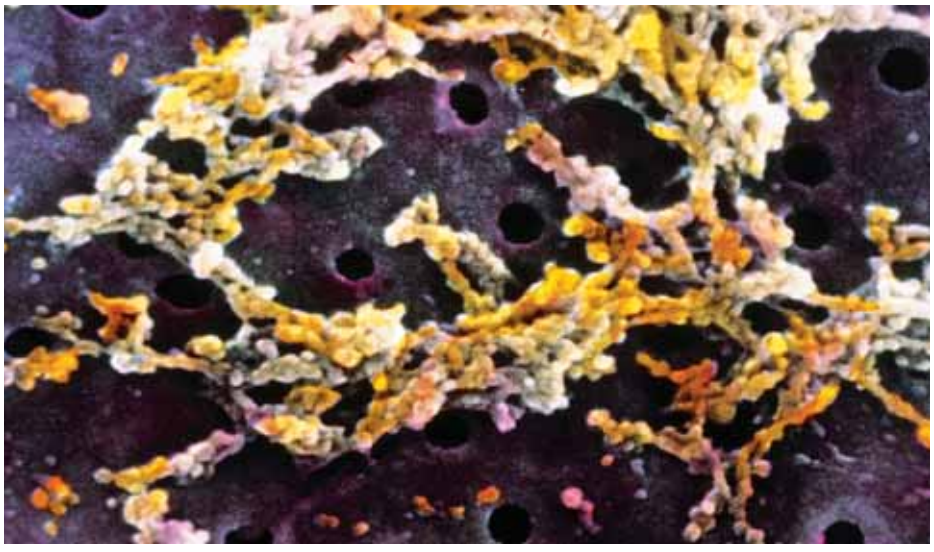


Figure 4.6 Chromatin (yellowish colour) inside the nucleus. The nuclear pores are also visible.

When a eukaryotic cell is ready to divide, each strand of chromatin coils up into a very compact, X-shaped structure called a **chromosome**. Figure 4.7 shows the relationship between DNA, chromatin, and chromosomes.

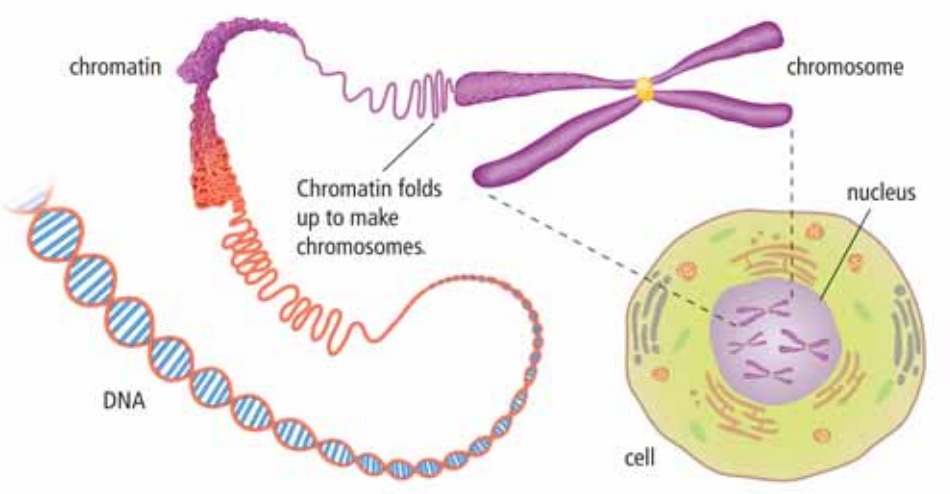
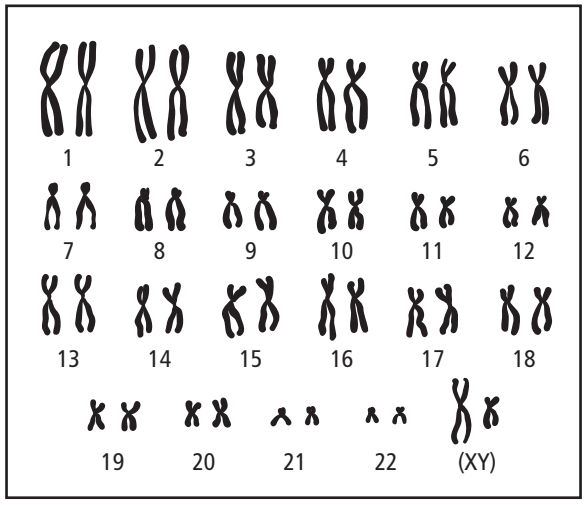


Figure 4.7 DNA, chromatin, and chromosome relationship

Every organism has a characteristic number of chromosomes

Chromosomes within the nucleus are found in pairs. Most human cells have 46 chromosomes arranged in 23 pairs, including one pair of chromosomes that help determine sex (Figure 4.8). In males, the 23rd pair of chromosomes is the XY pair. In females, it is the XX pair. Every living thing has a characteristic number of chromosomes, as shown in Table 4.1 on the next page.



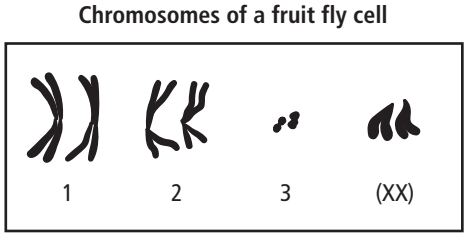


Figure 4.8 The chromosomes of a human cell compared with the chromosomes of a fruit fly cell.

Table 4.1 Comparison of Chromosome Number in Various Organisms

Organism	Chromosome Number	Organism	Chromosome Number
	46		20
	60		80
	78		44

Did You Know?

A genome is all the genetic information stored within the chromosomes of a living cell. The Human Genome Project, completed in 2003, found that human cells contain about 3 billion base pairs that carry the information to produce between 25 000 and 35 000 genes. (This number is currently thought to be 25 000 genes.) The British Columbia Cancer Research Centre participated in this project and since 2003 has supported many projects studying genome mapping to improve cancer research, diagnosis, and treatment.

Genes are found on chromosomes

Genes are small segments of DNA located at specific places on a chromosome (Figure 4.9). Genes store the information needed to produce 90 000 to 100 000 different proteins used in the cells of your body.

The arrangement of bases in a gene will usually be used to produce a specific protein. Genes can vary in length from hundreds to thousands of bases. Every chromosome carries thousands of genes and therefore contains the information to make thousands of different proteins.

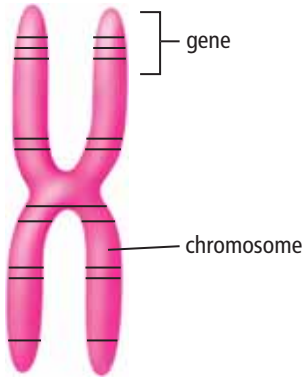


Figure 4.9 Genes are located on chromosomes and contain the information to produce a protein.

Proteins determine what body cells will become and how they will function

Each of your body cells has the same amount of genetic information stored within its 46 chromosomes. However, only specific genes are "read" in each cell to produce specific proteins. By making specific proteins, a cell becomes specialized to carry out a particular function. That is why the cells in your retina are different from the cells in your toenails. Specialized cells come together to form tissues (such as your retinas), and tissues come together to form organs (such as your eyes).

Therefore, proteins needed to make your muscles work are made only in your muscle cells. Proteins needed to help you read this page are made only in the cells of your eyes (Figure 4.10).

Thousands of different, specialized proteins called **enzymes** speed up the hundreds of chemical reactions that occur within each cell. For example, digestive enzymes work in chemical reactions to break food down into nutrient molecules that provide energy for the cell.

Some proteins act as chemical messengers called **hormones**. For example, growth hormone functions to prepare a cell for cell division by ensuring the cell has enough nutrients to divide.

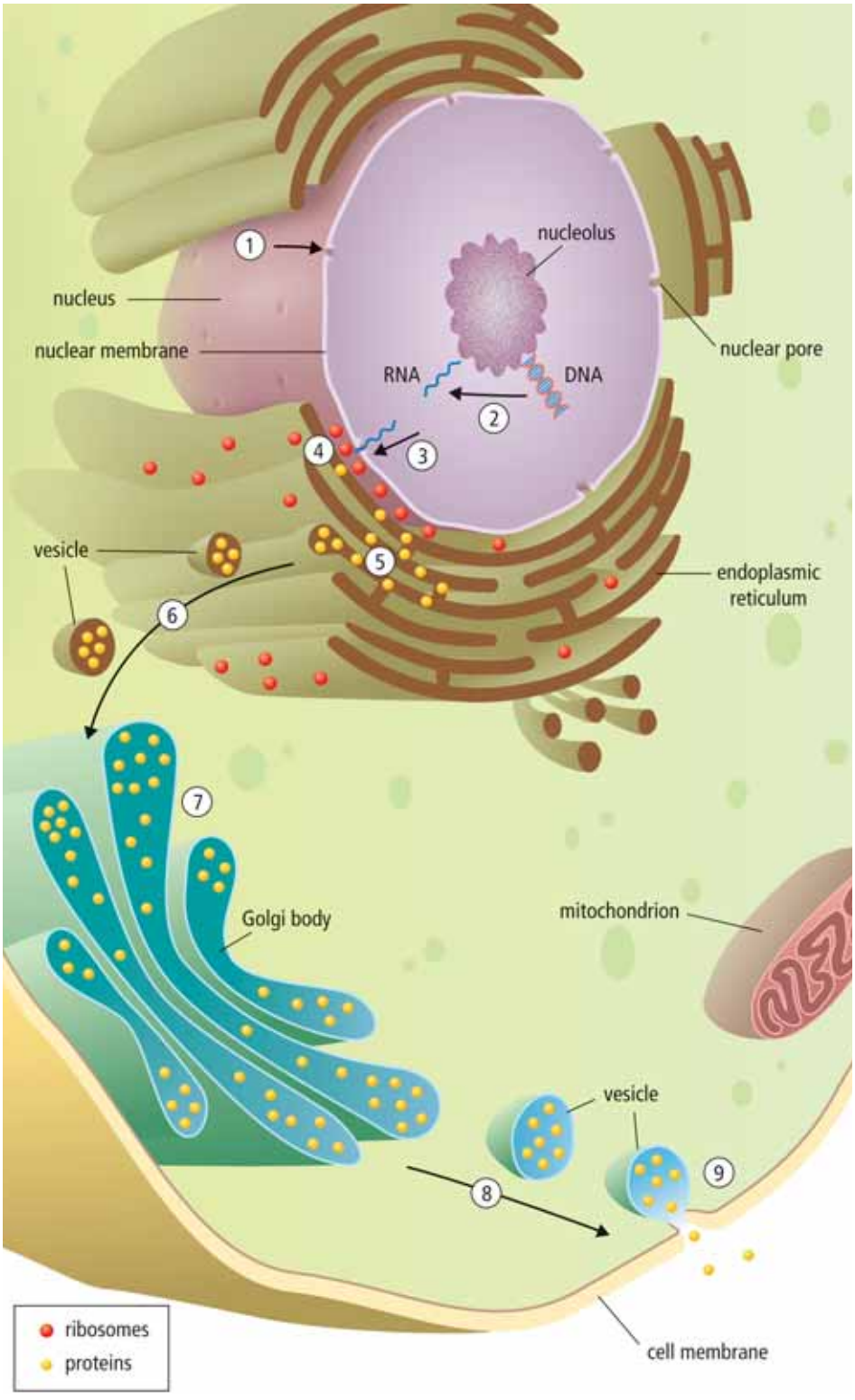
Figure 4.10 Although every cell in your body contains the same genes, only certain genes will be read to produce specific proteins, as shown in the three examples on the right.

Reading Check

1. What are the parts of the DNA molecule?
2. Describe how bases pair up in the DNA molecule.
3. What is chromatin?
4. How many chromosomes does a human body cell contain?
5. (a) What are genes?
   (b) Where are they located?
6. Your retina cells and muscle cells contain identical DNA. How are these cells able to function differently?

How Proteins Are Produced

So far in this chapter, you have read about the important function proteins perform in directing the activities of your cells. Figure 4.11 shows how a protein is produced in an animal cell and transported through a cell's membrane.



Key to Protein Production

1. The nucleus receives a chemical signal to make a specific protein.
2. The DNA message for a specific protein is copied into a small molecule called ribonucleic acid or RNA.
3. RNA leaves through a nuclear pore.
4. The RNA message is delivered to the ribosome, and the ribosome makes the protein.
5. The manufactured protein enters the endoplasmic reticulum.
6. A vesicle forms off the end of the endoplasmic reticulum and carries the protein to the Golgi body.
7. The Golgi body repackages the protein for transport out of the cell.
8. A vesicle forms off the end of the Golgi body to carry the protein to the cell membrane.
9. The vesicle attaches to the cell membrane, and its protein contents are released out of the cell.

Figure 4.11 The production of a protein in an animal cell

Explore More

Muscular dystrophy weakens the muscles in the body. In the late 1990s, to help find a cure, American scientist Dr. Lee Sweeney injected a gene into the leg muscles of rats and mice, which instructed the animals' muscles to grow more muscle tissue. Find out why athletes became interested in these experiments. Begin your research at **www.bcscience9.ca.**

A New Task for Scientists

Before the human genome was decoded, scientists hypothesized that one gene produced one protein. However, scientists know that there are at least 90 000 different proteins but only 25 000 genes in the human body. The new finding raises the question: How can one gene code for more than one protein? Scientists are currently researching the answer to this question.

Reading Check

1. What must occur before a new protein is made in the cell?
2. What is RNA?
3. How is the message carried from the nucleus to the ribosomes?
4. What happens to a protein once it is made?
5. What is the function of the Golgi body?

4-1C Modelling DNA

Find Out ACTIVITY

In 1953, American scientist James Watson and British scientist Francis Crick determined the structure of DNA without performing a single experiment. Piecing together information gained from other scientists' experiments, they constructed a model using cutouts of the shapes of the four bases. From conclusions reached by other researchers, Watson and Crick knew the following:

- The amount of base A equalled the amount of base T.
- The amount of base C equalled the amount of base G.
- Phosphates and sugars were on the outside of the molecule, and the bases were on the inside.
- DNA was a double helix made of two strands.
- There were 10 base pairs in each turn of the helix.

In this activity, you will use the same knowledge available to Watson and Crick when they constructed their model to help you build your own model of DNA.

Materials

- coloured paper templates of the parts of a DNA molecule
- scissors
- clear adhesive tape
- paper clips

What to Do

1. Your teacher will give you paper templates for the parts of a DNA model. You will model one turn of the DNA helix, so calculate how many of each template you will need. Cut out the correct number of parts.
2. Assemble your DNA model using clear adhesive tape.
3. Twist your model into a double helix and use the paper clips to hold it together. Then tape the ends.
4. Compare your completed DNA model with another group's completed model.
5. Attach the two completed models together.

What Did You Find Out?

1. How did your DNA model compare with another group's model? What was similar, and what was different?
2. If all the models in the class were attached together, would this simulate the entire DNA molecule in a chromosome or only part of the information on one chromosome? How do you know?
3. Explain how models are helpful to scientists.

4-1D Extracting DNA from Strawberries

Find Out ACTIVITY

DNA is often obtained from mouth swabs or from samples of blood, hair, or plants. Before technicians from a crime or genetics laboratory can conduct their analysis, they must first isolate the DNA and remove it from the sample. In this activity, you will perform this first step in DNA analysis.

Safety

- Do not eat or drink anything during this activity. Do not put your hands near your face.
- Handle rubbing alcohol or ethanol with care. Both are poisonous.
- Wash your hands thoroughly after this investigation.

Materials

- 1 frozen strawberry
- a small, resealable plastic bag
- measuring spoons
- 5 mL dish soap
- 2.5 mL table salt
- 25 mL tap water, approximately
- test tube and test tube rack
- flask containing rubbing alcohol or ethanol (ice cold)
- graduated cylinder
- wooden stick or paper clip hook
- paper towel

What to Do

1. Place the frozen strawberry into the plastic bag. Add 5 mL of dish soap, 2.5 mL of table salt, and about 25 mL of tap water. Seal the bag.
2. Gently crush the contents of the plastic bag with your hand so that the strawberry and other substances combine. Be careful not to damage the plastic bag.
3. Keep the bag at room temperature and wait for 5 min.
4. Cut a small hole in one corner of the plastic bag, and carefully drain about half of the strawberry solution into a test tube, filling it halfway.
5. Pour the ice cold rubbing alcohol or ethanol from the flask into the graduated cylinder. Then slowly pour a layer of rubbing alcohol or ethanol on top of the strawberry solution so that the test tube is about $\frac{3}{4}$ full.
6. Observe the DNA forming between the layers of alcohol and strawberry solution.
7. Using a wooden stick or paper clip hook, pull the DNA out and onto a paper towel. Record your observations.
8. Clean up and put away the equipment you have used. Dispose of the alcohol and strawberry solution as your teacher instructs.
9. Wash your hands thoroughly.

What Did You Find Out?

1. (a) Describe the appearance of the DNA.
   (b) Did the DNA look as you expected? Explain.
2. Do you think the DNA from another organism would have a different appearance? Explain why or why not.
3. Why do you think it was necessary to crush the strawberry in this activity?
4. What step was necessary to make the DNA visible?
5. If you wanted to maximize the amount of DNA that came out of the strawberry, which ingredient might you increase?

Wild, Weird, Wonderful

www Science

Glowing Genes

The process that makes fireflies glow brightly in the summer night to attract mates has also shone light on the field of biotechnology. Fireflies produce a protein enzyme, called luciferase [lu-SIF-uh-raze], which aids in a light-producing chemical reaction. When living things produce light, the process is called bioluminescence.

Bioengineers have identified the small piece of DNA, called a gene, in the firefly that contains the information to make luciferase. They are able to remove the gene from the firefly, make copies of the gene in the laboratory, and put the gene into another organism. The process where genes are taken from one organism and inserted into the DNA of another organism is called recombinant DNA.

Taking genes from one plant or animal and transferring them into another plant or animal creates a transgenic organism. A transgenic plant or animal has DNA in its nucleus from another plant or animal. Bioengineers have created transgenic organisms that glow in the dark. Glow-in-the-dark pigs, mice, and monkeys help scientists trace activities going on within a cell. The brighter the light shining from a cell tagged with luciferase, the more activity within the cell.

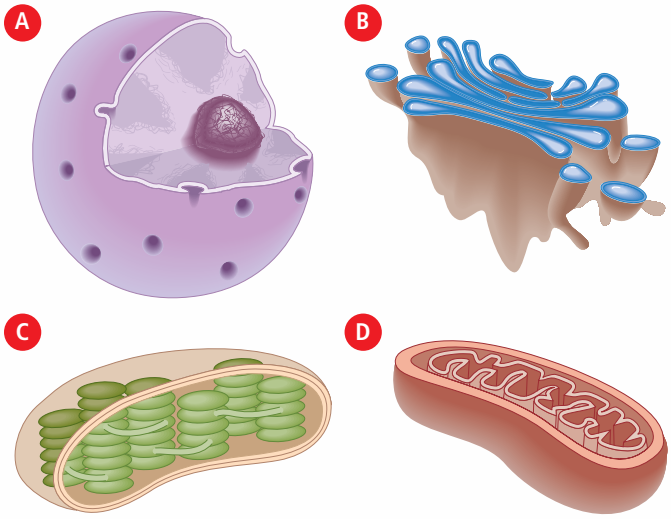
In the future, scientists may use the process of transferring genes from one organism to another to speed up the testing of new drug and gene treatments. For example, if light shines from the cell that receives the glow-in-the-dark gene, scientists will know that the correctly functioning gene has entered the cell successfully. Gene transfer procedures may be used to treat diseases such as diabetes, AIDS, and cancer. Glowing genes may help identify and treat cells injured by heart attacks or nerve-damaging diseases such as Alzheimer's and Parkinson's. Tumour cells that light up will tell surgeons exactly where to cut to remove a tumour.

The glowing genes of the firefly hold much more potential for medical discoveries in the future, since they are inexpensive and allow scientists to quickly trace cell activity. Unlike other chemicals used to monitor activity in cells, luciferase is non-radioactive, so it will not harm the organism it is transferred into.

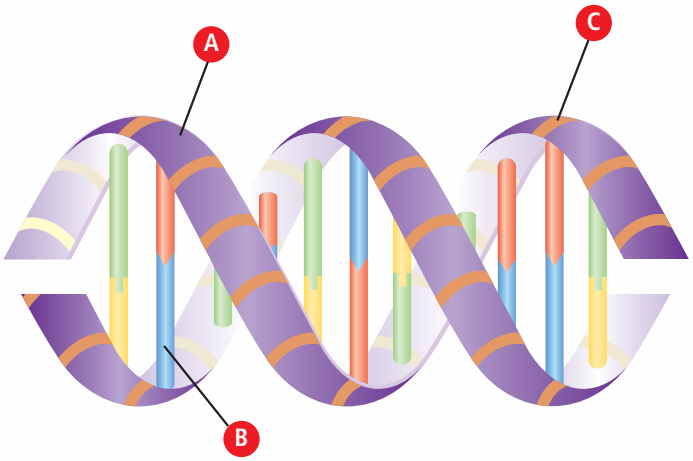
Check Your Understanding

Checking Concepts

1. (a) Which of the structures shown in the diagram below contains the information to make proteins?
   (b) Which of the structures shown in the diagram below is used to prepare proteins for transport out of the cell?
   (c) Identify the remaining two structures and describe their function.



2. Draw a simple diagram of a chromosome and indicate the location of a gene.
3. Explain the function of genes in a cell.
4. How is the information contained in DNA transported out of the nucleus?
5. Where are the ribosomes that manufacture proteins for transport out of the cell located?
6. What is the function of the Golgi body?
7. In the diagram below, identify which part is the phosphate, the sugar, and the base.



Understanding Key Ideas

8. Draw a nucleus and label the nuclear membrane, nuclear pores, and chromatin.
9. Explain how the nucleus controls the functions of life.
10. What makes a skin cell different from a nerve cell?
11. The protein hemoglobin, which carries oxygen in red blood cells, is not made in a skin cell. Explain why.
12. Predict what might happen to a cell if a required protein was not made in that cell.
13. One side of a DNA molecule contains the following sequence of bases.
    ACCTGCTAT
    Write the sequence of the bases on the other side of the molecule.
14. A DNA molecule is made when one strand of bases joins with a corresponding strand of bases. What do you think would happen if one strand lacked T (thymine)?
15. In which part of the DNA molecule would a change be more damaging to the cell: in the sugar-phosphate sides of the molecule or in the A, G, C, T bases? Explain.
16. Explain why DNA cannot leave the nucleus.

Pause and Reflect

DNA is sometimes referred to as the code of life. Explain why you think scientists have used these words to describe DNA.