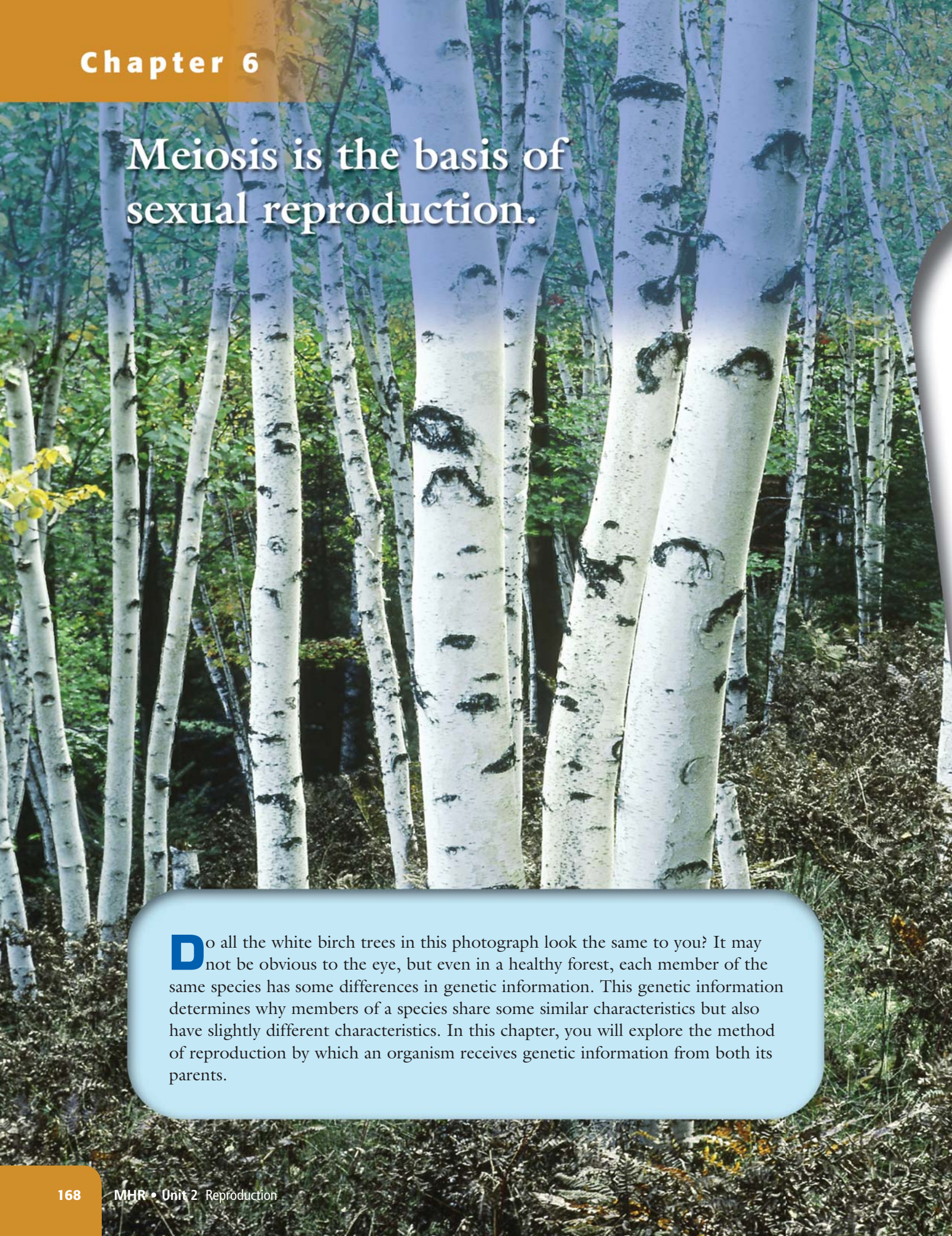
Chapter 6

Meiosis is the basis of sexual reproduction.



Do all the white birch trees in this photograph look the same to you? It may not be obvious to the eye, but even in a healthy forest, each member of the same species has some differences in genetic information. This genetic information determines why members of a species share some similar characteristics but also have slightly different characteristics. In this chapter, you will explore the method of reproduction by which an organism receives genetic information from both its parents.

What You Will Learn

In this chapter, you will

- **explain** how organisms maintain genetic diversity
- **describe** how various organisms reproduce sexually
- **distinguish** the process of mitosis from meiosis
- **describe** how our understanding of genetics has changed over time

Why It Is Important

Understanding meiosis and sexual reproduction is important for understanding how many species in our world maintain genetic diversity and how genetic disorders are inherited.

Skills You Will Use

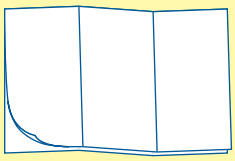
In this chapter, you will

- **predict** how genetic variation can affect the ability of organisms to survive
- **communicate** your understanding of how mitosis differs from meiosis
- **compare** the advantages and disadvantages of sexual and asexual reproduction

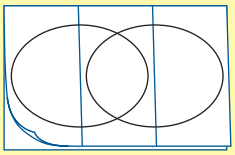
FOLDABLES™
Reading & Study Skills

Make the following Foldable and use it to take notes on what you learn in Chapter 6.

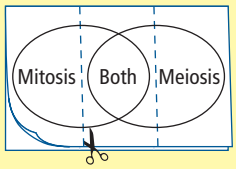
STEP 1 **Fold** a sheet of letter-sized photocopy paper in half from top to bottom and then fold it into thirds.



STEP 2 **Open** the Foldable, and **draw** a giant Venn diagram on one side.



STEP 3 **Label** as shown, then **cut** along the fold lines on the Venn diagram side to form three tabs.



Finding Common Characteristics

As you read this chapter, use the Venn diagram Foldable to compare mitosis and meiosis and to determine what they have in common.

6.1 Meiosis

The process of meiosis results in the production of special cells called gametes. Gametes have half the number of chromosomes as body cells. Cell division occurs twice in meiosis: once at the end of meiosis I and again at the end of meiosis II. In meiosis I, matching pairs of chromosomes called homologous chromosomes separate. In meiosis II, sister chromatids separate. The process of meiosis shuffles genetic information and results in variation in the gametes.

Key Terms

embryo
fertilization
gametes
genetic diversity
meiosis
sexual reproduction
zygote

When you look around your classroom, you will see students of differing heights, facial features, and hair colour. When you look at the photographs in Figure 6.1, you will see some organisms from the same species that look quite different from one another and some that look the same. What do all of these organisms have in common? They have all been produced by a process called **sexual reproduction**. Unlike asexual reproduction, which requires only one parent and produces identical offspring, sexual reproduction requires two parents. Sexual reproduction produces offspring that are genetically different from each other, from either parent, and from any other member of their species. Sometimes these genetic differences are visible, such as the coat colour of the llamas in Figure 6.1A. Sometimes, genetic differences are not visible, such as in the owls in Figure 6.1B.

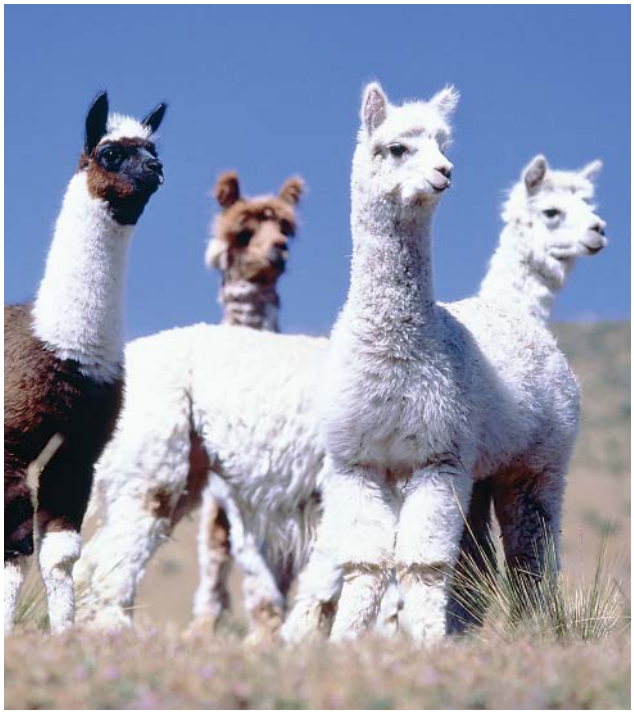


Figure 6.1A Offspring that result from sexual reproduction are genetically different.

Figure 6.1B Genetic differences may or may not be visible.

Variation, or inherited genetic differences in a species, is called **genetic diversity**. Genetic diversity is the result of sexual reproduction, which randomly sorts, or shuffles, DNA. Because of the combination of genes received from its parents, an organism may be better equipped to cope with changes in its environment. Therefore, one organism of a species may gain an advantage over another organism of the same species.

6-1A Eating Like a Bird

Find Out ACTIVITY

The genetic variation that results from sexual reproduction can give an organism a survival advantage. An organism may be stronger, better at escaping predators, or more skilled at obtaining food. In certain species of birds, for example, variation in beak size and shape can help a species survive in an environment with a specific food source. In this activity, you will determine which type of beak provides a survival advantage for a bird given a particular food source.

Safety

- Never eat anything in the science room.

Materials

- spoon
- chopsticks (one set)
- forceps or tweezers (one pair)
- marbles
- toothpicks
- cereal
- pennies
- timer

What to Do

1. Work in a group of four. Predict which "beak" (spoon, chopsticks, or forceps) will pick up each of the "foods" (marbles, toothpicks, cereal, pennies) the best. Record your predictions.
2. Design a chart to record data on how much food is collected with each type of beak.
3. Put the food in a pile in the middle of a table top. Three members of your group will each use one of the beaks to pick up food from the pile. The fourth person will time the group members for 1 min as they race to pick up as much food as possible. The fourth person will then record the data.
4. Decide on the best type of graph to illustrate your group's data. Construct a graph to display the data.
5. Clean up and put away the equipment you have used.

> **Science Skills**
>
> Go to Science Skill 4 for information about organizing your data into a graph.

What Did You Find Out?

1. Did your group's predictions match your results? Explain.
2. Compare your group's results with those of two other groups.
   (a) How are the results the same?
   (b) How are the results different?
3. Which beak would provide a survival advantage in an environment where marbles are the only food source? Explain.
4. Which beak would provide a survival advantage in an environment where toothpicks are the only food source? Explain.

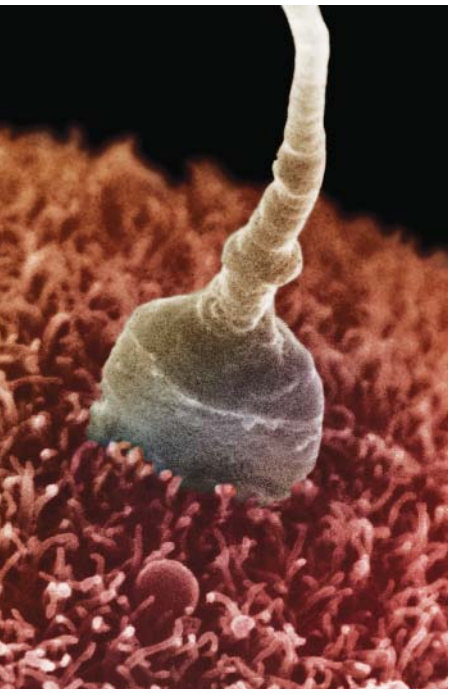


Figure 6.2 A human sperm enters a human egg cell, resulting in fertilization.

The Role of Gametes

Genetic information is passed along in the chromosomes an offspring inherits from its parents. In section 4.1, you learned that all organisms have a specific number of chromosomes in their body cells. In eukaryotic organisms, this chromosome number is referred to as the diploid number ($2n$). Diploid means that a body cell has two sets of chromosomes. The diploid number for humans is 46, or 2×23 chromosomes. Mitosis ensures that the diploid number always stays the same and that the genetic information contained within your body cells also remains the same, unless a mutation occurs.

So what makes humans genetically different from each other? Humans inherit one set of 23 chromosomes from their female parent and one set of 23 chromosomes from their male parent. Each set of these inherited chromosomes is referred to as the haploid number (n). Haploid chromosomes are carried in **gametes**, which are specialized cells necessary for reproduction. In animals, male gametes are called sperm cells and female gametes are called egg cells.

During a process called **fertilization**, an egg cell is penetrated by a sperm cell (Figure 6.2), and the haploid genetic information of both male and female gametes combines. The result of this process is a diploid cell called a **zygote**. A zygote receives half its chromosomes from its female parent and half from its male parent. The zygote then undergoes mitosis and cell division and develops into an **embryo**.

Figure 6.3 shows how a zygote inherits its diploid number and develops into an organism.

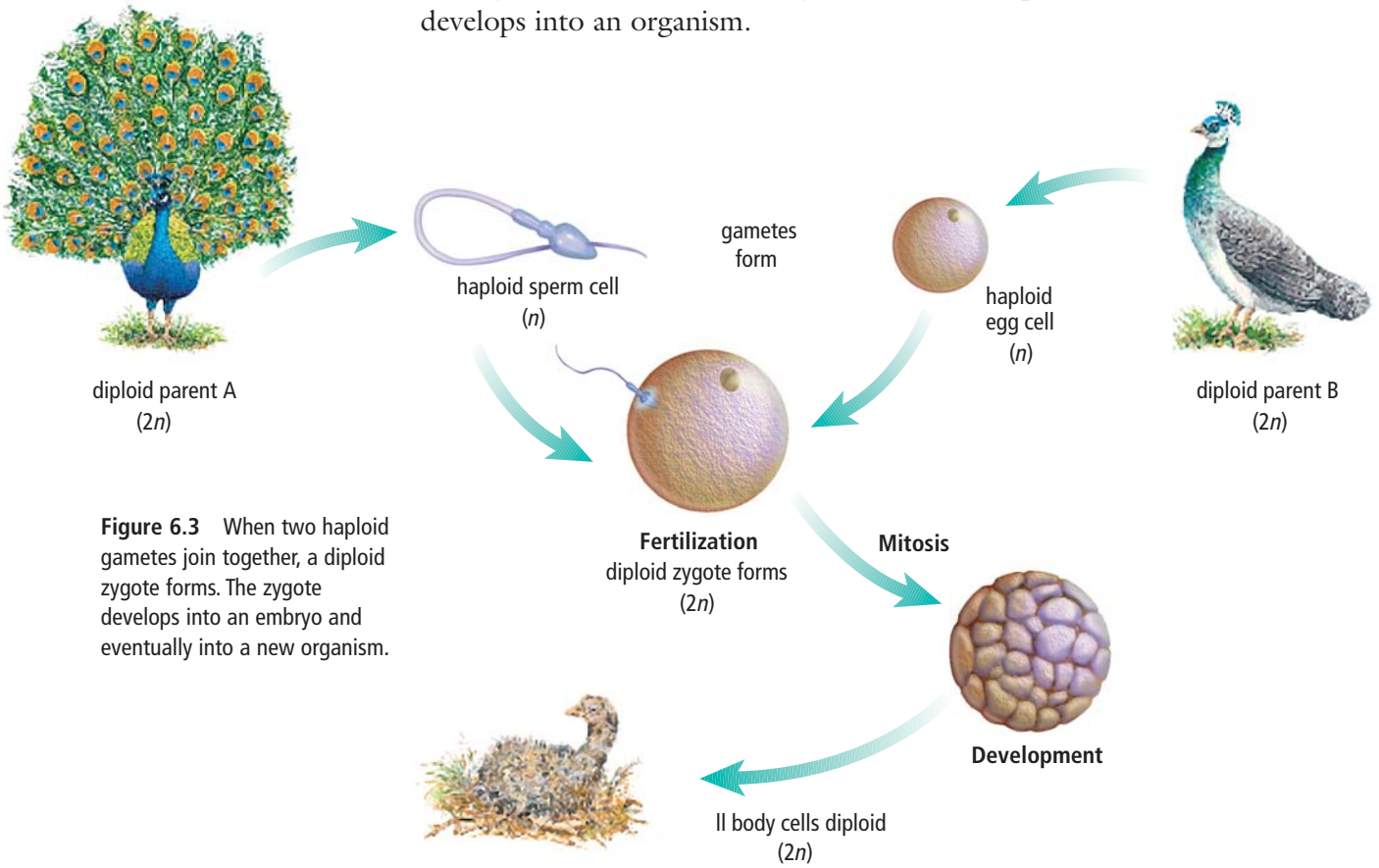


Figure 6.3 When two haploid gametes join together, a diploid zygote forms. The zygote develops into an embryo and eventually into a new organism.

Meiosis: Reducing Chromosome Number

The process that produces gametes with half the number of chromosomes as body cells occurs in sex cells, and is called **meiosis**. Without meiosis, the joining of a sperm cell and an egg cell during fertilization would produce an offspring with two times the original number of chromosomes as its parents. Figure 6.4 shows how meiosis produces gametes with half the number of chromosomes of the parent cells. As you look at Figure 6.4, notice that DNA replicates only once in the process, even though two cell divisions occur.

Word Connect

"Meiosis" is derived from the Greek word *meion*, which means to reduce.

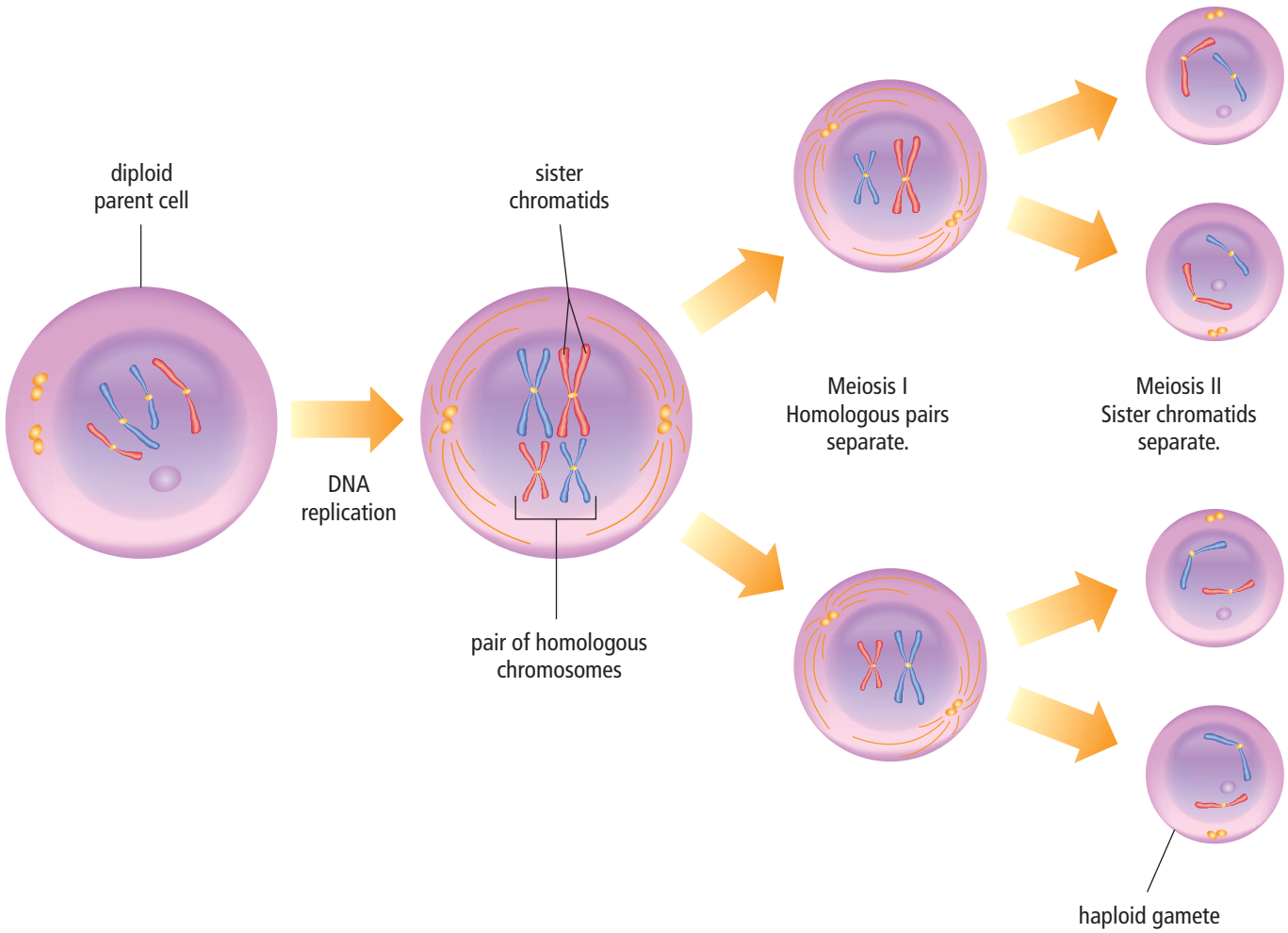


Figure 6.4 DNA replicates only once, in interphase, before meiosis begins. Two complete cell divisions occur, once after meiosis I and again after meiosis II.

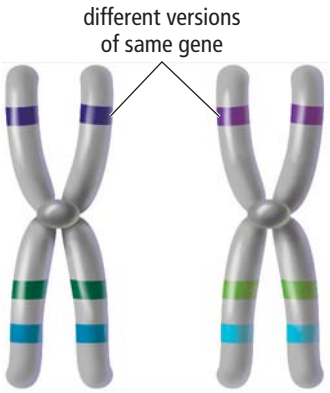


Figure 6.5 Homologous pairs are the same size and shape and have genes in the same location, as shown by the coloured bands in this illustration. Each chromosome may have different versions of those genes, as shown by the different shades of each colour.

Meiosis I

In Chapter 5, you saw that in mitosis, each of the 46 chromosomes lines up along the equator of the cell during metaphase. The sister chromatids then move to opposite poles of the cell. Meiosis I differs from mitosis because in meiosis I, a pair of matching chromosomes—one chromosome from each parent—lines up at the equator (Figure 6.6). Scientists refer to this pair of matching chromosomes as a pair of homologous chromosomes (Figure 6.5). In meiosis I, the homologous chromosome pair separates and moves to opposite poles of the cell. Two daughter cells result from meiosis I.

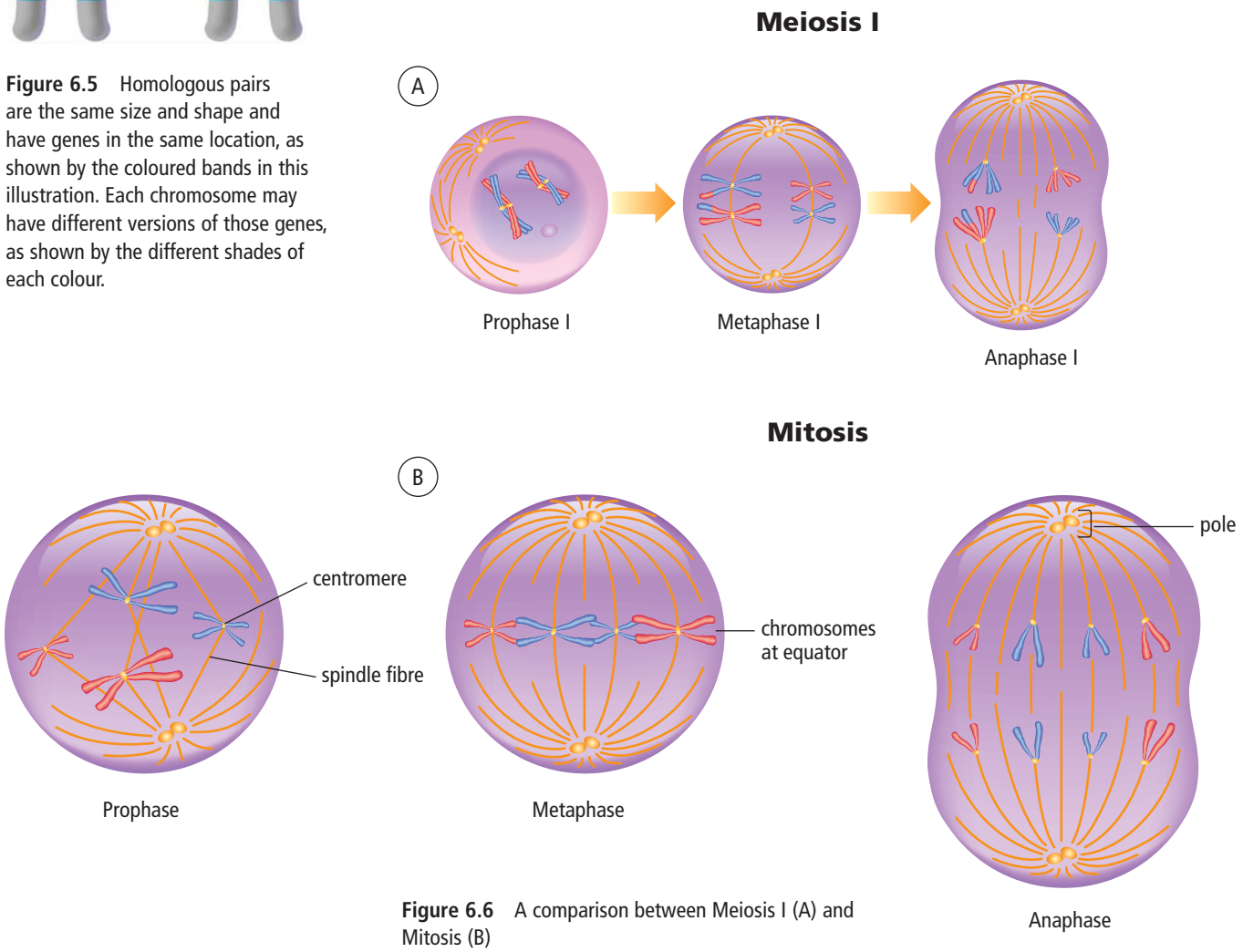


Figure 6.6 A comparison between Meiosis I (A) and Mitosis (B)

Meiosis II

DNA is not replicated again before meiosis II begins. Chemical messages trigger the cells to begin the cell division process. Meiosis II is like mitosis because in both processes, the chromatids of each chromosome are pulled to opposite poles. Each daughter cell inherits one chromatid from each chromosome. The result is four haploid cells, each with half the number of chromosomes.

Suggested Activity

Conduct an Investigation 6-1B on page 176

Gamete formation

Although the process of meiosis is the same for males and females, gamete formation is different (Figure 6.7). In males, meiosis I occurs and produces two cells. It is immediately followed by meiosis II if there are enough nutrients for cell division. The result is four cells with the cytoplasm and organelles equally divided among them. All four cells may develop into mature sperm.

In females, meiosis I occurs and produces two egg cells, but there is an unequal division of the cytoplasm and organelles. Following meiosis II, three of the cells will disintegrate. The remaining one large egg cell retains most of the cytoplasm and is available for fertilization.

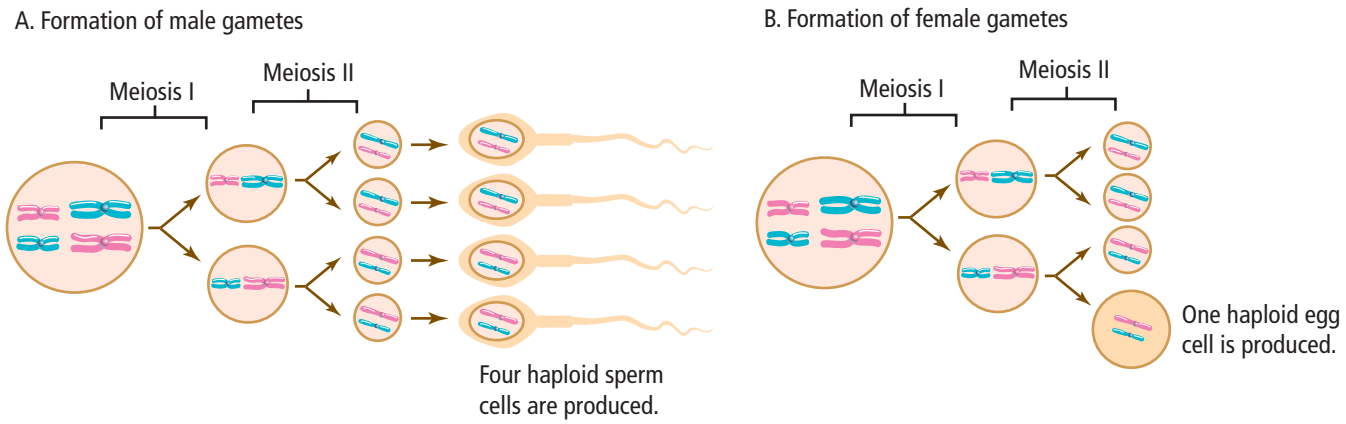


Figure 6.7 Meiosis occurs continuously in the testes of human males from puberty. In females, meiosis begins in the ovaries before birth, then stops until puberty and the onset of the menstrual cycle.

Reading Check

1. What does the term "genetic diversity" mean?
2. What is the function of meiosis?
3. What is another name for a fertilized egg?
4. When sex cells in a male undergo meiosis, how many sperm cells are produced from each parent cell?

6-1B Comparing Mitosis and Meiosis

SkillCheck

- Classifying
- Communicating
- Evaluating information
- Working co-operatively

Materials

- *Discovering Science 9* textbook

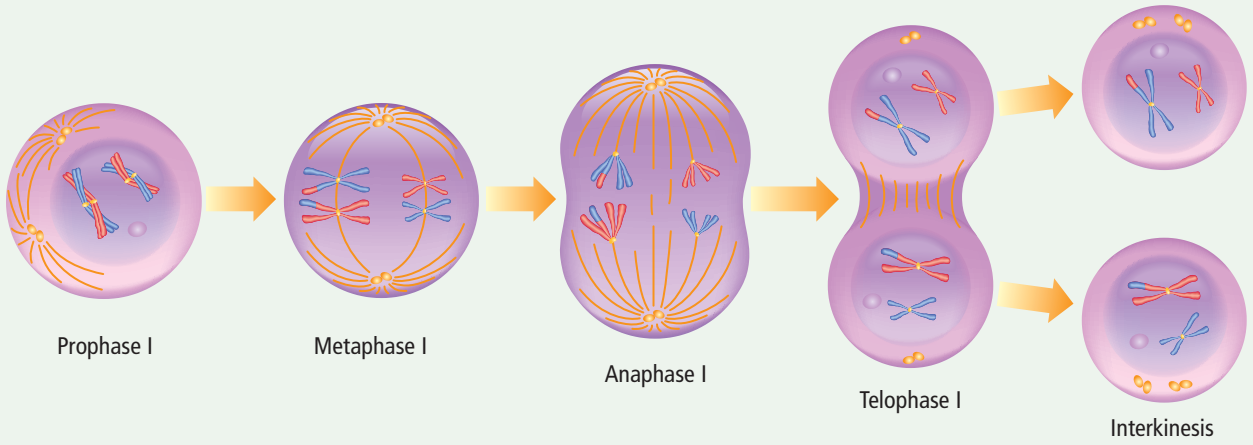
Mitosis and meiosis are two methods of cell reproduction. These two cell division methods have different purposes. Body cells divide by mitosis so that each of the two daughter cells receives a full set of chromosomes. Sex cells divide by meiosis with the result that each of the four cells produced receives half the number of chromosomes. In this activity, you will use your knowledge of mitosis to help further your understanding about the events in meiosis.

Question

How are the processes of mitosis and meiosis similar and how are they different?

Procedure

1. Work with a partner. Study the diagram shown here, which shows the events of meiosis. Carefully compare this diagram to Figure 5.8 of mitosis on pages 142-143 and the description of cytokinesis on page 144. Compare the activities of the chromosomes, nucleus, and cell membrane at each stage.



Meiosis I

Prophase I
Homologous chromosomes pair up.

Metaphase I
Homologous chromosomes pair up at the equator.

Anaphase I
Homologous chromosomes separate and are pulled to opposite poles.

Telophase I
One chromosome from each homologous pair is at each pole of the cell.

Interkinesis
Interkinesis is the stage between cell divisions. During this time, the cell will grow and make proteins as in interphase of mitosis. Unlike interphase in mitosis, there is no replication of DNA during this stage.

Inquiry Focus

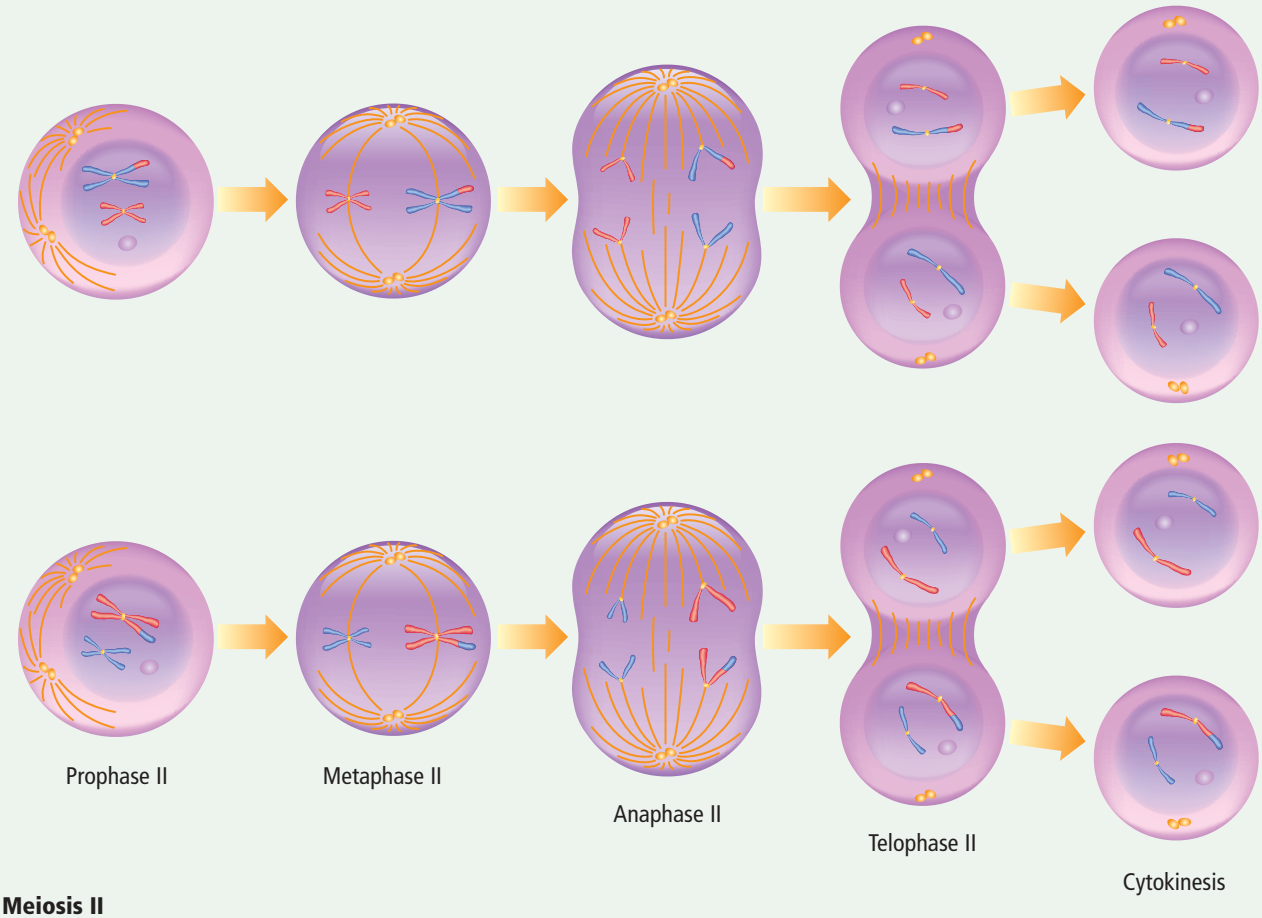
2. Your teacher will give you a chart in which you can compare meiosis I and II with mitosis. Write a brief description for each phase in the chart.
3. Compare your completed charts with another group's charts. Add any additional information to your charts.
4. Create a chart to compare specific aspects of mitosis and meiosis. Include headings for the types of cells involved, the number of daughter cells produced, the amount of genetic material in each daughter cell, and the role in asexual and sexual reproduction.

Analyze

1. Is meiosis I or meiosis II more similar to mitosis? Explain.
2. List three similarities between mitosis and meiosis.
3. List three differences between mitosis and meiosis.

Conclude and Apply

1. (a) In a paragraph, explain the differences between mitosis and meiosis.
   (b) Explain which method contributes to genetic variation and why.



Meiosis II

Prophase II
There is one chromosome of the homologous pair in each cell.

Metaphase II
The X-shaped chromosomes form a single line across the middle of the cell.

Anaphase II
Sister chromatids move to opposite poles of the cell. Once they separate, each sister chromatid is considered to be a chromosome.

Telophase II
A nuclear membrane forms around each set of chromosomes.

Cytokinesis
In cytokinesis, the two daughter cells are separated.

NATIONAL GEOGRAPHIC

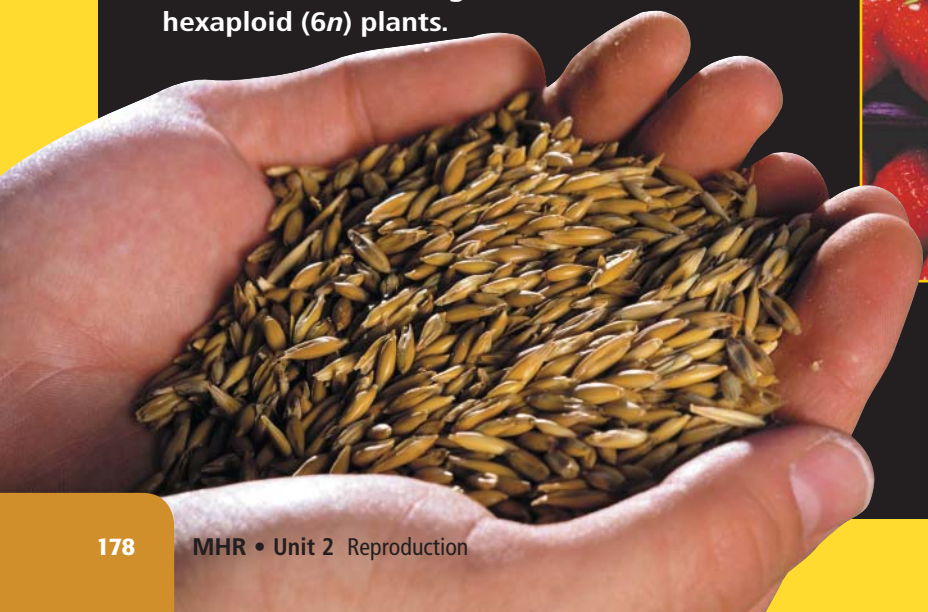
VISUALIZING POLYPLOIDY IN PLANTS

You received a haploid (*n*) set of chromosomes from each of your parents, making you a diploid (2*n*) organism. In nature, however, many plants are polyploid—they have three (3*n*), four (4*n*), or more sets of chromosomes. We depend on some of these plants for food.

▲ **TRIPLOID** Bright yellow bananas typically come from triploid (3*n*) banana plants. Plants with an odd number of chromosome sets usually cannot reproduce sexually and have very small seeds or none at all.

▲ **TETRAPLOID** Polyploidy occurs naturally in many plants—including peanuts and daylilies—due to mistakes in mitosis or meiosis.

▼ **HEXAPLOID** Modern cultivated strains of oats have six sets of chromosomes, making them hexaploid (6*n*) plants.



▲ **OCTOPLOID** Polyploid plants often are bigger than nonpolyploid plants and may have especially large leaves, flowers, or fruits. Strawberries are an example of octoploid (8*n*) plants.

Check Your Understanding

Checking Concepts

1. Compare the number of chromosomes in a human skin cell to the number of chromosomes in a human egg cell.
2. What characteristics could you use to identify a pair of homologous chromosomes?
3. What are the benefits of genetic diversity?
4. Identify whether each of the following is an event in meiosis I or meiosis II.
   (a) Individual chromosomes move to the equator.
   (b) Homologous pairs of chromosomes move together to the equator.
   (c) Homologous chromosomes move to opposite poles.
5. Copy the following table in your notebook. Complete the table comparing mitosis and meiosis.

Question	Mitosis	Meiosis
Where does it take place?		
How many cells are produced?		
What happens to the number of chromosomes?		
How do parent and daughter cells compare genetically?		
How do daughter cells compare to each other genetically?		

6. What is the difference between chromosomes in meiosis I and mitosis?
7. Does meiosis occur in sexual reproduction or in asexual reproduction?
8. In which phase of meiosis do four daughter cells form?
9. What is a gamete?
10. What happens during the process of fertilization?

Understanding Key Ideas

11. Why do muscle cells not undergo meiosis?
12. Explain why meiosis is important for the survival of organisms.
13. Explain how you can tell whether a sperm cell is in meiosis I or meiosis II.
14. Draw a cell undergoing fertilization.
15. A dog has 76 chromosomes.
    (a) How many pairs of homologous chromosomes does it have?
    (b) How many chromosomes would be in each sperm cell of a dog?
16. Explain why cells produced by mitosis cannot be used for sexual reproduction.

Pause and Reflect

Two types of twins can result from fertilization: identical twins and fraternal, non-identical twins. Identical twins result when one embryo splits in two. Such twins are genetically identical and look the same. However, their fingerprints will differ because fingerprints are caused by the movement of the fluid that surrounds the fetus as it grows inside the mother. As identical twins age, they will look less alike. What types of changes may occur that will make the twins less alike?

6.2 Sexual Reproduction

In sexual reproduction, a male gamete (sperm cell) must fertilize a female gamete (egg cell). As a result of meiosis and the union of sperm and egg cells, no two individuals will have the same DNA, except identical twins. Many aquatic animals reproduce through external fertilization. Most land animals reproduce through internal fertilization. Following fertilization, the zygote and embryo start to divide by mitosis, and cells will differentiate.

Key Terms

complete metamorphosis
incomplete metamorphosis
metamorphosis
pollen
pollination

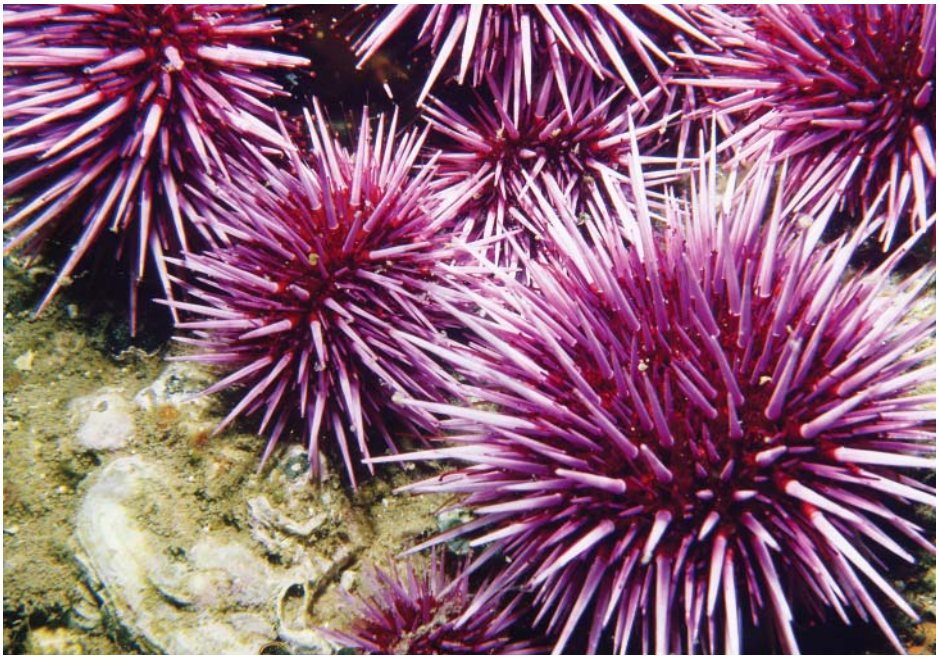


Figure 6.8 The purple sea urchin has been used extensively in scientific research.

Purple sea urchins (Figure 6.8) are one of the most useful models for scientific research. In fact, the sexual reproductive process of the sea urchin has been studied for decades, enabling scientists to gain a greater understanding of how animal sperm cells and animal egg cells meet and result in fertilization.

In Chapter 5, you learned that asexual reproduction requires only one parent and can occur wherever that parent is located if conditions are favourable. Sexual reproduction requires two parents who must bring two gametes together for fertilization to occur. To survive, sexually reproducing species must mate with members of their own species. For years, scientists wondered how different types of sea urchins living close together were able to accomplish sexual reproduction within their own species, since sea urchins bring gametes together by releasing great clouds of sperm and egg cells into the water.

Scientists wondered just how the sperm cells of the purple sea urchin were able to fertilize the egg cells of other purple sea urchins and not the egg cells of the green sea urchin, which reproduces in the same ocean waters. Researchers found that the sperm and egg cells of all species of sea urchins have unique proteins on their surfaces. Researchers also found that the surfaces of sea urchin eggs have unique sugars. In order for fertilization to occur, sugar-protein recognition must occur. In other words, fertilization in a particular species of sea urchin will occur only if the right sugar meets the right protein of that species.

Because sea urchin eggs are transparent, scientists can observe the changes that occur within the egg after fertilization to study how the fertilized egg begins to develop (Figure 6.9). Scientists can use these observations to gain a better understanding of fertilization among other animals.

Did You Know?

Molecular biologists at Simon Fraser University and the Michael Smith Genome Sciences Centre in Vancouver participated in an international study to map the genome of the purple sea urchin. They discovered that the sea urchin has many of the same genes as humans, including those linked to diseases such as hardening of the arteries, muscular dystrophy, and several brain disorders.

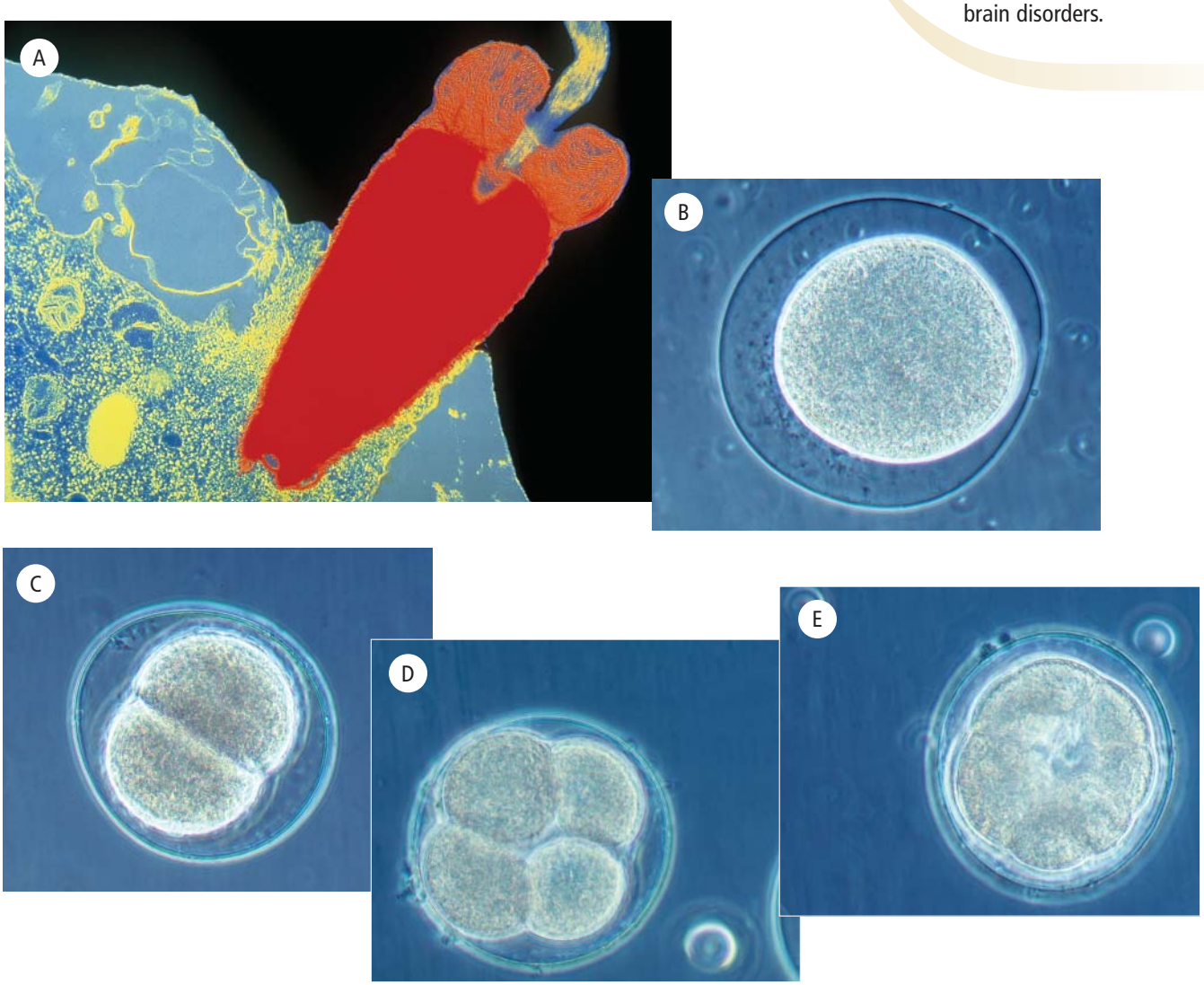


Figure 6.9 This series of photographs shows the process of fertilization and early development in the sea urchin (A to E). Sea urchin egg cells are the same size as human egg cells. Their size and transparency make them a model organism for the study of reproduction in humans and other animals.

Sexual Reproduction

In section 6.1, you learned how male and female gametes are formed and how meiosis produces gametes that are not genetically identical. Sexual reproduction is the process that brings these non-identical gametes together to form a new organism. Sexual reproduction has three stages: mating, fertilization, and development.

Mating is the process by which gametes arrive in the same place at the same time. Finding a mating partner often involves displays of colour, song, or strength. Mammals mate on land or in water, depending on the species.

Many animals mate at a time of year that ensures their young will be born in favourable environmental conditions, when food is abundant and temperatures are warm. For example, sheep, goats, and moose mate in the fall and winter so that their offspring will be born in the spring when conditions are less harsh. Horses mate in the summer, but because the time between fertilization and birth is longer in horses, their offspring are also born in the spring.

Land-dwelling mammals such as moose mate in forests (Figure 6.10). Males attract females with their call as well as their strong scent. Their antlers also play a role in mating. A male moose's antlers get larger every year so the size of the antlers shows how long the moose has survived. Antlers can also be used to compete for a mate with another male. Moose calves (babies) are born in places predators will find challenging to reach, such as in thick bushes or on an island. The helpless calf stays with its mother until the next calf is born the following spring.

Did You Know?

For the gametes of some animals to arrive in the same place at the same time, both parents must be at that place at that time. In some cases the male gametes are placed directly inside the female's body. In other cases the male gametes are deposited near the female gametes. This is not always the case, however. For example male gametes from many trees can travel through the air on gusts of wind.

Figure 6.10 Moose are born in the spring, when food becomes easier to find. About a third of moose births are twins.

Water-dwelling mammals such as whales mate in the ocean. Sperm whales usually produce one offspring every two to five years (Figure 6.11 on the next page). The males call to attract a female. The size of their nose affects the call they can make, and so affects their success in attracting a mate. Sperm whales are so loud that their calls can be recorded several kilometres away.

Figure 6.11 Sperm whales mate in the spring, but birth occurs about 15 months after fertilization, so their young are born in the summer.

Word Connect

Sperm whales get their name from the oil they produce. When cooled, it forms seed-like, waxy crystals that were once used in cosmetics and lubricants. Spermaceti comes from the Greek words *sperma* (seed) and *cetus* (whale).

Methods of Fertilization

For sexually reproducing animals and plants, there are two ways for the union of sperm and egg cells to occur—through either external fertilization or internal fertilization.

Once the egg is fertilized, cell division will occur only if certain conditions are met.

- There must be enough nutrients for the rapidly dividing embryo.
- The temperature must be warm enough so that proteins and enzymes will function properly during chemical reactions in the developing embryo.
- There must be sufficient moisture so that the embryo does not dry out.
- The embryo must be protected from predators and from other environmental factors such as ultraviolet radiation. (You will learn more about human embryonic development in section 6.4.)

External fertilization

In external fertilization, a sperm cell and an egg cell unite outside the bodies of the parents. If a sperm cell comes in contact with an egg cell of the same species, fertilization may occur. External fertilization is common in animals that live in the water. Fish such as salmon use this method. The males and females release their gametes into the water in a process called spawning.

Gametes may not connect, so not every egg will be fertilized. As they develop outside of the female's body, fertilized eggs are not protected from predators or weather, and many will not survive these environmental conditions.

External fertilization for salmon takes place in the gravel beds of rivers and streams (Figure 6.12A). With sweeping movements of her tail, the female salmon digs out a gravel nest. The male swims by and releases his sperm as the female deposits her eggs. Both the male and female salmon die after spawning (Figure 6.12B).

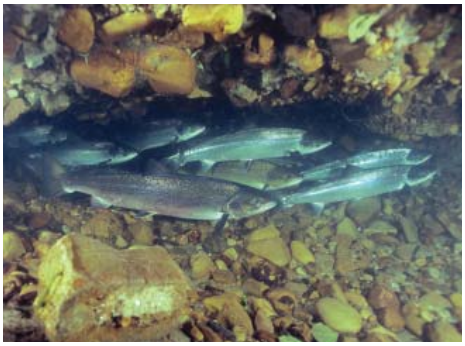


Figure 6.12A Atlantic salmon eggs are fertilized by sperm deposited in the gravel nests.

Figure 6.12B Soon after mating, adult salmon usually die.

External fertilization can also occur in plants such as mosses and ferns (Figure 6.13). Since many of these plants live in moist environments, water transports their gametes, enabling sperm cells and egg cells to meet.

Figure 6.13 Mosses live in moist environments necessary for their sexual reproduction phase.

Mosses do not have flowers or seeds, but in one part of their life cycle, mosses do reproduce sexually. The male and female sex organs develop on the end of the stems or branches of the plants (Figure 6.14 on the next page).

Fertilization cannot happen without water. Sperm cells produced by the moss either swim to egg cells across the damp ground or are splashed by raindrops into female parts of the plant. Fertilization results in a new plant that will mature and then reproduce asexually.

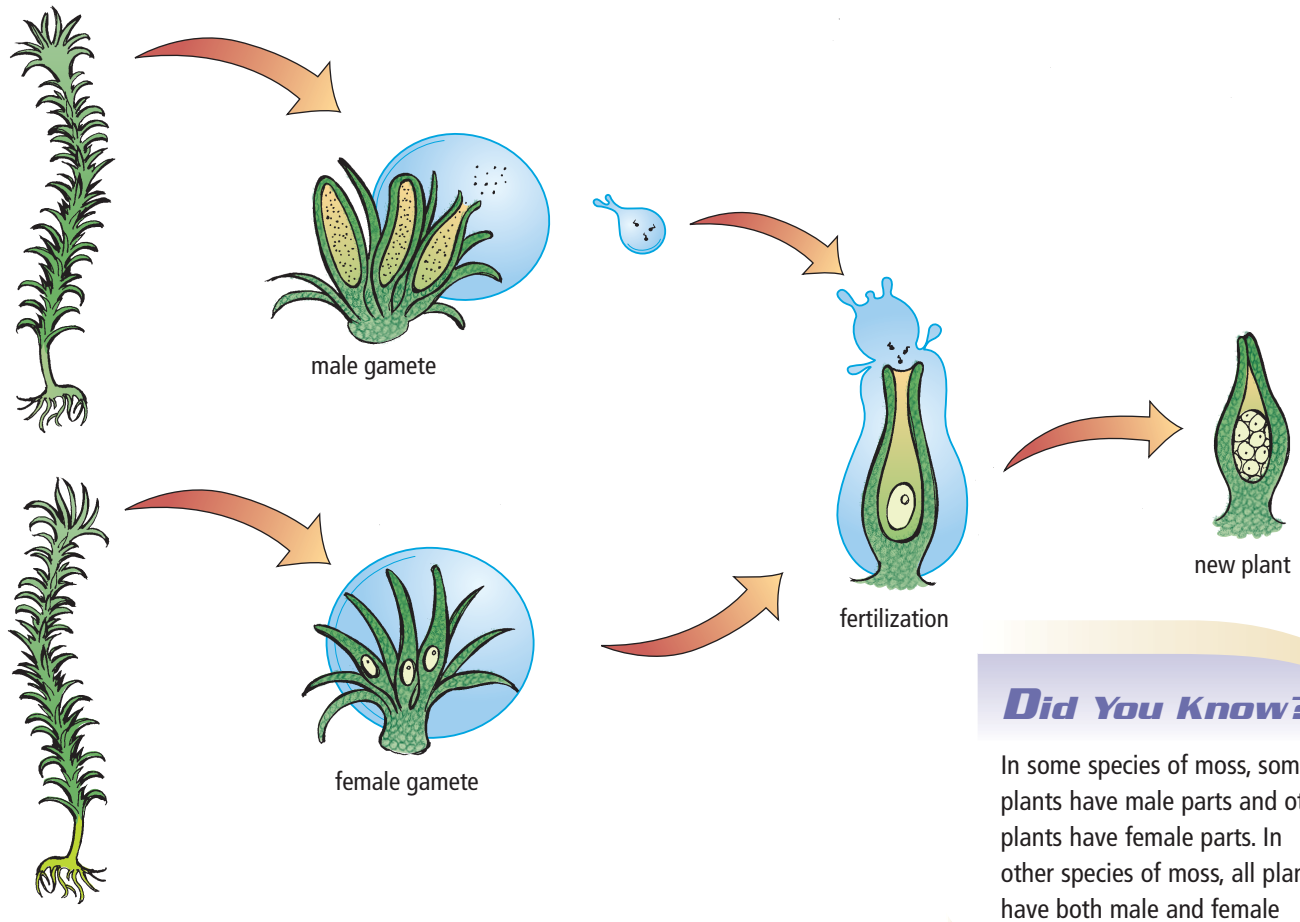


Figure 6.14 In one part of its life cycle, moss uses male and female gametes to reproduce sexually. Water helps the male gametes connect with female gametes for fertilization.

Did You Know?

In some species of moss, some plants have male parts and other plants have female parts. In other species of moss, all plants have both male and female parts.

External fertilization provides an advantage because very little energy is required to find a mate, and large numbers of offspring are produced at one time. The ability to produce many offspring at once means that some individuals of a population may survive to reproduce in the event of an environmental disaster, such as an oil spill that kills off most of the population. Since offspring are usually widely spread out, they do not compete with their parents for food. In addition, there is little chance that the egg from an offspring will be fertilized by the sperm of a parent, so genetic variation will be maintained.

There are, however, some disadvantages to external reproduction. Although millions of gametes are released, many will not survive outside the parents' bodies or meet to result in fertilization. Since zygotes and embryos form outside of the parents' bodies, they are unprotected and often preyed upon. In addition, since parents do not care for their offspring, few survive to adulthood.

Internal fertilization

Whales and most land-dwelling animals, such as moose and humans, reproduce by internal fertilization. In internal fertilization, sperm cells are deposited inside the female's body where they meet an egg cell. In humans, more than 100 million sperm cells are deposited at one time, but only about 100 sperm cells will meet a single human egg (Figure 6.15). Once a single sperm has penetrated an egg cell, the egg cell membrane changes its electrical charge, which produces chemical reactions that prevent any more sperm from entering the egg. A similar process occurs in all sexually reproducing animals, and all animals have a similar life cycle (Figure 6.16). As in external fertilization, preventing the entrance of more than one sperm ensures that only one set of male chromosomes can unite with chromosomes in the nucleus of the egg cell.

Figure 6.15 In internal fertilization, gametes meet inside the female's body. Only one sperm cell will fertilize the egg cell.

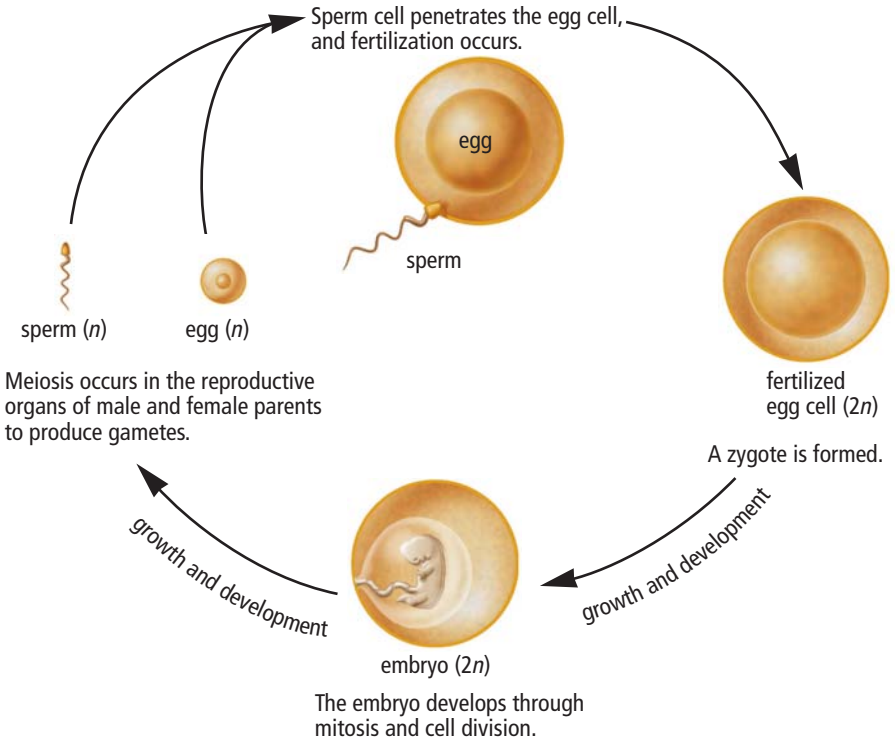


Figure 6.16 The life cycle of animals

In internal fertilization, the embryo develops and is nourished inside the mother's body for a period of time. This stage of internal development also means that the embryo is protected from predators.

After the offspring are born, most mammals continue to protect their young for months or years (Figure 6.17 on the next page). Animals that lay eggs, such as the mallard duck and the Atlantic puffin (Figure 6.18 on the next page), protect their eggs as the eggs develop outside the mother's body.

Figure 6.17 Black bear cubs learn from their mothers how to survive in the wild. Generally, cubs stay with their mothers for about a year and a half.

Figure 6.18 Both parent puffins take turns protecting their egg in a burrow on the rocky shoreline. They will continue to feed and protect the chick for at least a month and a half.

Figure 6.19 Male peacocks display their tail feathers and call out to attract females. Such mating behaviour uses a great deal of energy.

Internal fertilization provides an advantage because more offspring survive as a result of embryo protection and parental care. However, internal fertilization requires more energy to find a mate. Some animals, such as peacocks, have complex mating behaviours that require large amounts of energy (Figure 6.19). Internal fertilization also results in the production of fewer zygotes compared with external fertilization.

Pollination in flowering plants

In most plants, internal fertilization is achieved through a process called pollination. **Pollination** is the transfer of male gametes in structures called **pollen** (Figure 6.21 on the next page) from the male reproductive part of a plant to the female reproductive part of a plant. Pollen grains carry the sperm cells in a protective case to the ovules, which are the female plant structures that contain the egg cells. Figure 6.20 shows the main reproductive structures of a flowering plant. The reproductive organ of the male is the stamen. The reproductive organ of the female is the pistil.

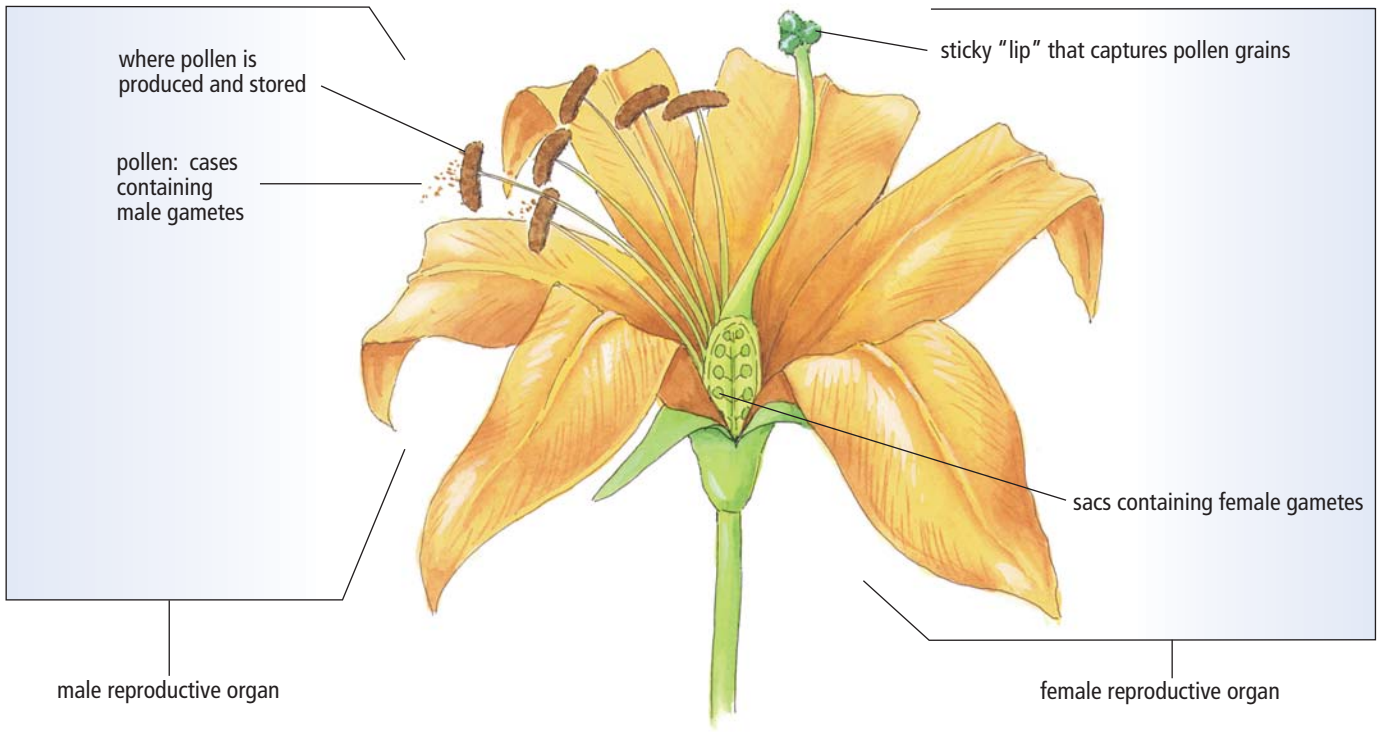


Figure 6.20 The reproductive structures of a flowering plant

After the pollen lands on the female part of the plant, one or more structures form to deliver the sperm cells to the egg cells. Following fertilization, a zygote grows into an embryo and is nourished by food stored within the seed in which the embryo grows. The seed's tough outer coating protects the developing embryo.

Figure 6.21 Pollen grains enlarged approximately 1900×

Pollen transport

Colourful flowers can attract bees and other insects that feed on plant sugars (nectar) and pollen. Bees collect pollen and nectar to feed themselves and their young. Special hairs on their hind legs and abdomen allow them to collect large amounts of pollen in pollen baskets. Since bees visit many flowers before returning to their hives or nests, they often transfer pollen between flowers of the same species (Figure 6.22). This activity is why bees are called pollinators. Other animals, such as fruit bats, can also pollinate flowers when they drink the nectar and eat the pollen of particular flowers. Bats are less attracted by the colour of the flowers, since they visit plants at night. Some researchers think that certain flowers visited by nectar-sipping bats may offer extra calcium, which would be helpful to female bats who are still feeding their young.

Figure 6.22 A honeybee gathers pollen from a blanket flower.

internet connect

Bees are attracted to flowers not only for their pollen and nectar. Bees can increase their body temperature by seeking out certain flowers that generate heat energy. To find out more about this relationship, go to **www.discoveringscience9.ca**

Suggested Activity

Find Out Activity 6-2A on page 191

Some flowering plants, such as willow and aspen, have flowers that do not have petals. Plants like these release their pollen into the air so that the wind can carry the pollen to the female reproductive parts of other flowers.

Genetic variation in flowering plants is maintained because seeds are often enclosed in a fruit (Figure 6.23) that can be transported away from the parent plant by animals who eat the fruit. Since many seeds have a tough outer coat, they are often not digested by animals. As a result, the embryo may survive, grow, and reproduce away from the parent. This process encourages diversity as the new plant reproduces with plants of different ancestry.

Figure 6.23 Bears love blueberries. The seeds remain undigested when eaten and may be deposited far from the parent plant.

Figure 6.24 The female cones of a black (bog) spruce tree are small and purplish. Pollen is released from the dark red male cones.

Plants such as black spruce trees do not have flowers. Instead, pollen is released from the male cones and is carried by the wind to the female cones (Figure 6.24). The embryo is protected within seeds in the female cone and completes its development there. The winged seeds that are eventually released are often transported by birds and small animals to new locations.

Since genes are reshuffled in meiosis during the production of egg and sperm cells, new black spruce trees may be resistant to disease or insect infestation. As a result, trees that survive with these favourable characteristics can pass them on to their offspring.

Reading Check

1. What is the name of the process that enables male and female gametes to meet in the same place at the same time?
2. Are mosses male or female? Explain.
3. How does the environment that mosses live in help them to reproduce?
4. What is pollination?
5. In flowering plants, what protects the developing embryo?

6-2A Predict a Pollinator

Find Out ACTIVITY

Flowering plants require pollination for sexual reproduction to occur. Since flowers differ in size, colour, and shape, depending on the species, they must be able to attract different types of pollinators. In this activity, you will predict what type of pollinator is needed for each flower shown in the photographs below.

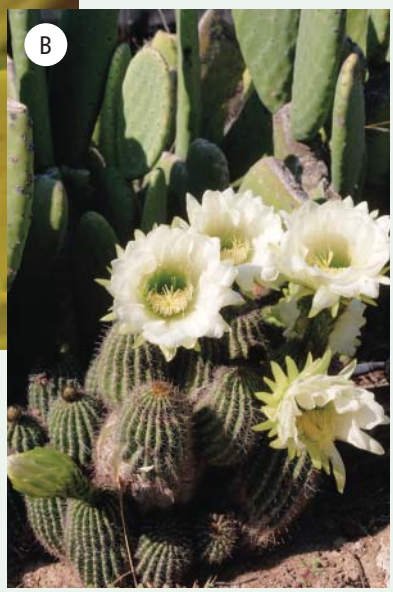
What to Do

1. Look at each of the photographs below and read the captions. Use this information to predict what type of pollinator is needed for each flower.
2. Record your predictions and explain why the predicted pollinator is suited to each flower.
3. Compare your predictions with those of another classmate.

What Did You Find Out?

1. What are some ways in which flowering plants attract pollinators?
2. Draw a flower that would be attractive to a specific pollinator. Use a different example from the examples given here.

Orchids offer a landing pad for their pollinators.



These white flowers are pollinated at night.

The flowers of these plants are not brightly coloured and do not have a strong odour.

Sexual Reproduction in Insects

Most insects reproduce sexually. Male and female gametes combine to produce a new individual. In many insects, such as grasshoppers and butterflies, the male deposits a package of sperm inside the female to fertilize the eggs. The female then deposits the fertilized eggs in a protected area under a leaf or in a burrow. Eggs develop and eventually hatch on their own, when conditions are right.

Insects often change drastically between hatching and adulthood. Sometimes the change is so dramatic and abrupt that it looks as though a new individual is created, but it is only a **metamorphosis**—a change in the individual's form. This change may be a complete alteration in structure and function, as when a caterpillar becomes a butterfly, or an incomplete alteration that allows the insect to grow larger and mature gradually. Sometimes metamorphosis also means a big change in habitat and behaviour, as when mosquito larvae leave the water and become the biting insects we are so familiar with.

Incomplete metamorphosis

Incomplete metamorphosis involves subtle changes through three life stages: egg, nymph, and adult. These changes are mostly to do with growing (Figure 6.25). The nymph (immature) phases look much like a smaller version of the adult. However, the nymph is usually wingless and unable to reproduce. Many insects have an exoskeleton—an external skeleton that supports and protects the body. This structure does not allow them to grow much.

Inside the insect, changes are happening as well. In the last metamorphosis, wings and the reproductive organs develop.

Word Connect

The term "exoskeleton" combines the Greek word exo, meaning outside, with the word "skeleton."

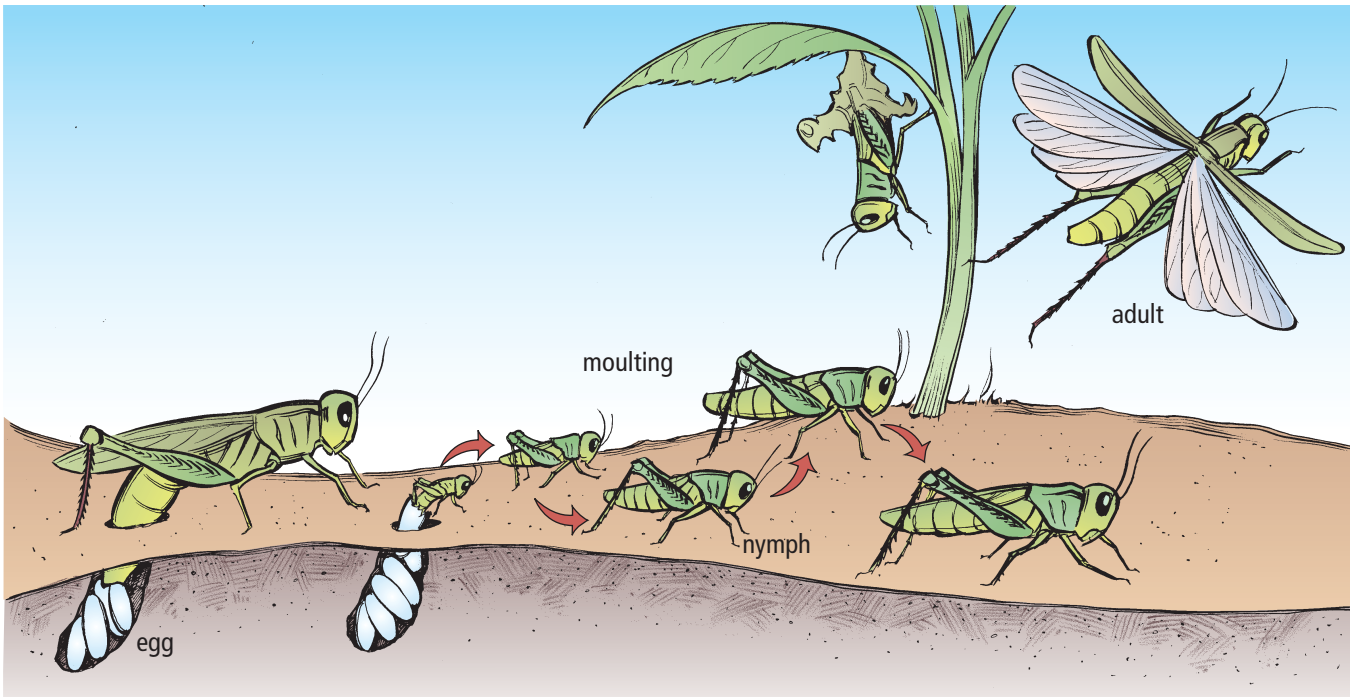


Figure 6.25 Grasshoppers are called nymphs through each phase of moulting until they reach adulthood and lay eggs.

Complete metamorphosis

Most insects undergo **complete metamorphosis** (Figure 6.26). The wingless, wormlike larva (called a grub or a caterpillar) is completely different from the adult. The larva's job is to eat and grow; it has simple eyes and a mouth designed for chewing. After several moultings during its growth, the larva becomes inactive. During this pupa stage, when the insect is often protected inside a cocoon, energy reserves are devoted to reorganizing organs and developing new adult structures such as wings and compound eyes. In the next moult, the adult crawls out of the cocoon and pumps blood through its wings until they are fully unfurled and the new exoskeleton hardens.

The adult's main job is to reproduce. In many species, the adult does not even eat. During mating, the male butterfly deposits sperm inside a female's reproductive system. Fertilization happens as the hundred or more eggs pass the sperm on their way to the nest.

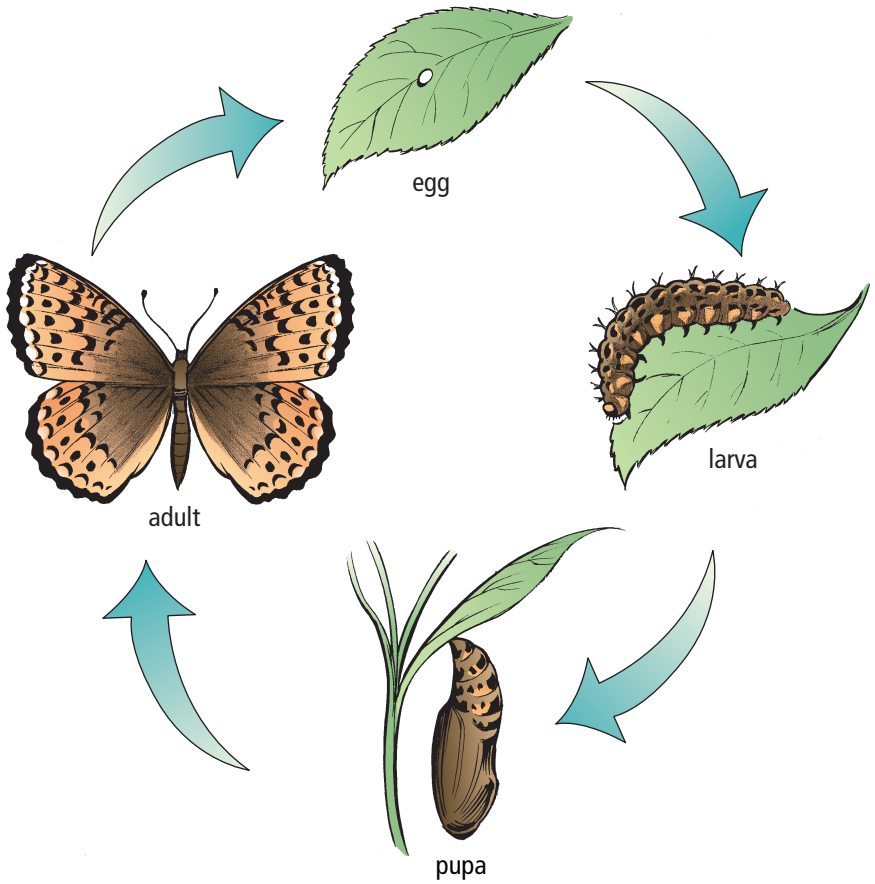


Figure 6.26 The four common stages of complete metamorphosis as seen in a butterfly

Explore More

In the summer of 2006, more than half the bee colonies throughout North America died. Evidence pointed to a virus causing this Colony Collapse Disorder (CCD). How might the reproductive process of bees have resulted in populations that were vulnerable to being wiped out by disease? Why might CCD be considered disastrous to the human food supply? Begin your research at **www.discoveringscience9.ca**.

Advantages and Disadvantages of Sexual Reproduction

In this section, you have read about how a variety of organisms reproduce sexually. Table 6.1 shows that sexual reproduction has both advantages and disadvantages for the organisms' survival.

Table 6.1 Advantages and Disadvantages of Sexual Reproduction

Advantages	Disadvantages
• Very little energy is required to find a mate (external fertilization).	• More energy is generally required to find a mate (internal fertilization).
• Greater numbers of offspring can repopulate an area after a disaster (external fertilization).	• Fewer offspring are produced, so if the number of predators increases, a population will decline (internal fertilization).
• More protection is given to the embryo and more parental care is given to offspring (internal fertilization).	• Gametes, embryos, and offspring are unprotected and are often preyed upon (external fertilization).
• Offspring are genetically different from their parents, so they may survive new diseases or other threats that appear in a population.	• Some beneficial traits may not be passed on from parents to offspring.

6-2B Comparing Sexual and Asexual Reproduction

Think About It

You have been studying asexual and sexual reproduction in various organisms. Now it is time to compare the advantages and disadvantages of these two types of reproduction.

What to Do

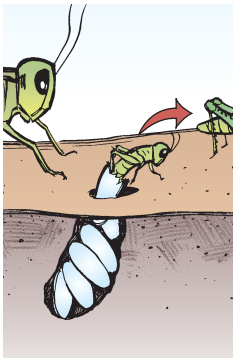
1. Working with a partner, locate and review the information in Table 5.1 on page 161 and in Table 6.1 on this page. You may also want to read the text in each section that appears before the tables.
2. Summarize each advantage and disadvantage in a few words and record each summary on a small piece of paper. In your summaries, include information about the number of parent cells, whether gametes are present, the types of organisms involved, the variation in offspring, the amount of energy required, and the amount of parental care required.
3. Organize all your summaries in a way that you believe best demonstrates your understanding of the advantages and disadvantages of asexual and sexual reproduction.
4. Working on your own, transfer your summaries into a graphic organizer of your choice. You may want to add pictures and additional information as needed. (For more ideas on graphic organizers, go to Science Skill 8.)
5. When you are finished, review a classmate's graphic organizer.
6. Add one more idea that you learned from your classmate's work to your own graphic organizer.

What Did You Find Out?

1. Imagine you had to list the advantages of asexual and sexual reproduction in order of importance. What do you think is the most important advantage for each type of reproduction?

Checking Concepts

1. What are two conditions that must be met for sexual reproduction to occur?
2. Name and briefly describe the three stages of sexual reproduction.
3. Mammals can mate on land or in water depending on the species. Describe an example of a mammal that mates in water.
4. Why is it important that only one sperm fertilizes an egg?
5. Why is water or water-containing fluid necessary for animals that reproduce sexually?
6. Describe one difference in how flowering plants and cone-bearing plants sexually reproduce.
7. Describe how moss reproduces sexually. Why is water important?
8. What is metamorphosis?



9. What are the three stages of incomplete metamorphosis?
10. List the following stages of butterfly metamorphosis in order.
    (a) egg
    (b) adult
    (c) pupa
    (d) larva

Understanding Key Ideas

11. Using a graphic organizer of your choice, compare sexual reproduction in flowering plants to sexual reproduction in insects.
12. In terms of the roles they play in reproduction, what is similar about eggs and seeds?
13. How do both a bee and the plant it visits benefit from pollination?
14. How do animals transport seeds to different locations?
15. What role does an exoskeleton play in the metamorphosis of many insects?
16. Does a grasshopper undergo complete metamorphosis or incomplete metamorphosis? What is the difference?
17. Copy and complete the following table comparing complete metamorphosis and incomplete metamorphosis.

	Complete Metamorphosis	Incomplete Metamorphosis
Number of parents		
Type of reproduction		
Number of stages in life cycle		
Habitat		

Pause and Reflect

Why does sexual reproduction provide more of an opportunity for genetic diversity in a species compared to asexual reproduction?

6.3 Human Reproductive Systems

The reproductive system is the only organ system in the body that differs between males and females. Male and female reproductive systems make the gametes necessary to make offspring. The human female's reproductive system also provides a space for fertilization and development of the embryo.

Key Terms

cervix
fetus
ovary
oviduct/fallopian tube
penis
reproductive system
scrotum
testes
urethra
uterus
vagina
vas deferens

Mammals reproduce by internal fertilization. This process requires both internal structures and external structures. The external structures provide the mechanism for connecting the gametes. The internal structures produce the gametes, and provide an environment for fertilization and for protecting the developing embryo. Eventually, these structures also provide the mechanism for the offspring to exit the mother's body.

Male Reproductive System

The purpose of the human male's reproductive system is to produce male gametes (sperm) and deliver them to the egg's environment for fertilization and development. The main structures in the human male's reproductive system (Figure 6.27) each perform a role in reproduction (Table 6.2).

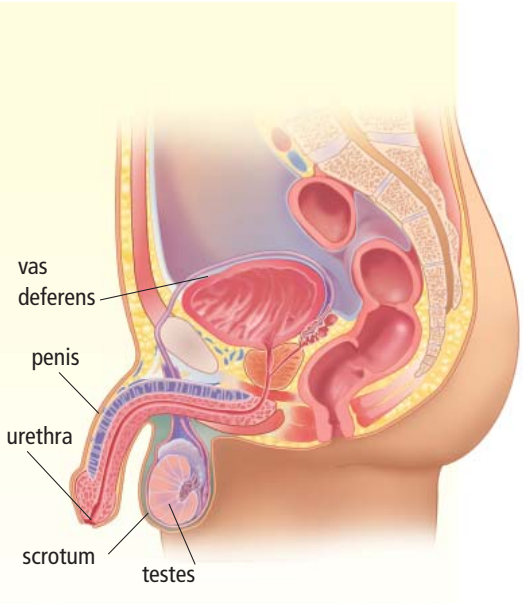


Figure 6.27 The human male's reproductive system is made up of structures inside and outside of the body.

Table 6.2 Function of Structures in the Male Reproductive System

Structure	Function
Testes	Produce sperm (male gametes) by meiosis and release hormones.
Scrotum	Protects the testes, maintaining them at a cooler temperature than the body core.
Vas deferens	Muscular tubes in which sperm mix with fluids to form semen as the sperm are moved from the testes to the urethra. Can house sperm for several months.
Urethra	Opening through which sperm leave the body.
Penis	Contains the urethra for delivery of sperm.

Female Reproductive System

The female mammal's reproductive system produces female gametes (eggs) and houses the developing embryo. The main structures in the human female's reproductive system (Figure 6.28) each perform a vital role in reproduction, fertilization, and embryo development (Table 6.3).

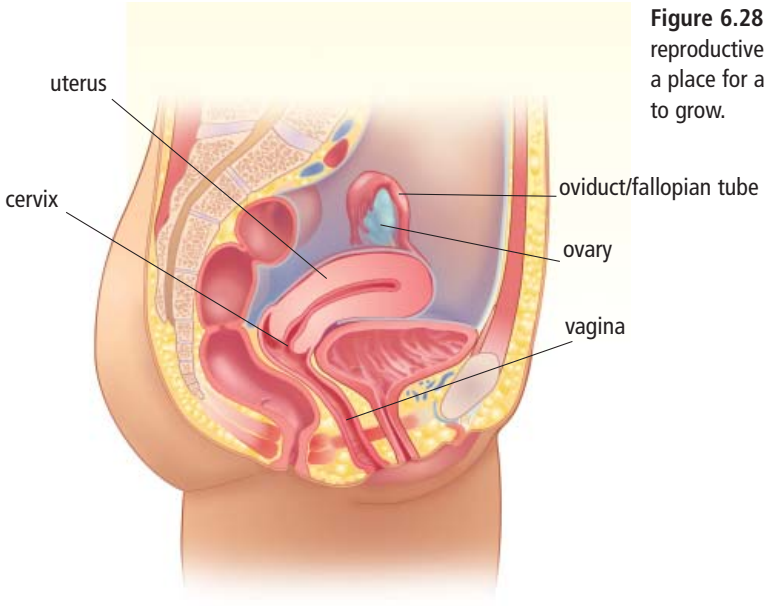


Figure 6.28 The female reproductive system provides a place for a fertilized egg to grow.

Did You Know?

In some mammals, sperm may stay in the oviducts for days until an egg is released. For one type of bat, fertilization can happen even months later. There is evidence that such a sperm reservoir exists in humans and that fertilization may occur up to five days after intercourse.

Table 6.3 Function of Structures in the Female Reproductive System

Structure	Function
Ovaries	Produce eggs (female gametes) by meiosis and release hormones.
Oviducts/ fallopian tubes	Location of fertilization. Connect the ovaries to the uterus, although the oviducts are not physically connected to the ovaries.
Uterus	Protects and nourishes the zygote during development. Connects the oviducts to the cervix.
Cervix	Sperm travel through this opening on the way to the uterus. Dilates (opens) to allow the baby to leave the body during childbirth.
Vagina	Sperm are deposited here, their first stop on the way to the egg. Opening through which the baby leaves the body, or through which unfertilized eggs leave the body.

Reading Check

1. What structures in the male and female reproductive systems produce gametes?
2. List the internal structures of the male reproductive system.
3. Where does fertilization take place?
4. In what male and female structures does meiosis occur?

Explore More

Scientists have been able to extract stem cells from the fluid that surrounds a developing embryo. Find out how this important discovery may help in the repair of tissues and the reproduction of organs for transplant. Begin your research at **www.discoveringscience9.ca**.

Suggested Activity

Find Out Activity 6-3A on page 202

Fetal Development

Human development begins with fertilization, forming a zygote by combining a sperm and an egg. The zygote begins dividing, first into two cells, then four, then eight, and so on, as it travels down the oviduct to the uterus—a journey that takes up to a week. Cell layers in the developing zygote will eventually form the organs and tissues of a human baby. This process called differentiation continues for a period of 38 weeks. Differentiation is often divided into three periods of time called trimesters. Each trimester is approximately three months long, and major developmental changes occur in each trimester.

First trimester: developing organ systems

During the first trimester, all the organ systems begin to develop and form. At four weeks, the brain and spinal cord are developing (Figure 6.29A). By eight weeks, bone cells are forming (Figure 6.29B), and the embryo is called a **fetus**. By 12 weeks in fetal development, the organ systems have formed (Figure 6.29C). On average, at the end of the first trimester, the fetus is about 28 g in mass and about 9 cm long.

Figure 6.29A The embryo at 4 weeks

Figure 6.29B The fetus at 8 weeks

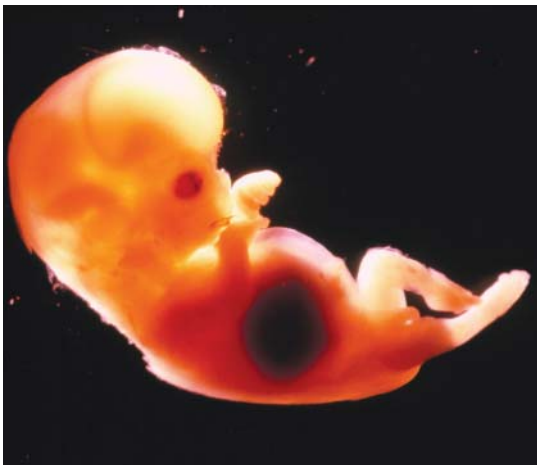


Figure 6.29C The fetus at 12 weeks

Second trimester: growth

The fetus grows rapidly from 12 weeks to 16 weeks (Figure 6.30 on the next page). Then growth slows between 20 weeks and 24 weeks. By 20 weeks, the mother can feel the fetus moving. By the end of the second trimester, the fetus weighs about 650 g and is 35 cm long.

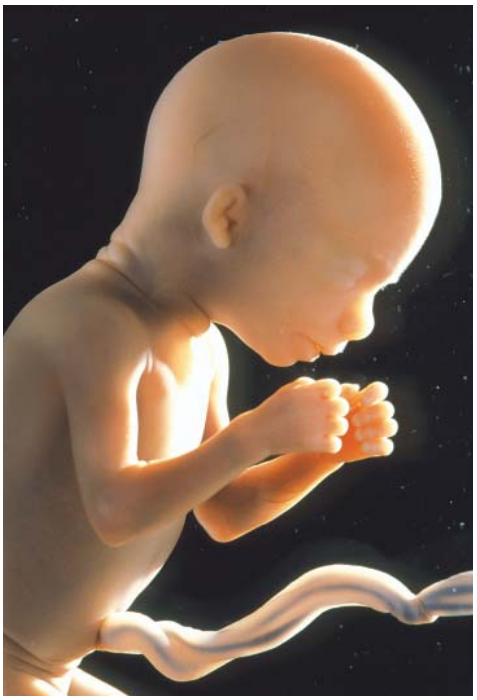


Figure 6.30 The fetus at 16 weeks

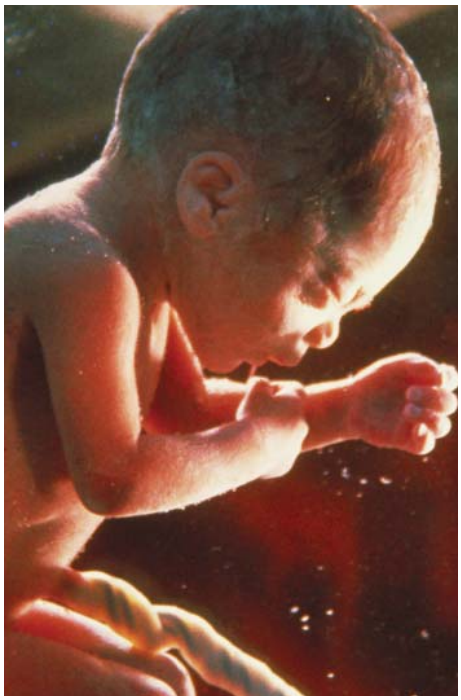


Figure 6.31 The fetus at eight to nine months

Third trimester: continued growth

In the third trimester, the fetus continues to grow in preparation for birth. This includes significant growth of the brain. By 32 weeks, or the eighth month, fat is deposited under the skin to help insulate and keep the baby warm after birth (Figure 6.31). At the end of the third trimester, the fetus weighs approximately 3300 g and is 40 to 50 cm long.

Table 6.4 summarizes some of the major events in fetal development.

Table 6.4 Main Events in Fetal Development

Trimester	Stage	Time from Fertilization	Length of Embryo/Fetus
First	• Brain and spinal cord are forming.	4 weeks	4 mm
	• Digits have appeared. Ears, kidneys, lungs, liver, and muscles are developing.	8 weeks	4 cm
	• Sexual differentiation almost complete.	12 weeks	9 cm
Second	• Fetal movements are felt.	16–18 weeks	20 cm
	• Eyelids open. Fetus can survive outside of the mother with specialized care.	24 weeks	35 cm
Third	• Rapid weight gain occurs due to the growth and accumulation of fat.	26–38 weeks	40–50 cm

internet connect

To follow the week-by-week development of an embryo and a fetus until birth, go to **www.discoveringscience9.ca**.

Did You Know?

As soon as the zygote implants in the uterus, hormones are released to prevent any more eggs from being released and to maintain the lining of the uterus to support the developing fetus. A simple urine test can detect this hormone and confirm pregnancy within days of a missed period.

Noticeable Signs of Pregnancy

How can you tell if a woman is pregnant? Changes in a woman's body are good clues. Some changes will only be known to the woman herself. Often, the first sign that a woman is pregnant are subtle physical changes that others may not notice (Figure 6.32).

Often the first sign that a woman is pregnant is that she will not menstruate. When a woman is not pregnant, the tissue and a small amount of blood that forms in her uterus is discharged every month. A pregnant woman's body will use this uterine tissue to protect and nourish the developing fetus.

A pregnant woman's hips will become slightly larger to support the developing fetus and prepare for the birth. Her breasts will also become larger to prepare to produce milk.

As the pregnancy progresses, others will likely notice signs of pregnancy. A woman will gain an average of 11 kg during pregnancy and her abdomen will bulge as the fetus grows.

Other signs of pregnancy are experienced by some women and not by others. Some women feel nauseated for several weeks or crave certain foods. Others find that they are exhausted or easily become dizzy.

Figure 6.32 Would it surprise you to learn that both of these women are pregnant? Some signs are easier to spot than others. Only a hormone test or ultrasound can tell you for sure.

Signs of Possible Pregnancy

- missed period(s)
- positive pregnancy test
- sore breasts
- widened hips
- enlarged breasts
- bulging belly
- nausea
- food cravings
- aversion to foods
- more frequent urination
- fatigue
- dizziness
- stronger sense of smell
- heartburn
- weight gain
- constipation
- mood swings
- higher body temperature
- cramping

Reading Check

1. When does a zygote become an embryo?
2. List the three major phases of fetal development.
3. When does mitosis begin?
4. What are three early signs of pregnancy?

Science Watch

Embryo Screening

As a result of embryo screening, this couple's baby will not develop Huntington disease.

Baby Roger started life in a laboratory dish, where eggs taken from his mother were fertilized by sperm from his father. Three days after fertilization, at the eight-cell stage, doctors removed a single cell from each of the fertilized eggs to conduct genetic tests. Roger's parents were concerned that Roger might carry the gene for Huntington disease, a fatal non-curable disease that appears in youth or middle age and affects the nervous system. One of Roger's parents carries the gene, and a grandparent and a great-grandparent had died because of the disease. Roger's parents were determined that the disease not be passed to future generations, so they chose to keep only the embryo without the gene for Huntington disease.

Embryo screening is currently used to identify genetic conditions such as cystic fibrosis, Tay-Sachs disease, Down syndrome, some inherited cancers such as forms of colon and breast cancer, and Huntington disease. In some countries, it is legal to screen embryos for the presence of these diseases, then implant only healthy embryos. Some couples use embryo screening purely for sex selection—for example, to test for the presence of the Y chromosome, which indicates that the embryo is a male.

Genetic screening is also used to tissue type embryos. If a sibling has a serious genetic condition that requires a perfect tissue match and no donor can be found, the umbilical cord or bone marrow from the selected baby can be used as a source of stem cells to treat the ill brother or sister. Controversy has arisen as couples with disorders such as gene-related deafness and dwarfism request selection for embryos carrying the defective genes in order to have children like themselves.

Embryo screening does not appear to harm the developing embryo, but the process is difficult and expensive. A slight possibility of making an error in screening still exists. Selection for particular traits such as eye colour is not currently occurring, but countries must continue to develop guidelines for genetic screening to guard against unethical choices.

Questions

1. List three reasons for embryo screening.
2. What are some ethical concerns about embryo screening?
3. Amniocentesis is a procedure in which fluid containing cells from the developing embryo is removed from the pregnant woman in the second trimester. The fluid is then examined for genetic abnormalities. What is the advantage of genetic screening over amniocentesis?

6-3A Comparing Differentiation in Embryos

Find Out ACTIVITY

Some animals have similar patterns of differentiation and development. In this activity, you will compare embryonic development in six embryos.

What to Do

1. Study the diagram below. The embryos are shown at three stages of embryonic development. Predict which series of embryos shows the development of a chicken, fish, human, rabbit, salamander, and tortoise.
2. List and describe three similarities and three differences in development among the embryos shown below.
3. Compare your findings with those of another group.

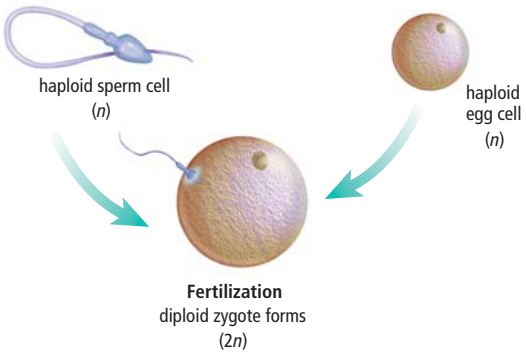
What Did You Find Out?

1. Were you able to predict which types of embryos are shown in the first stage of development? Explain.
2. At what stage of embryonic development does differentiation become most apparent?
3. Using the information you have learned in this chapter, explain why the organisms shown below appear to be similar in stage 1, but not in later stages of development.

Check Your Understanding

Checking Concepts

1. What human structures produce gametes?
2. (a) What is happening in the picture shown below?
   (b) What structures are involved?
   (c) Where does this process occur in humans?



3. Separate the following structures into male and female reproductive systems.
   (a) vagina
   (b) testes
   (c) scrotum
   (d) urethra
   (e) cervix
   (f) uterus
   (g) oviduct
   (h) vas deferens
   (i) ovary
   (j) penis
4. List the human female reproductive organs in order from the location of gamete formation to the exit of the fetus.
5. How does a zygote become an embryo?
6. Where does the human fetus develop?
7. In human fetal development, during which trimester do the major organs of the body develop?

Understanding Key Ideas

8. Which structures in the male and female human reproductive system do gametes travel through?
9. (a) Suggest five signs that this woman would notice to determine if she is pregnant.
   (b) How can she know for sure if she is pregnant?

10. List the four phases of human reproduction.
11. (a) What is one of the first structures to develop in a human fetus?
    (b) What are the last structures to develop in a human fetus?
12. Related to reproduction, what is the main function of each organ?
    (a) the testes
    (b) the vas deferens
    (c) the urethra

Pause and Reflect

Occasionally, a zygote does not implant in the uterus. Most often, this zygote does not continue to develop. Sometimes the embryo develops in an oviduct or outside of the reproductive system. Why can this type of pregnancy be life threatening for the mother and the fetus?

6.4 Studying Genetic Changes

Scientific understanding of genetics has changed greatly as new technology makes it possible to get a better look at genes. Each new discovery lays the foundation for future discoveries and for applications of the knowledge.

Key Terms

embryonic stem cell
genome
karyotype
stem cell
syndrome

The scientific understanding of genetics (the study of genes) has changed a lot, but the idea that traits are passed from parents to offspring has been around for at least 200 years. Farmers may have been the first to experiment with genes and reproduction, selecting seeds from the most successful plants. While this type of genetic selection may have been going on since the time of Egyptian kings, an understanding of the mechanisms is still pretty new.

The Changing Understanding of Genes

The agricultural revolution around 10 000 B.C.E. shows some of the first understanding of reproduction. Seeds were saved and cultivated into crops. It was in the mid-1800s that one of the most famous experiments began to show an understanding of the role genes play in reproduction. An Austrian priest named Gregor Mendel experimented with inherited traits in pea plants. Working with many generations of plants, Mendel's detailed notes and deliberate tests showed that traits were inherited from parent plants. He was even able to isolate the parts in the seeds that passed on specific traits such as colour and shape.

Still, there was not a clear understanding of what genes were until Francis Crick and James Watson, two scientists in Britain, described the structure of DNA in 1953. These scientists showed that DNA is an organization of genes into a double helix shape, like a twisted ladder. The specific pairing of bases on this "ladder" helped explain how a cell could make exact copies, as the two sides of the DNA came apart and each side acted as a template on which a new side formed.

The discovery of DNA is considered one of the most important discoveries of the 1900s (Figure 6.33). Like many discoveries, other scientists were drawing similar conclusions at the same time. Watson and Crick shared the Nobel prize for this discovery with another English scientist named Maurice Wilkins.

Did You Know?

A fourth scientist played a key role in uncovering the structure of DNA—chemist Rosalind Franklin. Because Franklin died before the Nobel prize was awarded, only Watson, Crick, and Wilkins received prizes for this discovery. Visit **www.discoveringscience9.ca** to learn more about Rosalind Franklin's work.

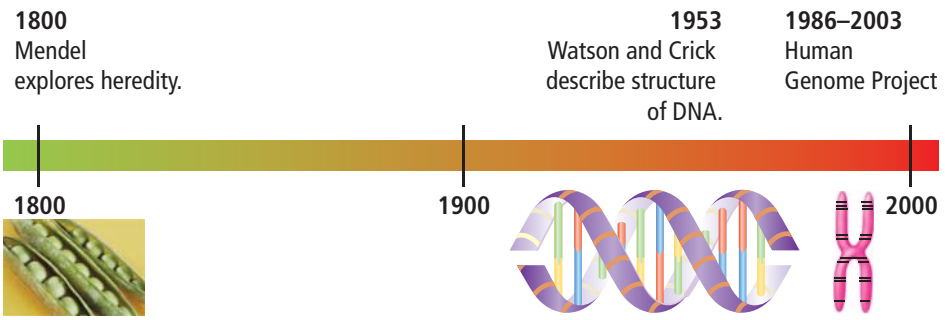


Figure 6.33 Each discovery lays the foundation for greater understanding of genes.

Current Understanding of Genes

You may have heard of the human genome project. Scientists around the world collaborated for about 20 years to identify every gene in the human DNA.

A **genome** consists of the full set of genetic material that makes up an organism. You saw in Section 4.1 that chromosomes are made up of genes (Figure 6.34). If chromosomes can be thought of as a train, you could say that the human genome project worked to locate and identify the function of each of the 25 000 gene "cars" on the 46 chromosome "trains" in human cells.

Though the project is finished, a lot of data remain to be analyzed. One of the big surprises was how few genes make up human cells. There are about one sixth the estimated number of genes that make up a human cell. Another surprise was how alike the genes of very different animals are. Mice, pigs, and humans have most of the same genes, though they are very different animals.

The human genome project made a sort of map that can be used to search for and identify particular genes. This information could be used to check whether the gene for a particular disease is present. Eventually, scientists may be able to alter or remove certain genes.

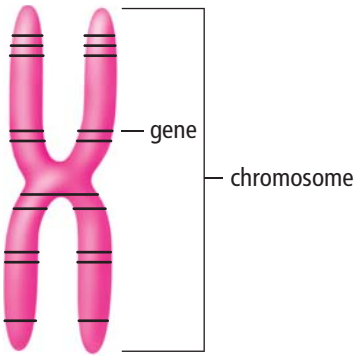


Figure 6.34 Genes are found on chromosomes and contain the instructions necessary to make proteins.

Allderdice syndrome

One genetic disease was discovered in the isolated community of Sandy Point, on the west coast of the island of Newfoundland. The community had become known for the high incidence of birth defects, which seemed to be inherited from parents. This high incidence of birth defects was believed to be due to Sandy Point's geographic isolation, resulting in little genetic diversity.

Scientists were able to determine that the group of symptoms was caused by a mutation of a single chromosome. Individuals with this seemingly small mutation have a low birth weight, hand and facial abnormalities, and psychomotor dysfunction (mental and physical challenges). The trait is passed from the mother. Each offspring of a mother with this syndrome has a 31% chance of inheriting the syndrome. Eventually this group of symptoms was named Allderdice syndrome, after Dr. Penny Allderdice, the scientist working at Memorial University who—in 1975—identified that people with this syndrome have part of one chromosome reversed.

Figure 6.35 Males and females have specific karyotypes.

Diagnosing Genetic Disorders

Figure 6.35 shows a picture of two teenagers. A geneticist can prepare a different type of picture of these individuals, one that shows all of their chromosomes arranged in a particular order. This picture is called a **karyotype** and is shown in Figure 6.36. Karyotypes are prepared by cutting and pasting chromosomes taken from body cells during mitosis. The homologous chromosomes are identified and paired by size, centromere location, and banding patterns.

Suggested Activity

Find Out Activity 6-4A on page 207

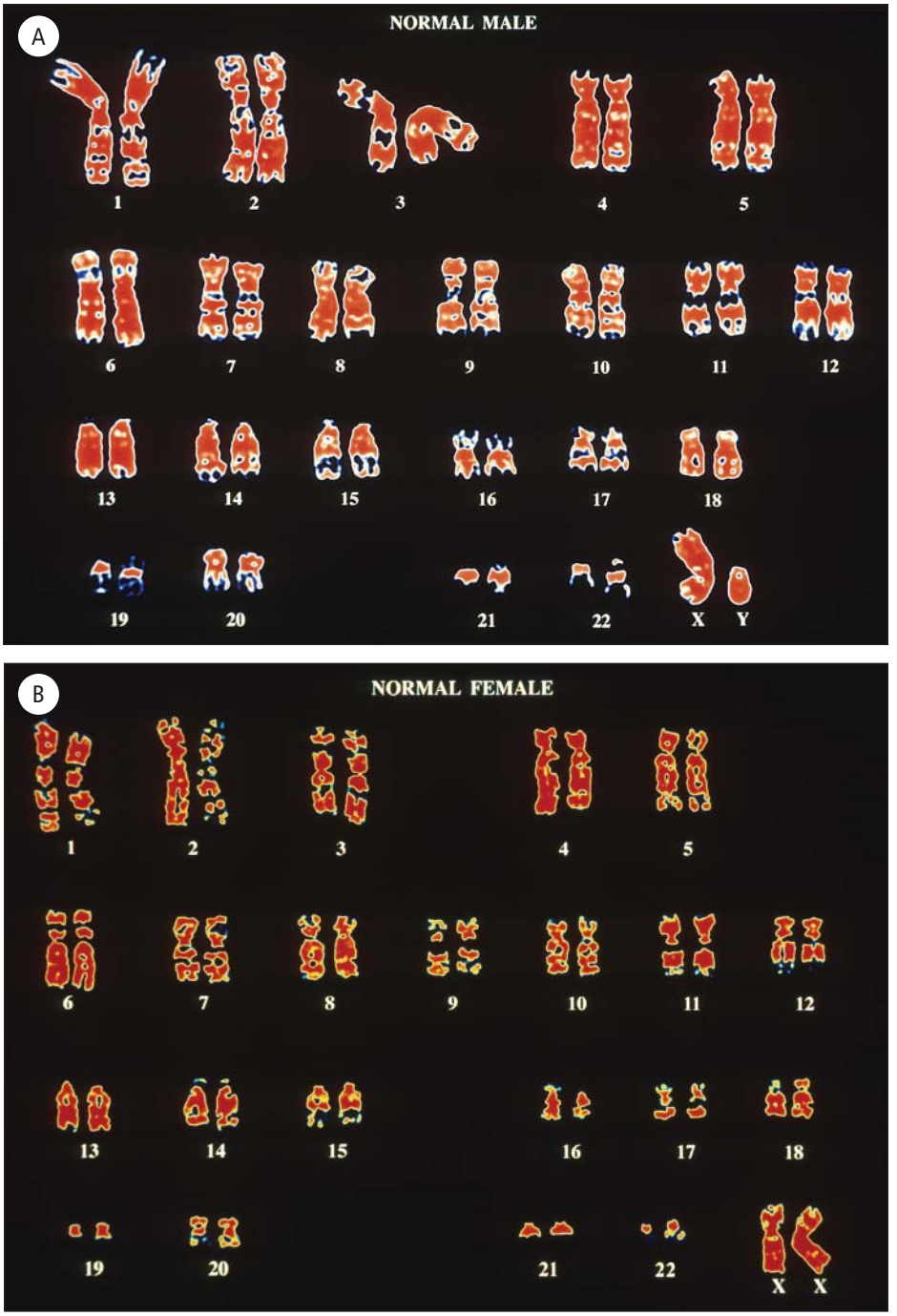


Figure 6.36 Karyotype of a normal male (A) and a normal female (B)

By analyzing karyotypes, geneticists can determine when a whole chromosome mutation has occurred. Understanding which chromosomes have been affected helps physicians diagnose and treat patients with genetic disorders or **syndromes**. A syndrome is a particular disease or disorder with a specific group of symptoms that occur together. One example is Down syndrome, which is one of the most frequently occurring types of chromosome mutations. Individuals with Down syndrome (Figure 6.37) have characteristic facial features and shorter stature and may be prone to developing heart defects and diseases such as Alzheimer's and leukemia. Ninety-five percent of the cases of Down syndrome are caused by an extra 21st chromosome (Figure 6.38).

Figure 6.37 People with Down syndrome are active participants in their communities.

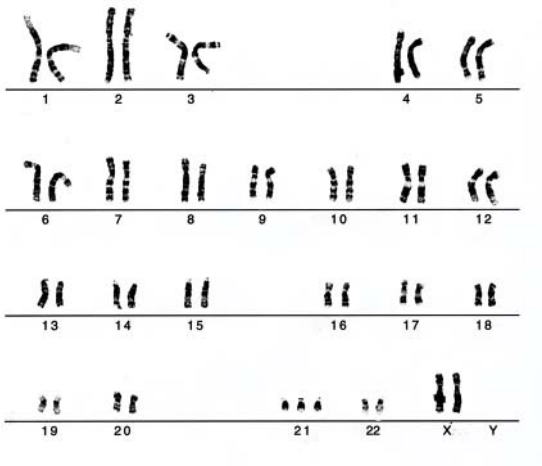


Figure 6.38 The karyotype of a person with Down syndrome

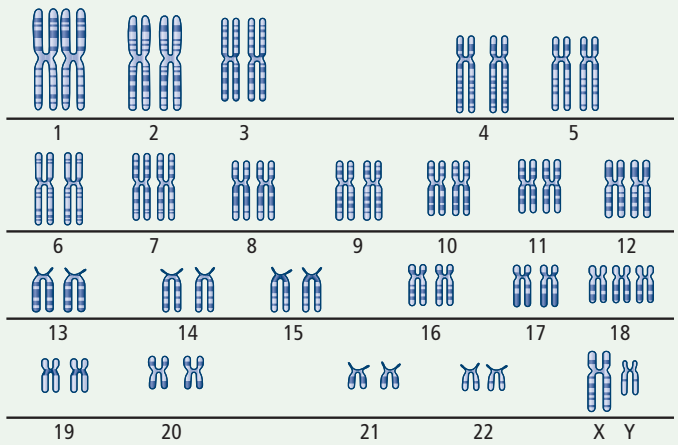
6-4A Analyzing a Karyotype

Find Out ACTIVITY

Geneticists study karyotypes to determine if any chromosome mutations have occurred. In this activity, you will analyze a karyotype of Edwards syndrome.

What to Do

1. Examine the karyotype of Edwards syndrome (right).
2. Count and record the total number of chromosomes and chromosome pairs.
3. Determine whether the individual is male or female.



What Did You Find Out?

1. What chromosome error did you identify?
2. (a) Would karyotyping identify a gene mutation?
   (b) Why or why not?

Human-assisted Cloning

You have learned that a number of asexual cloning methods occur in nature: binary fission, budding, fragmentation, vegetative reproduction, and spore production. In plants that reproduce asexually, each cell has the potential to grow into an identical plant. Because of this ability, researchers can clone plants from cuttings, as discussed earlier in this unit. Less complex animals such as sponges, hydras, and worms can clone themselves by asexual methods. Unlike less complex animals and plants, more complex, multicellular animals lose this cloning ability as their cells become specialized. In order for cloning to take place, human assistance is required.

Human-assisted plant and animal cloning can be used to save the genetic information from endangered animal species or to mass-produce an organism with a desired trait. For instance, in British Columbia, researchers are working to clone pine trees that are naturally resistant to the mountain pine beetle (Figure 6.39).

Explore More

Cloning can also be used to produce pigs whose organs are used for human transplants. Find out more about different types of cloning. Begin your research at **www.discoveringscience9.ca**.

Figure 6.39 Many forests of lodgepole pines have been killed by mountain pine beetles. Some trees have been able to produce enough sticky resin to keep the pest from boring deep inside the tree. Planting clones of these particular trees might stop the destruction of pine forests.

Reproductive cloning

Reproductive cloning is also called adult DNA cloning. The purpose of this type of cloning is to produce a genetic duplicate of an existing or previously existing organism with desirable qualities. For example, if you have a cow that produces a lot of milk, you might want to clone this particular animal. Since all the cow's cells have become specialized, you cannot turn just any body cell—say, a skin cell—into another individual. However, you could take the nucleus from the skin cell and put it into an egg cell that has had the nucleus removed.

The method used to clone Dolly, the world's most famous cloned sheep, transferred the nucleus from a mammary gland cell into an egg cell without a nucleus (Figure 6.40). The fused cell was then transplanted into a surrogate (substitute) mother, and Dolly was eventually born. A problem with this process is that only 10 percent of clones usually survive. Also, the surviving clones can be abnormally large and have higher rates of infection and cancer. Dolly lived for only six years, dying of a lung disease common in sheep. Before her death, she appeared to be aging faster than sheep usually do.

internet connect

Try simulating the cloning process yourself by going to **www.discoveringscience9.ca**

Therapeutic cloning

Therapeutic cloning is used to correct health problems. ("Therapeutic" means to have healing ability.) Both human embryonic stem cells and adult stem cells can be used for this purpose. **Stem cells** are cells that have the potential to become many different types of cells. **Embryonic stem cells** are more desirable for therapeutic cloning because they can become any one of our 200 types of body cells.

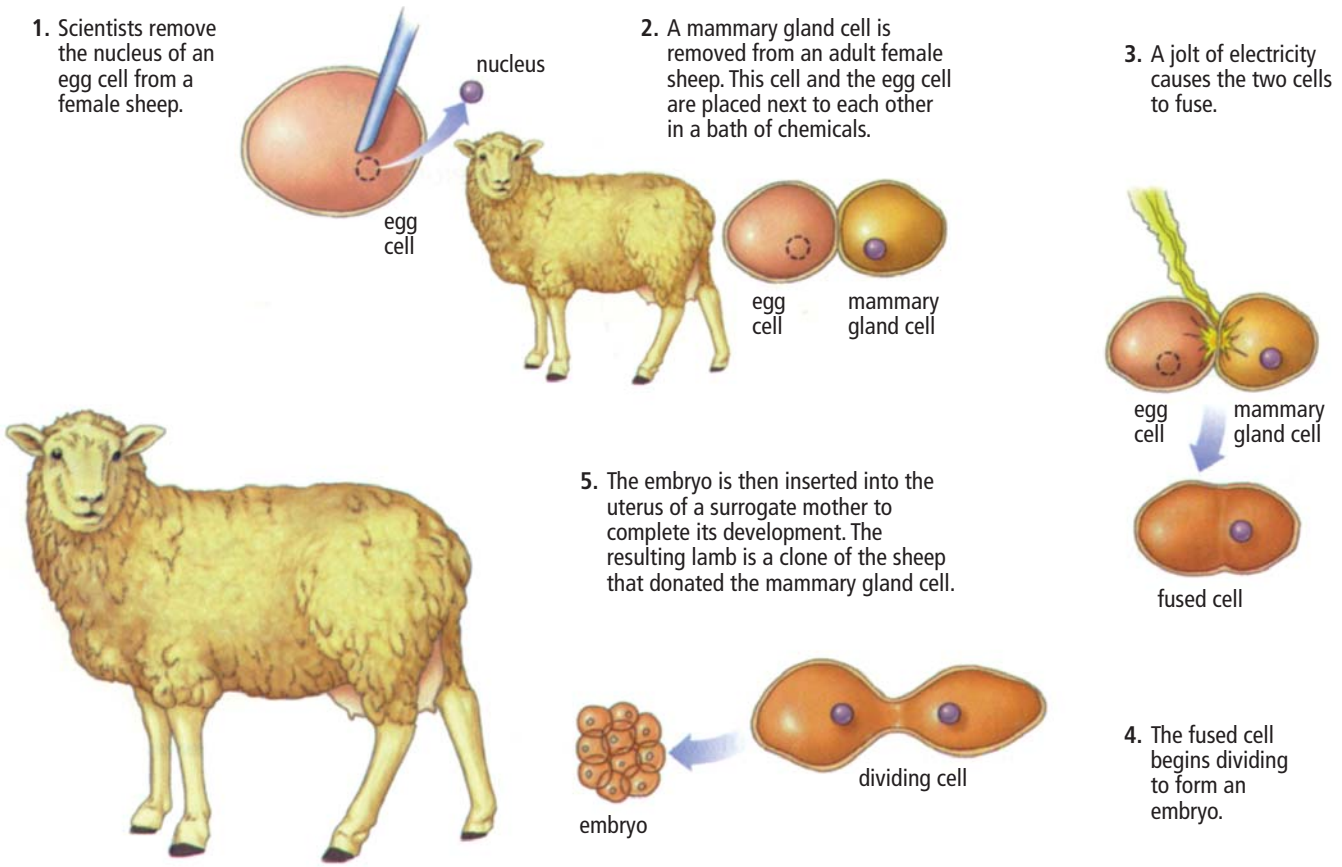


Figure 6.40 The reproductive cloning process

Career Connect

Dr. Terry-Lynn Young

When Dr. Terry-Lynn Young and other Memorial University researchers identified the gene responsible for a condition that causes the sudden death of young men, they solved a puzzle that will help many families. For generations, people in families affected by a condition called arrhythmogenic right ventricular cardiomyopathy (ARVC) have had to live with the knowledge that many of the men in their families face sudden death at a young age due to heart failure. Only about half of the men in affected families live to be 40 years of age. ARVC is prevalent in Newfoundland and Labrador.

Q. Why did you decide you wanted to try to identify the gene responsible for ARVC?

A. ARVC is a genetic condition that has affected the lives of many families in Newfoundland and Labrador and continues to do so. We hypothesized that the disease was probably caused by a mutation in a single gene. If we could locate the gene, we would find a mutation in it.

Q. What did you have to do to identify the gene?

A. Since we thought it was a mutation in a single gene, we took blood samples, extracted the DNA from the blood from everyone who was affected by ARVC and everyone who was not, and compared their genomes. We found that all those who were affected shared the same chromosome 3. When we sequenced genes on chromosome 3, we found that one gene, TMEM43, had a mutation on it. Everyone who had heart failure or who died in these families had the same mutation in TMEM43. However, we did not see the mutation in the other people. Then we knew we had the gene.

Q. What is the benefit of knowing the gene responsible for ARVC?

A. If we know who has the mutation, then we know who is at high risk of heart failure and sudden cardiac death. Once we know this, people with the mutation can have a life-saving device implanted in their chest that will shock their heart back to a regular rhythm if it becomes arrhythmic, and save their life. For family members who were lucky and did not inherit the mutated gene, we can spare them frequent trips to the hospital for heart checkups and also let them know that their children will not inherit the "bad" gene.

Q. What would you like people to know about studying genetics?

A. It is like being an investigator of a crime; you have to be very patient and gather a lot of evidence. This takes time. Sometimes you cannot figure it out. So, it is really important not to give up when the going gets tough. It may be time to try something new; review your hypotheses at each step. You have to be highly critical of your own work and ideas to be successful. Just because you think it is so does not mean it is so. You must keep an open mind and be constantly learning new things.

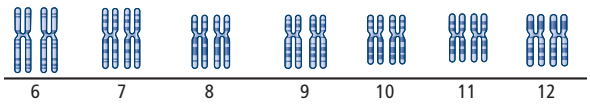
Questions

1. What is ARVC?
2. How was the gene responsible for ARVC identified?
3. How is a genetic researcher similar to a crime investigator?

Check Your Understanding

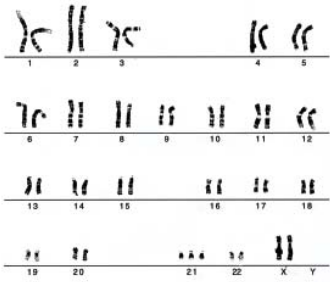
Checking Concepts

1. What are two possible causes of genetic disorders?
2. Give an example of a genetic disorder.
3. What is a genome?
4. What do genes do?
5. How is Allderdice syndrome linked to genes?
6. What is the relationship between genes and chromosomes?
7. What is the difference between a karyotype and a genome?
8. What structures are shown in this section of karyotype?



Understanding Key Ideas

9. Put the following ideas in order of their discovery.
   (a) 26 000 genes make up human cells.
   (b) DNA has a double helix shape.
   (c) Genes pass traits from parent to offspring.
   (d) Genes can be identified.
10. What stage of the cell cycle would be best to use for karyotyping? Explain.
11. How might karyotyping help people with genetic disorders?
12. How could geographic isolation lead to a higher incidence of a genetic disorder?
13. How do genes account for the huge variation among individuals?
14. Clones are produced artificially. Is clone production more like sexual reproduction or asexual reproduction? Explain.
15. How did Mendel, Watson and Crick, and the genome project contribute to the current understanding of genetics?
16. What is similar about the causes of Down syndrome and Allderdice syndrome?
17. What genetic disorder is shown in this karyotype? Explain how you know.



Pause and Reflect

Long before there was an understanding of genetics or DNA, farmers showed that they could improve production by mating the most successful plants or animals. Today, beneficial genes from the cells of one plant or animal can be inserted into the cell of a completely different plant or animal. Explain how both of these methods could be considered genetic modifications.

Prepare Your Own Summary

In this chapter, you investigated meiosis as the basis of sexual reproduction. Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 8 for help with using graphic organizers.) Use the following headings to organize your notes.

1. Meiosis
2. Genetic Variation
3. Sexual Reproduction in Mosses, Flowering Plants, and Insects
4. Changing Understanding of Genetics
5. Human Reproduction and Embryonic Development

Checking Concepts

1. Why is meiosis necessary for multicellular organisms?
2. Compare meiosis II to mitosis.
3. How do cells at the beginning of meiosis compare to the cells at the end of meiosis?
4. Describe two events that produce genetic variation in organisms.
5. With your knowledge of meiosis, explain why you do not look identical to your parents or to your brothers, sisters, or cousins.
6. How can a karyotype be useful to geneticists?
7. Identify the syndrome associated with an extra copy of the 21st chromosome.
8. Create a concept map using the following terms: embryo, fertilization, gamete, and zygote.
9. State whether each of the following sentences is related to sexual reproduction in mosses, flowering plants, insects, or humans.
   (a) Between the beginning and the end of an organism's life, it may undergo changes so great that it looks like a new organism.
   (b) Water brings male and female gametes together.
   (c) The fertilized egg develops for nine months inside one of its parents.
   (d) Wind can carry male gametes to female gametes.
10. The following table provides information about the growth of the human embryo and fetus during the three trimesters. Create a line graph to show the growth rate during this time by drawing a line to join all of the points.
    (a) Identify where the growth rate of the embryo or the fetus is the fastest.
    (b) Identify where the growth rate of the embryo or the fetus is the slowest.
    (c) How did you know which were the fastest and slowest periods of growth?

Growth of an Embryo and a Fetus

Trimester	Time after Fertilization	Size
First trimester	3 weeks	3 mm
	4 weeks	4 mm
	6 weeks	12 mm
	7 weeks	2 cm
	8 weeks	4 cm
	9 weeks	5 cm
	3 months	9 cm
Second trimester	4 months	15 cm
	5 months	25 cm
	6 months	35 cm
Third trimester	7 months	35 cm
	8 months	40 cm
	9 months	50 cm

Understanding Key Ideas

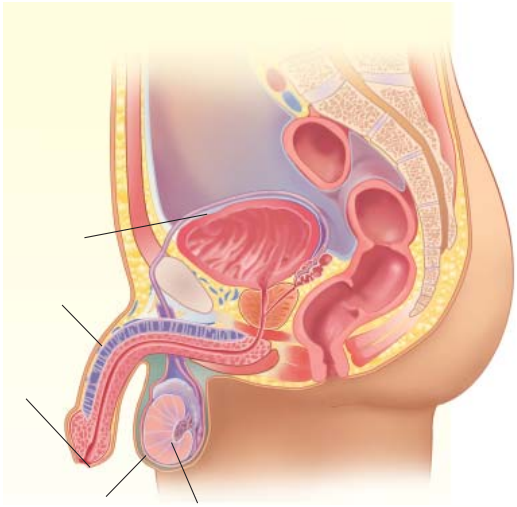
11. What is the purpose of fertilization?

12. Why do mosses need to live in moist environments?

13. Explain how a single fertilized egg grows into a multicellular embryo.

14. Collecting pollen from a crime scene can provide evidence as valuable as fingerprints, DNA, hair, or clothing fibres. From your understanding of meiosis and sexual reproduction, explain how pollen can be used to solve crimes.

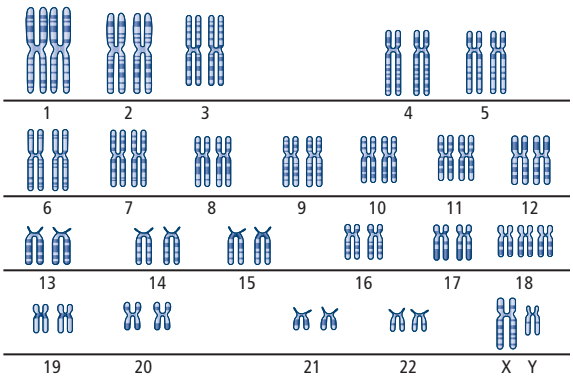
15. Study the illustration below.



(a) Name the organ system.
(b) Identify the structures shown.
(c) In which structure are gametes formed?

16. Rate asexual reproduction and sexual reproduction in terms of the amount of each of the following:
(a) energy required
(b) parental care
(c) genetic variety in offspring

17. Study the picture below. Describe what type of analysis a researcher could conduct using these data.



18. What role does metamorphosis play in reproduction?

Pause and Reflect

Asexual reproduction produces little diversity in a population. Sexual reproduction results in a lot of diversity due to the shuffling of genes in meiosis and the random meeting of an egg cell and a sperm cell. When, over time, a sea urchin becomes less and less like other sea urchins in a population, it may no longer be able to mate with sea urchins of that population. If other sea urchins change in the same way that this first sea urchin did, and if these changed sea urchins are able to mate and have fertile offspring, they may be considered a new species. Predict whether a new species of sea urchin is more likely to appear in a large population of sea urchins or in a small population. Draw a diagram to explain your prediction.

Unit Summary

4 The nucleus controls the functions of life.

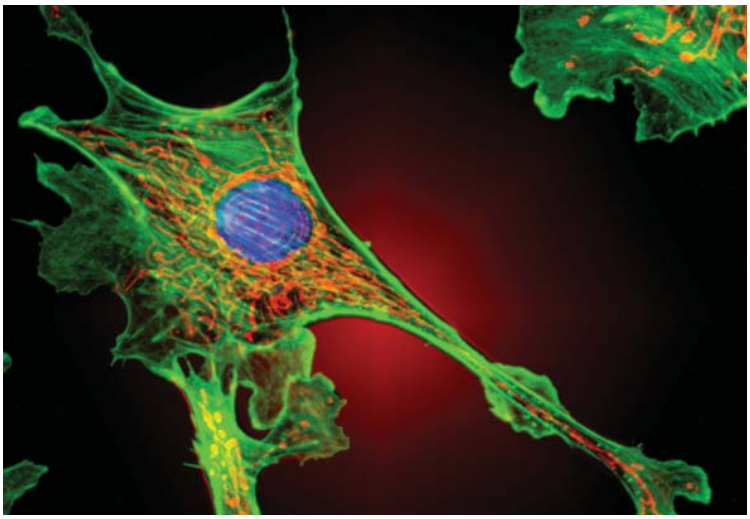
- Chromosomes found within the nucleus contain the genes that store the information to make proteins. (4.1)
- Genetic information determines the traits that are passed on from parents to offspring. (4.1)
- Proteins control the activities of cells. (4.1)
- A gene mutation is a change in the information stored in the nucleus. (4.2)
- Gene mutations can have a positive, negative, or neutral effect on the individual. (4.2)
- Mutations can occur when DNA is being replicated, or they can be caused by mutagens. (4.2)
- Mutagens can be produced in nature or by human activity. (4.2)
- Gene therapy attempts to correct gene mutations. (4.2)

5 Mitosis is the basis of asexual reproduction.

- There are three stages to the cell cycle: interphase, mitosis, and cytokinesis. (5.1)
- There are four phases to mitosis: prophase, metaphase, anaphase, and telophase. (5.1)
- Checkpoint proteins instruct the nucleus whether or not to proceed through the cell cycle. (5.1)
- An error in a checkpoint protein can cause diseases such as cancer, which is uncontrolled cell division. (5.1)
- Asexual reproduction requires only one parent, and the resulting offspring are genetically identical to the parent. (5.2)
- Types of asexual reproduction include binary fission, budding, fragmentation, vegetative reproduction, and spore formation. (5.2)
- Asexual reproduction can produce large numbers of offspring with a relatively low input of energy, but these offspring do not have the genetic variability to withstand drastic changes in their environment. (5.2)

6 Meiosis is the basis of sexual reproduction.

- Meiosis produces gametes with half the number of chromosomes as body cells. (6.1)
- The process of meiosis creates variation in organisms because genetic information is shuffled during meiosis I. (6.1)
- The three stages of sexual reproduction are mating, fertilization, and development. (6.2)
- For sexually reproducing plants and animals, a sperm cell and an egg cell may meet either by internal or external fertilization. (6.2)
- The early development of an organism takes place during a stage called embryonic development. (6.2)
- The reproductive systems are the only structural differences between males and females. (6.3)
- The understanding of genetics continues to grow, building with each new discovery and as new tools become available. (6.4)
- Genetic variations can be advantageous, neutral, or detrimental, such as with Down and Allderdice syndromes. (6.4)



Key Terms

- chromosome
- DNA (deoxyribonucleic acid)
- gene
- gene mutation
- heredity
- mutagen
- nucleus
- trait

Key Terms

- asexual reproduction
- binary fission
- budding
- cell cycle
- cytokinesis
- interphase
- fragmentation
- mitosis
- replication
- spore
- vegetative reproduction

Key Terms

- cervix
- complete metamorphosis
- embryo
- fertilization
- fetus
- gametes
- genetic diversity
- genome
- incomplete metamorphosis
- karyotype
- meiosis
- metamorphosis
- ovary
- oviduct/fallopian tube
- ovules
- penis
- pollen
- pollination
- reproductive system
- scrotum
- sexual reproduction
- stem cell
- syndrome
- testes
- urethra
- uterus
- vagina
- vas deferens
- zygote

Making a Decision for Genetown

You have been asked to attend a town council meeting in Genetown, Newfoundland and Labrador. Genetown is a small community just outside of a mid-sized Newfoundland-and-Labrador city. The nearby city has a rapidly expanding university with a well-respected biomedicine department. A biotechnology company called Stem Cells Now wants to build a $150 million research facility on the edge of town. The company is based overseas. The federal government has recently approved the company's proposal, but the location is still to be determined. Stem Cells Now wants to conduct research on human embryos in hopes of curing diseases and treating injuries.

Problem

Genetown's town council is holding a public meeting to decide whether Stem Cells Now is welcome in this community. You have an interest in the building of this facility in Genetown, and you have been invited to voice your opinion on whether Stem Cells Now should be allowed to proceed. Genetown's council members are depending on your knowledge and input to help them make their decision.

Criteria

- You will be given three minutes to state your point of view and convince the town council that your position is valid.
- Your position and perspective on the decision should be clear to the audience.
- You should present at least three strong arguments for your opinion.
- Your argument should be well researched.
- You should appear serious in your intent.

Procedure

1. Choose your role randomly from an envelope. Your teacher will give you a list of all the roles and may give you the opportunity to swap roles.
2. Record your name and the number of your role on the list of speakers to confirm your attendance at the meeting.
3. Research your role and issue. Begin your search at **www.discoveringscience9.ca**. When researching on the Internet, use key words such as "stem cells" and "diabetes" to help narrow your search.
4. Prepare your three-minute presentation. Use Science Skill 3: How to Do a Research-Based Project to help you make a decision about what information to include in your presentation.
5. Think about how you should dress for the role you are playing on the day of the presentation. Small props may be used to make your presentation more effective.
6. Practise your presentation. Try not to read from a script. Practise looking directly at your audience because eye contact is important.

Report Out

The mayor of Genetown will conduct the council meeting and call on the speakers to present their arguments. Following all of the presentations, town council members will meet with the mayor to make a decision about whether or not Stem Cells Now can build its facility. With the announcement of the decision, each council member will present arguments for the final decision of the council.

Just Because We Can, Does It Mean We Should?

As our understanding of the activity inside the nucleus grows, researchers are learning more about how and when cells divide. Geneticists are finding ways to change information in genes and move these messages to new locations. These advances in reproductive technology have an impact not only on the individual but also on society. In this research investigation, you will use print and electronic sources to research a reproductive technology issue.

Background

The Canadian government has made laws on reproductive technologies to ensure that research conducted in Canada represents the interests of Canadian citizens. The government recognizes that there are benefits and consequences related to the use of these technologies. The future of scientific research in Canada and around the world will depend on decisions by government lawmakers. As future voters, it is important that you become familiar with issues about reproductive technologies, as you have the power to shape the 21st century.

Find Out More

Choose a topic from the following list. You will need to become an expert on this topic to prepare for a debate or multimedia presentation of your research. Begin your research at **www.discoveringscience9.ca**, and use print sources such as magazines and newspapers. You may wish to contact your local member of Parliament for further information.

1. Should we donate frozen embryos left over from in vitro fertilization to science?
2. Should we patent genetic material?
3. Should we have the right to know the results of genetic testing?
4. Should we be able to select the traits to make a perfect baby?
5. Should we clone extinct species?
6. Should we be able to select against embryos carrying genetic diseases?
7. Should medical researchers be allowed to combine the genomes of two different species?
8. Should we clone humans?
9. Should individuals be allowed to buy or sell embryos, sperm, and eggs?
10. Should sperm donors be paid?

Report Out

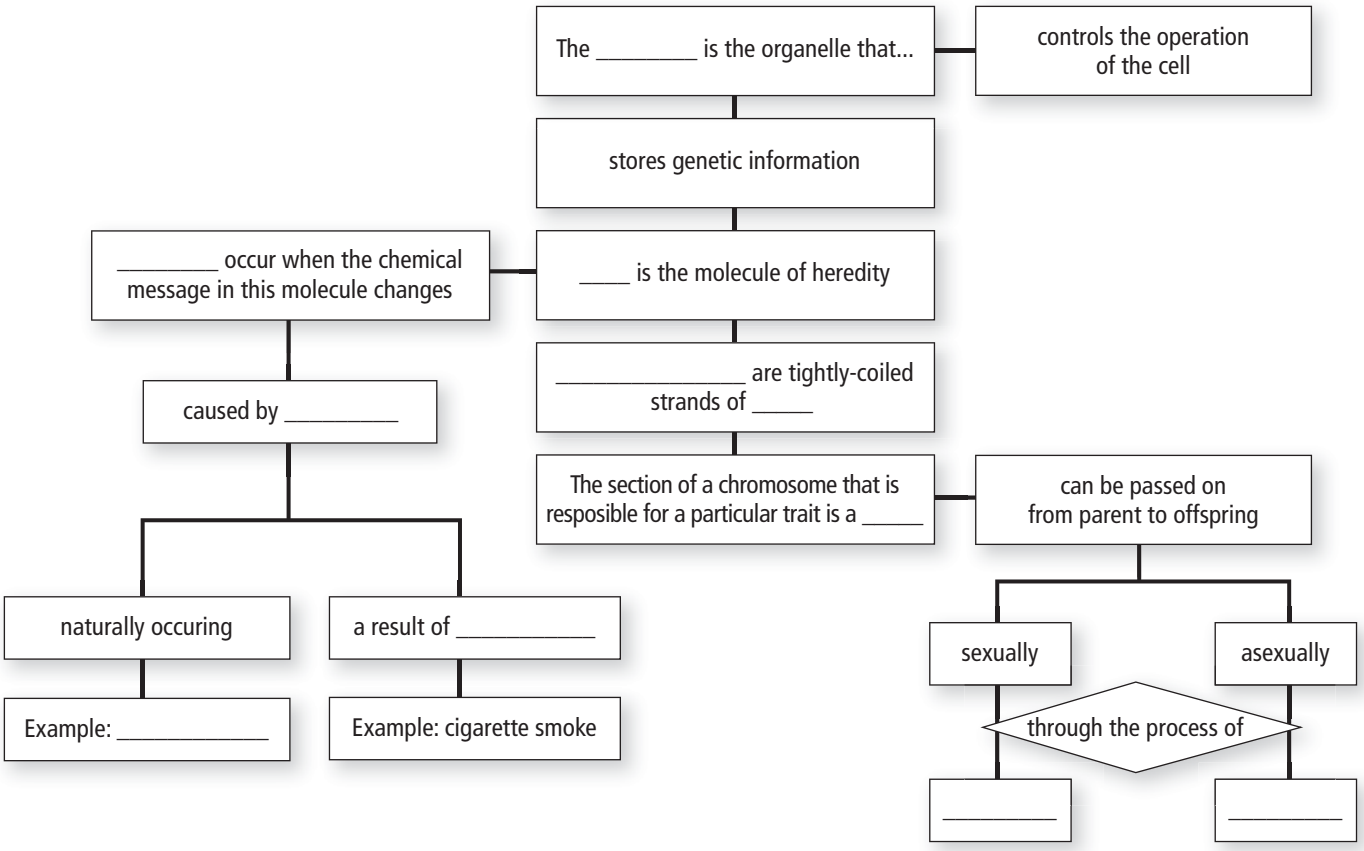
After you have thoroughly researched your topic, present either positive or negative arguments for the issue in a debate or multimedia presentation. Your presentation should be interesting and well rehearsed to make your argument convincing. Record all the source information for any graphics, facts, and quotations you have used.

Visualizing Key Ideas

1. Copy the following concept map into your notebook. Fill in as many terms as you can without looking in your textbook. After you have completed the map, go back through the unit to check your work. Fill in any missing terms using a different colour of pen.

Using Key Terms

2. For each of the lists of terms below, create a meaningful sentence that uses, and shows your understanding of, all three terms.
   (a) genes, chromosomes, traits
   (b) binary fission, budding, mitosis
   (c) cell cycle, DNA, replication
   (d) embryonic development, fertilization, gamete
   (e) embryo, stem cell, therapeutic cloning



Checking Concepts

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3. Why is the nucleus sometimes called the control centre of the cell?
4. How is information stored in the nucleus?
5. What is a chromosome?
6. How many chromosomes does a human cell contain when it is ready to divide?
7. Why are genes important to the functioning of a cell?
8. Each of the following terms is related in some way to the nucleus. Write a sentence for each of the terms that clearly explains this relationship.
   (a) trait
   (b) gene
   (c) chromosome
   (d) DNA
   (e) heredity
   (f) genome
9. List three factors that could change the cell's genetic information.
10. What are the three different effects of mutations?

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11. Why must body cells be able to reproduce?
12. Explain why each of the following is important for cell reproduction.
    (a) interphase
    (b) mitosis
    (c) cytokinesis
13. How is cell reproduction controlled?
14. In which stage of the cell cycle does replication occur?
15. In what phase of mitosis do the double-stranded chromosomes split and move to opposite poles of the cell?
16. Explain how the following events of the cell cycle differ in plants and animals:
    (a) mitosis
    (b) cytokinesis
17. Describe three forms of asexual reproduction.
18. What are two ways in which humans assist plant reproduction?
19. What are the benefits of plant grafting?

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20. What is the purpose of meiosis?
21. State the main differences between:
    (a) mitosis and meiosis
    (b) meiosis I and meiosis II
22. During which stage of meiosis do pairs of chromosomes separate?
23. Summarize the differences between:
    (a) the formation of sperm and eggs
    (b) the physical appearance of sperm and eggs
24. How does a gene mutation differ from a chromosome mutation?
25. Name a disease that is caused by a chromosome mutation.
26. Explain how animals aid plant reproduction through:
    (a) pollen transport
    (b) seed transport

Understanding Key Ideas

27. What is the function of a cell's nucleus?
28. Does a brain cell contain more DNA than a liver cell? Explain.
29. Compare and contrast sexual and asexual reproduction.
30. A classmate is having difficulty understanding the difference between a gene and a chromosome. Use an example other than a train to explain this concept.

31. How can you tell that a human or animal cell is from a male and not a female when examining chromosomes under the microscope?
32. Humans are unable to reproduce asexually. Is this inability an advantage or a disadvantage? Explain.
33. How are traits related to genes?
34. Explain why it is important that:
    (a) DNA uncoils during DNA replication.
    (b) DNA coils when it is not being replicated.
35. Construct a chart to compare what is happening to the chromosomes, nucleus, and cell membrane during each phase of mitosis.
36. Explain why it is important that the cell not divide when:
    (a) There are not enough nutrients.
    (b) DNA has not been replicated.
    (c) DNA is damaged.
37. Classify each of the following descriptions as being an event in:
    (i) mitosis (iii) both mitosis and meiosis
    (ii) meiosis
    (a) the method that produces genetically different cells
    (b) the method that doubles the number of chromosomes
    (c) the method necessary for growth in more complex organisms
    (d) the method in which the number of chromosomes in daughter cells remains the same
    (e) the method in which chromosomes replicate only once
    (f) the method that produces genetically identical cells
    (g) the method that produces gametes
    (h) the method in which cells divide two times
38. Genetic diversity results from meiosis I. Explain.
39. Why are some mutations not necessarily bad for the individual?
40. How does a mutation change the activities occurring in a cell?
41. Describe some natural and human causes of mutations.
42. Give two differences between reproductive cloning and therapeutic cloning.
43. Horses have 64 chromosomes. How many chromosomes will be in a daughter cell following meiosis II?
44. Create a graphic organizer that compares the structure and function of the human male and female reproductive organs.
45. Summarize the main events in fetal development in:
    (a) the first trimester
    (b) the second trimester
    (c) the third trimester
46. Compare and contrast complete and incomplete metamorphosis.

Thinking Critically

47. During development, some muscle cells join together to form cells with more than one nucleus. How do you think having more than one nucleus might affect the cell's ability to function?
48. Mitosis results in cell growth and/or replacement. What factors do you think determine how frequently mitosis occurs in different cell types?
49. Explain why mitosis does not produce genetic variation.
50. How can researchers use karyotypes to identify chromosome mutations?

51. By examining a karyotype, could you identify a gene mutation? Explain.

52. Would a mutation in a cell in your skin be inherited by your children? Explain.

53. A cell has a mutation in the protein that ensures DNA has replicated before cell division.
(a) What might occur in the daughter cells as a result of this mutation?
(b) Will the daughter cells be able to function normally? Explain why or why not.

54. The Human Genome Project has provided a map of our genetic material. What new techniques and technology might this map allow scientists to develop?

55. Should scientists change plant genes to resist insects and infection? Explain why or why not.

56. Defend this statement: Mutations are necessary for the survival of a species.

57. Explain why some scientists believe that gene therapy will cure diseases in the future.

58. Describe the effect of each of these factors on a fertilized egg. Explain the role each factor plays when an externally fertilized fish egg undergoes cell division and develops into a fish.
(a) moisture
(b) nutrients
(c) temperature
(d) predators

Developing Skills

59. Draw a diagram to show how genetic information is shuffled during meiosis I, resulting in genetic diversity. Then draw a diagram to show that mitosis does not result in genetic diversity.

60. A bacterium avoids your body's defence mechanisms and begins to replicate. This bacterium replicates itself every 30 min.
(a) Create a table to show how many bacteria will be in your body after 4 h.
(b) Explain why it is more effective for bacteria to reproduce by asexual reproduction instead of sexual reproduction in a situation like this.

61. Create a graphic organizer that demonstrates your knowledge of how an egg cell and a sperm cell unite and eventually become a fetus.

Pause and Reflect

Some scientists say that when a species that once reproduced both asexually and sexually begins to reproduce only through asexual reproduction, that species is heading toward extinction. Based on your knowledge of asexual and sexual reproduction, write a paragraph to explain whether you agree or disagree with this statement.