



Figure 1.20 This plant reproduces sexually and produces wind-borne seeds.

Everywhere you look there are examples of organisms that look more or less like their parents. How are these characteristics passed on from generation to generation? You have already learned that the characteristics of organisms vary greatly within a species. How does reproduction allow for variation?

Not only do the physical traits of organisms vary, but the ways in which organisms reproduce show variation as well. The plant shown in Figure 1.20 reproduces sexually (see page 32) and uses the wind to disperse its seeds. When a seed germinates

the new plant will have characteristics of both its parents. Whether you examine reproduction in bacteria, maple trees, or elephants, you will notice characteristics that are passed on from parent to offspring. These traits are said to be inherited or **heritable**. Such traits are passed on in the genetic material, a subject you will learn more about in Topic 5. Living organisms display a wide variety of methods or **reproductive strategies** for passing on their genetic information to their offspring.

binary fission



spores



vegetative growth in plants



budding



Figure 1.21 Here are some of the diverse forms of asexual reproduction we will look at in this Topic.

Asexual Reproduction

Reproductive strategies may be classified into two major types: asexual and sexual. **Asexual reproduction** occurs when only one parent supplies the information to the offspring. The genetic material of the offspring, and thus their inherited characteristics, are identical to those of the parent. This type of reproduction is common among bacteria and fungi. One advantage of asexual reproduction is that there is no need for an organism to find a mate. Also, reproduction can occur quite rapidly. As long as the environment does not change much, offspring produced by asexual reproduction will be able to survive and reproduce as their parents did.

Pause & Reflect

Organisms pass on their traits in various ways. How would the use of wind-borne seeds increase variation in the plant species shown in Figure 1.20? Record your thoughts on this question in your Science Log as you read through Topic 3.

Binary Fission

Many one-celled organisms such as the amoeba reproduce asexually using a form of cell division called **binary fission**. The cell first duplicates its contents, including its nucleus and other organelles. After the amoeba divides, each new cell has a copy of the genetic material, as well as half of the cytoplasm. As a result, the offspring are identical.

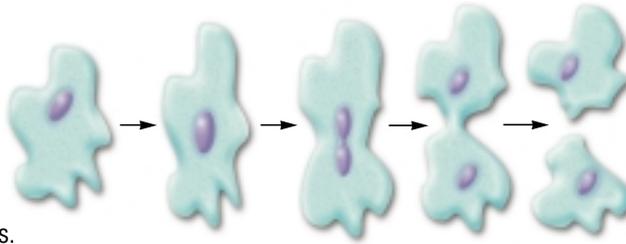


Figure 1.22 Binary fission in an amoeba results in two “daughter” cells.

Asexual Spores

Some fungi, such as mushrooms, can reproduce asexually by forming single-celled, reproductive structures called **spores**. When asexual spores are formed, only one parent organism supplies the genetic material. Many spores are produced to ensure that at least some of them survive. Some fungi and algae, such as the green algae *Chlamydomonas* and *Ulva*, produce **zoospores**, which move using tail-like flagella. Interestingly, fungi can also reproduce sexually — a process we will look at in more detail shortly.

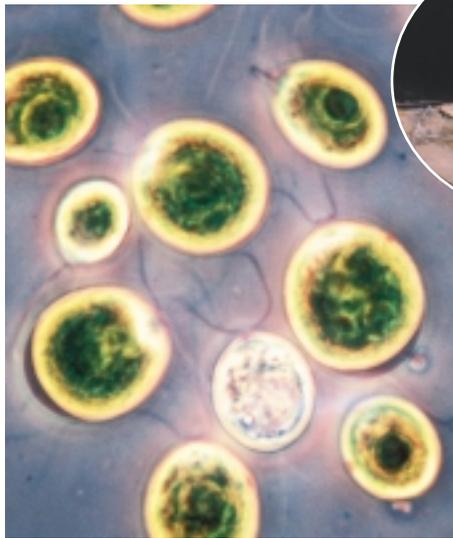


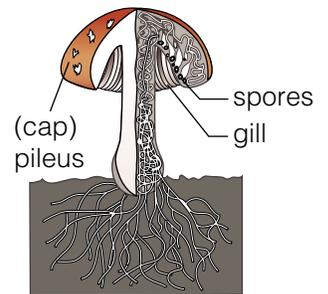
Figure 1.24 *Chlamydomonas* is a unicellular green alga (magnification: 500x). It can reproduce asexually by forming zoospores. Why do you think zoospores have flagella?



Figure 1.23 The Earth star fungus releases millions of tiny spores.

Math CONNECT

How many microscopic spores do you think might be produced by one mushroom? In one species, each of the gills underneath the cap of a single mushroom produces about 13 550 spores on one side of one gill. Keep in mind that each cap of this species of mushroom has about 150 gills. Calculate the approximate number of spores produced by the cap of one mushroom. (Hint: Remember that each gill has two sides.)



STRETCH Your Mind

Suppose you get on a bus to go to school. At 8:20 A.M., you yawn and a single *Streptococcus* bacterium drifts into your open mouth and settles in your throat. Under ideal conditions, a single bacterium can reproduce by binary fission in 20 min. So, by the time the bus drops you off at school at 8:40 A.M., there are two bacteria in your throat. When your homeroom period starts at 9:00 A.M., there are four.

1. Assume that the bacteria continue to reproduce asexually every 20 min and your body does not fight them off. How many bacteria will be in your throat by: (a) lunchtime (12:00 noon); (b) by the time you get the bus in the afternoon (3:20 P.M.); (c) supertime (6:00 P.M.); (d) bedtime (10:00 P.M.)?
2. Make a graph showing the growth of the *Streptococcus* population in your throat over the 14 h period. You may create your graph using a computer.
3. Do you think bacteria can keep multiplying in this way indefinitely? Explain.
4. At what time do you think your throat may feel sore? How many bacteria will be present in your throat?

Pause & Reflect

Why are relatively few mushrooms seen growing in our yards when the number of spores produced is so high? Write a possible reason in your Science Log.

Pause & Reflect

Research the African violet and make a sketch in your Science Log of a technique that could be used to grow several African violets asexually from a leaf.

Word CONNECT

Look up the origin of the word “clone.” Write a science fiction story that features a clone!

Asexual Reproduction in Plants

You may remember that asexual, or vegetative, reproduction in plants can occur without the formation of special cells such as spores. Unlike many animals, plants continue to grow throughout their lives. The growing tips of roots and stems contain areas of rapidly reproducing cells called **meristem**. At a certain point in the plant’s growth, meristematic cells specialize into the cells that make up the roots, stems, and leaves of the plant. If any of these structures are later damaged, the meristem function is activated. Meristematic cells are then able to make repairs to damaged roots, leaves, or the stem of the plant. Asexual reproduction can occur in plants by activating the meristematic cells in different plant structures.

You can make use of the meristem function by taking a cutting and planting it. Cuttings from a parent stem may be used to produce new plants that are **clones** (exact copies) of the parents.

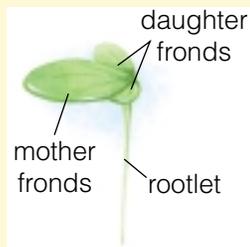


Asexual Reproduction in Duckweed

Duckweed is a very small aquatic plant with leaf-like structures called fronds. Duckweed reproduces asexually by producing two or three daughter fronds from each parent plant. As the daughter fronds grow larger, they break away from the parent frond. Under suitable conditions, a new plant with a genetic program identical to that of the parent may form within 24 h.

Materials

two small jars or culture dishes
100 mL distilled water
100 mL Knop’s solution
8 duckweed plants
wax pencil



Procedure Performing and Recording

1. Examine a duckweed plant. Identify the fronds, rootlet, and daughter fronds. Sketch the duckweed in your notebook.
2. Label two jars or culture dishes: A. Knop’s solution and B. distilled water. Place 50 mL of the appropriate solution into each container.
3. Place four duckweed plants into each container and place them in a well-lit area. Wash your hands when you are finished.

Find Out ACTIVITY



4. Over the next two weeks, count and record the number of separate plants in each container. Construct a table to show your results.
5. At the end of two weeks, construct a line graph showing the number of plants that were growing each day. Use two separate lines to compare the numbers of plants growing in the two solutions.

What Did You Find Out? Analyzing and Interpreting

1. Describe the difference between the parent and offspring plants.
2. How do you think the genetic material in the offspring compares with that of the parent?
3. What was the purpose of setting up one container with distilled water?
4. Which container showed the greatest number of new plants? Why? What does Knop’s solution contain?
5. Why do you think that the other dish displayed relatively less growth?

Skill

FOCUS

For tips on drawing graphs, turn to Skill Focus 10.



The Cloning Controversy

Think About It

You may have heard of Dolly the sheep. Dolly is a clone, an identical copy of another sheep. She is the first artificially cloned mammal. Cloning has many applications in the fields of agriculture, medicine, and forestry. However, the possibility of human cloning has attracted the most attention.



Could cloning be used to produce armies of super-soldiers or to make copies of great scientists or professional athletes? Will parents in the future be able to choose children from a catalogue? Laws are being put in place in Canada and other countries that will restrict the cloning of human beings.

Bioethics is the study of moral issues in the fields of medical treatment and research. Although there are many ways of analyzing bioethical issues, there are certain steps that are common to all discussions. In this investigation, you will consider the bioethics of cloning human beings. What are the advantages and disadvantages of human cloning? Should there be any controls on the experimentation? Might there be health risks for human clones that scientists are not aware of? Who should be allowed to perform human cloning and under what conditions?

How Can Science Help?

Scientists must first understand cell structures and processes in order to identify ways to clone organisms. To test their hypotheses about cloning, they must conduct many investigations. They must then make long-term observations of cloned mammals in order to monitor their health and check that

their development is normal. This is important in order to know whether or not human cloning would be safe.

Procedure

- 1 State what is involved in the cloning issue. This may be in the form of a question or a statement describing the dilemma, but it should summarize the issue briefly and clearly.
- 2 Gather information on cloning from newspapers, magazines, Internet sites, or television or radio broadcasts. How will you collect and record this information?
- 3 Present possible alternatives. Consider alternatives such as permitting the cloning of some species but not humans.
- 4 Identify different perspectives on the issue. Who would want to speak on this issue? Think of as many people or groups as possible.
- 5 Identify potential benefits and concerns for each alternative. Which alternative is likely to be most acceptable by the community?

Analyze

1. Choose one of the following ways to analyze this bioethical issue.
 - Write out your analysis of the issue in the form of a magazine or journal article.
 - Create a poem, play, or story that presents your analysis of the issue.
 - Make a poster that shows your position on the issue and your reasoning.

Skill

FOCUS

For tips on societal decision making, turn to Skill Focus 8.

Off the Wall

The Mexican whiptail lizard reproduces asexually. The females lay eggs, which develop into baby whiptails. The strange thing about these lizards is that the eggs are never fertilized by male whiptails. In other words, the offspring have only one parent! These offspring end up with the same genetic information as the mother lizard.



Budding

Some animals, such as sea sponges and hydra, reproduce asexually by **budding**. A cell, usually near the base of one of these organisms, produces a new group of cells called a bud. When the bud has completely developed, it detaches itself and becomes independent. Yeast cells also reproduce by budding. The bud, which contains its own nucleus, eventually becomes a single, independent cell.



Figure 1.25 Sponge buds may remain attached to the parent, which results in a colony. What advantage does the bud have by being attached to its parent?



Figure 1.26 Hydras are very small organisms that live in water. Based on what you have learned about budding, describe what is happening in this picture.

Sexual Reproduction

In general, **sexual reproduction** occurs when two parents supply genetic material to the offspring. Since both parents supply the genetic material, the offspring will not be exactly like either one. Instead, the offspring will display a combination of characteristics from both parents. While new combinations of characteristics occur in organisms that reproduce sexually, new combinations do not occur with asexual reproduction. Can you think of some reasons why involving two parents in reproduction might be a useful adaptation?

Figure 1.27 Different organisms use various forms of sexual reproduction. In fact, many organisms are capable of both sexual and asexual reproduction! Some of the forms of sexual reproduction we will examine are shown here.

Did You Know?

When each sporangium, or spore case, splits open, it releases spores that float about on air currents. Airborne spores have been found in the atmosphere at altitudes of more than 160 km.

zygospores	
bacterial conjugation	
sexual reproduction in plants	
sexual reproduction in animals	

The Best of Both Worlds

Many organisms are capable of both asexual and sexual reproduction. As you learned earlier, in order to reproduce asexually, some moulds, such as *Rhizopus*, produce spores. Spores may be black, blue, yellow, red, or some other characteristic colour. *Rhizopus* can also reproduce sexually by forming **zygospores**. As shown on page 31, unlike asexual spores, zygospores contain genetic material from two different sources.

☀ Initiating and Planning

☀ Performing and Recording

☀ Analyzing and Interpreting

☀ Communication and Teamwork

Making a Mould

You know that mould will grow on bread, but does any kind of bread provide the right food source? Is there a difference between homemade bread and store-bought bread? What other conditions must be present for bread mould to grow?

Question

Are certain conditions required for the growth of bread mould?

Hypothesis

With your group, agree on a hypothesis about why bread becomes mouldy in certain situations.

Safety Precaution



- Mould is a biological hazard.
- Never inhale mould spores.
- Wash your hands after removing your gloves.

Apparatus

culture dishes
microscope or dissecting scope
camera (optional)
tweezers

Materials

disposable gloves
different types of bread
sealing tape
water
blank paper
pencils

Procedure

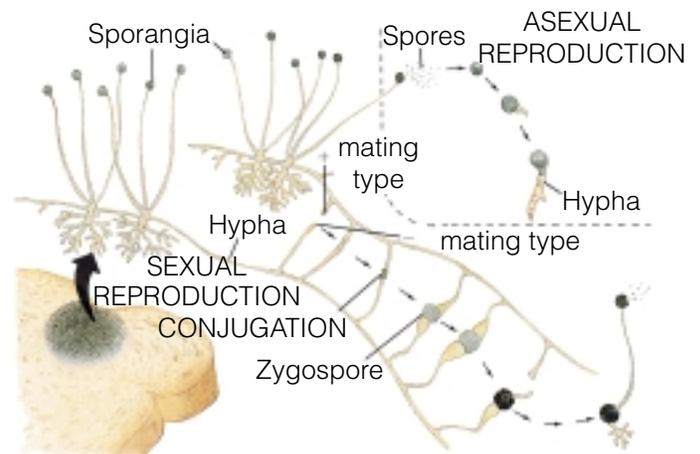
- 1 With your group, **design** a procedure that will allow you to test your hypothesis. Based on your hypothesis, **predict** what you expect to **observe**.
- 2 In your design proposal be sure to include your hypothesis, prediction, the materials you will need, how you will **record** your observations, and the steps you will follow

Analyze

1. Describe your results. Use charts, diagrams, or photographs. Write brief descriptions to accompany your illustrations.

Conclude and Apply

2. Did your results support your hypothesis? Why or why not? Did other groups get similar results using their procedures?



Long strands of cells called hyphae grow out of the *Rhizopus* spores. Where the tips of two hyphae touch, a zygospore, which contains genetic material from both hyphae, is formed.

3. How well does mould grow in different situations? Under what conditions did you observe the most mould growth?
- 3 When you have received approval from your teacher, conduct your experiment.
- 4 Wash your hands after this investigation.

Extend Your Skills

4. With your group, design an experiment to answer additional questions you have about the growth of mould.

Skill FOCUS
For tips on designing your own experiment, turn to Skill Focus 6.

DidYouKnow?

Some harmful bacteria are able to resist medicines such as antibiotics. Antibiotic resistance is a heritable trait. One bacterial cell can quickly pass this trait on to another through conjugation. As a result, the spread of antibiotic resistance in bacteria is very hard to control.

Pause & Reflect

There are about 35 000 species of spore-bearing plants, 700 species of gymnosperms, and 200 000 species of angiosperms living on Earth today. Why do you think angiosperms are so successful? Record your thoughts on this question in your Science Log as you read through the rest of Topic 3.

DidYouKnow?

Like angiosperms such as maples, ginkgo trees shed their distinctively shaped leaves in autumn. However, ginkgoes are actually gymnosperms, and the last of an ancient group whose other members are now extinct.



Bacterial Conjugation

Bacteria are able to transfer genetic material directly from one cell to another in a process called **bacterial conjugation**. As with conjugation in fungi, bacterial conjugation is a primitive form of sexual reproduction since two parent cells are involved. The benefit is that new combinations of inherited characteristics may be produced as a result.

It is interesting to note that bacterial conjugation results in genetic recombination but not reproduction, because there is no increase in the number of cells. Following conjugation, new cells will be produced by binary fission. At this time, the newly recombined genetic material (and characteristics) is passed on to the new cells.



Figure 1.28 In bacterial conjugation a connection forms between two cells. The one-way transfer of genetic material from one cell to another can then occur.

Sexual Reproduction in Plants

Plants have developed diverse adaptations and structures for reproduction. Ferns and mosses reproduce by forming spores. Angiosperms and gymnosperms reproduce sexually by forming seeds. As you may recall from your earlier work, angiosperms are flowering plants. Over half of all known plant species are angiosperms. Some have large and showy flowers like dahlias, chrysanthemums, or dandelions. Others, such as the flowers of grasses, are hard to see. Why do you think there are so many different kinds of flowers?

You may remember that gymnosperms do not produce flowers. Instead, they produce seeds inside of cones, which is why the largest group are called conifers. You are probably familiar with conifers such as spruce, fir, and pine.

Figure 1.29 Some angiosperms, such as these sunflowers, have large blossoms.



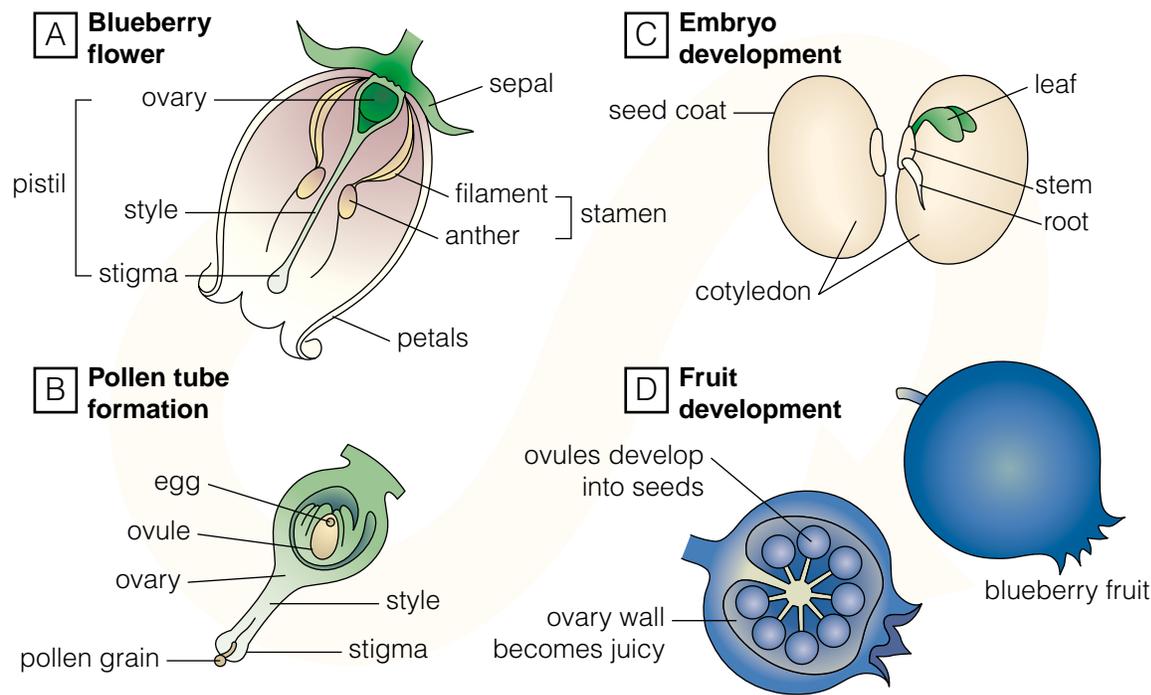


Figure 1.30 **A** The stigma, style, and ovary make up the pistil, the female part of the flower. The anthers, which are supported by the filaments, produce and store pollen grains containing sperm nuclei. Each stamen is composed of an anther and a filament. **B** When a pollen grain lands on the stigma, a pollen tube is formed. A sperm nucleus then travels down the tube to fertilize one egg. **C** Prior to fertilization, other cells in the ovule have been developing into a cotyledon, a structure that nourishes the embryo. Blueberry plants are dicotyledons, which means two cotyledons surround the embryo in each seed. **D** In angiosperms, a fruit, such as a pod, nut, or the fleshy fruit of a berry, surrounds the developing seeds. The fruit usually develops from the wall of the ovary.

In sexual reproduction in plants and animals, fertilization occurs when an egg and sperm cell, the female and male gametes, join to form a new cell. The first cell of the growing organism, which contains genetic information from both parents, is called a **zygote**.

You may recall that flowers are the reproductive organs of angiosperms. The female reproductive organ is called the **pistil** and the male reproductive organ is the **stamen**. Figure 1.30 shows the egg contained in the **ovule** at the base of the pistil. Pollen grains, each of which contains a sperm nucleus, are produced on the plant's stamens. Try to locate some of these reproductive structures on a real flower.

Pollination occurs after pollen reaches the pistil of a flower. As you can see in Figure 1.30, the pollen grain grows an extension called a **pollen tube**. The pollen tube grows into the pistil until it reaches the ovule. Once the pollen tube has reached the ovule, the sperm nucleus travels down the tube to fertilize the egg. The zygote then undergoes many cell divisions to form a multicellular **embryo** containing a miniature leaf, root, and stem. The embryo is supplied with food by one or two **cotyledons**, and together these structures make up the developing seed. When growing conditions are good in terms of warmth, moisture, and oxygen in the soil, the seed will germinate.

Pause & Reflect

In **self-pollination**, both sperm and egg cells come from the same plant. However, wind, water, insects, birds, and other animals often carry pollen over from one plant to another. In this case, **cross-pollination** occurs. In cross-pollination, gametes from two different parent plants are involved. Gardeners who grow orchids and other expensive show-flowers, often keep the flowers in enclosed greenhouses. Why? Why do you think cross-pollination would be a useful adaptation for plants in the wild? Why would self-pollination be an advantage in some cases? In your Science Log, list the advantages of cross-pollination and self-pollination.

Pause & Reflect

The Western wood lily grows wild in Alberta and Saskatchewan. Unfortunately, over-picking has made the flower rare in some areas. Picking the flowers damages the leaves that nourish the bulb. What advantage does the Western wood lily have by being able to reproduce asexually from bulbs? Does reproduction from bulbs add to variation in this species? How is variation increased in this wild flower? Write your answers in your Science Log.

Plants Reproduce Sexually and Asexually

Many plants have adaptations for both sexual and asexual reproduction. As you have seen, some plants reproduce asexually from meristem cells. For instance, the bulbs of some flowers are really modified leaves that store food for the plant. A new plant may emerge when the bulb is planted in the soil. Why do you think angiosperms, which can reproduce sexually, have adaptations for reproducing asexually?



Figure 1.31A The potatoes we eat are actually part of an underground stem called a tuber. The eyes of the new potato are the buds of a new plant. These plants reproduce asexually by growing new shoots from underground stems.

Figure 1.31B The spider plant reproduces asexually from special stems, called runners, shown here hanging from the main plant. Strawberries reproduce by forming runners that lie on the ground. Lilacs spread by producing suckers, which are outgrowths of the root or the lower part of the stem.



Figure 1.31C Asparagus is a flowering plant and part of the lily family. Asparagus plants die back to the ground in the winter. In the spring, new plants regrow from their roots. Since it is very easy to grow plants such as asparagus from the roots, growers may sell only the roots instead of the whole plant. Can you think of some advantages and disadvantages of developing and selling plants this way?

Figure 1.31D The life cycle of mosses is referred to as the alternation of generations. This is because during one part of the cycle, asexual spores are produced; in a later part of the cycle, egg and sperm cells are produced. The spores, which are produced in large numbers, are able to withstand unfavourable temperatures and dry conditions. They are also very light and can be carried great distances to locations with better growing conditions. On damp ground, a spore can develop into new moss. Sperm cells produced by the moss then swim to egg cells to complete the sexual stage of the life cycle.



Pause & Reflect

At one time, large spore-bearing plants were the most numerous of all plant species. In your Science Log, write a hypothesis to suggest the type of climate Earth must have had to support such populations of spore-bearing plants. Infer how climate change can affect plant survival. Hint: mosses and ferns require moisture to complete the sexual stage of reproduction.

Sexual Reproduction in Animals

Animals have many different reproductive strategies. In all cases for sexual reproduction to be successful in animals (or plants), certain requirements must be met. Both male and female gametes must arrive in the same place at the same time for fertilization to occur. The zygote requires specific conditions in order to develop. It needs enough nutrients and moisture, and in some cases, warmth and protection.

Gametes are delicate and dry out quickly. Their life spans are short, so the release of eggs and sperm must be carefully timed. A liquid environment is important because it prevents drying and gives the sperm a fluid to swim through to reach the egg. In animals such as sponges, most worms, and many fish and amphibians, fertilization occurs outside the female. However, in insects, reptiles, birds, mammals, and some fish and amphibians, fertilization occurs within the body of the female. Why might internal fertilization be a useful adaptation for life on land?



While mating, a female frog may try to dislodge the male who embraces her. Only males that can remain attached long enough will fertilize the eggs. How might this behaviour affect the characteristics of the offspring?



Figure 1.32 When frogs mate, the male and female release gametes into the water at the same time. With external fertilization, the risk to the sperm is extreme. Water must be present in order to keep the eggs and sperm alive. Fish or other animals may eat the gametes or water currents may sweep the sperm and eggs away from each other. Extreme temperatures, pollutants, or lack of oxygen may destroy the gametes. Since the majority of gametes are wasted, large numbers must be produced so that at least some will survive. Those that do may form zygotes, which will develop in the water.

Mammals carry out internal fertilization, which is one of the reasons for their high rate of successful fertilizations, or reproductive success.

With internal fertilization, egg cells are protected inside the body of the female parent where conditions are warm and moist. Sperm deposited by the male in the female's body moves almost directly toward the egg, so risks to the survival of the gametes are greatly reduced.

If a mature egg cell is present, fertilization may occur. As with flowering plants, the egg and sperm join to form a zygote. In the early stages of development, after the zygote grows and divides many times, it is called an embryo. In most mammals the embryo develops close to or within the female's body.



Figure 1.33 Internal fertilization removes the dangers of harsh climates and possible predators. The moist environment also helps the flagellated sperm to swim to the location of the egg within the female reproductive tract. As shown here, many sperm will reach the egg. However, only one sperm will fertilize the egg to form the zygote.



When sponges reproduce sexually, they use internal fertilization. Because sponges cannot travel for mating, sperm must be released externally into the water. Once the sperm find their way to another sponge, they are captured by special cells, taken into the sponge's body, and transferred to the eggs internally.

Did You Know?

The duck-billed platypus and the echidna are the only mammals that lay eggs. However, like other mammals, the young are fed their mother's milk and protected until they can look after themselves.



Figure 1.34 The female opossum gives birth to offspring that are smaller than a honeybee. To complete their development, they must remain in the mother's pouch for another three months.

Figure 1.35 The reproductive cycle of mammals and birds requires a great deal of one or both parents' energy.



Off the Wall

Many gastropods such as snails and slugs are hermaphrodites: each individual has both male and female reproductive organs. This is called simultaneous hermaphroditism. Others, however, are sequential hermaphrodites. They are male when younger and female when older and large enough to produce and carry eggs.

Pause & Reflect

There is great diversity in the strategies different organisms use to reproduce. Do you think that reproductive success contributes to variation within a species? How is biological diversity related to reproductive success? Answer these questions in your Science Log.

TOPIC 3 Review

1. Explain the difference between budding and binary fission.
2. **Apply** Name one type of organism that reproduces both sexually and asexually. Explain how this can occur.
3. In what way is conjugation a primitive form of sexual reproduction?
4. Describe the exact location of the egg cell and sperm nucleus of a flowering plant.
6. **Thinking Critically** Salmon lay eggs, while whales give birth to live young. Which animal do you think probably produces more young at one time: the salmon or the whale? Explain your choice.
5. **Thinking Critically** Fireweed flowers are shaped so that they cannot pollinate themselves. Near the end of the growing season, however, a change occurs in any flower that has not been pollinated. The stamens curve around so that the anthers touch the stigma within the same flower.
 - (a) Explain the reproductive advantage of preventing self-pollination in fireweed.
 - (b) Explain the reproductive advantage of permitting self-pollination in fireweed.