# Reproduction and continuity of species

## *Continuation of species has resulted, in part, from the reproductive adaptations that have evolved in Australian plants and animals*

## 3.1 Cell division and the production of gametes

- ***distinguish between the processes of meiosis and mitosis in terms of the daughter cells produced***

### The role of meiosis in maintaining chromosome number

Every species has a characteristic number of chromosomes per cell. For example, humans have 46 chromosomes, camels have 70, tomatoes have 24 and chickens have 78, the housefly has 12 and the fruit fly has 8. Analysis shows that the number of chromosomes does not necessarily reflect the complexity of the organism. The important thing to remember is that the chromosome number is constant for each organism and does not change from one generation to the next.

During **sexual reproduction**, two parents are involved in passing genetic material on to offspring. To prevent the chromosome number from doubling in each successive generation, a mechanism to ensure that each parent contributes only half of his or her chromosomes to the new offspring is necessary. The *importance* of **meiosis,** a type of cell division present in the reproductive organs of both plants and animals, is to ensure that the characteristic chromosome number is maintained during sexual reproduction.

The terms **diploid** and **haploid** refer to the number of *sets* of chromosomes within any cell. In most organisms, the **somatic** (body) cells contain *two sets* of chromosomes, i.e. the diploid number of chromosomes (e.g. in humans this number is 46 or 23 pairs). One set of chromosomes is inherited from the mother (**maternal** chromosomes) and one set is inherited from the father (**paternal** chromosomes). However when a cell involved in sexual reproduction divides by meiosis to produce **gametes** (sex cells), the chromosome number halves—that is, each resulting gamete contains only *one set* of chromosomes and is termed haploid.

- If $n = 1$ set of chromosomes, then in humans, $n = 23$.
- Human somatic cells are $2n$ (diploid) and have 46 chromosomes.
- Human gametes are $n$ (haploid) and have 23 chromosomes.

## Meiosis: an introduction

Meiosis is the type of cell division that occurs in the sexual reproductive organs of a plant or animal and it results in the formation of gametes (sex cells). When a cell divides by meiosis, it undergoes two successive divisions—*meoisis I* where the cell divides into two cells and then *meiosis II* where those two cells each divide again, resulting in four daughter cells (called a **tetrad**). Each daughter cell has half the original number of chromosomes that the parent cell had. These resulting daughter cells, or gametes, are:

- **egg cells** and *sperm cells* in animals
- **pollen grains** (in anthers) and egg cells (inside ovules) in seed-producing plants.

Gametes are often referred to as 'vehicles of inheritance' because they carry genes from one generation to the next.

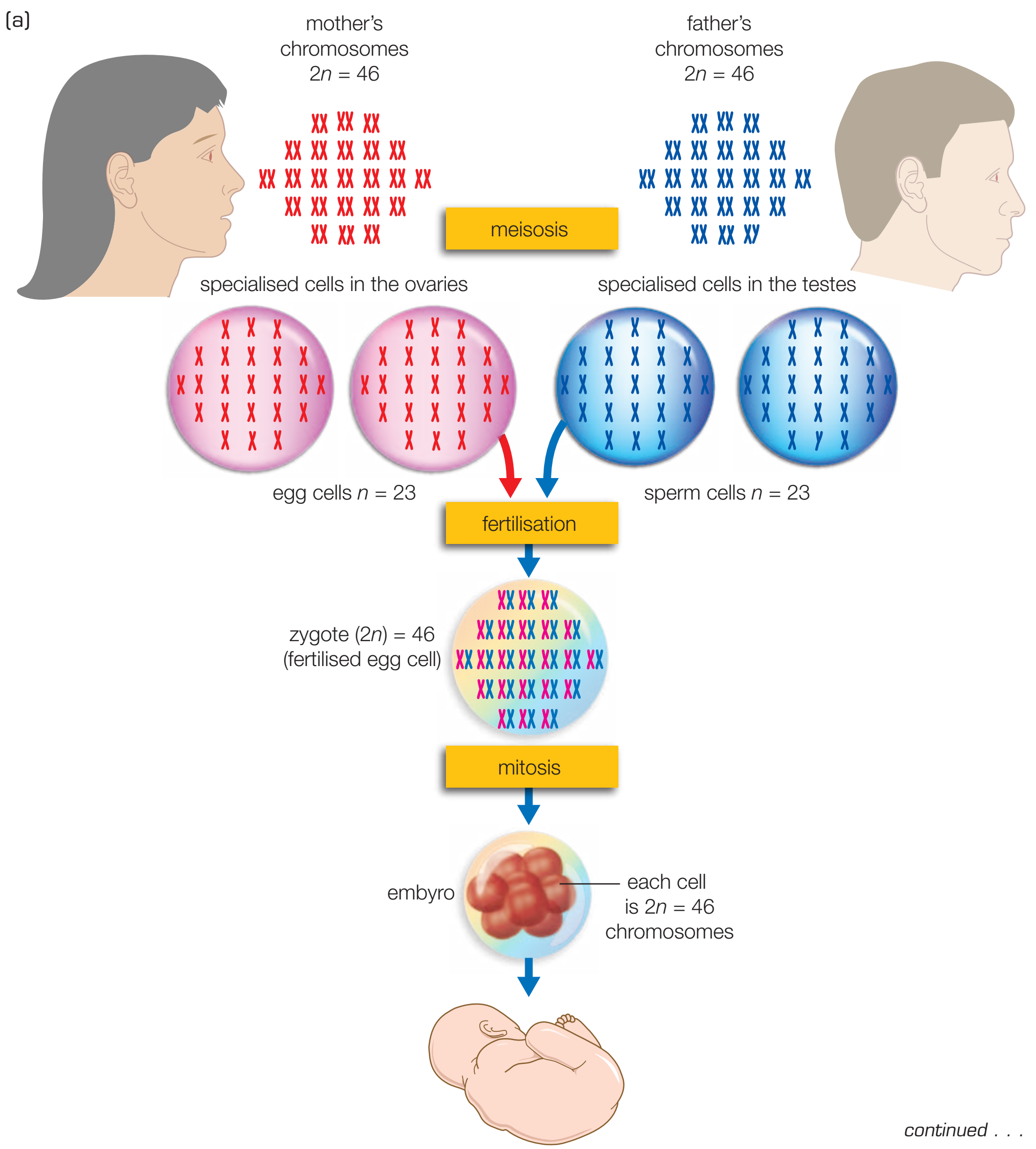
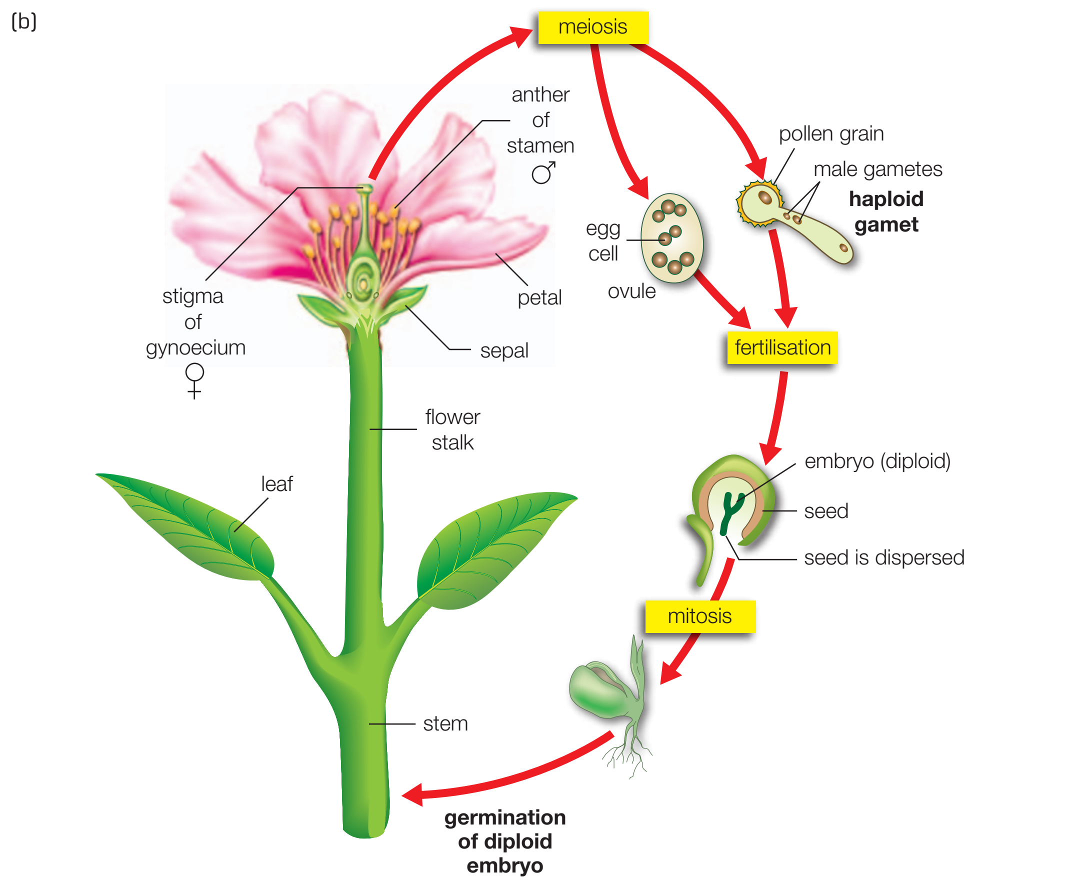



**Figure 3.1** Sexual reproduction cycle showing maintenance of chromosome number: (a) in humans

**Figure 3.1** Sexual reproduction cycle showing maintenance of chromosome number: (b) in flowering plants




## The process of meiosis

Meiosis can be defined as a reduction division whereby a diploid cell divides into four haploid daughter cells (a tetrad). Meiosis occurs in two stages, meiosis I (the first meiotic division) and meiosis II (the second meiotic division). The reduction in chromosome number occurs in meiosis I.

## Similarities with mitosis

- The names of the stages—interphase, prophase, metaphase, anaphase and telophase—are the same.
- Interphase occurs first, prior to the nuclear division. During this stage, the DNA replicates, so that each chromosome makes an identical copy of itself (see Fig. 3.2a).
- Chromatin material transforms into chromosomes in the same way during prophase in the first meiotic division (see Figs 3.2b and c).
- The breaking down of the nuclear material and the formation of the spindle are the same.
- Cytokinesis takes place in the same manner as for mitosis, depending on whether it is a plant or an animal cell dividing.

## Terminology associated with the process of meiosis

A **homologous pair** of chromosomes consists of two similar chromosomes: one of the pair is maternal in origin and the other is paternal. In humans, there are 23 homologous pairs of chromosomes. Each homologous pair of chromosomes may be termed a **bivalent** (see Fig. 3.2).

In the annotated diagrams in Table 3.1, meiosis is represented in a hypothetical (model) organism that has only *two pairs* of chromosomes, keeping the representation of the process simple.

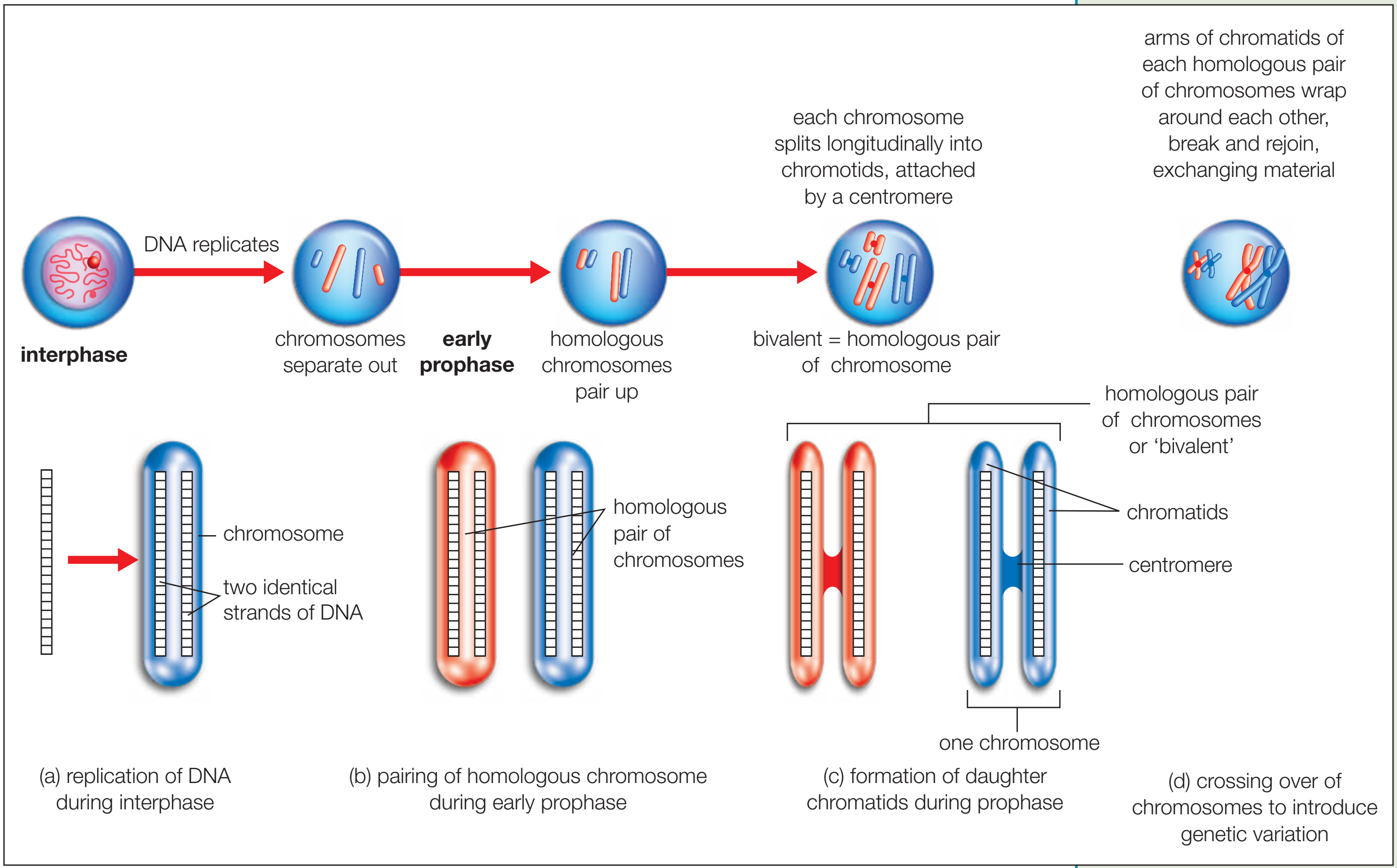



**Figure 3.2** Early stages of division in meiosis—interphase and prophase of meiosis I

**During meiosis I**

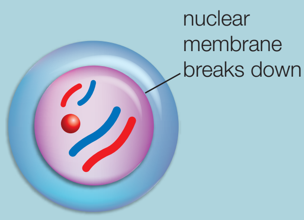
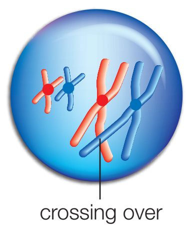
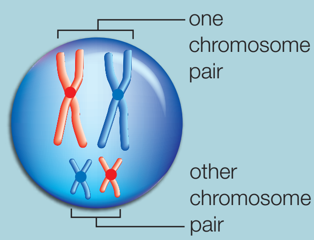
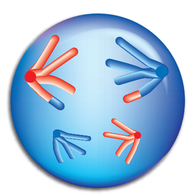
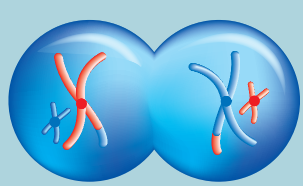
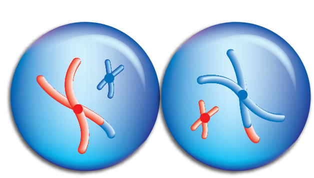
1. Chromosomes line up in pairs (one maternal and one paternal chromosome in each pair) during prophase I.
2. **Crossing over** occurs—arms of homologous chromosomes exchange genetic material (this introduces **genetic variation**).
3. Each pair of chromosomes separates (during anaphase I), so that one entire chromosome of each pair moves into a daughter cell. This not only halves the chromosome number in gametes, but it also leads to *genetic variation*, depending on which chromosome (paternal or maternal) of each pair ends up in which daughter cell. This is termed *independent assortment* of chromosomes and produces different combinations of genes in different gametes.

**During meisois II**

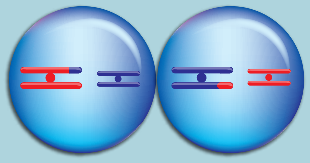
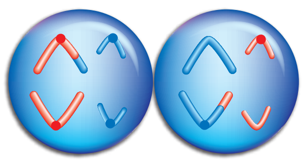
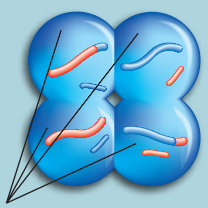
The two daughter cells that result from meiosis I each undergo meiosis II which is similar to mitosis:

- The centromere divides and chromatids separate from each other (during anaphase), moving to opposite poles (telophase), where a nuclear membrane forms around each set of chromosomes. Cytokinesis follows, resulting in *four* daughter cells (a tetrad), each with *half* the original chromosome number. Genetic variation has also been introduced, since the combination of paternal and maternal chromatin material in each resulting daughter cell is different.
- Fertilisation—there are many combinations of chromosomes possible in gametes as a result of meiosis, resulting in a variety of gametes forming. Variation is also dependent upon which gametes fuse during fertilisation.

**Table 3.1** Process of meiosis in animal cells

| Diagram | Annotation |
| --- | --- |
| Early prophase   | ■ Chromosomes separate out into homologous pairs |
| Late prophase   | ■ Nuclear membrane breaks down<br>■ Chromosomes spilt into chromatids<br>■ Crossing over occurs |
| Metaphase I   | ■ Chromosomes align in pairs in the middle of the cell |
| Anaphase I  | ■ Chromosome pairs separate and each chromosome moves to the opposite end of the cell |
| Telophase  | ■ Two daughter cells form<br>■ Chromosome number halved |
| Cytokinesis I  | ■ Daughter cells are not identical to each other and have half the original number of chromosomes |

*continued . . .*

| Diagram | Annotation |
|---|---|
| Metaphase II  | ■ Chromosomes align at the equator |
| Anaphase II  | ■ Chromatids ('arms' of chromosomes) move apart, to opposite poles |
| Cytokinesis II—tetrad   | ■ Four resulting daughter cells, not identical to each other and have half the original chromosome number. |

TR

Worksheet: outline of annotated diagram of meiosis

## Differences between mitosis and meiosis

- ***analyse information from secondary sources to tabulate the differences that distinguish the processes of mitosis and meiosis***

### Task

1. Analyse information from the following resources to determine the differences between meiosis and mitosis:
   - read the text on pages 280–1 and analyse the annotated diagrams in Figure 3.2 and Table 3.1
   - analyse the comparative diagram sequence on the Student Resource CD
   - refer to at least one other source that shows an animation of the process either on video or on a website, such as: http://biology.about.com/library/blmeiosisanim.htm This website has animations of mitosis and meiosis, showing an animation of mitosis and the first meiotic division occurring side-by side for direct comparison.
2. Draw up a table with the column headings Mitosis and Meiosis and describe the differences that distinguish the processes of mitosis and meiosis. Suggested areas to look at are the:
   - type of cells in which division occurs
   - number of divisions and resulting daughter cells
   - chromosome behaviour in early stages of division—prophase
   - chromosome behaviour in anaphase (first division)
   - end of cytokinesis (mitosis) and cytokinesis II (meiosis)

**SECONDARY SOURCE INVESTIGATION**

**BIOLOGY SKILLS**

P13
P14

SR TR

Comparitive diagram sequence

TR

Completed table comparing mitosis and meiosis

# 3.2 Reproductive adaptations in animals

## ■ *Compare and contrast external and internal fertilisation*

In animals, the union of male and female gametes (sperm and ova) can occur outside the body (**external fertilisation**) or inside the body (**internal fertilisation**).

### External fertilisation

Many marine organisms carry out external fertilisation as the water environment allows the union of gametes to occur without dehydration. Corals, for example, release large amounts of gametes at the same time in the hope that some will be fertilised and then survive to adulthood. Vertebrate sexual reproduction is thought to have started in the ocean before vertebrates colonised the land.

#### Bony fish

The females of most species of marine bony fish produce eggs (or ova) in large batches and release them into the water. This is generally followed by the males releasing their sperm into the area of water containing the eggs. This is where the union of gametes (eggs and sperm) occurs. When fertilisation occurs in the ocean gametes tend to disperse quickly so the release of large numbers of eggs and sperm from the females and males must occur almost simultaneously. This is why most marine fish restrict the release of gametes to a few brief and clearly determined periods. Although thousands of eggs are fertilised in a single mating of bony fish, many of the resulting offspring succumb to microbial infections or predation, and few grow to maturity.

**Figure 3.3** Eggs of frogs are fertilised externally

#### Amphibians

The amphibians invaded the land without fully adapting to the terrestrial environment, so their lifecycle is still tied to the water. Gametes from both males and females are released through the cloaca. Among the frogs and toads, the male grasps the female and discharges fluid containing sperm onto the eggs as they are released into the water (see Fig. 3.3).

### Internal fertilisation

The invasion of vertebrates onto the land posed a new danger of dehydration. The gametes could not simply be released near each other as they would quickly dry up and perish. This led to the evolving of internal fertilisation and **copulation** where the male gametes are inserted into the female reproductive tract via a penis or similar structure. This allows the union of gametes to occur in a moist environment, even though the animal is on land. The fertilisation environment is not only protected from dehydration and external elements, but it is also protected from predation or dispersal and loss of the gametes. This means that fewer eggs are required to ensure a successful number of offspring survive.

### Cartilaginous fish

In contrast to the bony fish, fertilisation in most cartilaginous fish is internal. The male introduces the sperm into the female through a modified pelvic fin.

### Reptiles

Most reptiles fertilise their eggs internally and then the eggs are deposited outside the mother's body for development. Male reptiles use a tubular organ, the penis, to inject sperm into the female (see Fig. 3.4). The penis, containing erectile tissue, can become rigid and penetrate far into the female reproductive tract.

### Birds

All birds practise internal fertilisation, though most male birds lack a penis.

**Figure 3.4** Reptiles such as tortoises carry out internal fertilisation

In some of the larger birds (e.g. swan), however, the male cloaca extends to form a false penis. As the egg passes along the oviduct, glands secrete proteins (egg white) and a hard calcium carbonate shell that distinguishes bird

**Table 3.2** Comparison of internal and external fertilisation

| | Differences | | |
|---|---|---|---|
| **Characteristics** | **External fertilisation** | **Internal fertilisation** | **Similarities** |
| Gametes | Large numbers of male and female gametes produced | Large number of male gametes and fewer female gametes produced | Male and female gametes required—sperm and egg (ova) |
| Union | Occurs in open water environments | Mostly on land, inside the reproductive tract of the female | Sperm fertilise the eggs when they unite |
| Conception mechanism | Simultaneous release of gametes | Male needs to insert the sperm into the female's reproductive tract via penis or cloaca (copulation) | Sperm will fertilise eggs when in very close proximity to each other, gametes require a watery environment for this to occur |
| Chance of fertilisation | Low chance of fertilisation because male gametes are released into a large open area where there is less chance of successfully uniting with female gametes | High chance of fertilisation because male gametes are released into a confined space where there is more chance of successfully uniting with female gametes | If male and female gametes are in close proximity to each other, fertilisation will usually occur |
| Environment for **zygote** | Zygote usually develops externally in a watery environment which is vulnerable to environmental elements such as temperature and predation, infection and rapid dispersal from the area | Zygote usually develops in a very protected environment inside the female's body. Temperature is controlled there is less chance of predation, infection and loss of zygote from the area | Zygote requires a watery environment for development |
| Number of offspring/ zygotes | After many zygotes perish a smaller number of offspring survive; however, the number of offspring produced is usually larger compared to internal fertilisation | Smaller number of zygotes produced because very few perish (higher success rate), therefore, smaller numbers of offspring compared to external fertilisation | All possible gametes will unite to form zygotes where possible during fertilisation |
| Breeding frequency | Will breed more frequently compared to internal fertilisation due to the lower fertilisation success rate | Will breed seasonally and less frequently due to higher fertilisation success rate | Breeding frequency will depend on the requirements of the species and the favourability of environmental conditions |

eggs from reptilian eggs. Most birds incubate their eggs after laying them, to keep them warm.

#### Mammals

Some mammals are seasonal breeders, reproducing only once a year, while others have shorter reproductive cycles. Cycling in females involves the periodic release of a mature egg (ovum) from the ovary (the process is called ovulation). Mammals require the insertion of sperm into the female's reproductive tract (copulation) for fertilisation to occur.

Table 3.2 summarises the main similarities and differences between internal and external fertilisation.

## 3.3 Relative success of internal and external fertilisation

- ***discuss the relative success of these forms of fertilisation in relation to the colonisation of terrestrial and aquatic environments***

Organisms in aquatic environments are successful in their reproduction and survival as they have adaptations suited to reproducing in this type of environment; however, this also means that they are completely dependent and reliant upon their environment providing the water required for successful external fertilisation. Water protects the gametes from desiccation and possible heat stress. However, in order to survive on land, organisms needed to overcome the dependence on aquatic environments for fertilisation by providing their own enclosed moist environment within the female reproductive tract, protected from the dry terrestrial environment.

Flowering plants have colonised the land by fertilising internally and avoiding gamete desiccation. Reptiles have also colonised the land successfully by producing adaptations to the dry environment by carrying out internal fertilisation and allowing their young to develop inside a waterproof egg to protect from desiccation. Even further, mammals allow internal development of their young after internal fertilisation has occurred. This ensures successful reproduction and survival of the respective species in colonising the land.

### External fertilisation

#### In an aquatic environment

Organisms attempting to carry out external fertilisation in an aquatic environment are usually highly successful. In this environment gametes do not dry out, or dehydrate; however, organisms must produce very large numbers of gametes to compensate for the losses from predation, disease and dispersal to unsuitable environments.

#### In a terrestrial environment

Organisms attempting to carry out external fertilisation on land are not successful at all due to their complete reliance upon a water environment for fertilisation and the transfer of gametes.

### Internal fertilisation

#### In an aquatic environment

Internal fertilisation is not a necessary adaptation for most aquatic species; however, it is a successful method of fertilisation in this environment. Fewer gametes are required because of the higher chance of the gametes uniting.

### In a terrestrial environment

Internal fertilisation has only been possible on land because of overcoming the need for water for fertilisation. This method of fertilisation is very successful as the mechanism for direct transfer of gametes avoids dehydration and loss by dispersal, so fewer female gametes are required. The success of this form of fertilisation is very high as the environment is enclosed in a confined space protecting from predation and disease. Even the driest environments can be colonised successfully by using this method.

## Success of internal and external fertilisation in terrestrial and aquatic environments

SECONDARY SOURCE INVESTIGATION

BIOLOGY SKILLS

P13
P14

- ***identify data sources, gather, process and analyse information from secondary sources and use available evidence to discuss the relative success of internal and external fertilisation in relation to the colonisation of terrestrial and aquatic environments***

### Aim

1. To identify data sources, gather, process and analyse information from secondary sources.
2. To use available evidence to discuss the relative success of internal and external fertilisation in relation to the colonisation of terrestrial and aquatic environments.

### Method

#### Part 1: Identify data sources, gather, process and analyse information from secondary sources

Refer to page 18 ('Searching for information') for suggestions and a reminder of how to approach the identifying of data sources, and gathering, processing and analysing information from secondary sources.

#### Part 2: Discuss the relative success of internal and external fertilisation

Read and summarise Sections 3.2 and 3.3, then copy (see Student Resource CD) and complete Table 3.3, describing the advantages and disadvantages of internal and external fertilisation in terrestrial and aquatic environments.

### Discussion/conclusion

1. Describe the characteristics of fertilisation in terrestrial organisms that provide an advantage for successful colonisation.
2. Briefly describe the characteristics of fertilisation in aquatic organisms that provide an advantage for successful colonisation.
3. Discuss the relative success of internal and external fertilisation in relation to the colonisation of terrestrial and aquatic environments.

SR TR

Table 3.3

### Results

**Table 3.3** Advantages and disadvantages of internal and external fertilisation in colonising terrestrial and aquatic environments

| Environment | Type of fertilisation | Internal fertilisation | External fertilisation |
|---|---|---|---|
| Terrestrial environment | Advantages | | |
| | Disadvantages | | |
| Aquatic environment | Advantages | | |
| | Disadvantages | | |

# 3.4 Mechanisms of fertilisation and development

- ***describe some mechanisms found in Australian fauna to ensure***
  ***—fertilisation***
  ***—survival of the embryo and of the young after birth***

## Marine animals

### Staghorn coral

Many marine animals, such as the staghorn coral, achieve fertilisation by simply shedding millions of gametes into the sea (see Figure 3.5). Environmental cues, such as water temperature, tides and day length, help synchronise the reproductive cycle. When one coral starts to spawn, pheromones released along with gametes will stimulate nearby individuals to spawn, resulting in co-ordinated spawning over a wide area. During the mass spawnings of coral on Australia's Great Barrier Reef, the number of gametes shed is so great that, for a time, the sea turns milky. Within one day, fertilised eggs develop, forming into swimming larvae. After a few days at the surface, the larvae descend to find a suitable site to form a new colony. Although millions of staghorn coral larvae are produced, almost all are eaten by predators. Of the few remaining, only a tiny fraction develop into adulthood.

## Amphibians

### Southern gastric brooding frog

Southern gastric brooding frog eggs are fertilised externally in a watery environment. The female releases eggs and, after they are fertilised by the sperm, the female swallows them. Rather than leaving the eggs to develop alone and unprotected, the young develop internally in the female's stomach. In the stomach, digestive secretions cease and the eggs settle into the stomach wall, where they are protected and absorb nutrients from the mother. This gastric brooding appears to last about 6–7 weeks, during which time the female does not eat. When the young frogs are ready, they are regurgitated through the mouth (see Fig. 3.6). Therefore, these animals have external fertilisation but internal development. This is an extreme example of parental care which was discovered in forests north

**Figure 3.5** Staghorn coral (*Acropora yongei* sp.) releases bundles containing sperm and egg

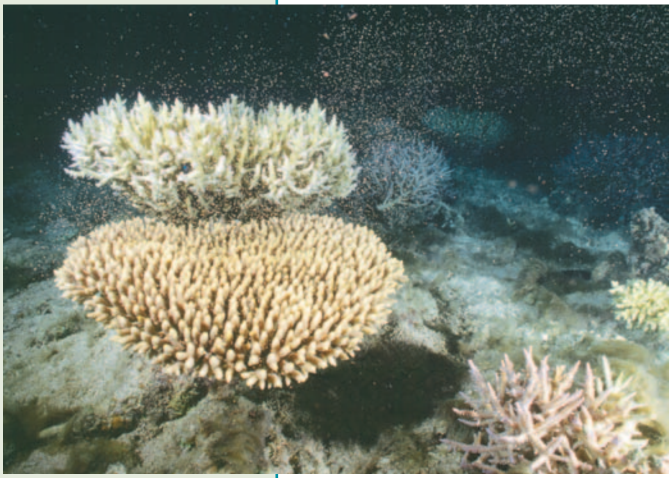


**Figure 3.6** Young froglets emerging from the mouth of a female southern gastric brooding frog (*Rheobatrachus silus*) after developing in their mother's stomach

of Brisbane in 1974. This mechanism would provide some protection for the underdeveloped young from predation, infection or dispersal which can significantly reduce the success of offspring survival.

## Birds

In birds, fertilisation is internal but the fertilised egg undergoes the majority of its development externally. Parental care is often needed continuously. Most species brood their eggs, with parents taking turns so that each can go and feed.

### Brush turkey

The megapodid birds, such as the brush turkey, build a mound from twigs, soil and leaf litter, into which they place their eggs (see Fig. 3.7). Heat from decomposition of the leaf litter keeps the eggs warm, but the male parent frequently tends the nest, adding or removing material to control the temperature of incubation.

**Figure 3.7** A brush turkey maintains the temperature of its nest by adding or removing leaf litter

## Reptiles

### Crocodile

Fertilisation occurs internally, then the female crocodiles (*Crocodylus porosus*) lay clutches of eggs in sandbanks beside the sea or river (see Fig. 3.8).

When an egg hatches, the offspring resemble a miniature adult, able to crawl up from the buried nest to the surface to find its way to the water and to feed independently. Female crocodiles produce small numbers of large yolky eggs containing sufficient food reserves for more elaborate development.

**Figure 3.8** Development in a yolky egg gives rise to tiny crocodiles (*Crocodylus porosus*)

## Monotremes

### Duck-billed platypus and the echidna

Both of these monotremes are oviparous, meaning their eggs after being fertilised internally are deposited outside the mother's body to complete their development. They incubate their eggs in a nest (see Fig. 3.9) or specialised pouch, and the young hatchlings obtain milk from their mother's mammary glands by licking her skin (as monotremes lack nipples).

**Figure 3.9** The duck-billed platypus with its young in a nest

The echidna does not lay eggs into a nest, but places them into an abdominal pouch where they stay for about seven weeks. The young suck milk from the skin of the mother's stomach.

## Marsupials

Marsupials from the kangaroo and wallaby family have an extraordinary ability to control embryonic development. Mothers are pregnant for a short period of time and can become pregnant again just after giving birth. Since milk production lasts much longer than the pregnancy, it is necessary to delay development of the new embryo until the pouch becomes vacant. This delay in development, embryonic diapause, is controlled by the suckling of the young in the pouch.

### Red kangaroo

The red kangaroo carries out both internal fertilisation and internal development of the young after birth. In good conditions, it can have three offspring at different stages of development. The female may have an older young out of the pouch but still being suckled, a newborn young in the pouch, and an embryo in diapause in the uterus. At this stage, the mother will be producing two different types of milk simultaneously. The newborn young will get low fat/ high carbohydrate milk from nipples of the mammary glands (see Fig. 3.10), while the young outside the pouch will feed from a different nipple (or teat) to get large volumes of high fat/low carbohydrate milk. In times of drought the mother may be unable to produce sufficient milk to sustain a growing young in the pouch. If the young dies, a new young will enter the pouch a month later. Since the newborn young is so small, it only needs a small quantity of milk for the first few weeks in the pouch. This ensures there is always a young ready when the drought ends. This 'production line' approach allows very rapid population growth when conditions are good. However, under prolonged drought conditions, breeding stops and only begins again when rain triggers a hormonal response in the female. This very effective mechanism controls the rate of reproduction depending on the favourability of the environmental conditions at the time.

**Figure 3.10** Kangaroos give birth to small foetuses which complete their development in a pouch

# Reproductive adaptations in plants

3.5

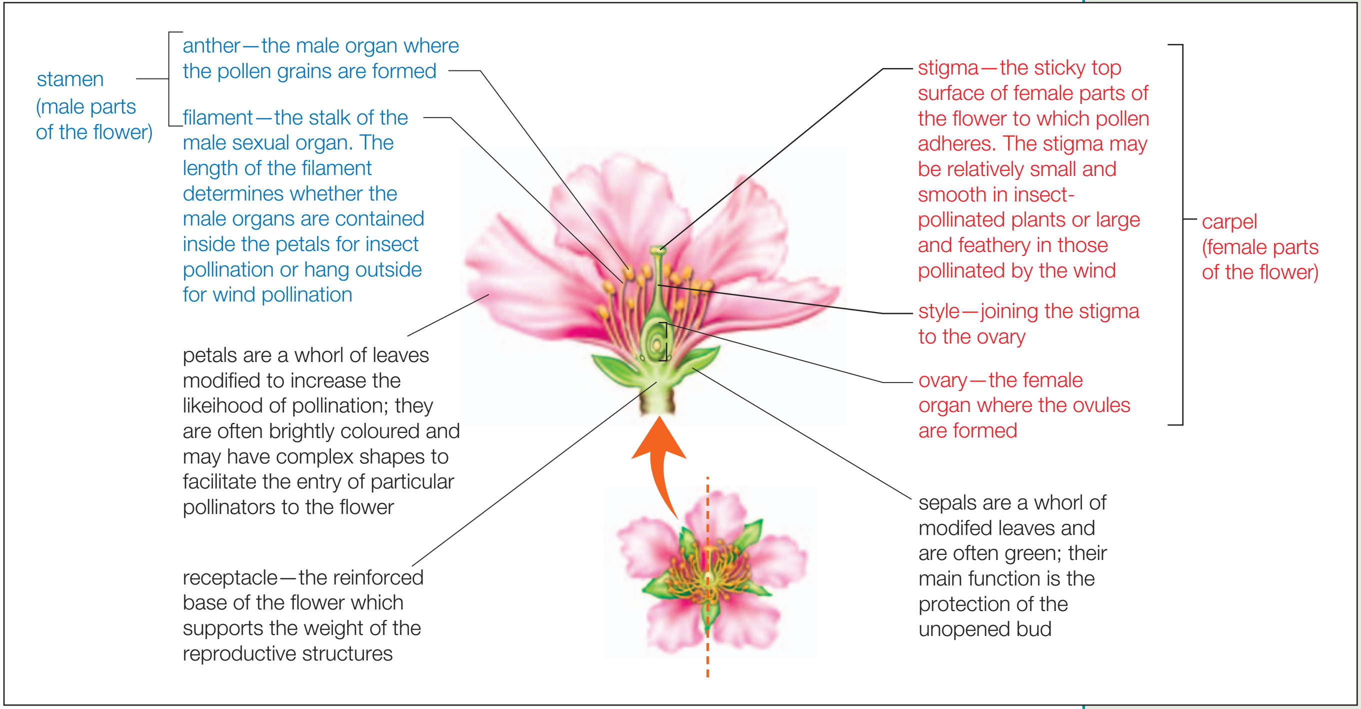
- ***describe some mechanisms found in Australian flora for:***
  ***—pollination***
  ***—seed dispersal***
  ***—asexual reproduction***
  ***with reference to local examples***

## Pollination

Pollination is the process required by plants for sexual reproduction. Flowering plants (**angiosperms**) and conifers (**gymnosperms**) sexually reproduce by fertilising internally like many animals do; however, the sperm is contained in pollen grains which prevent it drying out. Gymnosperms have only one mechanism for pollination, wind, whereas angiosperms, which evolved much later, have a high proportion of species (about 65 per cent) that use animals such as insects, birds and mammals as agents for pollination. Some angiosperms still continue as wind-pollinators.

To understand the process of pollination in flowering plants we first must understand the basic structure of the flower as the reproductive organ of sexually reproducing plants. The flower contains reproductive parts that are female (**carpel**) and male (**stamen**), as well as other non-sexual parts, illustrated in Figure 3.11. In order for fertilisation to occur in the flower, the male gametes (**pollen**) from the **anther** must firstly be deposited on the female part of the flower called the **stigma**. This process is called **pollination**. Once pollen has been deposited on the stigma, it germinates and is transferred down the **style**, within a pollen tube, to the **ovules** contained in the **ovary** (see Fig. 3.12). In flowering plants, fertilisation occurs in the ovary.

**Figure 3.11** Top view and longitudinal section of a typical flower—male parts labelled in blue and female parts in red



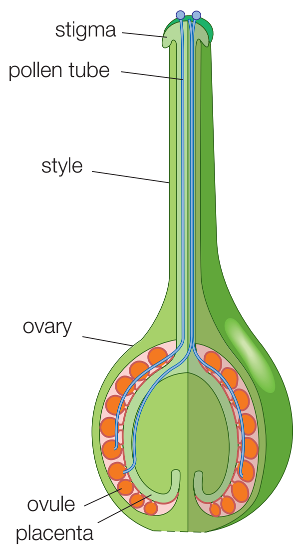



**Figure 3.12** The pathway pollen tubes take as they travel from the stigma to the ovary

Pollination is the process of the pollen being transferred to reach the stigma. Pollen may be carried to the flower by wind or by animals, or it may originate from the same individual flower. When pollen from a flower's anther pollinates the same flower's stigma, the process is called **self-pollination**. When pollen from a flower's anther pollinates a flower's stigma from a different plant, the process is called **cross-pollination**. In most species the pollen is produced at a different time from when the stigma can receive it, so that plants are not usually pollinated by their own pollen. In most instances, flowers are pollinated with pollen from other plants of the same species. This ensures greater variation in the offspring.

## Pollination by wind

Early seed plants were pollinated passively, by the action of the wind. As in present-day conifers, great quantities of pollen were shed and blown about, occasionally reaching the vicinity of the ovules of the same species. Individual plants of any given species must grow relatively close to one another for such a system to operate efficiently. Otherwise, the chance that any pollen will arrive at the appropriate destination is very small. The vast majority of wind-blown pollen travels less than 100 m. This short distance is significant compared with the long distances pollen is routinely carried by certain insects, birds and mammals.

Many angiosperms are wind-pollinated. The flowers of these plants are small, greenish, odourless, and with reduced or absent petals. Such flowers often are grouped together in fairly large numbers and may hang down in tassels that wave about in the wind and shed pollen freely (see Fig. 3.13). Wind pollination is very inefficient so large quantities of pollen are produced. Different pollen grain structures ensure compatibility with the same species (see Fig. 3.14). Wind-pollinated species do not depend on the presence of a pollinator for species survival.

**Figure 3.13** Grass flowers such as *Lolium perenne* are small and pollinated by wind

Wind is responsible for pollinating many Australian plant species, especially the grasses (Fig. 3.13). In these species the anthers are very long and produce large amounts of light pollen, which is easily picked up by the wind passing over the flowers. Usually the stigmas are also very large and spread out to receive pollen carried by wind.

**Table 3.4** Summary of features of wind-pollinated flowers

| Feature of flower | Wind-pollinated flowers |
|---|---|
| Petals | Small and inconspicuous, usually green or dull in colour |
| Scent | Usually absent |
| Nectar | None |
| Anthers | Anthers protrude outside the flower so pollen is easily blown off by the wind; abundant amount of pollen is produced |
| Stigma | Stigma protrudes from the flower, it is often long, feathery and sticky to increase surface area for trapping the wind-borne pollen |
| Pollen | Very small grains, light and powdery; large amounts produced |

## Pollination by animals

Flowers that attract animals are more effective in ensuring the transfer of pollen. This is of a considerable advantage since a one-to-one relationship between a plant and animal species reduces wastage of pollen by ensuring that it is deposited on the correct flower. Animals that act as pollinators search in flowers for a meal of nectar (a sugary liquid secreted by nectaries in the flower) or pollen. Flower scent, colour, markings, shape and nectaries are important in attracting animals, all differing between each flower species depending upon the type of animal they are attracting.

## Pollination by birds

Bird-pollinated plants must produce large amounts of nectar because if the birds do not find enough food to maintain themselves, they will not continue to visit flowers of that plant. Flowers producing large amounts of nectar have no advantage in being visited by insects because an insect could obtain its energy requirements at a single flower and would not cross-pollinate the flower.


(a) Grass



(b) Ash



(c) Daisy



(d) Wattle


**Figure 3.14** These flowering plants produce pollen that is carried by wind, each with different pollen grain structures (inset): (a) grass; (b) ash; (c) daisy; (d) wattle. Grass, ash and daisy pollen are all major causes of hayfever. Wattle pollen occurs in large clusters

Bird-pollinated flowers produce much less pollen than wind-pollinated plants. Such plants are rarely fragrant because birds have little sense of smell. Red does not stand out as a very distinct colour to most insects, but it is a very conspicuous colour to birds. The red colour of the flower signals to birds the presence of abundant nectar and makes that nectar as inconspicuous as possible to insects.

Birds may not be attracted by scents but are often attracted to bright flowers like the red flowers of the New South Wales waratahs. Waratah flowers are long, tubular and slightly curved; their rate of nectar production is relatively high and they are commonly visited by nectar-feeding honeyeaters (Fig. 3.15). Many Australian flowers are pollinated by birds, especially the honeyeaters such as wattle birds and noisy miners. Birds play a larger role in Australia compared to Europe where almost all flowers are pollinated by bees.

An example of a flower with a complex mechanism for securing pollination from birds is the 'bird of paradise' (*Strelitzia reginae*). The flowers indicate that there is something attractive on offer. Part of the flower acts as a perch, and the action of the bird inserting its beak to collect nectar forces the pollen to become exposed to the bird's neck. In this way the pollen is carried from plant to plant.

**Figure 3.15** The red colour of the New South Wales waratah (*Telopea speciosissima*) attracts birds as pollinators

When one flower is pollinated it folds back exposing the next flower. Each one opens out in succession like a fan.

**Table 3.5** Features of bird-pollinated flowers

| Feature of flower | Bird-pollinated flowers |
|---|---|
| Petals | Usually large and colourful, red or orange, often form a tubular shape, sometimes no petals at all |
| Scent | Rarely fragrant because birds have little sense of smell |
| Nectar | Large amounts of nectar produced in nectaries at base of flower |
| Anthers | Commonly lower than stigma, sometimes not enclosed by any petals and often colourful |
| Stigma | Higher than anthers, sometimes not enclosed by petals and often colourful |
| Pollen | Sticky or powdery pollen, small amount produced |

## Pollination by insects

Among insect-pollinated angiosperms, the most numerous groups are those pollinated by bees. Like most insects, bees initially locate food by odour, and then orient themselves on the flower or group of flowers by shape, colour, and texture. Flowers that bees characteristically visit are often blue or yellow. Many have stripes or lines of dots that indicate the location of the nectaries, which often occur deep within the specialised flowers. Some bees collect nectar, which is used as a source of food for adult bees and occasionally for larvae. One effective example of bee-pollinated flowers is the grass trigger-plant (*Stylidium graminifolium*) (see Fig. 3.16). When a bee crawls inside the flower to collect nectar the *Stylidium* is triggered to stamp pollen onto the bee in the exact spot where the stigma from another flower will pick it up.

Flower shape can restrict access to pollen and nectar to only those insects that have the appropriate tools or abilities. For example, the nectar at the base of a long tubular flower may only be accessed by insects that have long mouthparts, such as butterflies, moths, flies and bees with long, lapping 'tongues'.

The flower shape can be so restricting that a certain type of behaviour may be required to access the pollen. For example, 'buzz pollination' is needed to pollinate many *Hibbertia* species. It is practised by the blue banded bee (Fig. 3.17) and a number of native Australian carpenter bees, and involves the bee holding onto the plant and vibrating to get the pollen out.

Some other examples of Australian native plants that are pollinated by bees are:

- bottlebrush (*Callistemon*)
- eucalyptus
- grevillea
- *Hibbertia scandens*
- lemon scented tea tree (*Leptospermum polygalifolium*).

Native daisies use bright colours (often yellow) and sweet nectar to attract butterflies such as the Australian painted lady to assist pollination (Fig. 3.18).

Cycads found in central Australia rely on thrips for pollination (Fig. 3.19). The thrips are attracted by scent, which is then used to direct the insects to the male and female cones. Thrips are very small insects that cannot carry many pollen grains, so the plant needs to attract large numbers of them. A male cycad, cone laden with pollen, will emit a strong and pungent scent that will attract as many as 50 000 thrips. Female cones also emit a scent once they are ready to receive pollen, which then attracts the pollen-laden thrips.

**Figure 3.16** Grass trigger-plants (*Stylidium graminifolium*) are triggered to stamp pollen onto bees

**Figure 3.19** Cycads in central Australia rely on thrips for pollination

**Figure 3.17** Blue banded bee showing off her beautiful iridescent furry stripes

**Figure 3.18** Native daisies are pollinated by butterflies such as this Australian painted lady

**Table 3.6** Summary of features of insect-pollinated flowers

| Feature of flower | Insect-pollinated flowers |
|---|---|
| Petals | Usually large and colourful (yellow or blue), may be shaped to encourage specific pollinators |
| Scent | Often present because insects are highly attracted to scents |
| Nectar | Sometimes produced at base of petals so insect must enter the flower to reach the nectar |
| Anthers | Enclosed within flower, commonly lower than stigma |
| Stigma | Enclosed within flower, sticky, and commonly higher above the anthers |
| Pollen | Relatively large grains and often sticky; small amount produced |

## Pollination by deceit

There are some orchids whose flowers mimic the shape and colouring of female insects. The mimics are so realistic that male insects will attempt to mate with the flowers, thereby pollinating them. For example, the hammer orchids of Western Australia have a flower that resembles a wingless insect with shiny eyes, hairy thorax and a fat body (see Fig. 3.20). The flower is held outwards by a hinged arm. When triggered by an insect, the hinged arm moves towards the flower, effecting pollination.

**Figure 3.20** A hammer orchid (*Drakaea glyptodon*) mimics the female wasp whereby the male is deceived and mates with the orchid flower, effecting pollination

## Pollination by other animals

Other animals including bats, possums and small rodents may aid in pollination. The signals here are also species specific. These animals also assist in dispersing the seeds and fruits that result from pollination. Small Australian mammals like pygmy possums, some of the marsupial mice (e.g. *Antechinus stuartii*) and the honey possum (from Western Australia) pollinate common plant species found in the bush and gardens throughout Australia. These plants may include many of the *Callistemon* (bottlebrush), *Banksia* and *Grevillea* species (Fig. 3.21).

**Figure 3.21** Australian examples of species pollinated by birds: (a) *Banksia ericifolia*; (b) *Grevillea banksii*

(a)

(b)

The Australian honey possum is one of the few mammals that specialises in eating flower nectar (see Fig. 3.22).

**Figure 3.22** Australian honey possum (*Tarsipes rostratus*) feeding on and pollinating *Dryandra quercifolia*

## Comparison of wind, bird and insect-pollinated flowers

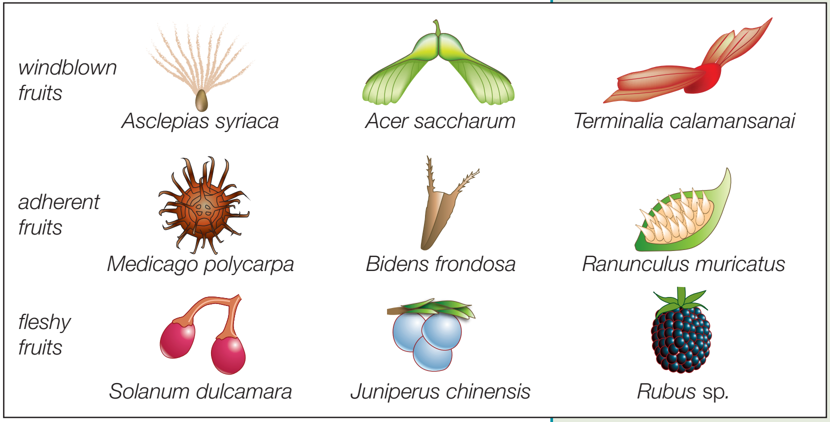
**Table 3.7** Comparison of features of wind, bird and insect-pollinated flowers

| Feature of flower | Wind-pollinated flowers | Bird-pollinated flowers | Insect-pollinated flowers |
|---|---|---|---|
| Petals | Small and inconspicuous, usually green or dull in colour | Usually large and colourful, red or orange, often form a tubular shape, sometimes no petals at all | Usually large and colourful (yellow or blue), may be shaped to encourage specific pollinators |
| Scent | Usually absent | Rarely fragrant because birds have little sense of smell | Often present because insects are highly attracted to scents |
| Nectar | None | Large amounts of nectar produced in nectaries at base of flower | Sometimes produced at base of petals so insect must enter the flower to reach the nectar |
| Anthers | Anthers protrude outside the flower so pollen is easily blown off by the wind; abundant amount of pollen is produced | Commonly lower than stigma, sometimes not enclosed by any petals and often colourful | Enclosed within flower, commonly lower than stigma |
| Stigma | Stigma protrudes from the flower, is often long, feathery and sticky to increase surface area for trapping the wind-borne pollen | Higher than anthers, sometimes not enclosed by petals and often colourful | Enclosed within flower, sticky, and commonly higher above the anthers |
| Pollen | Very small grains, light and powdery; large amounts produced | Sticky or powdery pollen; small amount produced | Relatively large grains and often sticky; small amount produced |

## Seed dispersal

After successful pollination and fertilisation of the flower, the seed develops. It is an advantage for a plant to spread or disperse its seeds over a wide distance. This prevents overcrowding from occurring within the same plant species and increases the chances of survival in situations of environmental change, such as in cases of fire or disease. Seeds are dispersed by wind or by animals such as insects, birds and mammals and are designed to disperse in many ways (Fig. 3.23). Australian native plants have evolved a variety of adaptations to aid in the effective and successful dispersal of their seeds.

**Figure 3.23** Some of the many adaptations of seeds to facilitate dispersal—seeds have evolved a number of different means of moving distances from their maternal plant



### Wind

Some seeds are aerodynamically designed to be blown long distances by the wind; for example, *Flindersia*, leptospermums, melaleucas (with very fine, light seeds), native daisies (with feathery pappus) and casuarinas.

### Animal

Other seeds have structures, such as hooks or barbs, which cling or stick to the fur or feathers of animals. This is so they can be carried long distances before they fall to the ground (e.g. *Pisonia* (birdlime tree) and *Pittosporum*).

Others seeds are enclosed in bright coloured fleshy fruits. Red is a very conspicuous colour to birds, so any fruit or berries containing seeds are highly likely to be dispersed by birds (e.g. lilypillys). Smaller birds are also interested in purple berries such as the tree violet (*Hymenanthera dentate*).

Seeds can pass through the digestive system of mammals or birds which unknowingly transport the seeds to new locations so that they germinate at the spot upon which they were defecated. Some seeds must pass through the gut of an animal to be able to germinate; for example, the nitre bush (*Nitraria billardieri*) depends on emus. Another example is the mistletoe; it has sticky seeds which are deposited on trees by mistletoe birds.

To bribe ants, wattle (*Acacia)* seeds have some lipids attached to their outsides. The seeds (like *Lomandra* and *Grevillea*) are carried by the ants to their nests where they consume the lipids but leave the hard seeds underground, safe from fire. Wattles then can flourish and grow after the hottest of bushfires.

### Fire

Eucalypts, banksias and many other Australian plants store their seeds until the fire destroys the branch or the entire plant. This allows the capsules to open, releasing the seeds for dispersal, usually by the wind. This provides a significant advantage to the seeds as the fire clears land areas and invites recolonisation by new plants. The fastest dispersing and germinating plants can colonise more areas of land. Not all banksias and eucalypts store their seeds waiting for fire. *Banksia integrifolia* and *Eucalyptus melanoxylon* release their seed once it is ripe. This is seen as a primitive feature compared with other species that are actually more suited to their environment and have more effective colonising mechanisms.

Of the dry simple fruits, some open and shed their seeds at maturity (Fig. 3.24). A follicle, which opens on the lower side, is formed from a single carpel (e.g. *Grevillea*). Pods or legumes open on two sides (e.g. *Acacia*). The dry fruits of many Australian native plants have thick, woody walls that protect the seeds from the heat of bushfires. In eucalypts, the top of the ovary forms three to four valves, the fruit splits open and a capsule matures and dries out. After a fire, the heat causes the valves of fruits held in the tree canopies to open quickly and seeds are released. The woody follicles of banksias are very fire resistant and open after fire. Each follicle has two seeds attached to a wing-like structure, the separator. When the separator is sufficiently wet by rain following a fire, it expands, pulling the seeds out of the fruit (Fig. 3.24d). Seeds will otherwise remain protected in the fruit until rain falls, providing suitable conditions for germination.

## Water

Some seeds rely on water dispersal, such as the water gum (*Syzygium francisii*) and the mangrove (*Avicennia marina*). Seeds may float small or large distances from the parent plant along rivers and estuaries or across seas.

## Explosion

Finally, some seeds are violently propelled from the base of the fruit in an explosive discharge. Seeds are ejected from the pod at high speeds caused by the drying and contraction of the pod. Some seeds such as the *Acacia cultriformis* can be thrown up to 2 m by this method; other plants such as the *Viola betonicifolia* also use such a mechanism to send their seeds distances.

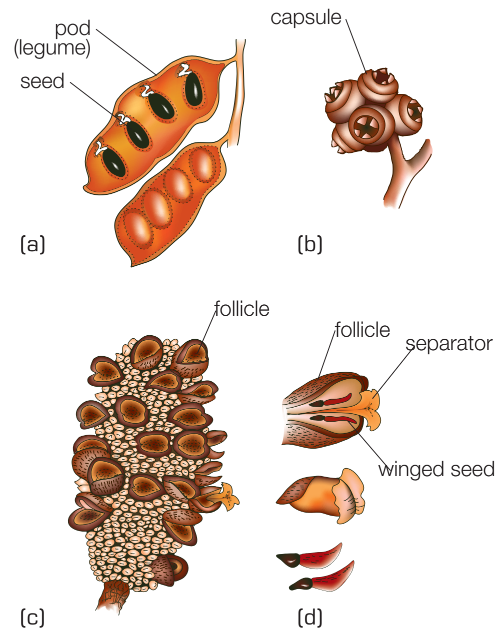



**Figure 3.24** Dry fruits include: (a) pods or legumes, *Acacia*; (b) capsules, *Eucalyptus*; (c) follicles, *Banksia*; (d) follicle separator in *Banksia*, which when wet pulls the two seeds out of the fruit

**Table 3.8** Summary of different seed dispersal mechanisms

| Method of dispersal | Description of dispersal mechanism(s) | Examples |
|---|---|---|
| Wind | ■ Seeds may have different mechanisms or adaptations to assist the dispersal over long distances by the wind | ■ Fine, light aerodynamic seeds (e.g. melaleuca and casuarina)<br>■ Winged seeds (e.g. hakea)<br>■ Feathery pappus (e.g. native daisies) |
| Animal | ■ Seeds may possess hooks or barbs to catch seeds on the outside of animals<br>■ Fruits may be eaten and seeds then carried in the gut and deposited in faeces in a new area | ■ Colourful fruit (e.g. lilypilly and tree violet)<br>■ Sticky fruit (e.g. mistletoe)<br>■ Burrs or hooks (e.g. birdlime tree and pittosporum)<br>■ Through animal gut (e.g. nitre bush) |
| Fire | ■ Some seeds are stored until fire causes pods to open | ■ Eucalypts, banksias, acacias and grevilleas |
| Water | ■ Seeds may float on water and be dispersed distances over different water bodies (rivers and oceans) | ■ Water gums and mangroves |
| Explosion | ■ Some seed may be ejected from pods at high speeds. The pods explode when ripe and shoot seeds away from the parent plant. | ■ Acacias and viola |

## Asexual reproduction

Asexual reproduction is the making of a new individual without the use of sex cells or gametes. Only one parent is required for the mitotic cell divisions to occur. Some types of asexual reproduction are:

- binary fission
- budding—e.g. *Hydra* (Fig. 3.25a) and coral
- spore formation—e.g. moss, fungi and ferns
- vegetative propagation—e.g. plant cuttings like roses
- regeneration—e.g. starfish (Fig. 3.25b) and earthworms
- parthenogenesis—e.g. Binoe's gecko (*Heteronotia binoei*).

Plants that reproduce asexually clone new individuals from portions of the root, stem, leaves or ovules of adult individuals. The asexually produced individuals are genetically identical to the parent. There are different types of asexual reproduction in plants as follows.

### Vegetative reproduction

New plant individuals are simply cloned from parts of adults, such as runners, rhizomes and suckers.

#### Runners

Some plants reproduce by means of runners which are long, thin stems that grow along the surface of the soil. In the cultivated strawberry, for example, leaves, flowers and roots are produced at every other node on the runner. Just beyond each second node, the tip of the node turns up and thickens, producing new roots and a new shoot that continues the runner. Another example is spinifex grass (Fig. 3.26) which has long stems that grow horizontally along the surface of the soil. At each node, leaves and roots are produced that can be subdivided into new plants.

(a)

(b)

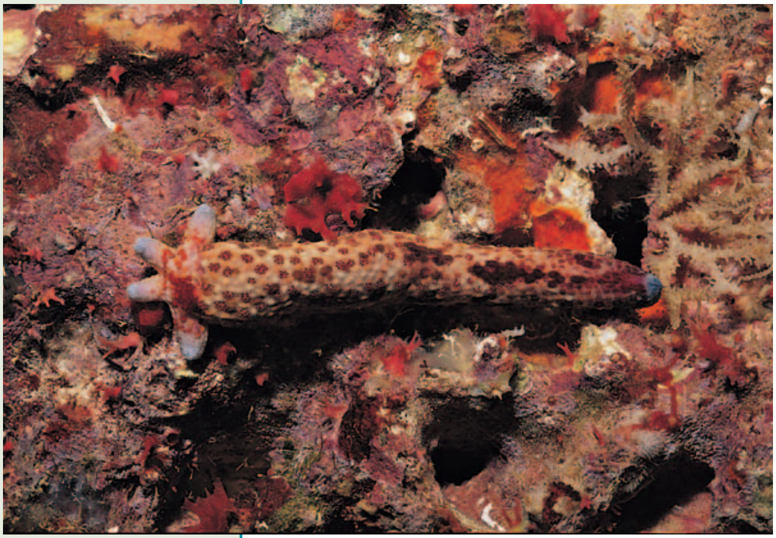


**Figure 3.25** Asexual reproduction: (a) budding: in *Hydra*, a new individual is produced from a bud that branches from the side of the parent body wall; (b) regeneration: a single arm of the sea star (*Linkia mulifora*) regenerating four new arms to form an entire new individual

**Figure 3.26** Spinifex grass (*Spinifex hirsutus*) has long stems that grow along the surface of the soil, producing new leaves and roots (plantlets) at each node

### Rhizomes

Underground horizontal stems, or rhizomes, invade areas near the parent plant with each node being able to give rise to a new flowering shoot. Corms (swollen stems, e.g. gladioli), bulbs (swollen leaf bases, e.g. daffodils) and root tubers (e.g. begonias and potatoes) (Fig. 3.27) are stems specialised for storage and reproduction. The eyes or 'seed pieces' of the potato give rise to the new plant. Rhizomes are characteristic of ginger, ferns such as bracken fern and many grasses.

**Figure 3.27** The potato develops new tubers from swollen regions of the stem

### Suckers

The roots of some plants produce 'suckers' or sprouts, which give rise to new plants. Trees and shrubs that sucker, such as reeds (Fig. 3.28), wattles and blackberries can spread quickly into a vacant patch of habitat after disturbance. When the root of a dandelion is broken when someone tries to pull weeds out from the ground, each root fragment may give rise to a new plant.

## Budding

Budding is one of the more unusual forms of asexual reproduction seen in plants. Budding involves the development of a new individual as an outgrowth of the parent plant. For example, *Kalanchoe* produces buds along leaf margins, which can break off and form new plants, eventually growing to adult size (Fig. 3.29).

**Figure 3.28** The common reed (*Phragmites australis*) spreads rapidly by suckering through aquatic habitats

## Apomixis

In certain plants, such as kangaroo grass (*Themeda triandra*), lemon and orange trees (*Citrus*) and dandelions, the embryos in the seeds may be produced asexually from the parent plant. The seeds produced in this way give rise to individuals that are genetically identical to their parents.

**Figure 3.29** Asexual reproduction by budding: *Kalanchoe* generates tiny plantlets by budding along the margins of its leaves

By reproducing asexually this way these plants also gain the advantage of seed dispersal, an adaptation usually associated only with sexual reproduction, as well as the rapid multiplication of plants.

#### Totipotency

An entire plant can be generated from a single plant cell. This property is known as totipotency and was first demonstrated in 1958 by F. C. Steward. He took a section of carrot root and, under sterile conditions, cut out tiny pieces of tissues. These were then cultured in a shaking flask in a liquid containing nutrients and minerals, plus green coconut milk to stimulate growth. Free cells separated off from the pieces of tissue and divided, forming embryo-like structures. These structures could be transplanted on to a solid medium and grown in the light into new carrot plants that were clones of the original plant.

#### Other examples of Australian plants reproducing asexually

- *Polystichum prolifeum*
- *Asplenium bulbiferum*
- *Viola hederacae*
- *Dichondra repens*
- Ground orchids

## Features of pollination in native flowering plants

FIRST-HAND INVESTIGATION

BIOLOGY SKILLS

P11
P13
P14
P15

- ***plan, choose equipment or resources and perform a first-hand investigation to gather and present information about flowers of native species of angiosperms to identify features that may be adaptations for wind and insect/bird/mammal pollination***

### Aim

1. To plan, choose equipment or resources.
2. To perform a first-hand investigation.
3. To gather, and present information about flowers of native species of angiosperms.
4. To identify features that may be adaptations for wind and insect/bird/mammal pollination.

### Equipment

Suggestions for equipment are:

- variety of native angiosperm (flowering plant) specimens
- hand lens
- scalpel
- forceps
- Petri dish
- binocular microscope
- labelled diagrams of longitudinal sections of flowers (bisected/cut in half) showing different arrangements of reproductive structures demonstrating the different types of pollination, such as those in Figure 3.30
- key to Australian flowering plants.

### Method

#### Part 1: Planning the first-hand investigation

This investigation will involve each group collecting four different native flower specimens, bisecting each flower longitudinally and scientifically drawing and labelling each flower's structure. You will then be expected to make deductions about each flower's method of pollination using the characteristics you observed in each flower.

Write up and describe the method you would undertake to carry out this investigation. Once you have completed this, list the equipment your group will need to carry out the method (see equipment suggestions). This includes selecting the four native flower specimens that your group will be observing. A suggestion would be to choose some from your own garden or ask your teacher about native flowers available in the school grounds.

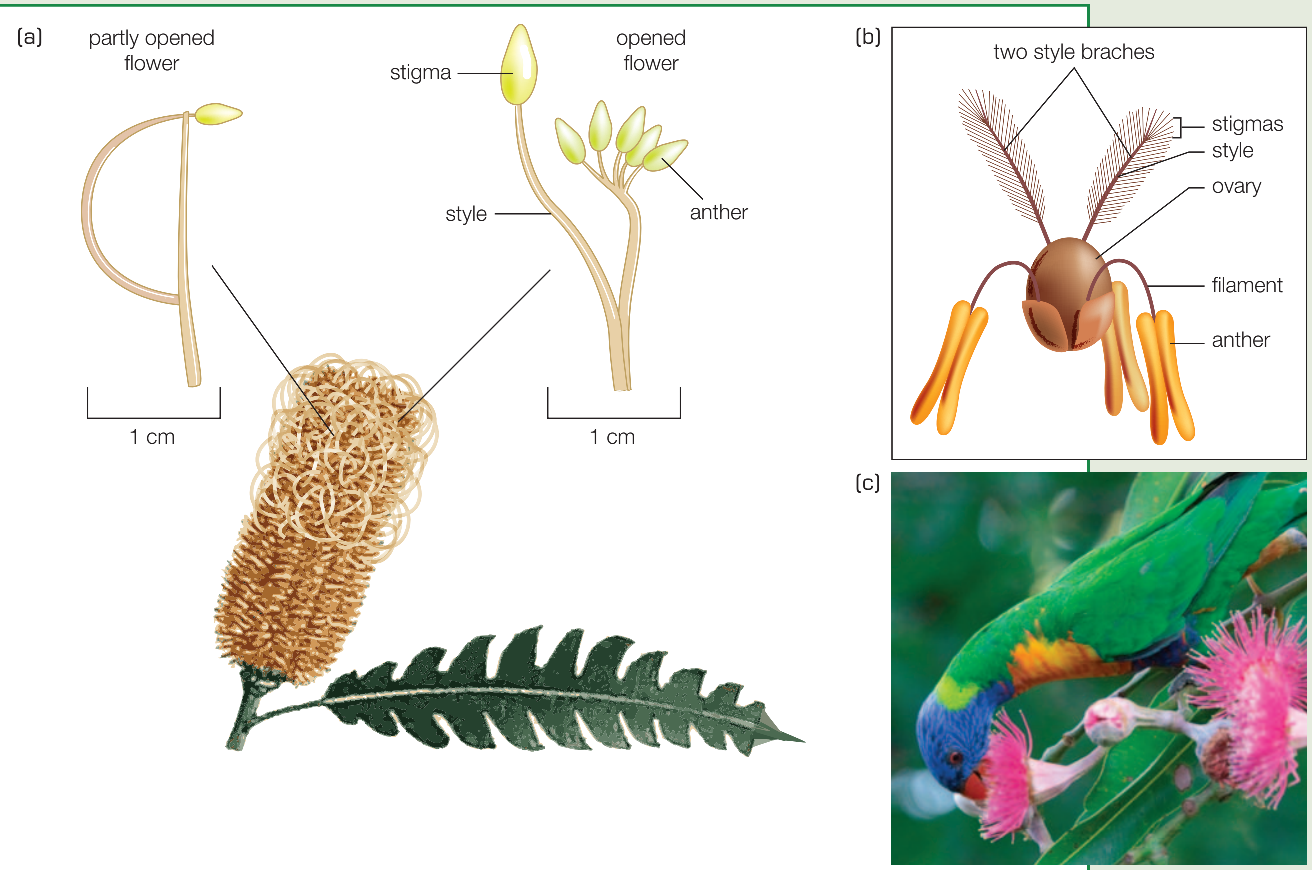



**Figure 3.30** Longitudinal sections of flowers: (a) *Banksia ericifolia*—insect pollination;
(b) Grass flower with large stigma surface—wind pollination;
(c) Eucalypt flower

## Part 2: Gather information about flowers of native species of angiosperms

Read Section 3.5 on pollination in plants (including Table 3.7), observe the flower diagrams in Figure 3.11, and research information from a variety of other secondary sources, in order to obtain information on the four native angiosperm flowers that you have selected for this investigation.

## Part 3: Present information about native flowers and identify features that may be adaptations for wind and insect/bird/mammal pollination

After writing up your investigation method and equipment list, carry out your investigation and present your information in two ways:

- Draw large, clear, fully-labelled diagrams of your four longitudinally bisected flowers (see Fig. 3.31).
- Copy (see Student Resource CD) and complete Table 3.9 with one example already provided.

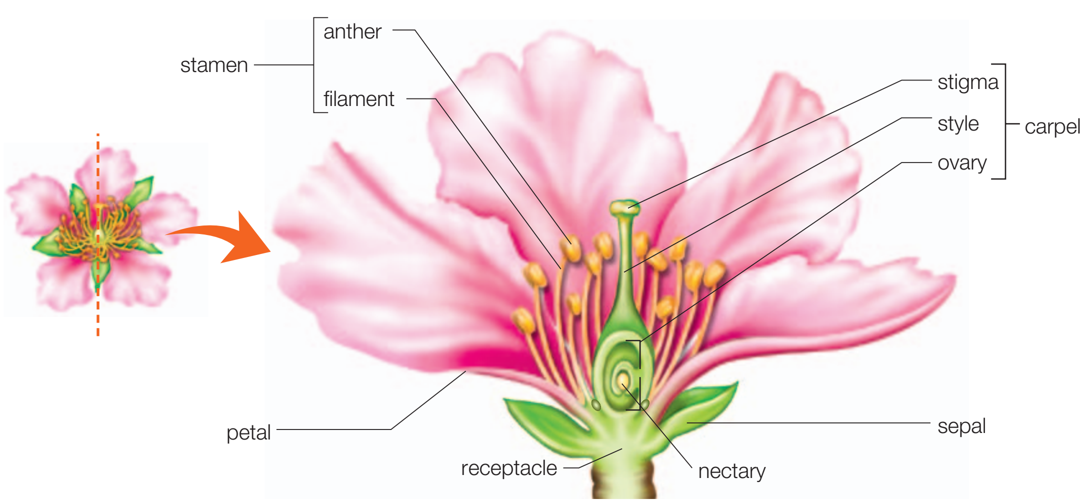
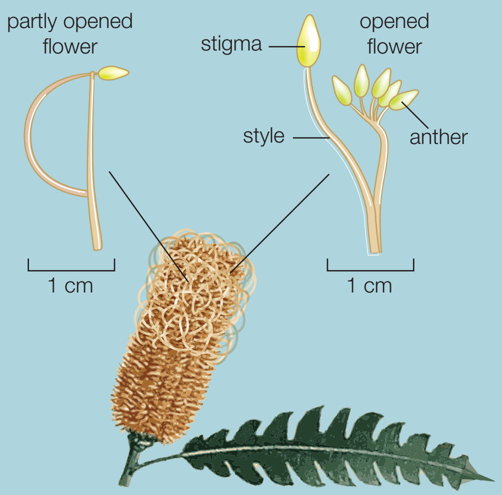



**Figure 3.31** Scientific, labelled drawing of the structure of a flower

## Results

**Table 3.9** Features of native flowers that may be adaptations for pollination

| Feature of flower | Scientific and common name of selected plant specimen | |
|---|---|---|
| | *Banksia ericifolia* (banksia)   | |
| Flowers | No single flowers but large number grouped together (inflorescence) | |
| Sepals | None | |
| Petals | Yellow | |
| Scent | Sweet | |
| Nectar | Present | |
| Anthers | Brightly coloured | |
| Stigma | Long and above anthers | |
| Type of pollination and justification | Insect pollination because yellow coloured petals suggest bee pollination, brightly coloured anthers suggest insect attractor, nectar reward for insects, and high number of flowers allow many insects to pollinate at the one time | |

SR TR

Table 3.9

## Discussion/conclusion

1. Identify the structures of native flowers that may be adaptations to wind pollination?
2. Identify the structures of native flowers that may be adaptations to insect/bird/mammal pollination.
3. (a) Was any particular type of pollination more common than others in your specimens? If so, which one?
   (b) Can you explain possible reasons for this?
4. Briefly describe how and why the features of wind-pollinated flowers differ from insect- and bird-pollinated flowers.

# Evolutionary advantages of sexual and asexual reproduction

3.6

- ***explain how the evolution of these reproductive adaptations has increased the chances of continuity of the species in the Australian environment***

As organisms have evolved from aquatic environments moving onto the land, the evolution of reproductive adaptations has ensured survival of species. Over time, organisms have continued to develop and become more specialised in their reproductive adaptations surviving in harsh arid Australian conditions with extremes of drought and fire.

## Asexual reproduction

Reproduction is not necessary for individual success, but for the continuation of the species. There are a number of strategies of reproduction depending on the environment of the organism. Organisms that reproduce asexually do not have to rely on another individual organism to provide gametes and are at an advantage when sudden or unexpectedly favourable conditions arise because they can quickly reproduce themselves (with offspring identical to the parent). This can become a competitive edge if the organism lives in an environment that is often disturbed, and they are particularly well suited to a certain environment or habitat. Asexual reproduction among plants is far more common in harsh environments where there is little margin for variation. The main disadvantage to asexual reproduction is if extremely harsh conditions arise, the whole group of species is particularly vulnerable to these conditions, or to disease, parasitism and predation.

## Sexual reproduction

Sexual reproduction produces offspring that are genetically different and possibly better adapted to new and changing environmental conditions than their parents. This gives the species a better chance at surviving in ever-changing environments. However, sexual reproduction is often a more energetically expensive process, compared to asexual reproduction, and may be the first thing an organism abandons in times of hardship.

### External fertilisation

The chances of successful external fertilisation are increased by the synchronisation of the release of gametes, reproductive cycles and the mating behaviours of each species. External fertilisation and development means that parents spend less time looking after the young, but more gametes have to be produced to ensure that some eggs get fertilised. The advantage of this method is the high dispersal of young. The gametes are thrown into the sea and fertilised eggs are carried away to settle in an area different to their parents. This reduces competition for food and living space for the parent generation, and allows quick recovery of populations away from damaged areas.

### Internal fertilisation

Organisms that use internal fertilisation tend to be more adapted to terrestrial environments and reproducing successfully on land. Fewer gametes are produced because there is a much higher rate of fertilisation and survival.

The move to internal fertilisation and development has demonstrated new adaptations for reproduction on land, which may have started with the ovules of flowers becoming enclosed in the ovary to provide adequate protection from desiccation.

## Parental care

Parental care varies between aquatic and terrestrial organisms. Many aquatic species simply abandon the fertilised eggs and leave them to risk development in the open sea. This means that less energy is put into caring for the young and the survival rate of the young is much lower; therefore, more eggs have to be produced to compensate. Mammals are generally **viviparous** (give birth to live young); fish, birds, some reptiles and many invertebrates are **oviparous** (egg-laying). Oviparous animals will devote varying amounts of energy to caring for their eggs. Some oviparous animals brood their eggs until they hatch to increase the survival rate of their eggs, while others will stand guard over a nest of eggs until they hatch.

## Plants

In plants, self-pollination expends less energy in the production of pollinator attractants and can grow in areas where the kinds of insects or other animals that might visit them are absent or very few. These plant species contain high proportions of individuals well-adapted to their particular habitats.

In cross-pollinators, animal agents such as insects, birds and mammals have become a more effective way of transferring pollen to the stigma. As flowers become increasingly specialised, so do their relationships with particular groups of insects and other animals.

Many features of flowering plants seem to correlate with successful growth under arid and semi-arid conditions. The transfer of pollen between flowers of separate plants, sometimes over long distances, ensures cross-pollination and may have been important in the early success of angiosperms. The various means of effective fruit dispersal that evolved in the group were also significant in the success of angiosperms. As early angiosperms evolved, all of these advantageous features became further elaborated and developed, and the pace of their diversification accelerated. In addition to insects, birds and mammals now assist in pollination and seed dispersal.

## Reproduction—Australian species

Individual Australian species have variations in their reproductive structures and mechanisms. If the environment changes, the individual species most suited to the change will survive and reproduce, passing on their characteristics to their offspring. As the Australian environment becomes more arid (drier and often hotter), organisms possessing reproductive adaptations that enable their young to survive should be able to increase in numbers.

### Adaptations for colonisation and survival

Reproductive adaptations are needed for successful colonisation and survival in the Australian environment. Australia has many areas of harsh arid conditions (and sometimes drought or fire), making it difficult for effective fertilisation and development unless the organisms possess adaptations suitable for successful reproduction in harsh environments. Reproducing offspring in times favourable to the organism—suitable climate and resources, available water and food supply— increases the chances of continuity of the species.

Possessing adaptations for survival and the ability to flourish after extreme harsh conditions pass (eg. drought or fire) also increases chances of continuity of the species. Species need to survive the harsh times and maintain their population numbers (without becoming extinct) until conditions improve, then utilise adaptations to rapidly increase species numbers afterwards (e.g. the kangaroo with its embryo on standby). Many Australian plants possess adaptations to harsh conditions like fire, for example hakeas have woody seed pods able to survive the high temperatures of fire. The pods do not usually open unless stimulated by the heat of fire, landing on soil enriched by ash from the fire. This means that the seed is not released and dispersed until environmental conditions are favourable for rapid increase and therefore continuity of the species. Hakeas also regenerate and ensure continuity of the species after fire by growing lignotubers from the fire-damaged plant.

## 3.7 Conditions under which asexual reproduction is advantageous

- ***describe the conditions under which asexual reproduction is advantageous, with reference to specific Australian examples***

### Advantages of asexual reproduction

- Only one parent is required so energy is not wasted on producing large numbers of gametes or on finding a mate. This is advantageous:
  —in arid conditions or where environmental conditions are not as favourable; for example, spinifex grass survives and reproduces successfully by sending out runners in harsh sand dune conditions such as high temperatures, high salinity and wind erosion (Fig. 3.26)
  —when food supply may be short and there is a need to use less energy to reproduce
  —when there is a small mating population or time constraints on finding a mate.
- It is a relatively quick process and large numbers of offspring can be produced rapidly. This is an advantage when rapid recovery is needed after a decline in numbers (e.g. after a bushfire or drought). The colony wattle (*Acacia murrayana*) (Fig. 3.32) can send up shoots from the outer roots which grow into separate plants if the parent shrub dies. This allows for regrowth to occur quickly. It often forms colonies from root suckers. Another example is the scaevola misty blue (*Scaevola striata*) (Fig. 3.33) which can also recolonise damaged areas such as sand dunes by reproducing asexually. It is a hardy groundcover that is adaptable to most soil types and full sun.

**Figure 3.32**
Colony wattle

**Figure 3.33**
Scaevola

- If there is no variation in the environment then the identical offspring will always be adapted to their surroundings and survive to reproduce successfully. Corals, such as the grooved brain coral (Fig. 3.34), reproduce by budding when conditions are favourable, however if the environment does change (eg. a new disease or pest enters) the entire species may rapidly decline and die out.
- Asexual reproduction is advantageous when environmental conditions are stable. In this situation the offspring of the parent plants are identical, having features that make them suited to the environment and likely to survive to reproduce themselves. This type of reproduction allows rapid colonisation after harsh conditions such as fire or drought which may decrease the species population numbers. Many Australian plants have adaptations for survival in this situation where reproduction is stimulated.

**Figure 3.34** Grooved brain coral

**Table 3.10** Summary of examples of the advantages of asexual reproduction in Australia

| Australian example | Asexual reproduction mechanism | Why it is an advantage |
|---|---|---|
| Spinifex grass | Reproduces by runners which put out individual stems and roots at nodes along the ground | Reproduces successfully in harsh conditions, requires less energy to reproduce by runner, very rapid method of reproduction |
| Colony wattle | Sends up shoots from outer roots which grow into separate plants | Rapid method where large numbers can be reproduced quickly, an advantage when rapid recovery is needed after a decline in numbers (e.g. fire or drought) |
| Grooved brain coral | Reproduces by budding, where a new bud can form a new individual separate from the parent plant | An advantage when there is no variation in environmental conditions, it will always have adaptations to its surroundings and survive to reproduce successfully, all offspring are genetically similar to parents. |

## REVISION QUESTIONS

1. Identify the type of cells which divide by meiosis.
2. Explain the importance of meiosis.
3. Describe what is meant by the following terms:
   (a) homologous chromosomes
   (b) diploid and haploid
   (c) chromatid.
4. Draw a cell with three pairs of chromosomes:
   (a) towards the beginning of meiosis, while it is undergoing crossing-over in one of its pairs of chromosomes
   (b) after the first meiotic division
   (c) after the second meiotic division.
5. Compare the number of chromosomes in a cell that has completed meiosis with that of the parent cell.
6. Explain why the daughter cells that result from meiosis are not genetically identical to each other.
7. State one similarity and two differences between the processes of mitosis and meiosis.
8. Describe the similarities and differences between the characteristics of internal and external fertilisation, using two examples of each.
9. Compare the relative success of internal and external fertilisation in relation to the colonisation of terrestrial and aquatic environments.
10. Describe two mechanisms found in Australian fauna to ensure the survival of the embryo and young after birth. Give one example of each.
11. (a) Describe the pollination mechanism found in two *named* Australian plants.
    (b) Identify two ways that the reproductive structures differ between wind-pollinated and insect-pollinated plants.
12. Identify two different methods used for seed dispersal in *named* Australian plants.
13. Describe three types of asexual reproduction in plants. Give one Australian example for each.
14. Explain how the evolution of reproductive adaptations has increased the chances of continuity of the species in the Australian environment.
15. Describe the conditions under which asexual reproduction is advantageous using a *named* Australian example.

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Answers to revision questions