Australian National Botanic Gardens

Teachers' Notes

Module 3

Pollination

We acknowledge the Traditional Owners of Country throughout Australia and recognise their continuing connection to land, waters and culture. We pay our respects to their Elders past, present and emerging.

Plant Science Learning Hub

Students need a space to learn that is fun and rewarding. The Australian National Botanic Gardens has developed a Plant Science Learning Hub that aims to inspire and engage students in plant science and the stories surrounding Australian flora. With clear links to the Australian Curriculum for school years four to six, the Plant Science Learning Hub will provide a valuable resource for students and educators.

1. Plant Life Cycles
2. Plant Structure
3. **Pollination**
4. Seeds

This series provides educators with authoritative plant science content that has a uniquely Australian perspective. The Gardens manages globally significant scientific collections of living plants and herbarium specimens of Australian native flora. We provide educational experiences for students from pre-primary to tertiary levels, leveraging our scientific collections, participation in national and international conservation projects, and outreach programs to engage the community in valuing, conserving and appreciating Australia's diverse plant heritage.

Document overview

This document provides educators with supporting notes for the Pollination module.
It focusses specifically on flowering plants native to Australia.

- Pollination is the movement of pollen from the male parts (anther) to the female parts (stigma) of a flower and is essential for the sexual reproduction of plants.
- Self-pollination occurs when pollen is transferred within a single flower or between flowers on the same plant. Cross-pollination occurs when pollen from one plant is transferred to another.
- Pollination can be assisted by pollinators such as wind, water, insects, birds, mammals or reptiles.
- Flowers and animal pollinators have co-evolved over millions of years, and pollination is often a symbiotic relationship where each participant benefits from the interaction.
- A pollination syndrome refers to floral characteristics that have evolved to correspond with a particular pollen vector, and this can be used to predict the pollinator of a flower.
- Pollination is essential to maintaining healthy ecosystems and productive agricultural industries.

Contents

LESSON ONE: TEACHERS NOTES

Module Learning Objectives

1. Understand why and how pollination occurs.
2. Explore how plants and animals interact in the pollination process and how they rely on each other for survival.
3. Identify the structural features/adaptations of pollinators and flowering plants and describe common 'pollination syndromes'.
4. Identify ways of taking action to ensure the survival of flowering plants and pollinators.

CURRICULUM LINKS

This material provides opportunities for students to engage in the following Australian Curriculum content descriptions **(Version 9.0)**:

Biological Sciences

AC9S4U01 Explain the roles and interactions of consumers, producers and decomposers within a habitat and how food chains represent feeding relationships (Year 4)

AC9S5U01 Examine how particular structural features and behaviours of living things enable their survival in specific habitats (Year 5)

AC9S6U01 Investigate the physical conditions of a habitat and analyse how the growth and survival of living things is affected by changing physical conditions (Year 6)

Science as a Human Endeavour

AC9S4H01 Examine how people use data to develop scientific explanations (Year 4)

AC9S4H02 Consider how people use scientific explanations to meet a need or solve a problem (Year 4)

AC9S5H01 Examine why advances in science are often the result of collaboration or build on the work of others (Year 5)

AC9S5H02 Investigate how scientific knowledge is used by individuals and communities to identify problems, consider responses and make decisions (Year 5)

AC9S6H01 Examine why advances in science are often the result of collaboration or build on the work of others (Year 6)

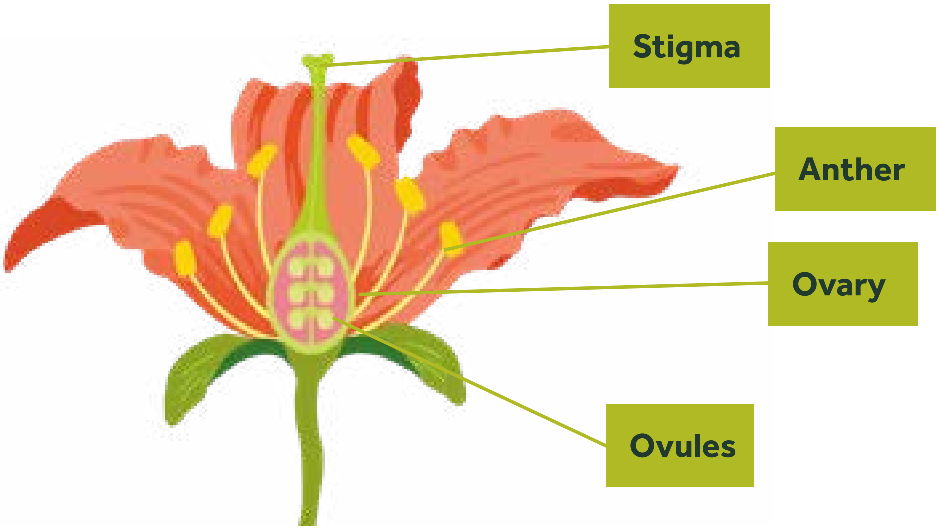
AC9S6H02 Investigate how scientific knowledge is used by individuals and communities to identify problems, consider responses and make decisions (Year 6)

INTRODUCTION TO POLLINATION

Pollination is one step in the process of **sexual reproduction** in seed-producing plants.

Pollination involves pollen being delivered from the male parts of a plant to the female parts. In a flower,
pollen travels from the **anther** (part of the male reproductive system) to the **stigma** (part of the female reproductive system). Pollen contains male reproductive or sperm cells, which contain the plant's
genetic information. Successful pollination can lead to **fertilisation** and the production of seeds.

Pollination can occur when pollen is moved by wind, water or animal pollinators, including birds and insects. Approximately 65% of all flowering plants, and non-flowering seed-producing plants (such as cycads and pines), rely on insects for pollination.



HOW DOES POLLINATION HAPPEN?

There are two types of pollination: **self-pollination** and **cross-pollination**.

Self-pollination occurs when a plant is pollinated with its own pollen. This can happen within a single flower or between flowers on the same plant.

Cross-pollination is the transfer of pollen from the anther (male part) of a flower on one plant to the stigma (female part) of the flower on another. This often involves the help of animal pollinators such as bees, flies, ants, beetles, thrips, wasps, butterflies, birds, bats, possums or even reptiles.

An **adaptation** is any trait, feature or behaviour that allows an organism to be better suited to its environment. Over millions of years, seed-producing plants and their pollinators have evolved many adaptations that enable pollination to be more successful. These are explored below.

SELF-POLLINATION

Often plants that can self-pollinate have both male and female reproductive organs within the same flower. There are several adaptations that flowers have evolved to assist with self-pollination.

- In some plants, self-pollination occurs within specialised, closed flowers (**cleistogamy**). This happens in crops such as rice, wheat, peas and beans and Australian species such as Wallaby-grass (*Rytidosperma caespitosum*), Twining Glycine (*Glycine clandestina*), Australian Desert Rose (*Gossypium australe*) and Bush Tomato (*Solanum cleistogamum*).
- In some flowers, the anthers and stigma mature at the same rate so pollen can readily land on the stigma when it is receptive.
- In some flowers, the anthers and stigma grow close together, allowing for easy self-pollination.
- Some plants only self-pollinate at the end of their flowering period, after there has been a chance for cross-pollination to occur. This means that if cross-pollination is unsuccessful, the plant can still reproduce.

Benefits

- Self-pollination allows plants to save energy, as very little pollen is required, and there is usually no need to attract pollinators with sweet nectar.
- Plants do not need to rely on external factors such as the availability of insects for pollination to occur, instead needing just their own pollen to complete the process.
- Plants produced via self-pollination have the same genetic makeup as their parent, so if environmental conditions remain stable, this offspring should be well adapted to these conditions.

Limitations

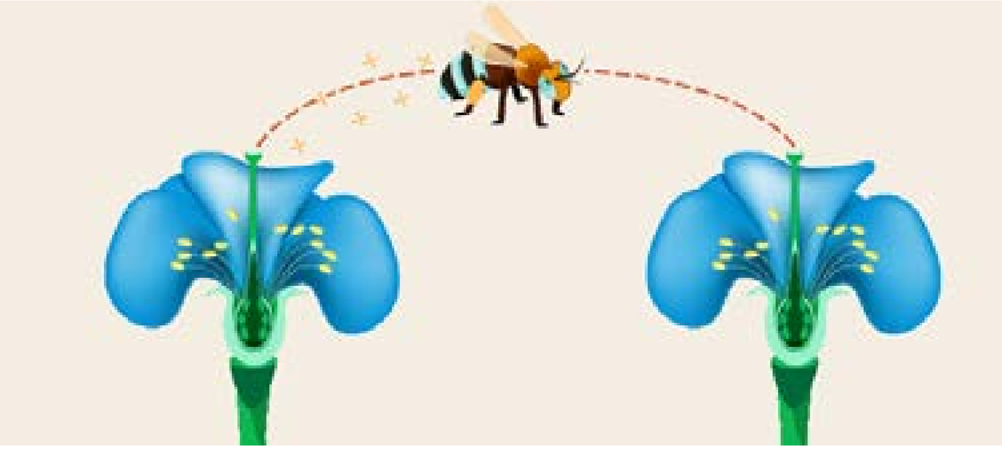
- The lack of genetic diversity amongst self-pollinating plants means there is no possibility for variation in the plants' features (such as flower colour, shape or size). Therefore, no new species can develop through evolution and adaptation.
- Lower genetic diversity in a species can make it more susceptible to diseases.

CROSS-POLLINATION

There are several floral adaptations that have evolved to increase the chances of cross-pollination or to prevent self-pollination.

- In some plants, the anther and stigma do not mature at the same time so self-pollination cannot occur.
- The anthers and stigma of a flower can be well separated to prevent self-pollen from reaching the stigma.

Some plants reject or prevent the germination of self-pollen grains that do reach the stigma.



Benefits

- There is more genetic diversity, which means more differences in the DNA between plants.
- With more genetic diversity, if a disease or change in the environment kills some of the species, it's likely that some plants will survive.

Limitations

- Cross-pollination wastes a lot of pollen as it sometimes has to travel quite a distance and a stigma is a very small target.
- Cross-pollination relies on a pollinator to take the pollen from one flower to another flower on a different plant, If the pollinator doesn't visit the right flower, no pollination.

WHY IS POLLINATION IMPORTANT?

Many of the Earth's systems rely on plants; without them, **food chains** and **ecosystems** would stop functioning. This is also true for humans, as agricultural industries grow cereal crops, such as wheat and rice, and fruit and vegetable crops, such as oranges and broccoli, to provide food for us and livestock. Many of these agricultural plants require pollination to maximise the volume and quality of production, and two-thirds of Australia's crops benefit from the presence of pollinators.

Crops that require cross-pollination, such as apples and watermelons, rely on the presence of animal pollinators to produce fruit that is good enough to be sold. Wheat, corn and rice are pollinated by the wind, so do not require animal pollinators. Some crops can self-pollinate, requiring pollination to produce fruit and seeds but not relying on external pollinators.

WHAT WOULD HAPPEN WITHOUT POLLINATION?

Seed-producing plants can reproduce **sexually** or **asexually**, but only sexual reproduction requires pollination.

- Plants that rely on sexual reproduction for survival would become extinct without pollination!
- Asexual reproduction produces genetically identical plants through **cloning**, so there would be no genetic diversity amongst the remaining plants. This may make them more susceptible to diseases and changes in environmental conditions (such as **climate change**).
- The distribution of these plants would be limited, as asexual reproduction (including dispersal via **rhizomes**, **tubers**, **suckers**, **corms** and **stolons**) can only occur near the parent plant.
- Changes to the distribution and diversity of plant species would reduce the availability of food and habitat for many animal species, including humans, thereby reducing global biodiversity.

INTRODUCTION TO POLLINATORS AND POLLINATION SYNDROMES

A pollinator helps move pollen from the male parts of a flower to the female parts to allow pollination to occur. There are two categories of pollinators: **abiotic** and **biotic**.

- **Abiotic** relates to things that are not living. **Abiotic** pollination includes the movement of pollen by wind or water.
- **Biotic** relates to things that are living. **Biotic** pollination refers to the movement of pollen by animals, such as birds, insects, mammals and reptiles.
- About 80% of all plant pollination is performed by animals and the remaining 20% is completed by **abiotic** methods.

Plants have adapted to make pollination more successful by developing a huge diversity in flower colour, form, scent, nectar reward, structure and position on a plant. This has given rise to **pollination syndromes**, which describe flower features that tend to occur together to maximise pollination success via a specific pollinator. Wind-pollinated plants have a wind **pollination syndrome** that enables their pollen to be released into the wind and carried away. In contrast, butterfly-pollinated plants have a butterfly **pollination syndrome** that allows them to attract butterflies with certain colours, nectar and scents.

ABIOTIC POLLINATORS

Wind pollination

- Plants pollinated by the wind do not generally produce scents or nectar, and their flowers are often small and not showy.
- The anthers and stigmas project outwards into the air to drop and pick up pollen easily.
- The stigmas can be feathery or sticky to increase the chance of catching pollen.
- The anthers often possess a long, slender filament.
- Wind-pollinated flowers tend to have small or no petals so, they do not get in the way when the wind blows pollen onto them.
- Wind-pollinated flowers are open during the day and night.
- They produce large quantities of smooth, lightweight pollen that can be carried hundreds of kilometres!
- The imprecise nature of wind pollination means that a large amount of pollen never encounters a stigma and is wasted.
- Examples of commercial crops of wind-pollinated plants include wheat, rice, palms, walnuts and oats. Australian native examples include *Themeda* grasses, *Livistona* palms and *Allocasuarina* trees.
- Gymnosperms proliferated around 319 million years ago by using wind-pollination, which means they evolved wind-pollination 70 million years before dinosaurs existed! Approximately 98% of gymnosperms are still wind-pollinated today.

Livistona palms.
Image: ©M.Fagg,1987

Themeda grasses.
Image: ©M.Fagg,1999

Water pollination

- Plants pollinated by water tend to live in aquatic, estuarine or marine environments.
- They can release pollen or sometimes the whole male flower into the water. This floats to the surface, or in rare cases travels underwater, to encounter other flowers and facilitate pollination.
- Female flowers are usually held above the waterline and have long feathery stigmas for catching pollen.

***Posidonia australis* is a native seagrass species that occurs in estuaries throughout Australia and is pollinated by water.**

- Specific water temperatures trigger the release of pollen.
- Its pollen is contained in sticky capsules that are launched into the water to avoid being stuck in the leaves and to ensure it moves away from the parent plant.
- Its pollen is highly modified for transport by water: the grains are elongated and are so small they are almost invisible in water!
- *Posidonia australis* flowers have bright red anthers that are in or above the leaf canopy.
- The flowers have both male (anthers) and female (stigma) parts, but self-pollination is reduced by the anthers releasing pollen before the stigmas become receptive. This mechanism prevents self-pollination but also reduces the chance of pollen contacting any receptive stigma, making pollination difficult.
- *Posidonia australis* has a low pollination rate but is successful enough to ensure that the species continues.

Posidonia australis is a species of native seagrass that reproduces via water pollination.
Image: ©S.Shepherd, 1969

BIOTIC POLLINATORS

Flowering plants have evolved with animal pollinators over millions of years in a process called **co-evolution**.

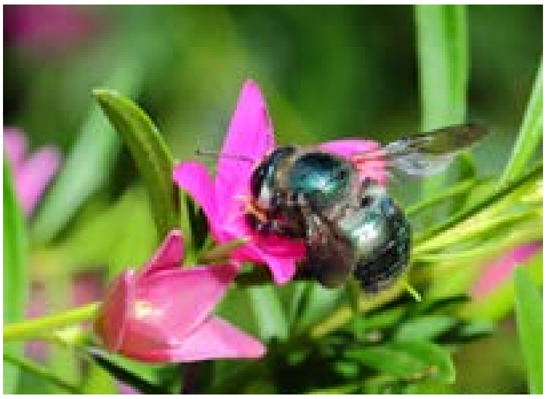
- Both plant and animal pollinators have developed physical and physiological adaptations to make pollination more successful, giving rise to corresponding flower-pollinator features.
- Particular flower traits appeal to particular types of animal pollinators so, **pollination syndromes** can be used to predict the pollinator of a plant without seeing it.
- The flowers of animal-pollinated plants are usually large, clearly visible, scented and nectar-producing. Their pollen grains are often sticky, so they will attach to their pollinator and be transported to another plant.
- Pollination is often a mutually beneficial **symbiotic relationship** between plants and their animal pollinators.
    - Plants benefit because pollinators move their pollen to another flower, allowing them to reproduce.
    - Animal pollinators benefit from the increased access and reduced competition for food (pollen and nectar) that results from being specially adapted to a particular type of flower.

INSECT POLLINATION

It is estimated that almost two-thirds of all flowering plants (65%) and some other seed plants (such as cycads and pines) require insects for pollination! Insect-pollinated flowers often use visible 'runways', strong scents and mimicry to attract pollinators. Both the plant and insect usually receive mutual benefits in a **symbiotic relationship**, as the insect uses some pollen or nectar as a food source while facilitating pollination through the movement of pollen to another flower. The insect pollinators discussed below include bees, beetles, butterflies, moths, ants, flies and wasps.

BEE POLLINATION

Bees are very important pollinators, and in Australia, both introduced bees and native bees pollinate native plants and crops. There are an estimated 2000–3000 native bee species in Australia, and unlike the non-native Honeybee (*Apis mellifera*), native bees are solitary and do not live in hives. They make a nest for their eggs in soil or wood and fill the opening with soil, resin or leaves. Ground-dwelling native bee species visit low-growing flowers like daisies that are easy to access. Native bees can be yellow, black, blue or even iridescent green!



Green Carpenter Bees (*Xylocapa* species) are up to 17mm long.

Image: ©T.Leach

Blue-banded bees (*Amegilla species*) have distinctive stripes of metallic blue fur on their abdomen.

Image: ©S.B.Rogers, 2020

Visiting a variety of flowers allows bees to maximise their nectar and pollen collecting, as different flower species produce different quantities of both substances. For example, *Banksia*, *Callistemon* and *Melaleuca* species produce a lot of pollen, and *Macadamia* and *Leptospermum* species produce a lot of nectar. Many native bees selectively visit just one native species and have evolved to be its only pollinator.

Not all bees make honey, but those that do use nectar as its raw starting material. They suck up the nectar with their **proboscis** and store it in their stomach, absorbing what they need and transporting the rest to the hive to be converted into honey. As the bees collect nectar, they also come into contact with pollen, allowing them to transfer it between flowers and pollinate them. Bees do not transfer all the pollen on their bodies to other flowers, however, as they have another use for it. Bees take pollen back to their hive for their **larvae** to eat, as it is very high in protein.

Larvae in the nest of a solitary bee.

Image: ©K.Hogendoom

Flowers pollinated by bees often have a **nectar guide** directing them to the food inside the flower (and to the pollen). Nectar guides are often only visible under ultraviolet (UV) light, meaning they are invisible to humans but visible to bees and other insects that can see in that part of the spectrum. From a bee's perspective, a nectar guide can look like a dark area leading to the centre of the flower, where the pollen and nectar are located.

Euroa Guinea-flower, Hibbertia humifusa, under normal light (top) and UV light (bottom). The stamens and anthers appear grey to black under UV light which helps insect pollinators to navigate towards the pollen and nectar.

Image: ©David Oldfield, 2020

The pollination syndrome for bee-pollinated flowers:

- blue, yellow, purple, cream or white (bees cannot see red)
- sweet or minty scent
- may be tubular with nectar at the base of the tube
- provide a landing platform
- open during the day

Adaptations to pollination: bees

Buzz Pollination

- Many native flowers, such as *Hibbertia* species and some crop plants such as tomatoes only release pollen when a flower is vibrated rapidly. This is called **buzz pollination**.
- Australian tomato growers use electronic bees that mimic buzz pollination to pollinate their tomato flowers, which is very time-consuming.
- Blue-banded Bees (and some other native bees) buzz pollinate. A bee uses its legs to clamp onto a flower where it can vibrate its body while banging its head against the anther up to 350 times per second, causing the pollen to be released. Researchers from the University of Adelaide found that tomato plants pollinated by Blue-banded Bees produce larger and tastier tomatoes!

A native Blue-banded Bee buzz pollinating a flower.

Image: ©S.B.Rogers,2018

Other adaptations

- Bees' bodies carry an electrostatic charge that causes pollen to cling to them.
- They have special hairs on their hind legs that form pollen 'baskets' and allow them to carry large amounts of pollen.
- Bees see the world in grainy images through their compound eyes, but as their eyes flicker, they can see individual flowers as they fly past.
- Bees can see polarised light patterns on flowers, which they use to navigate and find where the food is stored inside a flower.

- Honeybees in hives communicate with each other about the location of flowers by doing a **waggle dance**. They walk in a circle while waggling their abdomen to indicate the direction (north, south, east or west) and the distance from the hive.

BEETLE POLLINATION

It is believed that beetles were the first-ever insect pollinators. Beetles crawl or fly to nearby flowers but cannot travel long distances, meaning they do not transport pollen far from the parent plant. This means they are less efficient pollinators than those that can travel long distances, such as bees, birds, and mammals. Beetles eat pollen, and as such a flower must spend extra energy producing enough pollen to feed the insect and to pollinate other flowers. Some flowers ensure beetles pick up more pollen by trapping them or forcing them to leave through a tight space covered in pollen. Some flowers even 'glue' pollen to the back of beetles by attaching a blob of resin to which the pollen will stick.


Soldier beetles feeding on pollen and nectar and potentially pollinating flowers in the process.

Images: ©ANBG,2017

Weevils are the largest group of beetles and can act as pollinators for plants such as cycads. Weevils and cycads have co-evolved over millions of years, leading cycads to develop an intricate sequence of chemical signalling to attract weevils to pollinate them.

The pollination syndrome for beetle-pollinated flowers:

- dull white, cream or green
- strong fruity, spicy or rotten scent
- large, flat or bowl-shaped
- easily accessible pollen
- produce large amounts of pollen
- open during the day

BUTTERFLY POLLINATION

Butterflies are well-known pollinators that use their **proboscis** like a straw to drink nectar from flowers. This gives the insects the energy, sodium and other minerals they need for reproduction. Butterflies can use their antennae to detect the scents of flowers and are attracted to flowers growing in groups. Butterflies seek out native trees such as eucalypts, acacias and banksias, as they provide food for their **larvae** (caterpillars).

The pollination syndrome for butterfly-pollinated flowers:

- vivid red, magenta or pink
- often sweetly scented
- narrow tubular shape
- grow at different heights
- have a landing pad
- open during the day

A Red-spotted Jezebel butterfly pollinating flowers of a Pimelea species.

Image: ©S.B.Rogers

MOTH POLLINATION

Moths are very similar to butterflies but are usually **nocturnal**. While accessing nectar in flowers, some moths beat their wings rapidly to hover, whereas others settle on the flower to drink. While drinking, pollen can attach to their **proboscis** and furry body, allowing them to transfer it to the next flower they visit. Like butterflies, moths are attracted to plants that produce nectar and provide food for their **larvae**, such as *Melaleuca*, *Alyogyne* and *Grevillea* species.

The longer a moth's **proboscis** is, the deeper it can reach into a flower to access the nectar inside. In the case of the Madagascan orchid *Angraecum sesquipedale*, this evolved to the extreme! Charles Darwin predicted the existence of the pollinator of *A. sesquipedale* before it had been discovered, as he knew the pollinator would have to have a 'tongue' to match the length of the orchid's 30-centimetre nectar-containing floral spur.

The giant moth *Xanthopan morganii* praedicta was proven to be the exclusive pollinator of A. *sesquipedale* 130 years after Darwin first made this prediction.

The pollination syndrome for moth-pollinated flowers:

- pale colour such as red, purple, pink, cream or white
- strong scent that may increase at night
- has an open cup or tubular shape
- open at night

A moth on a flower.

FLY POLLINATION

Flies are the second most common pollinator after bees and may have been one of the earliest pollinators (like beetles). Flies usually visit animal carcasses or dung, so they are attracted to flowers with a rotten or foul smell. Some plants generate heat to help them spread their bad smell further, such as Indonesia's Titan Arum (*Amorphophallus titanum*). See the Smelly Plants section below for more information on plants that attract pollinators using strong smells.

Fly-attracting flowers that have nectar are especially appealing to flies if there are also aphids present. After a fly feeds on the nectar, it will often lay its eggs nearby, and when their **larvae** hatch it will feed on the aphids. Scientists have found that flies can distinguish between the flowers of different species and will remember those they have already visited.

The pollination syndrome for fly-pollinated flowers:

- dull white, brown or yellow
- strong foul or rotten scent
- shallow, funnel-shaped or trap-like
- easily accessible nectar
- open during the day or at night

A Lucilia fly on a Brachyscome *mutifida* daisy.

Image: ©B.Lessard,2022

ANT POLLINATION

Ants are not well suited to act as pollinators because they produce antimicrobial secretions that can kill pollen. They are sometimes called 'nectar robbers' as they are small enough to access nectar in a flower without touching its reproductive structures. They can also transport fallen pollen from the ground to their nest without visiting other flowers to facilitate pollination. Despite these 'unhelpful' behaviours some plants enlist the help of ants to protect themselves from attack by other insects. The ants' presence deters other insects from visiting the plant, and in return, the plant provides nectar outside of the flowers for the ants to access easily. This relationship is a trade-off for the plant, as it limits both the predators and beneficial pollinators that will visit.

In environments where ants have adapted to become pollinators, they generally produce secretions that are less damaging to pollen. This has been observed most often in Mediterranean climates, such as the south-west corner of Western Australia. Scientists studying ant-pollinated plants in Western Australia discovered a *Conospermum* species (Smokebush) that has adapted so that its pollen is less susceptible to the effects of the ants' microbial secretions. This is the first time in the world that an ant-pollination relationship has been discovered that developed because of the plant adapting, rather than the ants!

The pollination syndrome for ant-pollinated flowers:

- small
- growing close to the ground
- growing close to the stem

Ants pollinating a flower.

Image:©Steve Parish

WASP POLLINATION

There are more than 10,000 species of native Australian wasp. Wasps feed on nectar similarly to bees but are less efficient pollinators. They are generally not covered in the same fuzzy hairs so cannot transfer as much pollen as bees. Most native wasps are solitary, and many female wasps cannot fly. When they are ready to mate, these flightless females climb onto a plant, emit a **pheromone** (chemical) to attract a male and wait. Once they have mated, the female lays her eggs in a burrow, nest, amongst the leaf litter or in another animal such as a spider, beetle, or fly.

The solitary, ground-dwelling lifestyle of female wasps makes male wasps easy targets for **deceptive** flowers. Many Australian orchids, including Spider Orchids (*Caladenia* species) and Hammer Orchids (*Drakaea* species), use sexual deception as a pollination strategy to attract male wasps. These orchids mimic the appearance, pheromones and even the UV wing reflectance of female wasps, so male wasps visiting the orchid flower are tricked into thinking they will be able to mate with it. When the male tries to mate or fly away with what they perceive as a female wasp, the orchid flower moves, causing it to deposit pollen on the male wasp's body. See the **Deceptive plants** section below for more information on the tricks that orchids play on pollinators.

The pollination syndrome for wasp-pollinated flowers:

- dull-coloured
- no scent or produce pheromones
- easily accessible or absent food reward

A *Bembix* wasp pollinating a flower.

Image: ©B.Harvey, 2022

A wasp pollinating a Spider Orchid (Caladenia sp.).

Image: ©T.Hayashi,2017

BIRD POLLINATION

Many species of birds pollinate flowers, drinking nectar from inside flowers or eating insects and spiders that live inside or on the flowers. Nectar is a major food source for 20 species of birds in Australia and a minor food source for another 20 species.

- Birds are more efficient pollinators than insects because they can visit more flowers in less time. Due to their increased size and activity, birds have greater energy needs than insects, so they require more nectar to feed on. This is a trade-off for plants, as birds are more efficient pollinators, but attracting them requires extra energy to make additional nectar. If a plant produces a lot of nectar, a bird may stay nearby and become territorial over that food source.

- Honeyeaters are the most common pollinators in Australia, followed by lorikeets, sunbirds and parrots. Lorikeets take pollen as well as nectar.
- Birds are major pollinators for 30 genera of native plants, including *Eucalyptus*, *Banksia*, *Callistemon*, *Grevillea*, *Adenanthos*, *Epacris*, *Astroloma*, *Amyema*, *Correa*, *Xanthorrhoea*, *Anigozanthos* and *Eremophila*.
- Flowers from the Proteaceae family (including Banksia and Grevillea species) have **pollen presenters** that protrude from the flower after opening.
- The **pollen presenter** is made of a modified style tip, which bears pollen from the anthers, with the stigma maturing later to prevent self-pollination.
- The pollinator brushes against the **pollen presenter** and pollen sticks to its body.
- A bird putting its beak into a flower to drink nectar could have the **pollen presenter** touch its head and deposit pollen. The bird could then visit another flower and transfer pollen from the first flower onto the stigma of the second flower.

The flowers of *Pimelia physodes* require birds with long beaks to pollinate them. Here you can see pollen on the beak of the Red Wattlebird.

Image: ©G.Gall, 2019

Nectar in bird-pollinated flowers is often hidden deep inside to encourage birds to come as close as possible to the flower.

- Close contact allows more opportunity for pollen to stick to the birds' heads or bodies while they feed.
- The pollen is often sticky, so it will stay on the birds' heads, bodies and beaks as they fly.
- When a bird flies to the next plant, it will incidentally transfer the pollen to another flower.

Some flowers encourage bird visitation while deterring that of insects to maximise their chances of being pollinated by birds.

- *Banksia ericifolia* produces most of its nectar at night or early in the morning, as birds are very active around dawn. Birds require about 10–50 **kilocalories** per day and must visit hundreds to thousands of flowers every day to meet this energy quota.
- Some species of *Astroloma* have hairs inside their tubular flowers that make it difficult for insects to enter and do not produce scents to attract insects.
- An experiment into the pollination of Kangaroo Paws (*Anigozanthos* species) found that when birds were prevented from visiting the flowers, the plants produced 95% less seed.

Flowers of *Anigozanthos* species are tubular.
Image: ©S.B.Rogers, 2018

The pollination syndrome for bird-pollinated flowers:

- bright red, yellow, or orange
- lacks a strong scent
- tubular, cup- or brush-shaped
- strong supports for perching on
- open during the day
- does not produce large amounts of pollen
- produces a lot of nectar
- often have clusters of flowers
- may hang down for access by hovering birds
- petals bent backwards to allow birds to access deep inside the flower

Adaptations for pollination: birds

- Birds often have slender, sometimes curved beaks to push deep inside a flower.
- Birds such as honeyeaters have tongues which extend well beyond the end of their beaks. Their tongues are often tube-shaped, brush-tipped and covered with bristles to help soak up and drink nectar.
- As birds stick their tongue and beak in the flower, pollen gets stuck to their bodies and heads. Often flowers have protruding parts called **pollen presenters**, which are long enough to brush pollen on the bird's head as they probe for nectar in the lower part of the flower.
- Birds do not have a very good sense of smell and cannot see UV light like insects can. They have a powerful sense of sight and good colour vision, especially in the red part of the spectrum. As a result, birds are often attracted to red flowers.
- Some birds will drill a hole in the base of the flower to get to the nectar straight from the nectary ('nectar-robbing'). This allows them to bypass the anthers and stigma as they extend beyond the opening of the tube.

Astroloma species can deter insects from visiting their flowers without deterring birds. This maximises their chances of being pollinated by birds.

Image: D. Greig ©ANBG, unknown date

MAMMAL POLLINATION

Australia has many mammal pollinators, including possums, sugar gliders, antechinus, mice and bats. Birds and mammals can generally travel longer distances than insects and can pollinate flowers far away from the original pollen source, which increases genetic diversity in plant populations. Mammal-pollinated plants often have sturdy branches and flowers to support the weight of visiting pollinators.

BATS

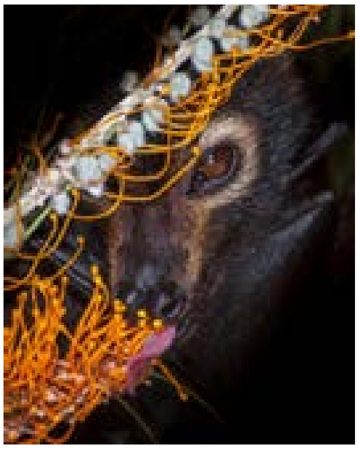
Many bats are **nocturnal**, so pollinate flowers at night. They feed on insects inside the flower, as well as nectar, flower parts and fruits. Bats are constantly on the move, making them very good at pollinating many flowers in one night. Additionally, many plants depend on fruit-eating bats for seed dispersal.

The pollination syndrome for bat-pollinated flowers:

- pale white, green or purple
- produce fermenting, musky or fruit-like scents
- very fragrant at night
- bell- or bowl-shaped
- open at night
- large
- produce a lot of nectar

A flying fox feeding on nectar from a *Banksia* cone.

Image:©Steve Parish



A flying fox feeding on nectar. Note the rough tongue that assists in lapping up nectar.

Image: ©Steve Parish

Adaptations for pollination: flying foxes

Flying foxes (*Pteropus* species) are an Australian example of pollinating bats.

- Bats can travel and carry pollen over long distances, which helps increase plant genetic diversity and improve the health of ecosystems.
- Being nocturnal helps them avoid competition from other pollinating animals that are active during the day (**diurnal**).
- Bats generally have long tongues to lick nectar contained within a flower.
- Pollen sticks to their furry bodies, so they transfer it as they move between flowers.
- Bats have a great memory and will visit flowering plants repeatedly.
- Flying foxes can travel up to 50 kilometres in one night looking for food. They do not **echolocate** like other bats, instead relying on their well-developed senses of smell and vision to navigate through the environment.

POSSUMS, SUGAR GLIDERS AND ANTECHINUS

Non-flying mammals such as possums and sugar gliders play an important role in pollinating Australian plant species.

- Many plants pollinated by mammals have very sturdy flowers to support the animal's weight, and some plants produce flowers very close to the ground so that small mammals can brush against them as they feed.
- Possums, sugar gliders and antechinus are known to pollinate various plants, including *Banksia* species.
- The south-west of Western Australia is a unique **biodiversity hotspot**.
    - o There is a huge variety in plant and animal species found there, and many of the species are found nowhere else in the world (**endemic**).
    - o More plants are pollinated by **vertebrates** (animals with a backbone) here than anywhere else on Earth! In fact, 15% of the flowering plants in this biodiversity hotspot need birds and mammals to transfer their pollen.

Mammals play an important role in pollinating Australian plant species.

Image: ©Steve Parish

Many plants pollinated by mammals have sturdy flowers to support the animal's weight.

Image: ©Steve Parish

Adaptations for pollination: Honey Possums

Honey Possums (*Tarsipes rostratus*) are the world's only non-flying mammal that is completely reliant on nectar and pollen for food.

- They have a long snout and protruding tongue ideal for accessing nectar in flowers.
- While feeding on nectar, they get pollen on their snouts and bodies and transfer it to other flowers.
- They have sharp claws to help them grip to bark and leaves as they climb, and their tail allows them to hang from branches as they search for food.

REPTILES

Reptiles can be pollinators! Reptiles are one of the least understood group of pollinators, and only a few reptile pollination syndromes have been discovered worldwide.

A reptile's diet often consists of animals including arthropods (like insects) and plants, but in environments where food is scarce, some species of lizard have been observed to consume nectar. Pollen can attach to their scales while they feed on the nectar, which they can then spread to the next flower they visit. Reptiles can be **nocturnal** (active during the night) or **diurnal** (active during the day), so which plants they pollinate will depend on the flowers' opening time.

In 2017 scientists in South Africa investigated what was pollinating the unusual Hidden Flower, *Guthriea capensis*.

- The common name Hidden Flower refers to its flowers being 'hidden' under its leaves.
- Because the flowers grow close to the ground and produce huge quantities of nectar, scientists initially believed that small mammals such as mice pollinated them.
- Instead of mammals, however, their study revealed that Drakensberg Crag Lizards (*Pseudocordylus subviridis*) were visiting the flowers to eat the nectar and in the process pollen stuck to their snouts. When they drank nectar from the next flower, the pollen was transferred, allowing pollination to occur.
- When lizards were prevented from visiting the flowers, the plants produced 95% fewer fruits, highlighting the importance of Drakensberg Crag Lizards for the survival of the Hidden Flower.

A Drakensberg Crag Lizard pollinates *Guthriea capensis* (Hidden Flower) by drinking its nectar and transferring the pollen stuck to its snout to the next flower it visits.

Image: ©R. Cozien and S. Johnson, 2020

Reptiles are also important seed dispersers. Scientists have discovered that in New Zealand many plants with white or blue fruits and **divaricating** branches (branches that grow at wide angles from each other) are adapted to lizard dispersal. Lizards can transport seeds up to 20 metres away from the original plant, giving them a chance to germinate away from their parents.

The pollination syndrome for reptile-pollinated flowers:

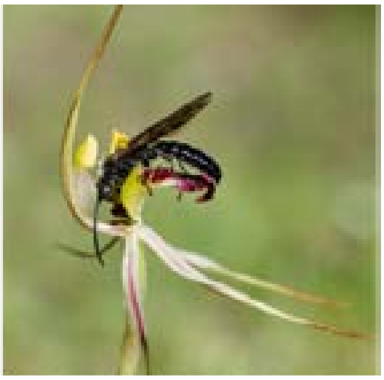
- may be red, as this may repel insects and leave more nectar for lizards and geckos
- strong scent
- produce a lot of nectar
- growing close to the ground or able to support a reptile's bodyweight
- open during the day or at night

DECEPTIVE PLANTS

Many plants have developed **symbiotic relationships** with their pollinators, where they both benefit from their pollination interaction. Other plants have developed methods of deceiving pollinators into visiting them, where they do not provide the pollinator with a reward.
In some cases, pollinators participate in this interaction to their detriment, in a kind of **parasitic** relationship.

This pollinator **deception** is seen most often in orchid species, with some flowers mimicking insects or other flowers to attract pollinators.

- Some orchids mimic insects by replicating their **pheromones**. A pheromone is a chemical produced by an organism that affects the behaviour or physiology of members of its own species. By releasing these **pheromones**, the orchid tricks insects into thinking they are an insect of the same species.
- Insects attracted to the orchid are covered in pollen while they visit it, which they then carry to the next flower that tricks them into visiting.
- Many orchid species use this ability to be **sexually deceptive**, meaning that they trick male insects into thinking the orchid flowers are a female of their species through physical and/or chemical mimicry. Although they do not provide a pollinator reward, these orchids are almost guaranteed to be visited by males trying to mate with the flowers.
- Hammer Orchid (*Drakaea species*) flowers mimic the appearance and pheromones of female thynnid wasps. Male thynnid wasps visiting a flower try to mate with it, activating a hinge that releases the orchid's pollen 'hammer'. This hammer hits the wasp on its back and deposits its sticky pollen, allowing the wasp to transfer the pollen when it is tricked into visiting another Hammer Orchid.
- Some orchids mimic the flower appearance or nectar guides of non-orchid plants. The insects visiting these orchids assume they contain the same nectar as the flowers they are mimicking, saving the orchid from producing their own nectar. Flower-mimicking orchids will often grow near to and flower at the same time as the 'real' flowers, so insects have difficulty distinguishing between them.
- The pollination syndromes of orchids are sometimes specific to one insect pollinator, meaning that a whole species of orchids relies on just one pollinator species for survival. This can make orchid conservation complex, as it also requires consideration of pollinator species.



A male thynnid wasp (*Lophocheilus anilitatus*) mating with a Brown-clubbed Spider Orchid (*Caladenia phaeoclavia*).

Image: ©T. Hayashi, 2022

SMELLY PLANTS

Flower scents are not always sweet, and some flowers produce foul-smelling odours to attract pollinators. This is true for *Amorphophallus titanum* (Titan Arum), which occurs in Sumatra, Indonesia.

- It is one of the smelliest plants on Earth!
- It is known as the Corpse Flower due to the foul smell of rotting flesh it produces when in bloom. It has the largest unbranched **inflorescence** (flower spike) in the world.
- Its smell attracts beetles and flies.
- Titan Arum only flowers for a single evening so needs to have its unpleasant odour travel as far as possible during this time. The flower spike produces heat while flowering, helping the smell to travel further and attracting pollinators from up to 800 metres away!

Thismia megalongensis, another plant with a foul-smelling flower, occurs in the Blue Mountains in New South Wales.

- The flower is two centimetres tall and initially smells 'fungal' but later like rotting fish. These smells are believed to be derived from the plant's parasitic relationship with fungi.
- The smell attracts gnats as pollinators, which usually feed off algae, fungi, blood and other insects.
- Species in the genus *Thismia* are commonly known as Fairy Lanterns because of their shape and warm, glowing colour. There are almost 50 known species of Fairy Lanterns around the world.

Thismia megalongensis is only 2 centimetres tall, and the flowers smell like rotting fish to attract gnat pollinators.

Image: ©Dave Noble, 2015

OTHER POLLINATION INTERACTIONS

Rhizanthella orchids flower completely underground, where they can be pollinated by insects such as termites, fungus gnats, flies and wasps.

Many pea flowers have concealed nectar that can only be accessed by large, strong insects like Leaf Cutter or Resin Bees (*Megachile* species).

- The flowers of these plants are closed, so the bees must push down on parts of the flower to open it and allow them to access the nectar.
- As the flower springs open, the anthers are pushed forward and pollen sticks to the underside of the bee's body.

Insects with long tongues are often the only pollinators able to access nectar in flowers with a long, tubular shape. These insects include butterflies, moths, flies and bees.

- These insects come into contact with pollen as they access the nectar, allowing them to transfer it to the next flower.
- Some insects can cheat this system by 'drilling' a hole in the base of the tube and accessing the nectar without coming into contact with the flower's pollen.

Triggerplants, or *Stylidium* species, are named for the way the flower uses a 'trigger' mechanism to ambush an unsuspecting insect.

- When an insect lands on a Triggerplant's flower, a spring-loaded central column containing both male and female reproductive parts (stamen and stigma) snaps out from behind the flower's petals.
- The column hits the insect and deposits pollen on its body, which it can then transfer to the next flower it visits.
- Triggerplant flowers come in a variety of shapes and sizes. Different species tend to strike insects on different parts of their bodies to help ensure that pollination only occurs between individuals from the same species.

Flies visiting a Triggerplant (*Stylidium pycnostachyum*) with its column ready to strike.

In flowers that perform 'ballistic pollen dispersal', also known as **explosive flowering**, pollen is launched from inside the flower when an insect heavy enough to trigger the mechanisms for pollen release lands on the flower.

- If explosive flowering does not successfully cover a pollinator in pollen, it can allow for wind pollination instead.
- *Synaphea stenoloba* is an Australian species that has explosive flowering and is pollinated by insects such as native solitary bees (*Leioproctus* species).
- In *Conospermum* species, an insect stimulates the flower and causes the style to snap from one side of the flower tube to the other, dabbing an adhesive on the insect. The anthers then explode and cause pollen to stick to the insect.

Image: ©M. Fagg, 2011

SUSTAINABLE DEVELOPMENT GOALS

Our education materials support the following Sustainable Development Goals:

- ensure inclusive and quality education for all and promote lifelong learning (SDG 4)
- demonstrate actions that work towards making cities inclusive, safe, resilient and sustainable (SDG 11)
- inform and empower students to preserve our forests and halt biodiversity loss (SDG 15)

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