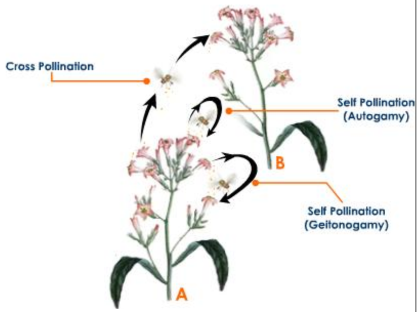



Insects as Pollinators and Biocontrol agents


- **Pollination** is the process by which pollen is transferred in the reproduction of plants, thereby enabling fertilisation and the production of fruit and seeds (sexual reproduction).
- **Abiotic pollination**: pollination without the involvement of other living organisms (e.g. wind or water). Only 10% of flowering plants are pollinated without animal assistance.
- **Biotic pollination**: pollination by a **pollinator** (insects are the most important pollinating animals, but birds, bats and rodents are also pollinators of some plants).


Self- & cross-pollination

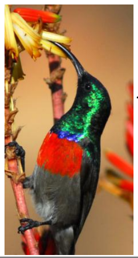
- **CROSS-POLLINATION**: the transfer of pollen from an anther of the flower of <u>one</u> plant to a stigma of the flower of <u>another</u> plant.
- **SELF-POLLINATION**: fertilisation by transfer of pollen from the anthers of a flower to the stigma of the same flower (autogamy) or to the stigma of another flower on the same plant (geitonogamy)



Self: no exchange of genetic material
Cross: exchange of genetic material

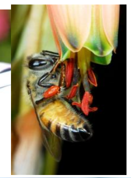
Agents of pollination

Cross-pollination depends on insects visiting flowers of the same species in sequence. To help ensure that this happens, the plants have various characteristics that help pollinators locate the right flowers, including the colour, size, shape and scent of the flowers, as well as the food reward.



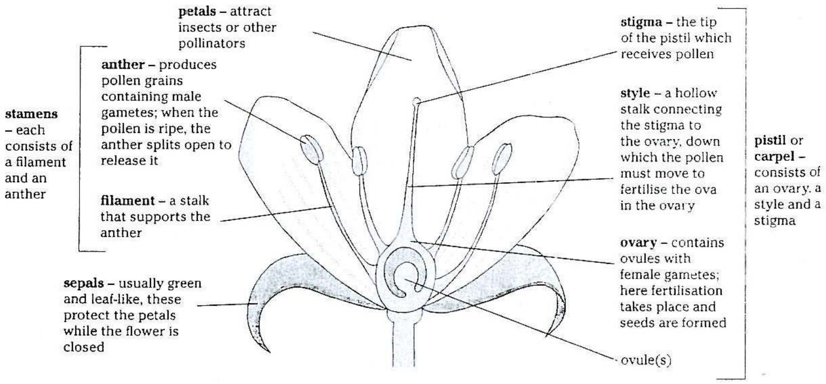
Sunbird: tubular, colourful flowers

Beetles: flat or cup-shaped (big) flowers

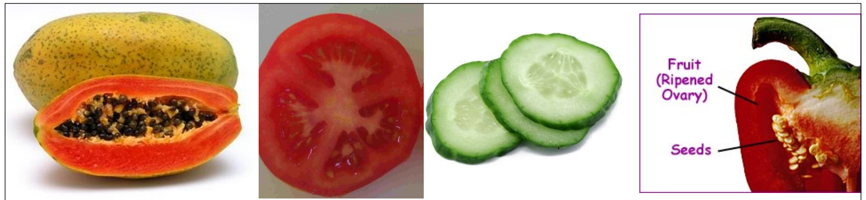



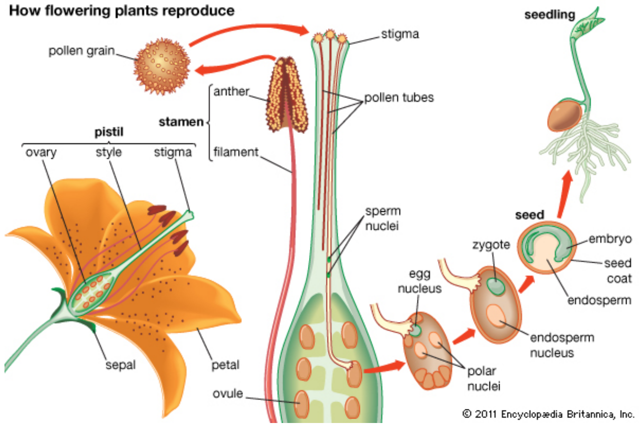

Honeybee: many varied flower types

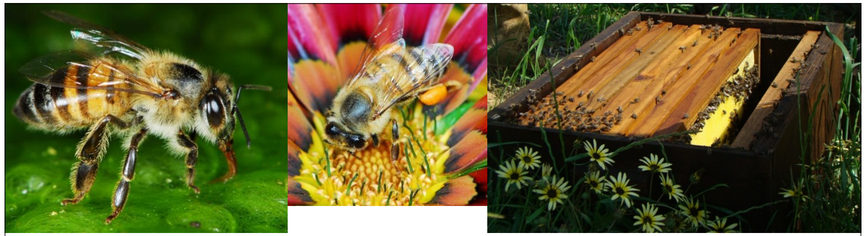
Parts of the flower



The sexual reproductive structures of a flower, that play a role in the production of seeds







Importance of honeybees & their relationship to our food

ECOLOGICAL VALUE OF POLLINATION

- Valuable in their own right
- Part of ecology

HUMAN VALUE OF POLLINATION

- Crops for human food + animal fodder
- Fibres, wood and other materials
- Plant breeding & flowers
- Medicines
- Aesthetic value

Pollinators and our food

Insect pollination is essential for 35% of global food production. *“You can thank an insect pollinator for 1 out of every 3 bites of food you eat!”*

Insects pollinate the flowers of the fruit and vegetable plants we rely on for a healthy and balanced diet… (apples, melons, pumpkin, avocado, etc)

…while most of the staple food plants can self-pollinate or are wind-pollinated (like rice, maize and wheat), or reproduce vegetatively (like potatoes).

A world without insect pollinators would mean a world of far fewer food choices, more expensive food, and vastly different agriculture.

Pollinators and plants

- Plants and pollinators have **co-evolved physical characteristics** that make them more likely to interact successfully.
- The plants benefit from **attracting a particular type of pollinator** to its flower, ensuring that its pollen will be carried to another flower of the same species and hopefully resulting in successful reproduction.
- The pollinator benefits from **its adaptation to a particular flower type** by ensuring that it will be able to find and access important food resources - nectar and pollen. Such relationships are considered mutualistic.
- The **flower type, shape, color, odor, nectar, and structure** vary by the type of pollinator that visits them. Such characteristics are considered pollination syndromes and can be used to predict the type of pollinator that will aid the flower in successful reproduction.

Pollinator Syndrome Traits Table

Trait	Bats	Bees	Beetles	Birds	Butterflies	Flies	Moths	Wind
Color	Dull white, green or purple	Bright white, yellow, blue, or UV	Dull white or green	Scarlet, orange, red or white	Bright, including red and purple	Pale and dull to dark brown or purple; flecked with translucent patches	Pale and dull red, purple, pink or white	Dull green, brown, or colorless; petals absent or reduced
Nectar Guides	Absent	Present	Absent	Absent	Present	Absent	Absent	Absent
Odor	Strong musty; emitted at night	Fresh, mild, pleasant	None to strongly fruity or fetid	None	Faint but fresh	Putrid	Strong sweet; emitted at night	None
Nectar	Abundant; somewhat hidden	Usually present	Sometimes present; not hidden	Ample; deeply hidden	Ample; deeply hidden	Usually absent	Ample; deeply hidden	None
Pollen	Ample	Limited; often sticky and scented	Ample	Modest	Limited	Modest in amount	Limited	Abundant; small, smooth, and not sticky
Flower Shape	Regular; bowl shaped – closed during day	Shallow; have landing platform; tubular, c	Large bowl-like, Magnolia	Large funnel like; cups, strong perch support	Narrow tube with spur; wide landing pad	Shallow; funnel like or complex and trap-like	Regular; tubular without a lip	Regular: small and stigmas exerted

Types of insect pollinators

Ants

- Ants form a great group of social insects that are great lovers of nectar.
- They are often observed visiting flowers to collect energy rich nectar.
- Ants are wingless and must crawl into each flower to reach their reward.
- Ants are more likely to take nectar without effectively cross-pollinating flowers.
- It has been discovered that some ants are not important pollinators, even though they visit flowers and may have pollen grains attach to their bodies.

Ants (cont.)

- Some ants and their larvae secrete a natural substance that acts as an antibiotic.
- This secretion protects ants from bacterial and fungal infections.
- Unfortunately for the flowers which are visited by these ants, this secretion also kills a pollen grain very rapidly when it comes in contact with this natural antibiotic.
- The flowers that are visited by ants are typically:
  - Low growing
  - Have small inconspicuous flowers
  - Have flowers that are close to the stem

Ants (cont.)

- Many tropical plants have nectar outside of the flowers to attract ants. These plants rely on the defensive capabilities (biting and stinging) of the ants to protect them from various kinds of attack from other insects including nectar robbers.
- The plants have floral structures that make it difficult for bees and other pollinators to access internal nectar. Thus, it is tempting for such insects to simply pierce the flowers from the outside.
- Plants that secrete nectar on the outside of the flower and on their leaves have "ant-guard" system that prevents other insects from robbing nectar. These plants apparently have a chemical deterrent to keep the ants from entering the inside of the flower while rewarding them for protecting the outside of the flower.

Beetles

- Beetles were among the first insects to visit flowers and they remain essential pollinators today.
- They are especially important pollinators for ancient species such as magnolias and spicebush.
- Beetles will eat their way through petals and other floral parts.
- They even defecate within flowers, earning them the nickname "mess and soil" pollinators.
- Research has shown that beetles are capable of color-vision.

Beetles (cont.)

- Fossil records show that beetles were abundant during the Mesozoic (about 200 million years before present). Beetles were flower visitors of the earliest angiosperms.
- Many present-day beetle pollination associations like that of *Magnolia*, a primitive woody angiosperm, have ancient evolutionary origins.

Bees

- Bees visit garden flowers are the colorful, fuzzy, yellow-and-black striped bumblebees, metallic-green sweat bees, squash bees, and imported honeybee.
- These flower-seeking pollen magnets purposefully visit flowers to collect pollen and nectar for food for themselves and their young.
- All bees have very high-energy needs that must be met for their survival. Bees need key resources such as pollen and nectar from a variety of flowers.

Bees

- Many of the flowers pollinated by bees have a region of low ultraviolet reflectance near the center of each petal.
- This region appears invisible to humans because our visual spectrum does not extend into the ultraviolet.
- However, bees can detect ultraviolet light. The contrasting ultraviolet pattern called a nectar guide. This helps a bee quickly locate the flower's center.
- This adaptation benefits both the flower and the bee. The bee can more rapidly collect nectar and the flower is more effectively pollinated.

As human sees it

As a bee sees it

Honeybees

Many commercial pollinator-dependent crops are reliant on the honeybee as their pollinator.

For many crops around the world, ***honeybees are the most economically valuable pollinators*** because they are:

- Very effective pollinators.
- Indigenous (i.e. they are naturally found).
- They can be managed in the huge numbers needed to supply the pollination service to large-scale commercial crops.

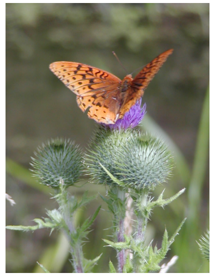
Beekeepers supply the pollination service to growers/farmers, as well as harvest the honey from the bees to bottle and sell.

Honeybees in South Africa

- Two sub-species: *Apis mellifera capensis* and *A.m. scutellata.*
- Both good pollinators, especially if handled correctly.
- Wild & managed populations are the same, as they are indigenous honeybees; and because beekeepers trap swarms and sometimes managed bees swarm off into the wild.
- *Eucalyptus* flowers probably responsible for >60% of honey production in South Africa.

Butterflies

- Butterflies are very active during the day.
- Butterflies are less efficient than bees at moving pollen between plants. Highly perched on their long thin legs, they do not pick up much pollen on their bodies and lack specialized structures for collecting it.
- Butterflies probe for nectar, their flight fuel, and typically favor the flat, clustered flowers that provide a landing pad and abundant rewards. Butterflies have good vision but a weak sense of smell. Unlike bees, butterflies can see red.

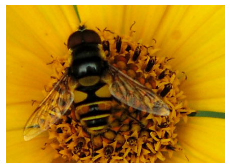


Flies

- The two-winged insects (flies, gnats, mosquitos) is a very large group.
- Many of them specifically visit flowers, such as the Syrphid flies or flower flies.
- They are not as hairy as bees and as efficient in carrying pollen, but some are good pollinators.
- The flowers that are pollinated by flies are typically:
  - Pale and dull to dark brown or purple
  - Sometimes flecked with translucent patches
  - Putrid order, like rotting meat , carrion, dung, humus, sap and blood
  - Produce pollen
  - Flowers are funnel like or complex traps

Flies (cont.)

- Some flies, such as syrphids, masquerade as bees and wasps.
- The flies have only one pair of wings while bees and wasps have two pairs of wings.
- Putrid smelling blossoms are an adaptation to attract certain fly pollinators.
- Even male mosquitoes get in on the act since they pollinate certain orchids. Long-tongued flies (e.g., syrphids, bombylids) feed on same flower types that bees do.
- Short-tongued flies feed on flowers that imitate the main source of food for flies.



Know your veg pollination!

Pollination requirements of vegetables can be discussed according to what part of the plant is eaten:

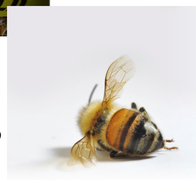
- If the 'vegetable' is a '**fruit**' then pollination is required both for the production of <u>the vegetable AND for seed</u> production; e.g. tomatoes, peppers, eggplant, peas, beans, pumpkins, marrows, butternut, cucumbers, etc.
- If the 'vegetable' is in the form of **leaves or shoots** (e.g. lettuce, cabbage, kohlrabi, broccoli, Brussels sprouts, spinach, Swiss Chard, leeks, onions, etc.) or is a '**storage root**' (e.g. carrots, beetroot, turnip, parsnip, etc.) then pollination is not required or desired for the production of the vegetable, but <u>ONLY for seed production</u>.
- If the 'vegetable' is a '**storage stem**' then pollination is <u>not required for EITHER</u> the production of the vegetable or seed because seed is not required for propagation; e.g. potatoes, Jerusalem artichokes.

What's for dinner?
Examples of parts of the plant we eat:

- **Flowers**: broccoli, cauliflower.
- **Fruit**: apple, peach, tomato, cucumber, pumpkin, avocado, watermelon, bean.
- **Stems**: sugar!, asparagus, celery, potatoes (modified stem).
- **Leaves**: lettuce, cabbage, tea, Brussels sprouts.
- **Roots**: carrot, sweet potato, radish.
- **Seeds**: nuts, maize/corn, peas, rice.

Chemical misuse

Threats to honeybees



American Foulbrood

Varroa mite on honeybee larva

Stress on honeybee health

- <u>Pests and diseases</u> (American Foulbrood, *Varroa* mite).
- <u>Chemicals</u> such as pesticides.
- <u>Global change</u> factors (e.g. land use change & climate change).
- <u>Over-working</u> during the pollination season (being moved large distances in short timeframes).
- <u>Scarcity of good forage</u> resources.

Many of the stresses that affect honeybees also impact other wild insect pollinators, and therefore any efforts we make at protecting the honeybee should help protect our wild insect pollinators.

Scarcity of good forage resources

- Land use changes (such as urbanisation or deforestation) may lead to habitat degradation and destruction.
- Intensified agriculture and forestry practices contribute to:
  - loss of surrounding natural vegetation (monocultures).
  - planting of nutrient-poor crops and non-flowering cultivars.
- Removal of good forage resources, such as some *Eucalyptus* some indigenous species.

What we can do


UTAH PESTS fact sheet
Gardening for Native Bees in Utah and Beyond

- The planting of honeybee-friendly plants can help the issue of the scarcity of forage resources.
- Campaign for the planting of honeybee-friendly plants in your neighbourhood (e.g. city parks, in gardens, along road verges).
- Never kill honeybees or other pollinators with chemicals.
- Find out about the fruit and vegetables that you buy (are they in season, have chemicals been applied correctly and in a bee-friendly manner?).
- Become a researcher or help researchers. Much research is still needed, e.g. the impacts of climate change; pollination research; hive strength; etc.

Insects as Biological Control Agents

Introduction

- Biological control is a method of controlling pests such as insects, mites, weeds and plant diseases using other organisms.
- It relies on predation, parasitism, herbivory, or other natural mechanisms, but typically also involves an active human management role.
- It can be an important component of integrated pest management (IPM) programs.

History of biological control

- The earliest report of the use of an insect species to control an insect pest comes from “Nan Fang Cao Mu Zhuang” (南方草木狀 Plants of the Southern Regions) (ca. 304 AD), which is attributed to Western Jin dynasty botanist Ji Han (嵇含, 263-307), in which it is mentioned that “people sell ants and their nests attached to twigs looking like thin cotton envelopes, the reddish-yellow ant being larger than normal.
- Without such ants, southern citrus fruits will be severely insect-damaged”.
- The ants used are known as huang gan (huang = yellow, gan = citrus) ants (*Oecophylla smaragdina*).

History of Biological Control

- The first international shipment of an insect as biological control agent was made by Charles V. Riley (USA in 1873, shipping to France the predatory mites *Tyroglyphus phylloxera* to help fight the grapevine phylloxera (*Daktulosphaira vitifoliae*) that was destroying grapevines in France.
- The first importation of a parasitoid into the United States was *Cotesia glomerata* in 1883-1884, imported from Europe to control the imported cabbage white butterfly, *Pieris rapae*.

- In 1888-1889 the vedalia beetle, *Rodolia cardinalis*, which is a ladybug, was introduced from Australia to California to control the cottony cushion scale, *Icerya purchasi*.
- This had become a major problem for the newly developed citrus industry in California, and by the end of 1889 the cottony cushion scale population had already declined.
- This great success led to further introductions of beneficial insects into the USA.

Vedalia beetle feeding on cottony cushion scale

What are natural enemies?

A. <u>Organisms found in nature that attack insects</u>
  i. Reduce numbers via death of host or prey
  ii. Reduce numbers by affecting reproductive potential
  iii. Promotes its own survival at the expense of others
  iv. Keep non-pests from becoming pests and help reduce numbers of problem pests - part of natural control
  v. All insect populations have natural enemies.
  vi. For many species, natural enemies are the main regulating factor.

What are natural enemies?

B. Using Natural Enemies
  i. Pest management tactic is called Biological Control.
  ii. Differs from Natural Control because it only uses Natural Enemies.
  iii. Involves the purposeful manipulation of predators, parasitoids and diseases which may be introduced or endemic for the purpose of reducing pest populations.

History of biocontrol

A. Earliest account - 400 A.D. in china - ants to control citrus pests.

B. Other attempts include the use of insects, birds, lizards, toads to control insects, vertebrates to control vertebrates and insects to control weeds.

C. First U.S. attempt & success - 1888 - Vedalia beetle to control cottony cushion scale (introduced from Australia in 1888) in California. Controlled by 1889.

D. Other successes - Moth larva to control prickly pear in Australia, Chrysomelid beetle to control Klamath weed in Western U.S.

E. Worldwide Successes
  i. 602 classical biocontrol attempts.
  ii. Complete Success rate is 16%
  iii. Partial Success is 58%
  iv. Most success against Homoptera (30%), Hemiptera (15%), Lepidoptera (6%), and Coleoptera (4%).

Agents of Biological Control

A. Agents of cause may be insects but can also be birds, nematodes, microorganisms, other invertebrates.

B. Divide natural enemies into three categories - parasites (some are non-insects), predators (some are non-insects) and pathogens (non-insects).

Parasites (1)

1. A parasite is an animal that lives on or within a larger animal or host. It feeds on the host, usually weakening and sometimes killing it. A parasite only requires one or part of one host to reach maturity.

2. Parasites that have the greatest impact on insect populations are other insects and nematodes.

Parasites (2)

Insects that parasitize insects are best called <u>parasitoids</u>.

a. A parasitoid is parasitic in its immature stages and free-living as an adult.

b. Parasitoids always kill their host, however, host may live out most of its life.

c. Can attack any stage of the host.

d. Used most frequently in BioControl

e. 6 orders covering 86 families - Hymenoptera, Diptera, Coleoptera, Neuroptera, Strepsiptera and Lepidoptera.

f. Either lay inside host or on host surface (Larvae burrow inside after hatching).

g. Effective because of: 1. Good Survival, 2. One or fewer hosts needed, 3. Pops can survive at low levels, 4. Narrow Host Range

h. Disadvantages:
   1. Host searching affected by weather, etc
   2. Only females search
   3. Often the best searchers lay few eggs.
   4. Synchronization

Parasitic wasp *Cotesia congregata* on tobacco hornworm *Manduca sexta*

Parasitic wasps

Figure 16: Parasitic wasps puncturing the American cockroach oothecae to lay eggs (left: *A. hagenowii*; right: *E. appendigaster*) (photos by HS Tee).

These parasitic wasps will puncture the ootheca and lay an egg inside. Upon hatching, the larva will begin eating the contents of the ootheca and eventually pupates. Upon emergence from the pupa, it will leave the egg case.

Predators

1. Free Living animals that feed on other animals - prey.
2. May attack as both immatures and adults
3. Need more than one prey to develop
4. Includes fish, amphibians, birds, reptiles, mammals, other arthropods and even plants.
5. Most successful - insects and mites
6. Usually use Coleoptera (Lady Bird beetles), Neuroptera (Lacewings), Hymenoptera (ants), Diptera (Syrphids) & Hemiptera (Damsel & Minuter Pirate Bugs).
7. Some have narrow host range - may be best to use - Monophagous - Vedalia beetle, Oligophagous - Syrphid Flies
8. Most have wide host range: Polyphagous - Lady Bird Beetles.

Syrphus hoverfly larva feeding on aphids

Practice of biocontrol

i. Also known as **<u>importation</u>**

ii. Termed Classical Biological Control

iii. Vedalia Beetle, Edovum are examples

iv. Most successes in orchards and forests

v. Alfalfa Weevil - Major Success
   1. Introduced 11 para and 1 pred, mostly by 1959
   2. By 1970 6 hymenop parasites were established throughout NE USA and attacked egg, larvae and adult.
   3. By late 1970's causing 70% mortality, 73% of acreage needs no more treatment with insecticides

vi. Pattern for introduction
   1. Find host origin
   2. Go to origin and find agents
   3. Best are ones that operate at low levels
   4. Quarantine agents for evaluation
   5. Import/rear/release
   6. Evaluate

vii. Usually done for exotic pests

Augmentation

i. Purpose is to increase the numbers or effect of existing natural enemies

ii. Releasing additional numbers is similar to introduction except they are expected to only be temporary. Dampen pop rather than change EP.

1. <u>Inundative</u> Releases
   a. Purpose is to swamp pest with high numbers. Not intended for progeny to have impact, just those released.
   b. Used as an insecticide, multiple releases
   c. Best successes - *Trichogramma*, Bti, Viruses.
2. <u>Inoculative</u> Releases
   a. Purpose is to colonize agent into new area so that it reproduces and spreads.
   b. Made only once
   c. Progeny have most significant effect
   d. *Edovum puttleri*, *Encarsia formosa*, Milky Spore.

Conservation

i. Most widely practiced technique

ii. Protect and maintain existing populations

iii. Less frequent mowing of field edges

iv. Provide alternate food - Lady Bird Beetles

v. Use less insecticides - # of applications, less toxic to pred/para, and reduce rates.

Advantages

- <u>Relatively permanent</u> once it is established. The natural enemies on which it depends are self-perpetuating (barring natural catastrophes and interference by man), and they continually adjust to changes in the pest population size.
- Biocontrol has <u>no side-effects</u> such as toxicity or environmental pollution and they are not hazardous to use.
- In the long run, biocontrol is <u>more economical</u>, compared with chemical control.