Intermediate Scientific

FIBKA Exam Study Notes

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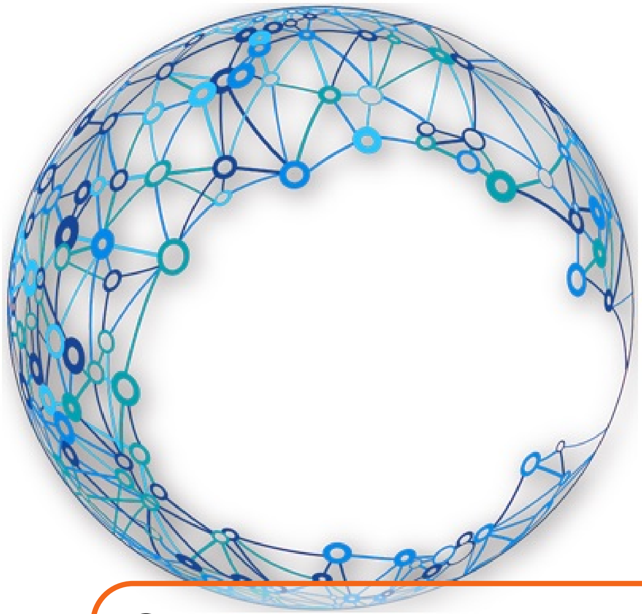

Contents

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0.1 Acknowledgements

This document was created based on personal study notes and has had a lot of other reference material added. In particular some of the graphics have been simply collected from the internet in a random fashion and consequently could well infringe someone's copyright. As a result, it is important not to share this outside the LBKA study group, at least until such time as any questionable graphics have been replaced with ones for which the provenance is known.

Much of the anatomy information is more completely covered in Snodgrass' *The Anatomy of the Honey Bee*, from where many diagrams have originated. This book may be downloaded in its entirety from here. Note that this book is out of copyright so it can be freely downloaded.

Another source of images is Adam Tofilski.

1. Natural History

1.1 Castes

A caste is the form of a social insect having a particular function. There are three castes:

- Worker - A female from a fertilised egg with 32 chromosomes
- Queen - A female from a fertilised egg with 32 chromosomes
- Drone - A male from an unfertilised egg with 16 chromosomes

1.1.1 Lifecycle

Stages in the lifecycle

Stage	Worker	Queen	Drone	Moults
Open cell				
Egg	3 days	3 days	3 days	
Larva	5 days	5 days	7 days	4
Sealed cell				
Larva/prepupa	3 days	2 days	4 days	1
Pupa	10 days	6 days	10 days	1
Egg to emergence	21 days	16 days	24 days	
After emergence				
Summer bee	6 weeks	3 years	4 months	
Winter bee	6 months	3 years	4 months	

Description of stages (worker)

Day	Description
1	Egg vertical, stuck to the bottom of the cell, parallel to the cell wall
2	Egg at an angle of 45 degrees
3	Egg horizontal at the bottom of the cell. Egg hatches after 3 days.
4-8	Larva grows, moulting every 24 hours, until it fills the cell diameter. The cell is sealed on day 8, after the larva's last meal.
8-21	- The connection between the ventriculus & hind gut opens. - The malphigian tubes open into the hind gut and excreta is voided into the cell. - The larva changes position and stretches full length in the cell, head outwards, and spins a cocoon. - Metamorphosis occurs and the larva changes to a pupa (5th moult) three days after sealing. - The pupa is still white but with adult form. It completes development, slowly changing colour and emerges on Day 21 by nibbling the cell capping. The 6th moult occurs just before emergence.

The queen and drone are similar to the above, but with different timings.

1.1.2 Feeding

Larvae can eat immediately after hatching. The queen and worker are both derived from fertilised eggs, so the difference is not genetic, but is instead due to feeding. Queen larvae are fed exclusively on copious amounts of royal jelly - a glandular secretion from the mandibular and hypopharengeal glands of the worer bee - throughout the larval stage, and are generally overfed and continue to feed when the cell is capped. Workers are fed brood food the first 2-3 days, and then a mixture of brood food, honey and pollen until the cell is sealed. No excess is left in the cell as in the case of the queen.

Up to recently it was thought that the royal jelly was what made the queen, but recent research has shown that the converse is true: the workers' food cause the larvae to become workers.

1.1.3 Functions of the castes

Functions of the three castes in the life of the colony:

Worker functions

Day 1-3	Cell cleaning & brood incubation
4-6	Feed older larvae (brood food + honey + pollen)
7-12	Feed young larvae (brood food)
13-18	- Processing nectar into honey- Making wax- Packing pollen- Evaporating water
19-21	Guarding and starting to forage
22+	Foraging for nectar, pollen, propolis and water.

Drone functions

Day 1-12	Generally confined to the hive, except for cleansing and orientation flights.
12-14	Mature & ready to mate, his primary function
Autumn	Ejected from the hive to die.

Queen functions

Day 1	Seek rivals and kill them
3-5	Orientation flights to locate the hive
6-21	Mating flights (multiple)
up to 3-5 years	3-4 days after mating, the queen starts to lay. From then she lays eggs and produces pheromones for social cohesion.

The times are variable up to the time the queen begins to lay. If she has not mated satisfactorily within 20 days, she usually becomes a drone layer and is said to be stale.

1.2 Reproduction

1.2.1 Parthenogenesis

Parthenogenesis is reproduction without fertilization, from the Greek words meaning "virgin birth". The queen has sperm but has the ability to lay either fertilised or unfertilised eggs. This theory was propounded by Dzierzow in 1845.

The queen has the ability, at will, to lay a fertilised or unfertilised egg. She uses her front legs to measure the width of the cell to determine if it is a worker or drone cell, and if the egg should be fertilised or not respectively.

In rare cases an unfertilised egg can become a queen (Apis mellifera capensis).

1.2.2 Sexual Reproduction

The queen mates on the wing 5-20 days after emerging. The workers in a colony with a virgin queen become more and more aggressive towards her until she mates: this behaviour may be responsible for driving her out to mate before she becomes too old (stale). After mating, the workers are very attentive towards her, grooming her and forming a court around her.

Drones have areas where they congregate (Drone Congregation Area - DCA). The congregate from a wide area, ensuring a variety of genetic lines, thus minimising inbreeding.

1.2.3 Mating Flight

Mating happens at heights of 10-30m (30-90ft). The height at which mating occurs is unversely proportional to the windspeed, i.e. if the wind is slight, the flights are high, but if the wind is strong, the flights are closer to the ground.

The sequence of events of the mating flight is:

- Mating flights happen in good weather when plenty of drones are flying, typically noon-4pm.
- The queen flies to the level of the drones.
- Drones are attracted by pheremones from the queen's mandibular and other glands: they can detect the pheremone at 50m and can see her at 1m.
- The first drone mates with her, on ejaculation his endophallus detaches, and he falls to the ground and dies.
- Further matings occur on2 or 3 separate flights. Each drone removes any prior drone's penis that is still in the queen.

- Mating continues until the spermateca is full of sperm. This will last her her life, i.e. 3-5 years.
- When the queen returns to the hive, if her vaginal opening contains the drone's endophallus, it is removed by the workers.
- The queen starts to lay 2-4 days after mating.

1.3 Pheromones

A pheromone is a chemical secreted from an exocrine gland of an animal, that elicits a behaviour or physiological response by another member of the same species, and so acts as a chemical message.

1.3.1 Queen Substance

Queen substance is a pheromone produced mainly in the queen's mandibular gland, discovered by Colin Butler in the 1950's. it may also be produced in small quantities by glands in the queen's abdomen. Worker bees do not produce queen substance in their mandibles. (The queen's mandibles are larger than workers' which are larger than drones');

Queen substance or Queen Mandibular Pheromone (QMP) is primarily made up of:

- 9-Oxydecanoic Acid (9-ODA) - inhibits queen rearing as well as ovarian development in worker bees; strong sexual attractant for drones when on a nuptial flight; critical to worker recognition of the presence of a queen in the hive
- 9-Hydroxydecanoic Acid (9-HDA) - promotes stability of a swarm, or a calming influence.

The substance becomes spread all over the queen's body when she grooms herself 2-3 times an hour. It is transferred to the workers feeding the queen, and then in turn to other workers, and so on throughout the colony, both by food transfer and by antennal contact with the queen.

Queen substance has a profound effect on workers:

- It inhibits the development of worker ovaries
- It inhibits the building of queen cells in the colony

For the effects to work, workers need to receive a certain amount of queen substance every day. The queen produces around 5000µg in year 1, dropping to 2500µg in year 2, and so on, which indicates that colonies with an older queen are more likely to swarm.

Similarly, crowded colonies tend to prevent adequate food transfer with a consequent breakdown of chemical communications, meaning they are more likely to create queen cells and swarm.

A colony that has been queenless only a few hours will be affected and will start to build queen cells.

Insufficient queen substance can be caused by:

- An aging queen
- A damaged queen
- Overcrowding or congestion
- A physically small queen (scrub queen)

1.4 Food sharing

Food exchange (trophallaxis) occurs in a colony constantly: It is the prime mechanism for exchanging pheremones. Nectar or honey is passed from one bee to one or more receiving bees. Food is passed from worker to worker, from worker to queen and from worker to drone, although the food for the queen is always royal jelly. Reciprocal feeding continues for the life of the bee. A bee that is up to 2 days old receives more than she gives.

The transfer starts by one bee *begging* or *offering* food. Begging bees hold out their proboscis, while offering bees fold back their proboscis and open their mandibles exposing a droplet of food. The effect of this is that the crops of adult bees in the colony contain the same mix of nectar and other substances at the same concentrations.

While feeding, the antennae of both bees are in contact, passing scent messages.

The food transferred also provides information on the availability of food and water in the colony:

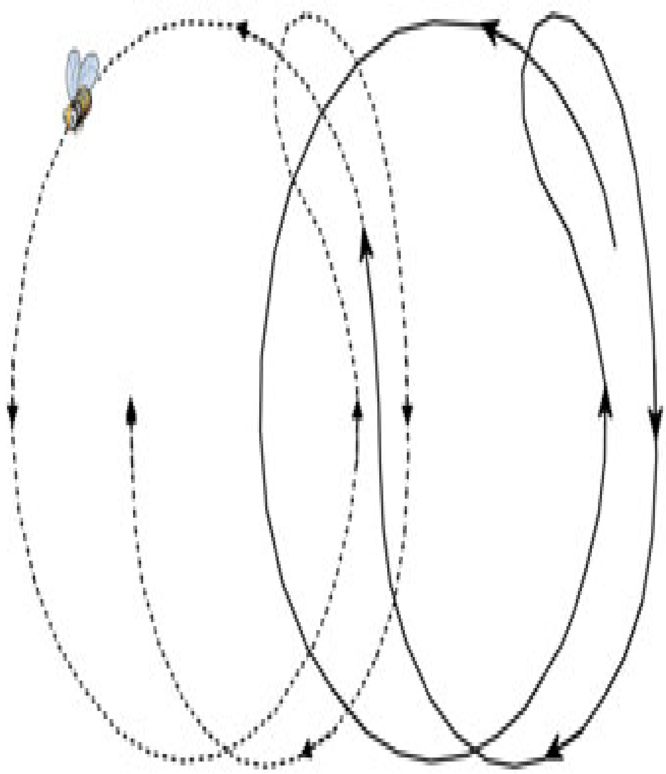
- If no nectar is coming in, the honey crops contain honey (80% sugar), it indicates that water is required for dilution.
- If nectar is coming in, the honey crop contains dilute nectar, indicating that there is no need to collect water, but that nectar needs evaporation.
- WHen young bees feed foragers with protein-rich food, it indicates that there is plenty of pollen available and that less pollen needs to be collected. It may also encourage the queen to lay more.

1.5 Communication Dances

Around 2% of the bees are scouts, and they use two dances to communicate about pollen and nectar sources:

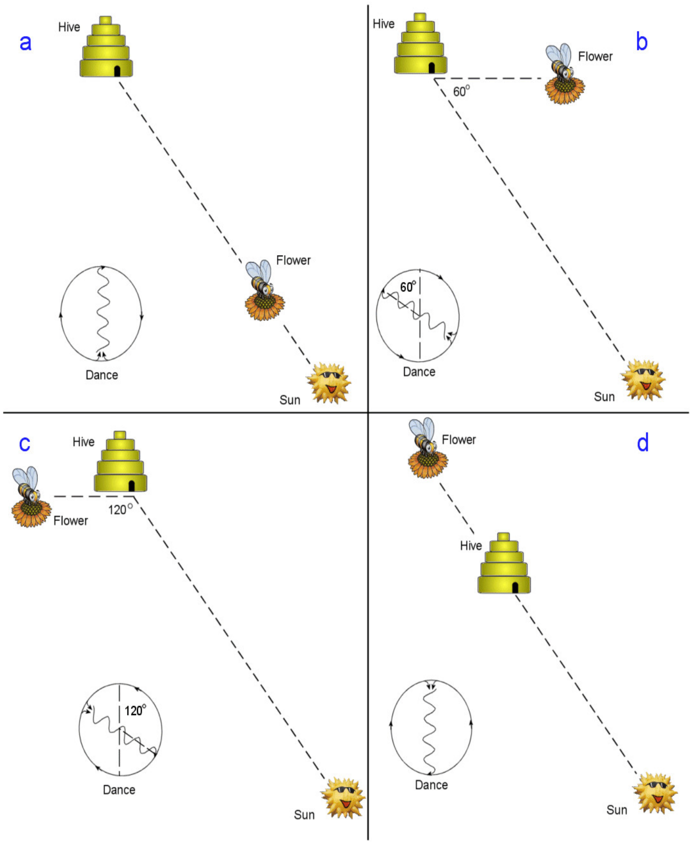
- the round dance, and
- the waggle dance

1.5.1 Round dance



This dance conveys very little information, merely indicating that a source of food is close by, within 100m. Foragers recruited by the round dance search in all directions from the hive. This behaviour can lead to robbing - this is why it's important to feed late in the day, and to avoid syrup spills.

1.5.2 Waggle dance



The waggle dance provides precise information on the direction and the distance from the hive and, in a way, the time the resource is available, i.e. now, when the dance is being performed.

Direction is given as an agnle between the food source location and the sun. This angle is translated as the same angle between the vertical and the wagging direction of the run. The top of the comb always represents the sun. For example, if the source is to the right as viewed from the hive entrance, the waggle run will always be to the right of the vertical. The bees can allow for the lapse of time, i.e. 15°()/hour

Distance information is given by the length of the run

- 100m - 9-10 runs every 15 sec
- 600m - 7 runs every 15 sec
- 1000m - 4 runs every 15 sec
- 6000m - 2 runs every 15 sec

The recruiting (dancing) bee also provides foragers with samples, illustrating the quality of the food source.

1.6 How the bee orientates to the hive

Orientation is the faculty of an insect to find its way home from a distant location. In the case of the honeybee, this involves:

- Landmarks in proximity to the hive

- Position of the sun - azimuth and angle
- Ability of the bee to detect polarised and ultra-violet light

Young bees, while they are house bees, take short flights around the hive, noting landmarks in the vicinity. These flights become longer and further afield so by the time the bee becomes a forager she has a very precise knowledge of the vicinity up to around ½mile radius.

Moving the hive even a short distance disorients the bees until they have a chance to re-orient.

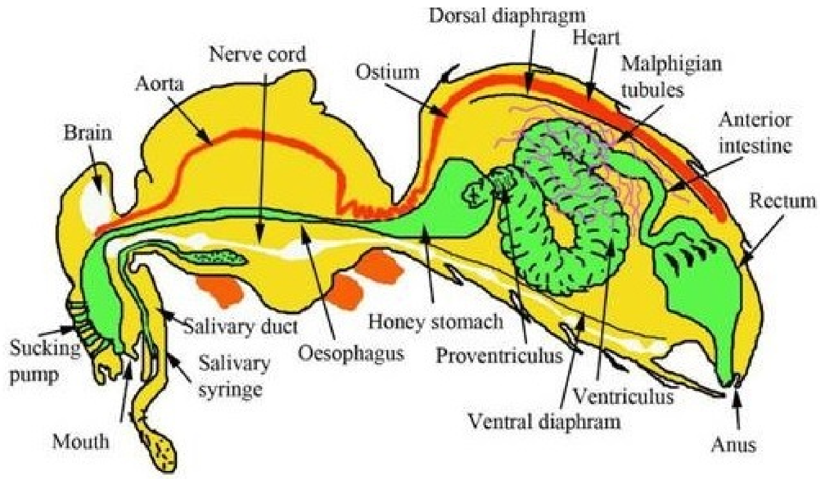
With no immediate local landmarks, bees will tend to drift to neighbouring hives, a factor in the spread of disease, particularly folling periods of confinement (they have a ca. 2 week memory). Consequently it's important to take precautions:

- Introduce landmarks
- Paint hives in distinctive colours/patterns
- Vary the direction of the hive entrance

The Nasanov gland is used as a direction aid, attracting back bees to the hive, particularly after a disturbance.

The honeybee flies diring the day using its eyes for navigation - it cannot fly at night:

- The *ocelli*, the 3 simple eyes on top of the worker's and queen's head, behind the compound eyes (on the drone they are located in front of the enlarged compound eyes), cannot focus on an image, and are only used to measure light intensity.
- The *compound eye* produces a rather poor image, but they can detect U.V. light as well as the plane of polarised light.
  - The sun is a powerful source of U.V. light: even when cloudy, the bee can detect the location of the sun.
  - Light becomes polarised as it passes through the earth's atmosphere: the plane of polarizationi varies depending on the direction. The bee can detect the plane of polarization and use that to calculate the angle to the sun.
  - The bee can also allow for the passage of time (15° per hour) and use that to compensate when navigating.
  - When she reaches a source of forage, the bee moves from flower to flower, but returns to the starting flower before setting off for the hive.

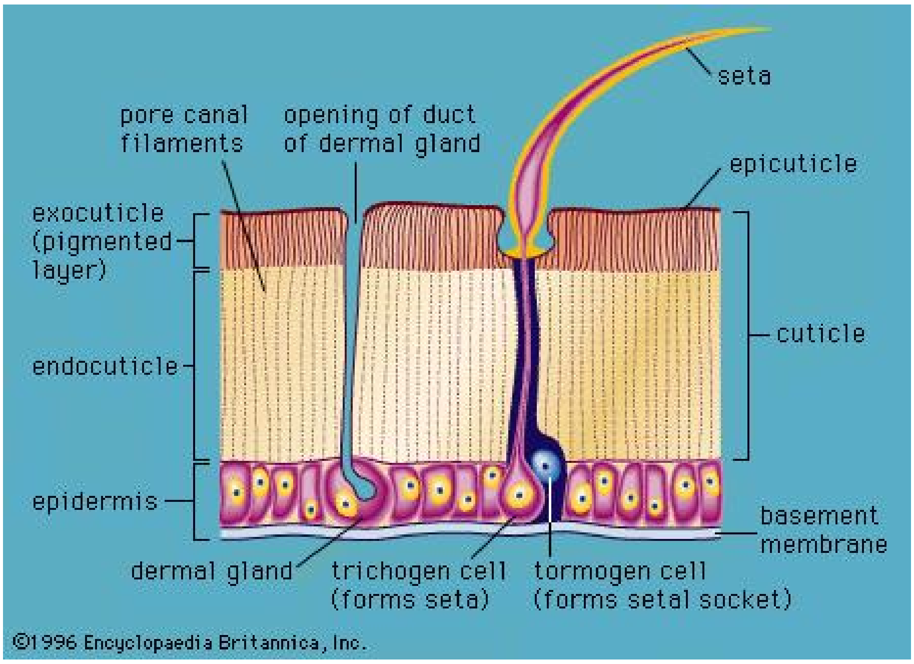


2. Anatomy

2.1 Exoskeleton

A large part of the exoskeleton is covered with hair, a vital part of the anatomy allowing it to collect pollen. Flexible joints consisting of a membrane with a thin layer of cuticle connects the rigid plates of the exoskeleton.

2.1.1 Exoskeleton structure

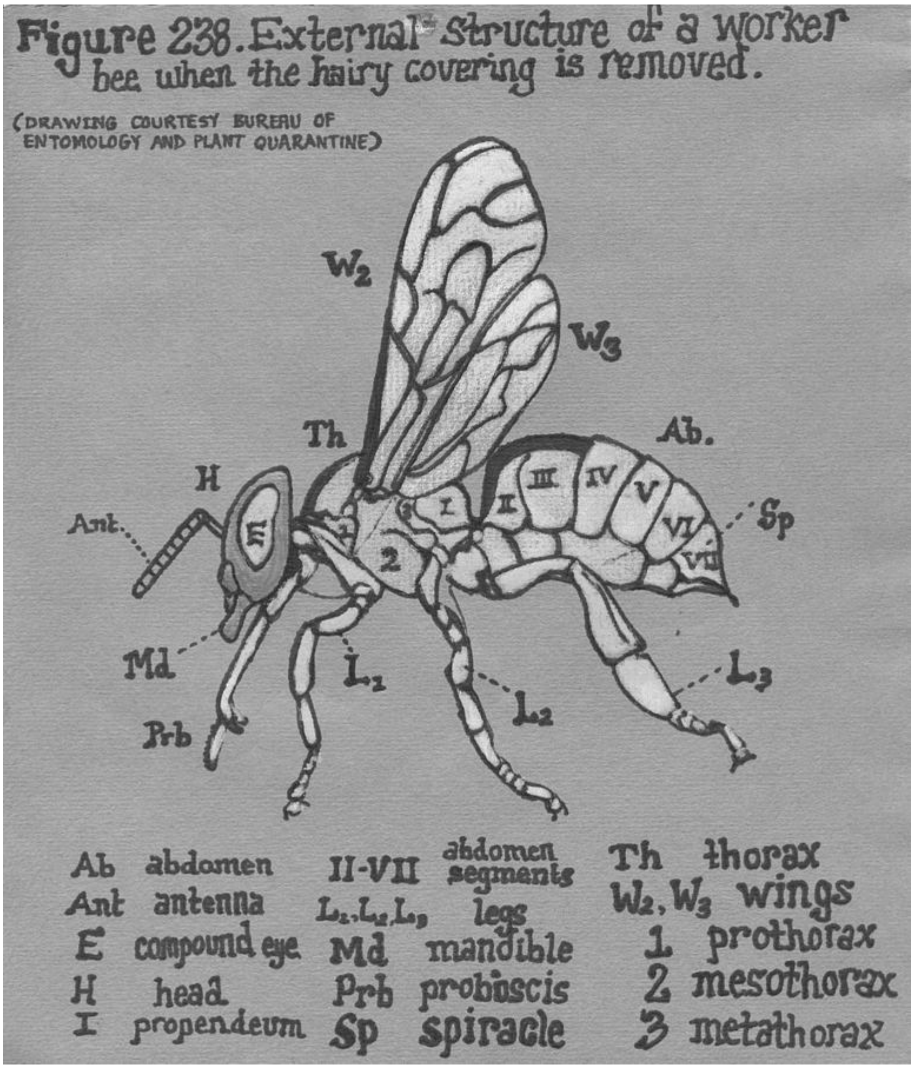


The exoskeleton consists of:

- Epicuticle - the thin outside greasy waterproof layer
- Cuticle, consisting of two parts:
  – Exocuticle - hard slerotin, pigmented
  – Endocuticle - soft chitin
- Epidermis - a layer of cells which secretes substances that form the cuticle. This is where the sensilla are formed.
- Basement membrane - below the epidermis, to which muscles are attached.

The queen and worker have triangular-shaped heads, while the drone's is rounder. The drone's compound eyes are much larger too, and are across the top of his head, pushing the ocelli to the front. The drone's thorax is also much broader, making him a stronger flier. The workers abdomen is slender, while the queen's is longer and the drone's is rounder and fatter.

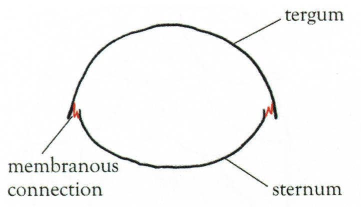
2.1.2 Segmentation



The exoskeleton is divided into three parts:

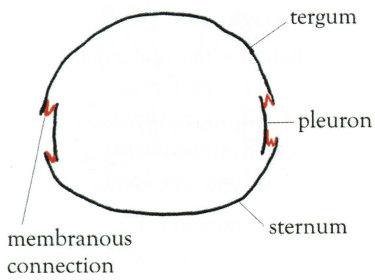
- The head, derived from the 6 basic segments of hich there has been extensive specialization to form:
  – 2 antennae

  - 5 eyes (2 compound eyes and 3 ocelli)
  - moutparts
- The thorax consisting of 3 thoracic segments, each of which is composed of a dorsal tergite, a ventral sternite and two lateral pleurites, and the first abdominal segment which has no pleurites:
  - T1 - Prothorax, with 2 forelegs
  - T2 - Mesothorax, with 2 middle legs, and two front wings connected between tergites and pleurites.
  - T3 - Metathorax, with 2 rear legs, and two rear wings connected between tergites and pleurites.
  - A1 - Propodeum, actually the first segment of the abdomen. In many insects there is a constriction between the thorax and abdomen; in *hymenoptera* the petiole has developed between the first and second abdominal segments.
- The abdomen,containing 9 abdominal segments, A2-A10 (A1 is on the thorax). Only A2-A7 can be seen, with A8-A10 hidden.



Abdominal segment

(includes the propodeum)



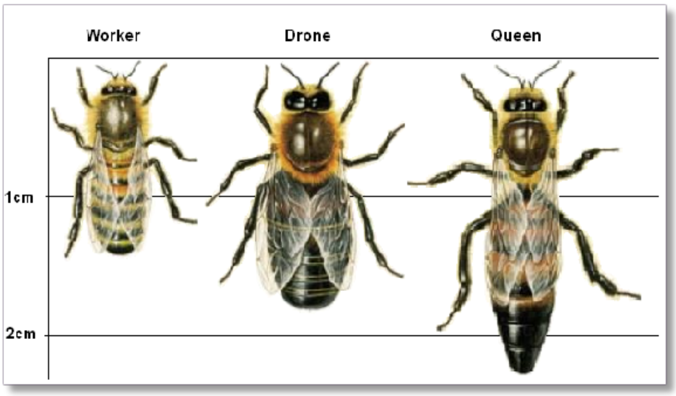
Thoracic segment

It is difficult to see the structure in the thorax of the bee because the segments are modified

Other parts visible on the exoskeleton are:

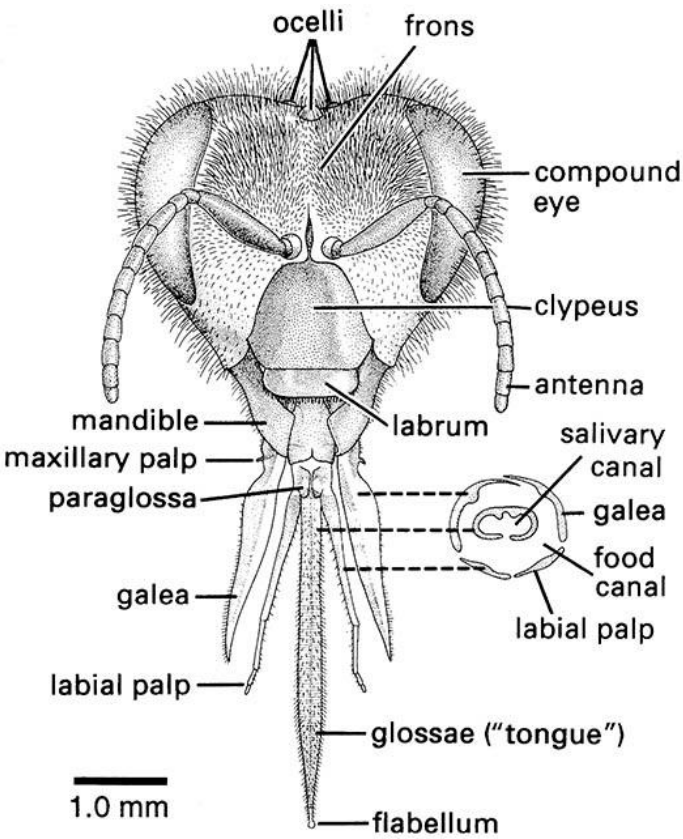
- Nasonov gland - located on the dorsal side on the joint between A6 and A7 on the worker.
- 10 pairs of spiracles of which 9 are visible and the 10th pair are on A8.
  - First and largest on T2 cannot be closed
  - Second and smallest on T3
  - Largest outlet on A1
  - Fourth-ninth visible on A2-A7
- 4 pairs of wax glands on A4-A7 of the worker. These are not usually seen, but the wax scales are often visible during a nectar flow.

2.1.3 Caste variation



- Head
  - All have 2 compound eyes, 3 ocelli, 2 antennae, 2 mandibles and 1 proboscis
  - Worker - Triangular in shape with long proboscis
  - Queen - Similar to worker in shape but rounder, with short proboscis
  - Drone - Almost circular with very large eyes, mandibles are very small, one extra segment in antenna flagellum
- Thorax
  - All have four segments, T1-T3 and A1, with 3 pairs of legs (on T1, T2 & T3) and 2 pairs of wings (on T2 & T3).
  - Worker - Small, hairy
  - Queen - Similar to worker in shape but dorsal side appears hairless (making it easy to mark).
  - Drone - Larger and stronger with larger wings.
- Abdomen
  - All have six visible segments, A2-A7, and three hidden segments, A8-A10. There are 10 pairs of spiracles on T2-A8, the last being hidden inside the abdomen.
  - Worker - Specialised - wax & Nasonov glands
  - Queen - Distinctive long tapering abdomen.
  - Drone - Fat and furry
- Legs
  - All have three pairs of legs
  - Worker - Has pollen press and pollen basket on rear legs.
- Wings
  - The forward pair are large with a fold to engage the hamuli on the smaller rear wings.
  - The wings are folded at rest and lie on the dorsal side of the abdomen
  - Drone wings are much larger

2.2 Mouth Parts



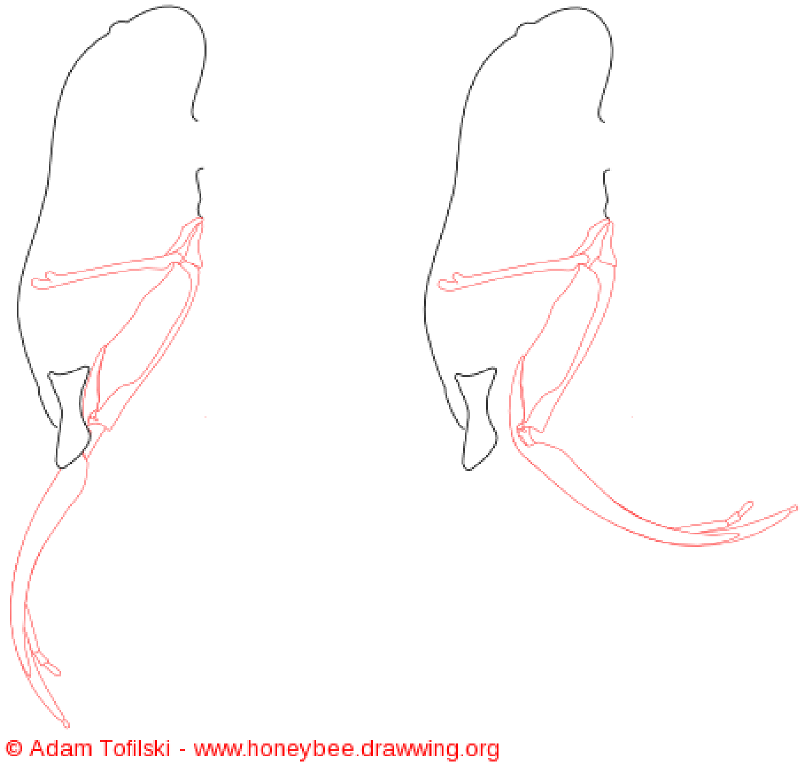
- Labrum - across the face (upper lip)
- Mandibles - worker: spoon, queen: toothed, drone: small
- Proboscis
  - Galae - protect the glossa, outside of proboscis
  - Glossa - hairy surface to collect liquid sucked into the proboscis
  - Labial palps - test the food
  - Labellum - helps saliva dissolve food

Feeding:

- The labial palps test the nature and quality of the food
- The labrum forms a seal around the proboscis so that food can be sucked up
- Saliva runs down the inside of the glossa and mixes with the food
- The labellum helps saliva to dissolve food, e.g. crystallised honey
- The glossa's hairy surface collects nectar/water/honey which is sucked up into the mouth

The mandibles are used for:

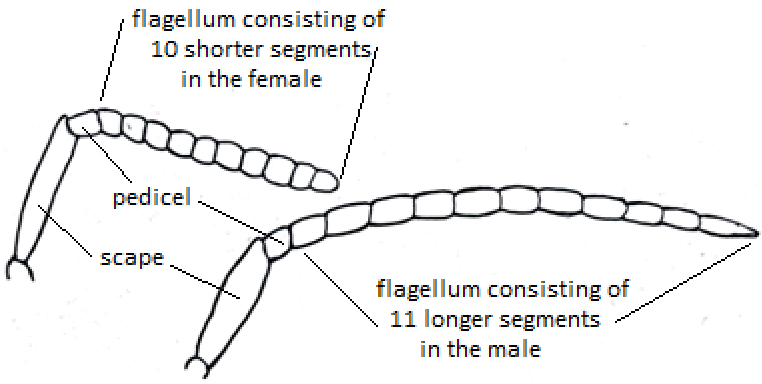
- Gripping the proboscis to hold it steady
- Manipulating & shaping wax
- Feeding the brood & queen
- Eating pollen
- Grooming and hygiene
- Colony defence
- Unloading propolis from incoming bees



When at rest, the proboscis is folded underneath, hinged at the paraglossa.

When in use, the proboscis is extended forward and raised to mouth level, sealed by the epipharynx and gripped by the mandibles to steady it.

2.3 Antenna



- Scape attaches to the head
- Flagellum - 11 segments in queen & worker, 12 in drone
  - Pedicel - first flagellum segment containing Organ of Johnston, receives vibrations & calculates wind speed

Contain many sensilla:

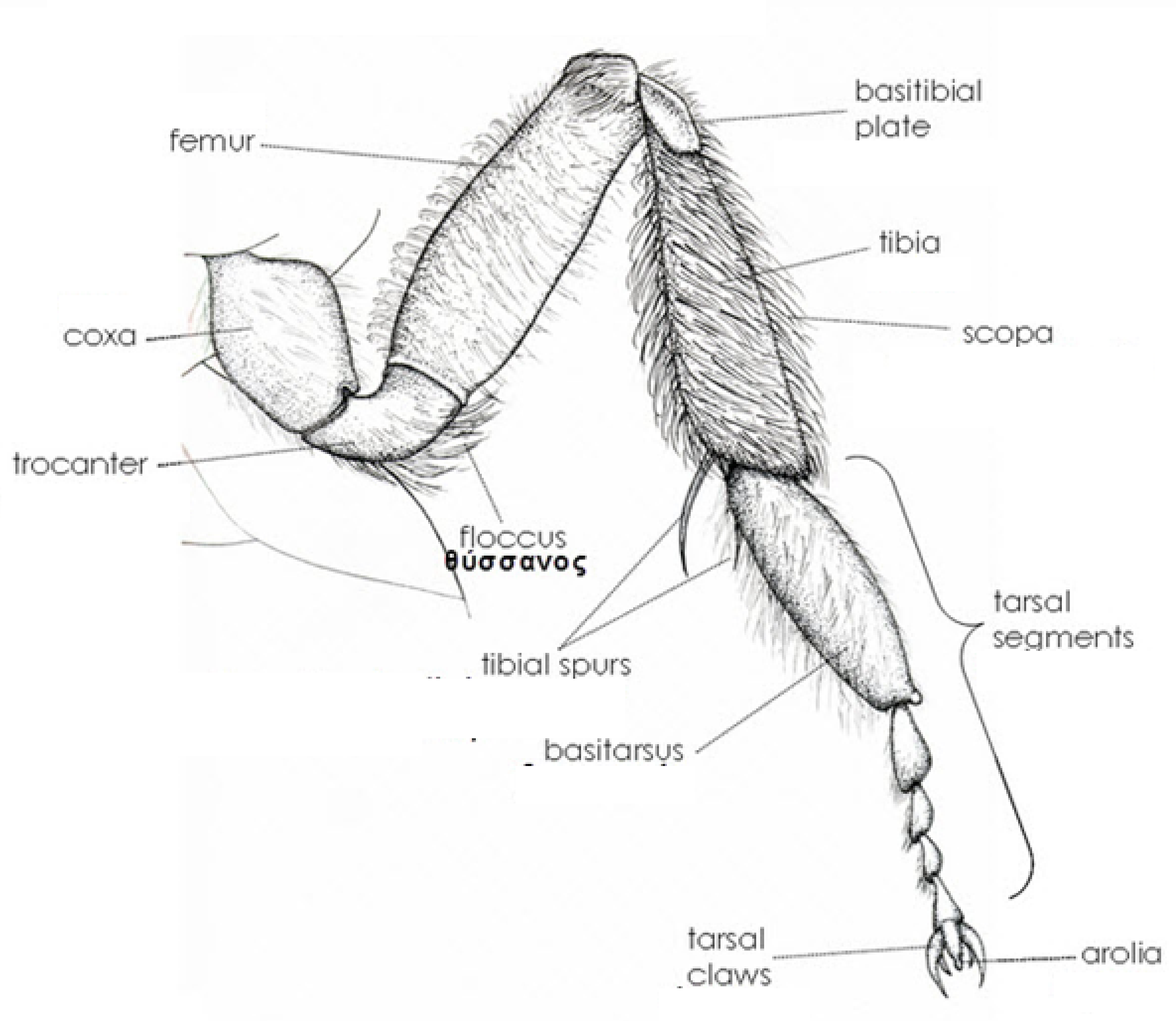
- Trichodia - touch - hairs
- Basiconica - smell - pegs
- Coeloconica -CO_2, humidity, temperature - pit-pegs

- Campaniformia - stress/strain in cuticle - bells
- Placodea - plates with pores - smell

These vary according to caste, e.g. placodea

- Queen: 2-3000
- Worker: 5-6000
- Drone: 30000 (detects queen substance in flight)

2.4 Legs



Can This Fecking Thing Be That Awkward (Feck, Rat Arse)

Coxa, Trochanter, Femur, Basitarsus, Tarsus, Arolium (Fibula, Rastellum, Auricle)

- Coxa
- Trochanter
- Femur
- Tibia - fore leg: Fibula, hind leg: Rastellum, Corbicula
- Tarsus
  - Basitarsus - hind leg: Auricle

  - And 4 more Tarsomeres
- Arolium - on pretarsus for walking on smooth surfaces, with 2 claws for rough surfaces.

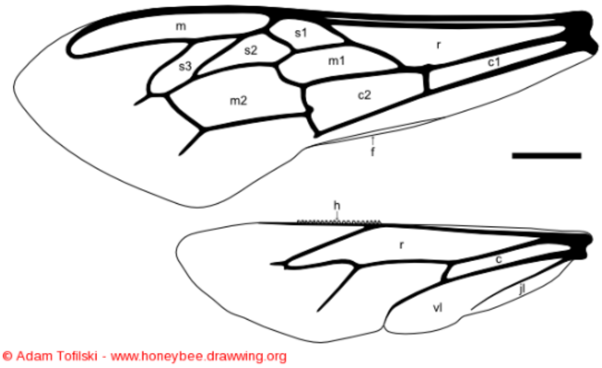
- Foreleg:
  - On T2, hairs on basitarsus & first tarsomere Tused to clean pollen from the head
  - Notch in the basitarsus with fibula spur on tibia used to clean antenna
- Middle leg:
  - On T3, hairs on basitarsus used to clean the thorax, and pass it to rear legs
- Hind leg:
  - Pollen collects on hairs of basitarsus
  - Worker hovers, rubbing legs together
  - Pollen is raked by the rastellum of the opposite leg into the auricle
  - The tibia-basitarsus joint is closed, squeezing the pollen out into the corbicula where it is caught on the hairs
  - Back in the hive, the bee sits over the cell, the pollen pellets are disengaged by the middle legs and drop into the cell.

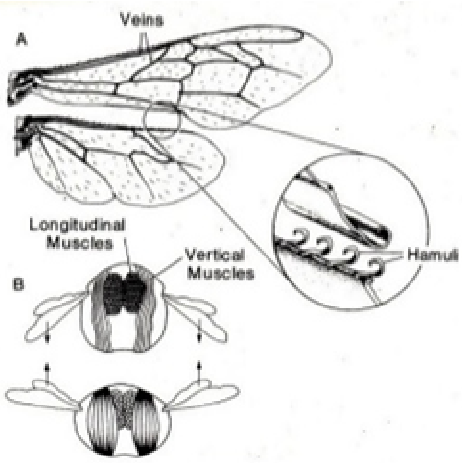
Propolis is bitten off by the mandibles and packed into the corbiculae. On return to the hive, another worker helps unload it.

Wax plates are removed from the mirrors of the abdomen by the rear legs.

The hind legs have no special purpose fin the queen and drone.

2.5 Wings



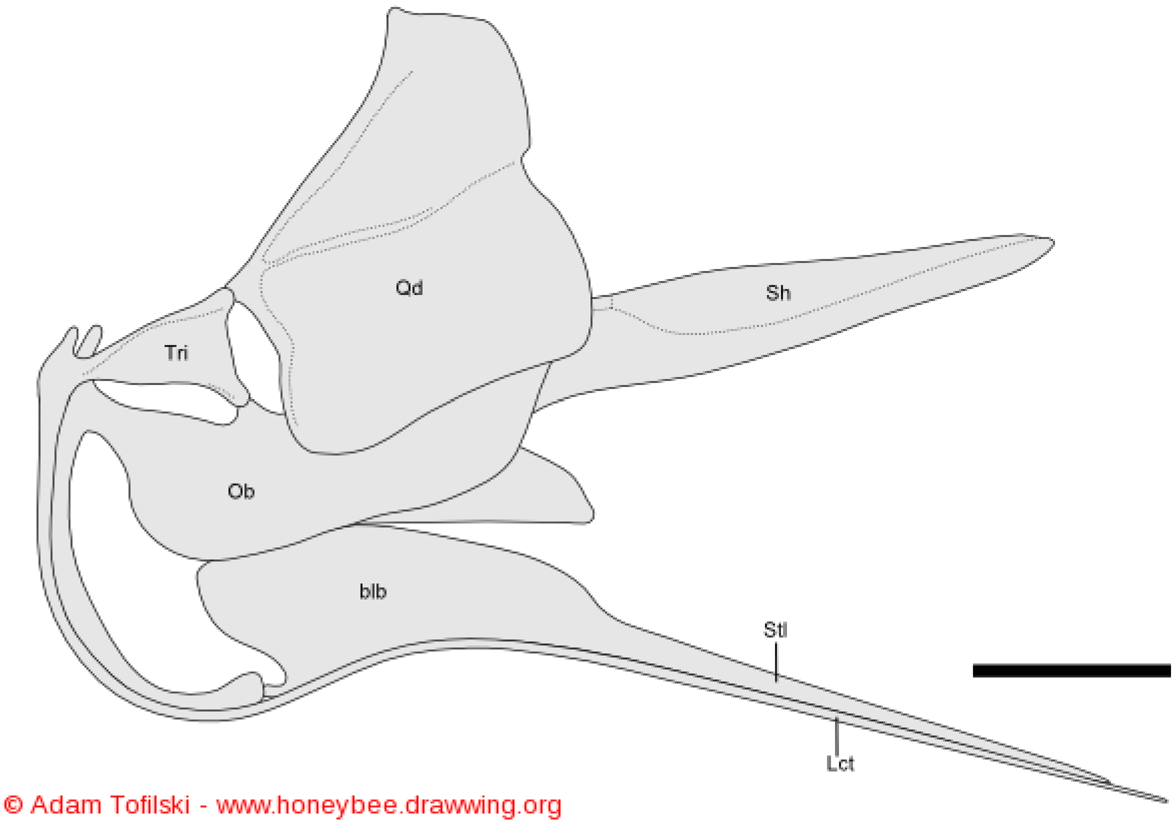


- Two pairs of wings
  - Fore-wing - on T2 - has fold (f)
  - Hind wing - on T3 - has ca. 20 hamuli (h) that hook into fold in fore-wing, but separate and lie flat on the back when at rest.
- Consist of a thin membrane supported by a system of tubular veins
  - The pattern of veins can be used to differentiate between species and subspecies
- Flight is due to a propeller-like twist to each wing, rather than flapping
- Beat at 200 beats/sec, producing an audible sound at 400Hz
- Flight controlled by two sets of muscles:
  - Indirect - vertical & longitudinal muscles - control up & down movement, drive the front wings only
    - Vertical muscles relax, longitudinal contract = thorax extends vertically, pushing the wings down
    - Vertical muscles contract, longitudinal relax = thorax extends horizontally, pushing the wings up
  - Direct - used for furling, unfurling and trimming the wings
    - 4 on front wings
    - 2 on rear wings
- Flight speed is around 24kph (15mph), but can reach 25mph for a short distance. Range is 15 mins flight = 4-5 miles, extended by resting when the body converts glycogen to sugar.
- Blood sugar for flight is around 2%. At 1% it can't fly and at 0.5% it can't move. Sugar consumption is around 10mg/hour during flight, 50x the consumption at rest.

The wings are used for:

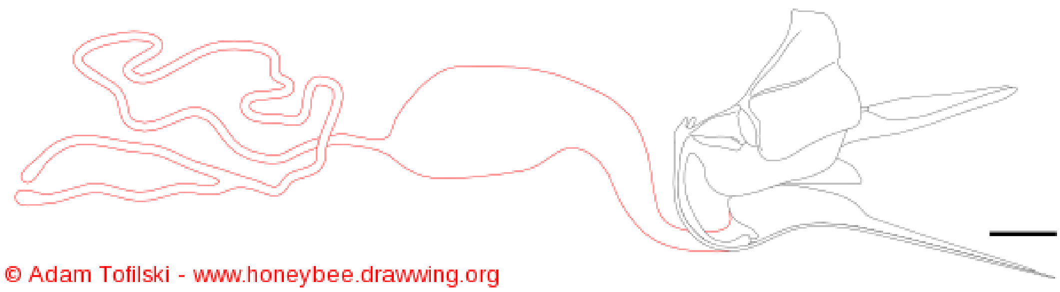
- Flying and hovering - forwards, backwards, up, down
- Ventilation (cooling & evaporation)
- Ripening honey (evaporation)
- Distribution of pheromones (Nasanov gland)

2.6 Sting



Oh Queen, take royal ladies shopping
Oblong, Quadrate, Triangular, Ramus, Lancet, Stylet

- *Ob* - Oblong plate - immobile
- *Qd* - Quadrate plate - retractor muscle pushes
- *Tri* - Triangular plate - rotates around fulcrum on oblong plate
- *Ramus* - pushed when triangle plate rotates
- Shaft
  - *Lct* - Lancet - extensions of ramus
  - *Stl* - Stylet - Lancets slide on this - only single stylet
- *Sh* - Sheath
- *Blb* - Venom bulb



Venom gland -> Venom sac -> Venom bulb -> umbrella valve -> lancet

The stylet is swollen into the venom bulb which contains tge umbrella valves.

The muscle between the oblong and quadrate plates contracts, pushing the triangular plate forward, pushing the ramus and lancet forward; the venom is pushed down the lancet by this movement, using the umbrella valve. This occurs on each side in turn. Since the sting is barbed and cannot retract, this has the effect of pushing the sting further into the victim.

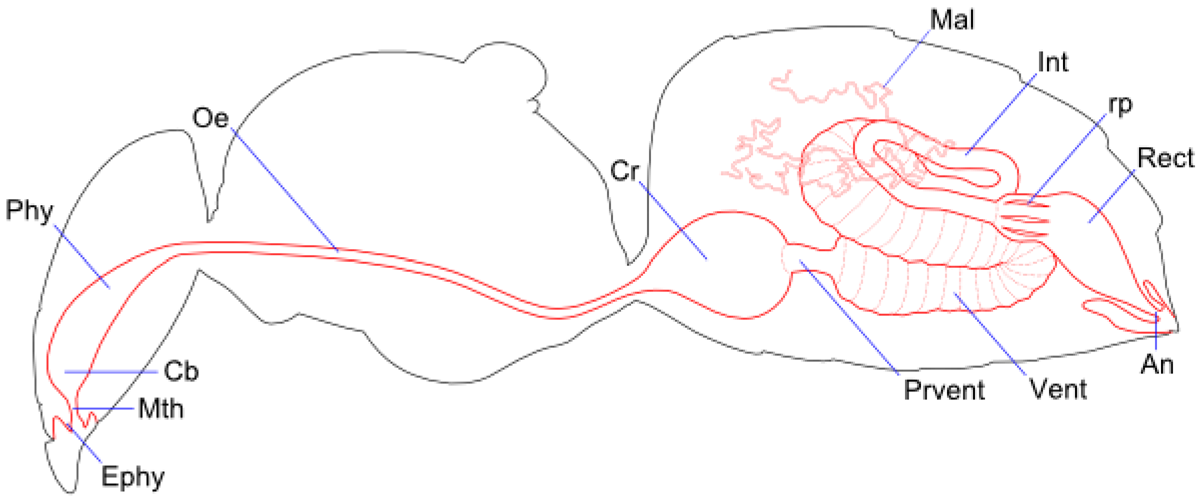
The queen's sting is not barbed and can be reused. She only uses it to kill rivals.

When the bee pulls away, the sting detaches from her body and continues to pump venom into the victim.

Venom contains

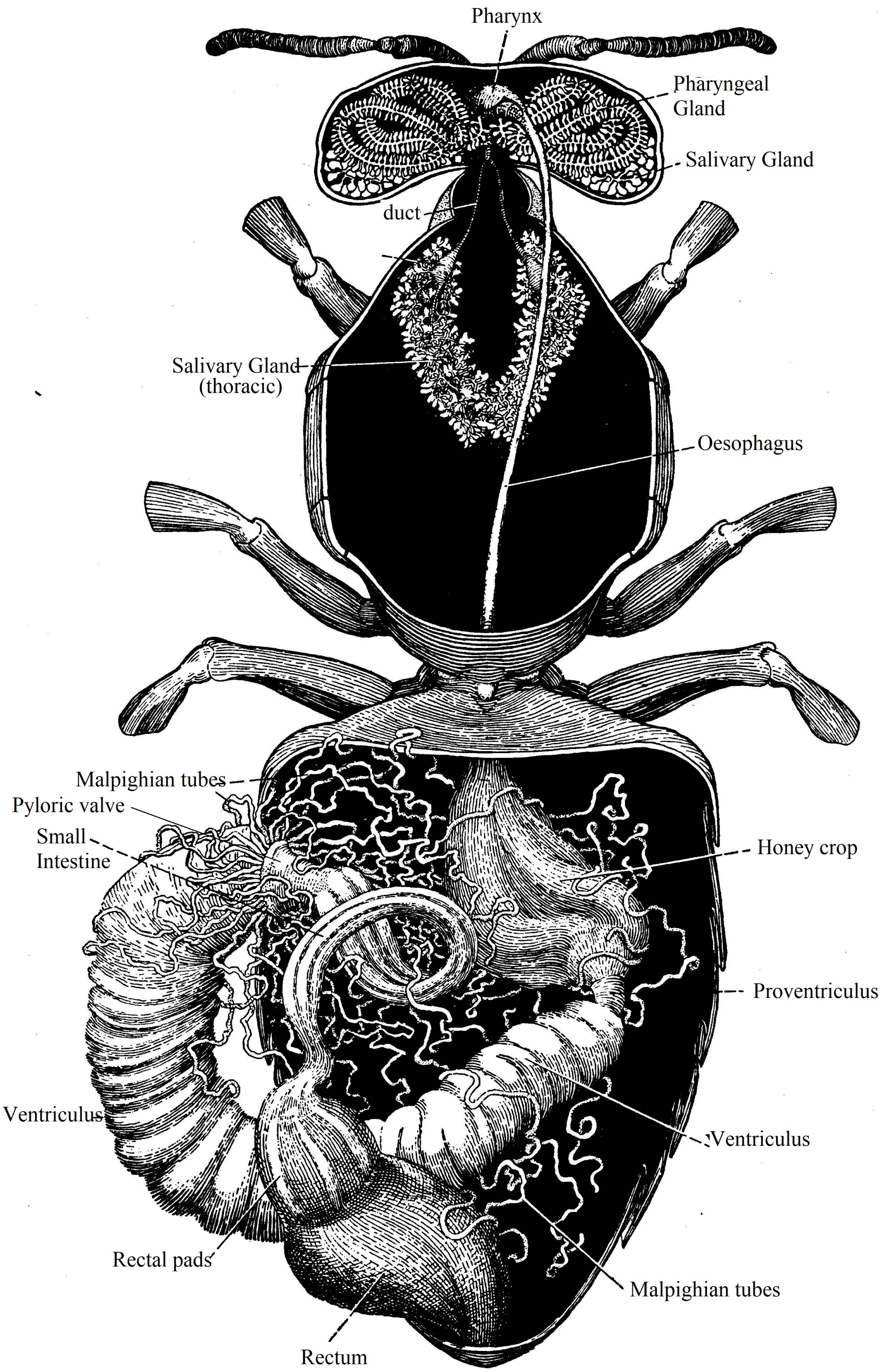
- Melittin - 50% - ruptures blood & mast cells
- Phospholipase - causes breakdown of cells & pain - synergistic with melittin
- Hyaluronidase - attacks cell connective tissue, allowing the others to penetrate

2.7 Digestive System



- *Ephy* - Epipharynx
- *Mth* - Mouth
- Mouth Cavity
  - *Cb* - Cibarium
  - *Phy* - Pharynx - Post-cerebral & thoracic salivary glands empty into the pharynx, and the hypopharangeal gland through the hypopharangeal plate,
- *Oe* - Oesophagus - muscular tupe that cruns through the thorax, connecting the pharynx to the honey sac. Carries food along using peristalsis.
- *Cr* - Crop - typically holds 40mg of water or nectar or honey. It can be regurgitated, or passed down the alimentary canal.
- *Prvent* - Proventriculus - a one-way valve to prevent nectar etc from flowing into the ventriculus. It also has fine hairs that function as a filter for pollen, sending a bolus of pollen into the midgut.
- *Vent* - Ventriculus - Most digestion takes place here. It's lined with a gelatinous peritropic membrane from where epithelial cells a released and disintegrate, releasing enzymes (invertase, amylase, etc.) to break down the pollen and release amino acids. Fats are broken down to fatty acids and glycerol, and the remaining sugars are broken down.
- Pyloric valve - just after Malpighian tubes enter - thickening joint to small intestine
- Small intestine - 6 flute-like folds provide a large surface area, slowing food throughput and permitting further digestion.
- *Rect* - Rectum - can store large amounts of waste in winter - 6 rectal pads (rp) to allow reabsorption of water
- *An* - Anus - excretion point - uric acid, pollen husks, fats, salts, water

2.8 Excretory System



The excretory system consists of:

- Malpighian tubes
  - Approx 100 tubules enter the ventriculus adjacant to the pyloric valve.
  - Spread through the entire abdomen, surrounded by haemolymph and closed at the distal end.
  - The walls of the tubules are composed of a single layer of cells. Nitrogenous waste (uric acid) and salts are absorbed from the blood. The waste is passed down to the ventriculus and then into the small intestine.

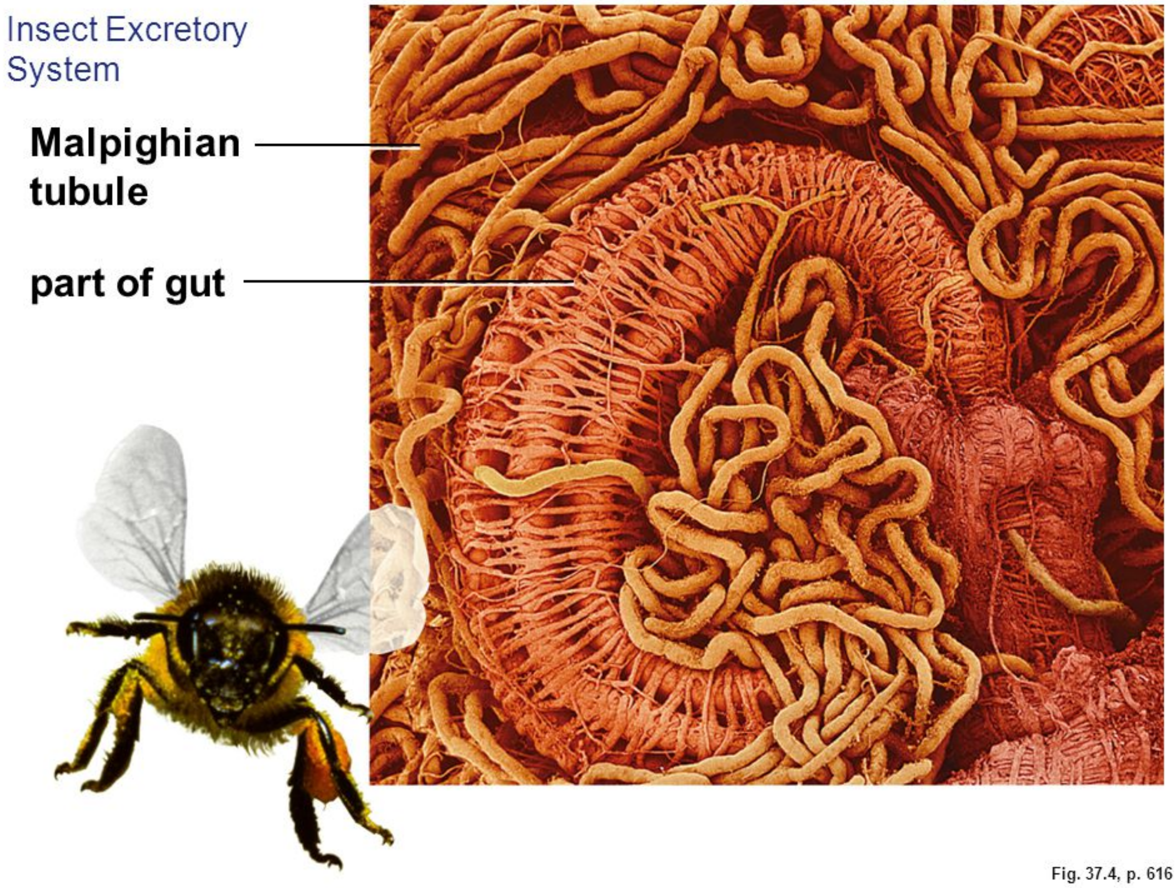


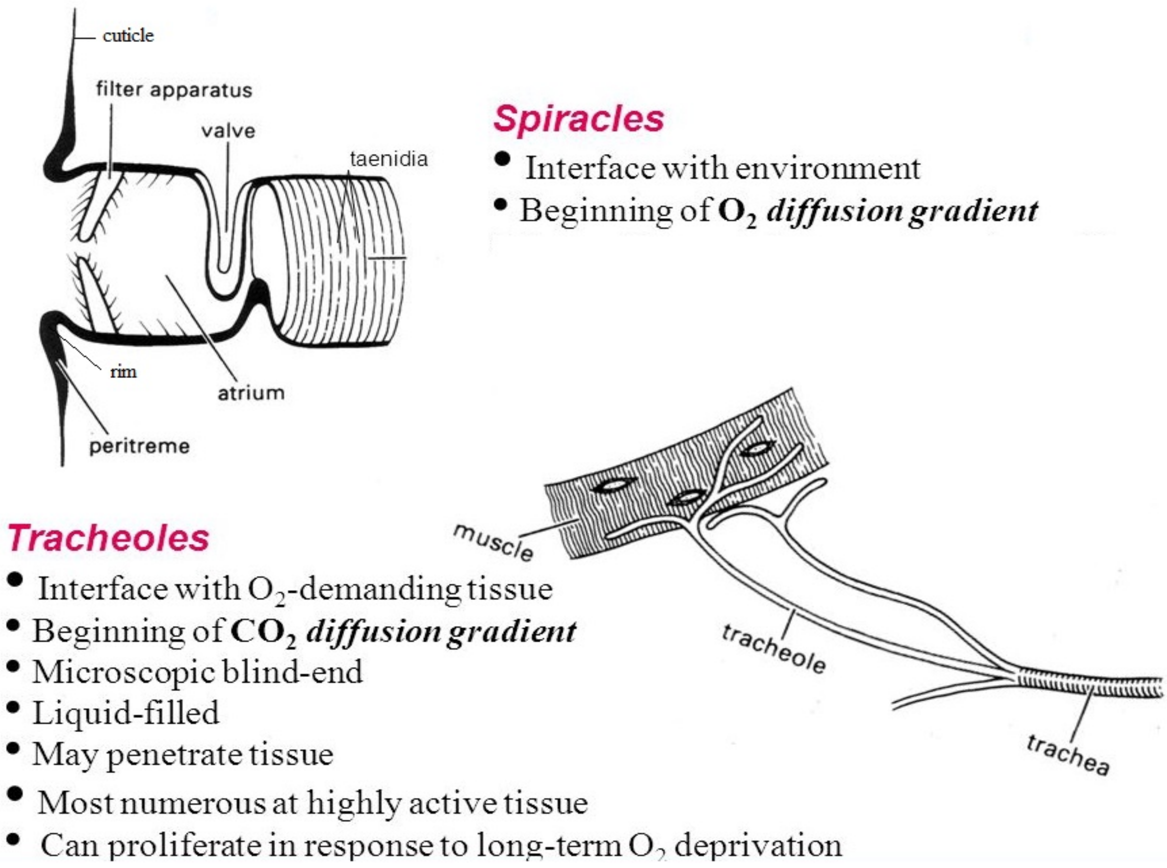
Fig. 37.4, p. 616

- Small intestine
  - Entry is from the ventriculous via the pyloric valve. The small intestine is constructed in a fluted fashion (6 flutes), providing a large surface area.
  - This slows down the passage of food and its absorbtion in the small intestine. Excess water is absorbed through the cell walls and passed with other waste into the rectum.
- Rectum
  - The rectum is a flexible bag with 6 rectal pads that correspond to the fluting of the small intestine.
  - The rectum stores the faeces until the bee can exit the hive and fly. The bee normally defecates on the wing.
  - When the bee cannot fly, e.g. in winter, the rectom is capable of expanding to fill a very large part of the abdomen.
  - Excess water, causing dysentry, cannot be retained in the rectum, and is the basic cause of any comb fouling in winter.
- Anus

  Faeces are evacuated and consist of:

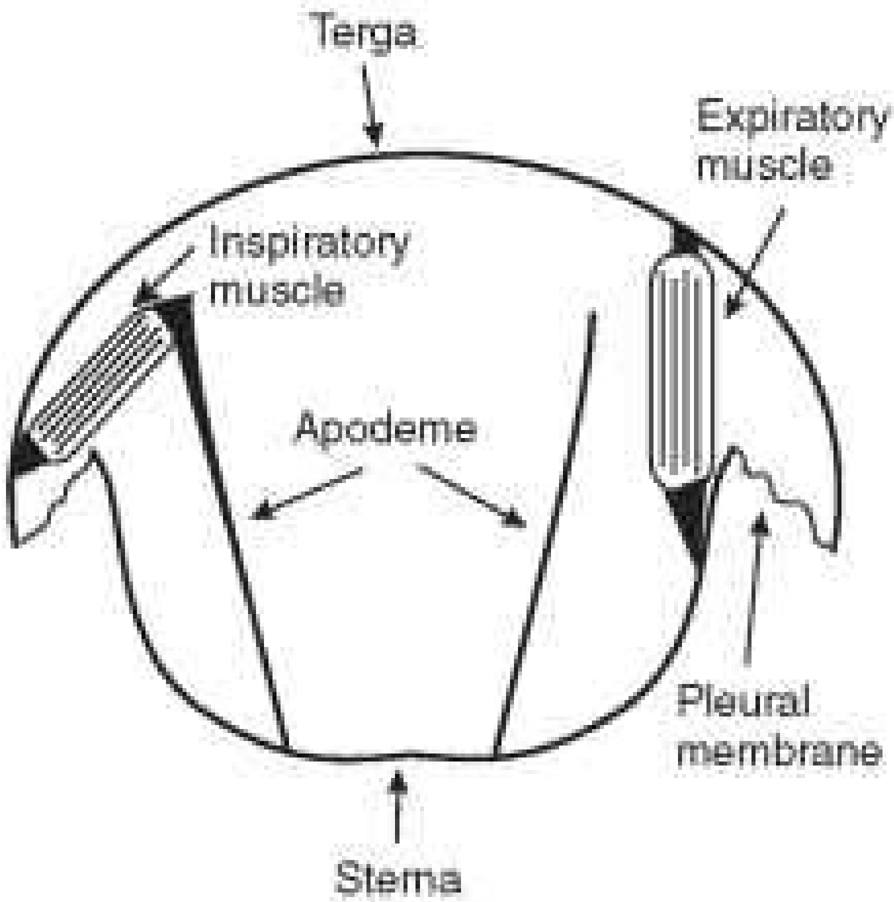
  - Indigestible starch
  - Pollen fats
  - Pollen husks
  - Used epithelial cells
  - Nitrogenous waste, in the form of uric acid
  - Salts
  - Water
- Trachea
  The trachea discharges CO_2 and water vapour from the spiracles and are technically part of the excretory system

2.9 Respiratory System



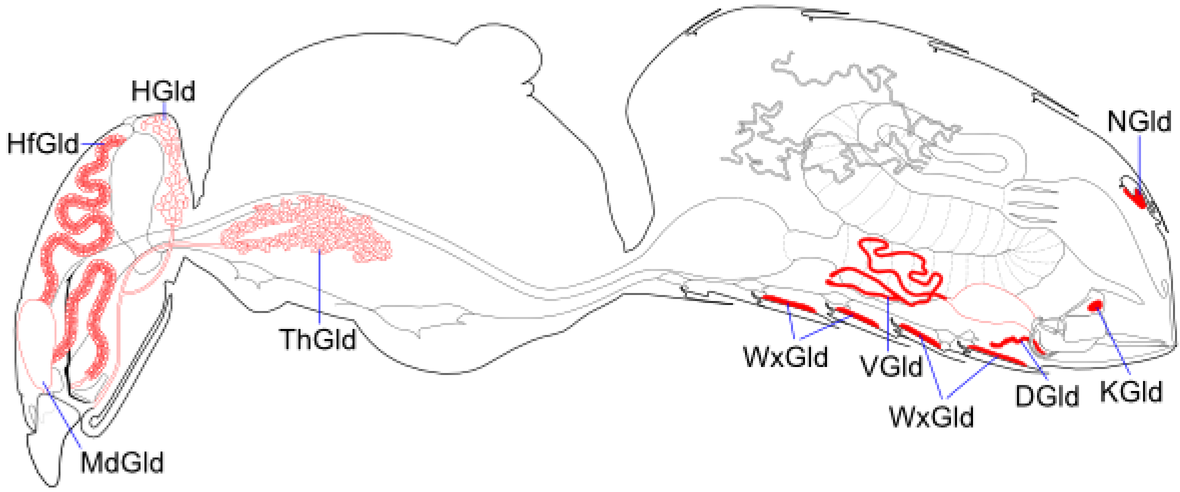
- Spiracles: 10 - Larvae only use one side since the other is submerged in food.
  - T2 (O_2 intake in flight - cannot be closed)
  - T3 (smallest)
  - A1 (largest - CO_2 emission in flight)
  - A2-6, A7 (hidden in sting chamber).
- Trachae: tube with a spiral chitinous thickening (*taenidium* - part of exoskeleton, so shed during moulting), which keeps them open.
- Tracheal sacs: thin-walled inflatable stores of air - large in abdomen, smaller in thorax and head.

- Tracheoles: liquid filled tiny branches reaching the tissues, where the oxygen diffuses into the haemolymph, and CO_2 produced by metabolism is removed via the same route.



Air intake happens by expanding the abdominal wall by contracting the inspiratory muscles, and it's forced out by contraction of the expiratory muscles.

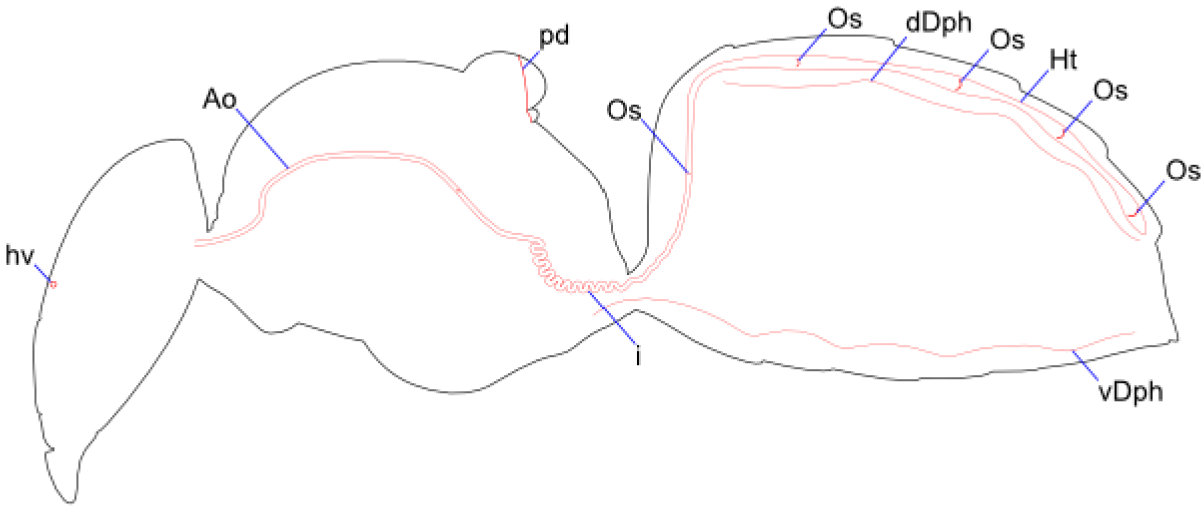
2.10 Exocrine Glands



- *MdGld* - Mandibular - immediately above the mandibles, emptying into grooves in the mandibles. In young workers the secretion contains protein + 10-HDA and in older workers, 2-heptanone alarm pheremone. In the queen, the glands are very large, and produce queen substance - 9-ODA, 9-HDA, and 13 other identified pheremones.
- *HfGld* - Hypopharangeal - pair of glands located above the pharynx, with a duct emptying into the pharynx through the hypopharangeal plate. In young workers it produces protein-rich food; in older workers, invertase + glucose oxidase.
- Salivary glands - 2 pairs, Post-cerebral (*HGld*) behind the brain, and Thoracic (*ThGld*) in the thorax. A duct from each joins up in the common salivary duct. It runs down the glossal tube to mingle with food which is sucked up. It's used to dissolve crystals in and dilute honey, particularly when water is scarce.
- *VGld* - Venom gland - melittin, phospholipase, hyaluronidase
- Worker glands
  - *WxGld* - Wax glands - located inside the exoskeleton on the sternites for A4-A7, which develop when the bee is 12-18 days old. The glands secrete a liquid which passes through the wax mirrors and oxidises as a flake of wax in the wax pockets. Requires temperatures of 33-36°C after consumption of large amounts of honey (5-8lb honey to produce 1lb wax). The composition of beeswax varies quite a lot, but it contains around 300 different consituents, the most important being:
    - Hydrocarbons 14% (dark wax contains more unbranched n-alkanes than virgin wax)
    - Esters 67%
    - Free acids 12%
    - Others 7%
  - *NGld* - Nasanov - located in a groove between the tergites for A6 & A7, when exposed the pheremone is evaporated and fanned by the bees. The production is highest in foraging bees, high in Spring and low in Winter. It contains (E)-citral (most active), genariol, genaric acid
- Queen glands
  - *KGld* - Koshevnikov - (Sting chamber) Queen only: queen court
  - *DGld* - Dufour - (Sting chamber) - Queen produces more than laying worker who produces more than worker - retinue substance

- Tergal - Queen only - between tergites on abdomen - retinue substance

2.11 Circulatory System



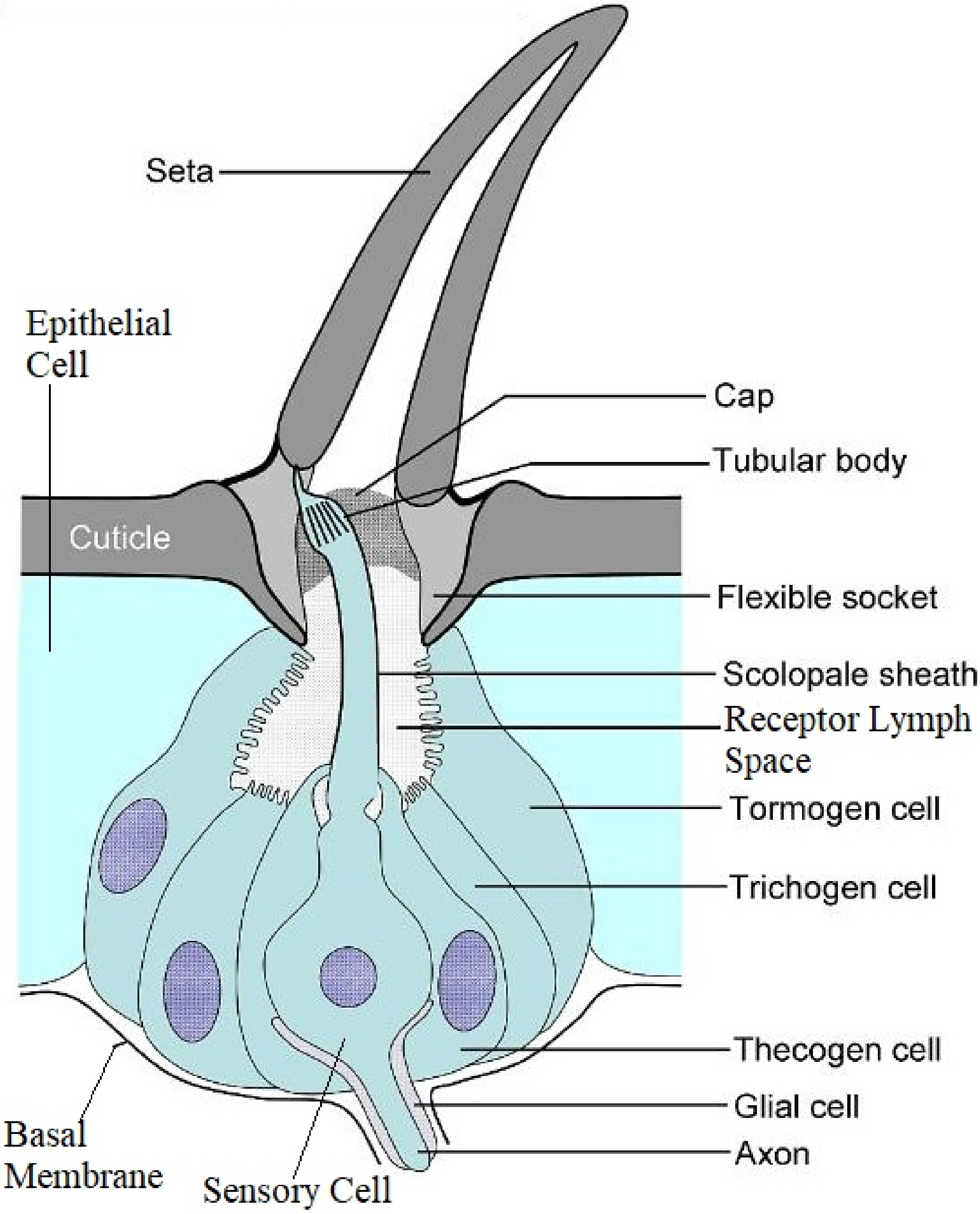
- *vDph* - Ventral diaphragm - undulates - haemolymph pushed backwards - reaches into thorax
- *dDph* - Dorsal diaphragm - undulates - haemolymph pushed forwards - completely in abdomen
- *Ht* - Heart - 5 ostia (Os) - contract: ostia close, pushes blood forwards; relax: haemplymph enters via ostia
- *Ao* - Aorta - continuation of heart through the thorax to head. Just inside the thorax it becomes convoluted (i) for a while before continuing to the head.
- *H* - Pulsatile vesicle - supplies antenna with haemolymph

Function of the blood:

- Trans[ort of food from the gut to all cells, and transport of waste away from the cells to the Malpighian tubes.
- Oxygen diffuses through the blood at the end of the tracheoles.
- CO_2 diffuses through the blood to be eliminated via the spiracles.
- Transports hormones from the glands to the target organs.
- Fills the complete body cavity, maintaining the body shape under pressure.

2.12 Sensilla

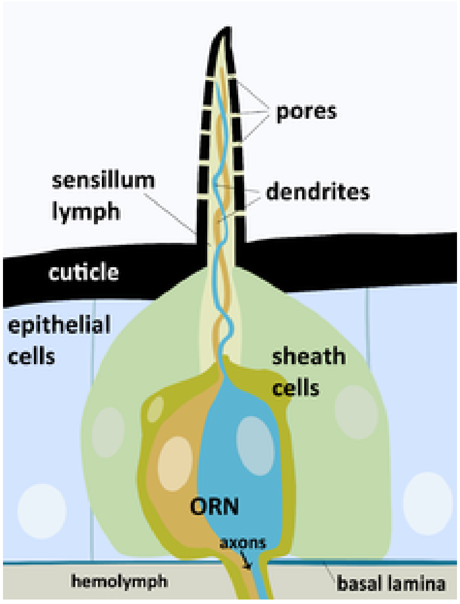
2.12.1 Trichodia



The Trichodium Sensillum is a hair that senses touch.

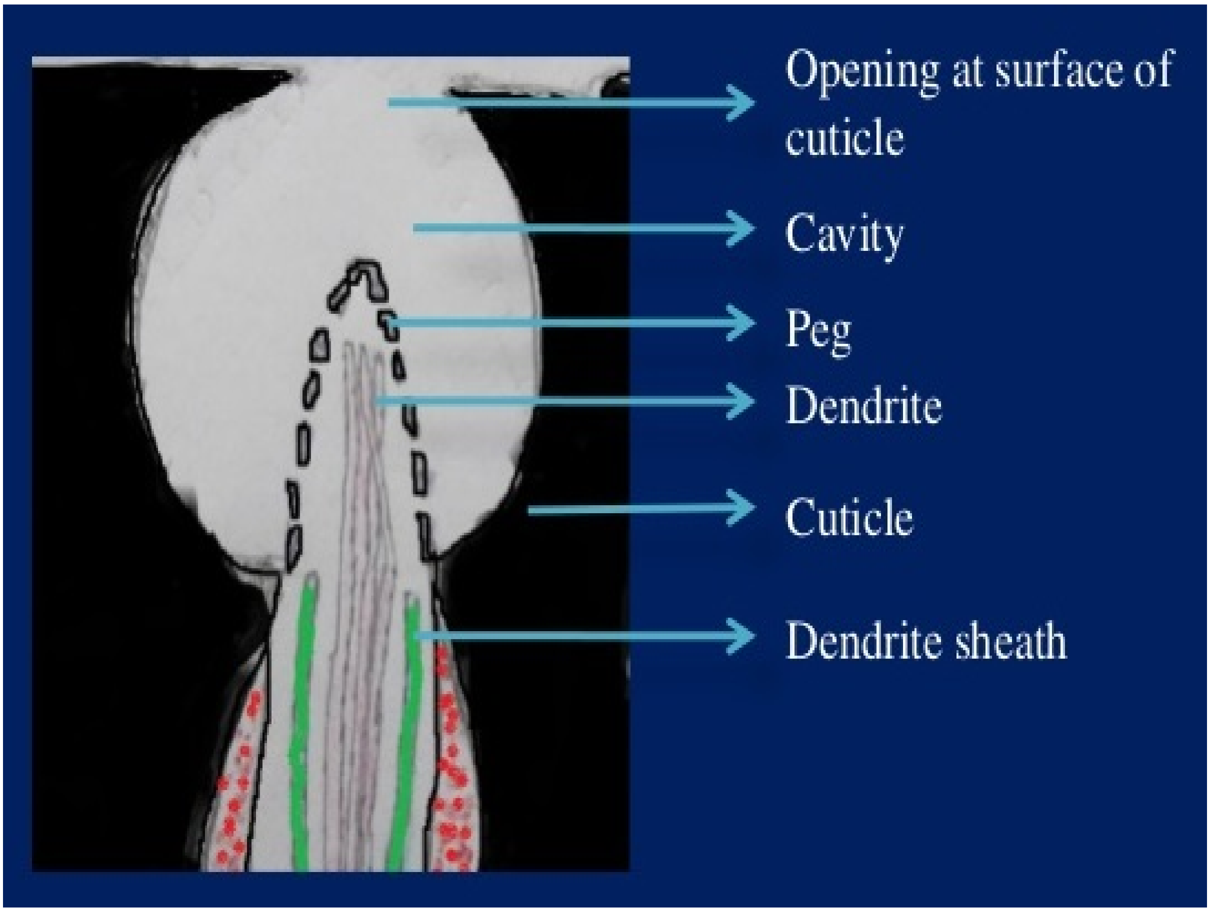
- Tormogen cell - produces membrane
- Trichogen cell - produces seta
- Seta - hair
- Nerve cell - captures event
- Membrane - flexible

2.12.2 Basiconica



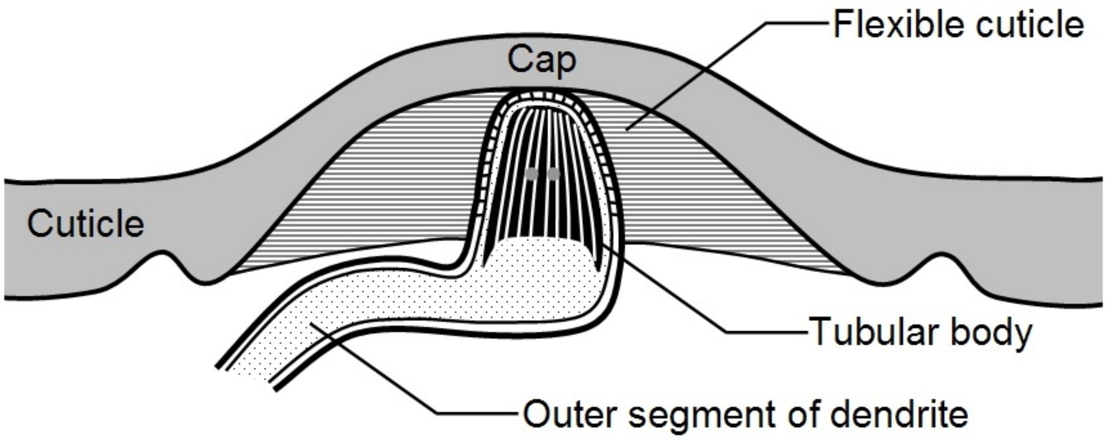
The Basiconic Sensillum are pegs with pores that are used for smell and taste.

2.12.3 Coelocinica



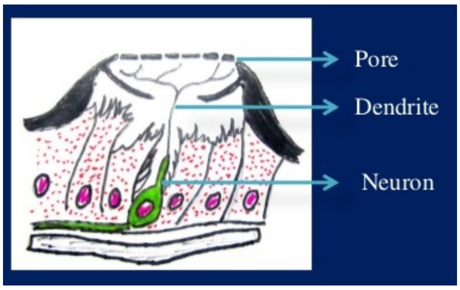
The Coeloconic Sensillum is a pit with a peg in the middle, sunk below the general surface of the cuticle, used to detect CO_2, humidity, and temperature

2.12.4 Campaniformia



The Campaniform Sensillum is a bell-shaped sensory cell in the cutical that is used to detect stress or strain on the cuticle.

2.12.5 Placodea

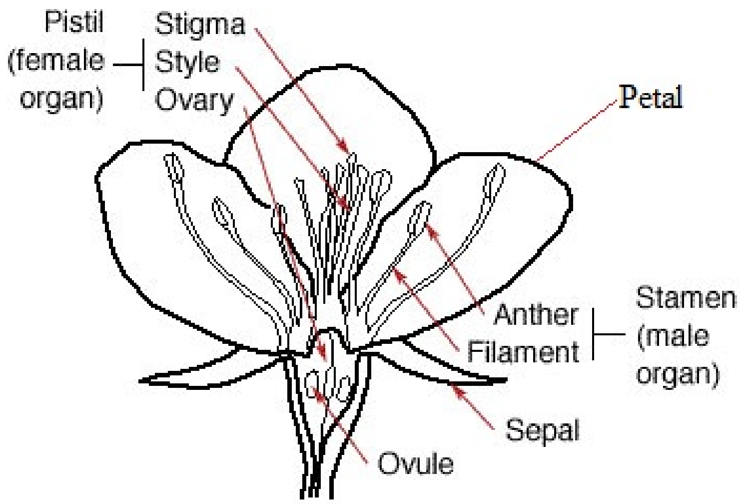


The Placodeum Sensillum is a plate/pore that can be flat or raised into a slight dome. It too is used for smell. There are many of these on the antennae.

3. Honey & Pollen

3.1 Flowers and Pollination

3.1.1 Structure of a Flower



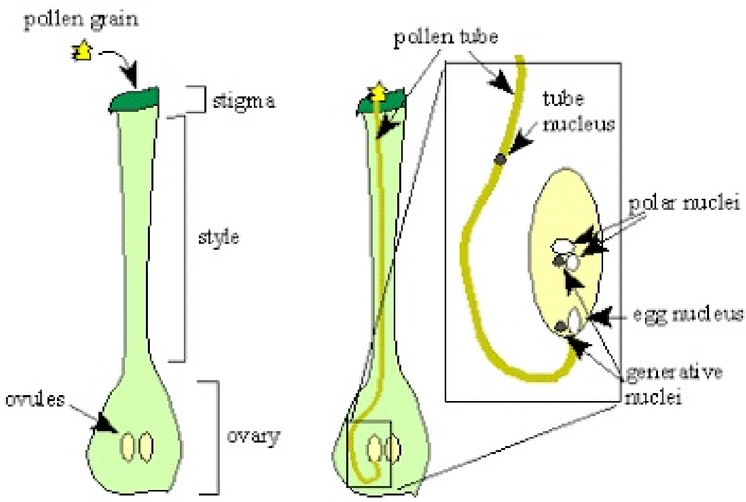
There are two parts of a flower, the male and the female. Most flowers have both, but occasionally then can be exclusively male or female, e.g. a cucumber has separate male and female flowers. The sexual parts of the flower can be remembered by the initial letters: *POOSS-SFA*. These parts of the flower are surrounded by petals and sepals.

- Pistil - female
  - Ovules

  - Ovary
  - Style
  - Stigma - this has the function of capturing the pollen grains and providing them a suitable surface to germinate. While it is in this state it is said to be "receptive".
- Stamen - male
  - Filament
  - Anther

3.1.2 Pollination and Fertilization

Pollination is the transfer of pollen from the anther of a flower to the stigma. Self-pollination is where the pollen grain is transferred to the anther of the same flower or to another flower of the same plant. Cross-pollination is where the transfer is to a flower on another plant. Cross-pollination may require that the receiving flower be on a closely related plant, e.g. some apple trees require pollination by flowers on a different type of apple tree. Some plants, such as Willow (Salix) have separate male and female plants, so that the bee has to fisit the male tree to collect pollen, and then the female tree to cause pollination to occur. Pollination can be achieved without help, e.g. using wind or gravity, or by means of pollinators such as honeybees or butterflies.



Fertilization is the union of male and female gametes that takes place after pollination. The pollen grain, once it has germinated, sends a pollen tube down the style. This has three nuclei - the *tube nucleus* which directs this growth, and two *generative nuclei* which can be compared to sperm. Once the tube reaches the ovule, one of the generative nuclei combines with the ovule nucleus to form a zygote which becomes the seed. The third nucleus combines with the nuclei of the ovary which becomes the fruit body.

Note that bees pollinate and do *not* fertilize.

Apple example

- When the flower opens it generally remains open for 5 or 6 days.
- the stigma is receptive from day 3 after opening. Pollination must occur at this time.
- After germination on the stigma it takes around 5 days for the pollen tube to grow and for fertilization to take place. In warmer climated, the tube can grow in 2-3 days.

- There is a 3 day deadline: 3 + 5 = 8 days - the flower aborts after 8 days if it has not been fertilized.
- After fertilization, the ovules become the seed and the ovary becomes the fruit.

Success factors for pollination/fertilization:

- Availability of an adequate number of pollinators (bees, etc.).
- Suitable weather conditions to allow the pollinators to fly.
- Temperature to cause the plant to produce nectar to attract the pollinators.
- Low enough humidity to allow the pollen to be viable.
- High enough temperature to allow the pollen ture to grow fully before the flower aborts.

3.2 Nectar and Honey

3.2.1 Composition of Nectar

Nectar is composed of

- Water
- Sugars can make up 5-60%, but typically 20-40%. The main sugars are:
  - Sucrose
  - Glucose
  - Fructose
- Others - salts, acids, enzymes, proteins, aromatic substances

The variation in nectar depends on the plant species with each species having a specific composition. The composition is also dependant on weather conditions (temperature, humididy, sun, wind, rain), and soil (water content, pH, type). Sunlight is important to promote the conversoin of hydrocarbons to nectar, and the temperature has to be above a minimum value for the plant's enzymes to cause nectar secretion.

Nectar types are described by their relative amounts of sugars:

- Sucrose dominant: long-tubed flowers such as clover
- Balanced: roughly equal amounts of sucrose and glucose+fructose
- Hexose dominant: More glucose + fructose than sucrose, e.g. rape which has more glucose. The Glucose/Fructose ratio has an impact on the honey:
  - High, i.e. more glucose: granulates quickly with a fine grain
  - Low, i.e. more fructose: granulates slowly with a coarse grain

Foraging for nectar indicates that the colony density to minimise disease is around 1 colony in 7 km^2. The foraging area of a colony is given by πr^2 - with a 4km radius, this gives around 50km^2, i.e. the maximum for an apiary is around 7 colonies.

3.2.2 Crystallisation of Honey

Honey crystallises because it is a supersaturated sugar solution, i.e. there are more sugars dissolved than would normally dissolve in that amount of water. Such a solution is more or less unstable and, in time, will revert to a stable saturated solution. Honey high in glucose tends to granulate more quickly, e.g. rape and other brassicas. Usually some flavour is lost in granulation because of evaporation of volatile oils.

For granulation to occur, a seed must be available onto which the crystal can build. THe seed can be dust, pollen, a bubble or other crystals. Adding a finely crystallised honey to liquid honey can promote the production of similarly small crystals, which is the technique used when making creamed (soft set) honey. A seed is more likely to occur in a large volume like a bucket than in a jar.

THe size of the crystals in naturally crystallised honey is determined by how fast the process occurs. High viscosity honeys (dark) crystallise slowly, producing large crystals. Conversely, low viscosity honeys (light) crystallise quickly producing fine crystals.

The ration of glucose/fructose is widely used to suggest which honey will granulate readily. However the glucose/water ratio is more closely related to granulation:

- $\leq$ 1.7 - no granulation occurs
- $\geq$ 2.1 - rapid granulation

The optimum temperature for granulation is 13-15°C:

- <13°C - viscosity increases, slowing molecular movement
- >15°C - molecular activity increases, causing crystals to melt

3.2.3 Honey Quality

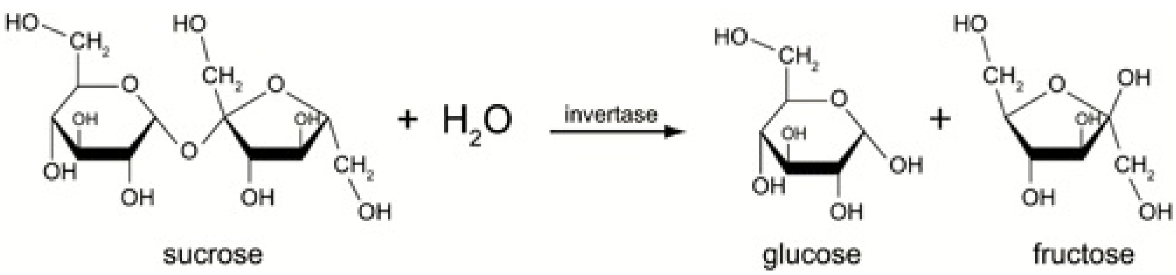
There are two indicators used to determine the age of a honey sample, and if it has been subject to heating.

- *Diastase* is an enzyme present in honey, which breaks down starch. Over time it breaks down and the amount in the honey is reduced. A measure of the amount present is called the diastase number and can be used to age the honey. It also breaks down when the honey is heated, and a low diastase number can indicate that the honey was heated.
- *Hydroxymethylfurfural*, abbreviated to *HMF* is an organic compound produced when sugar breaks down, either due to age, or because of heat treatment, and a high value can be used to indicate old or heated honey.

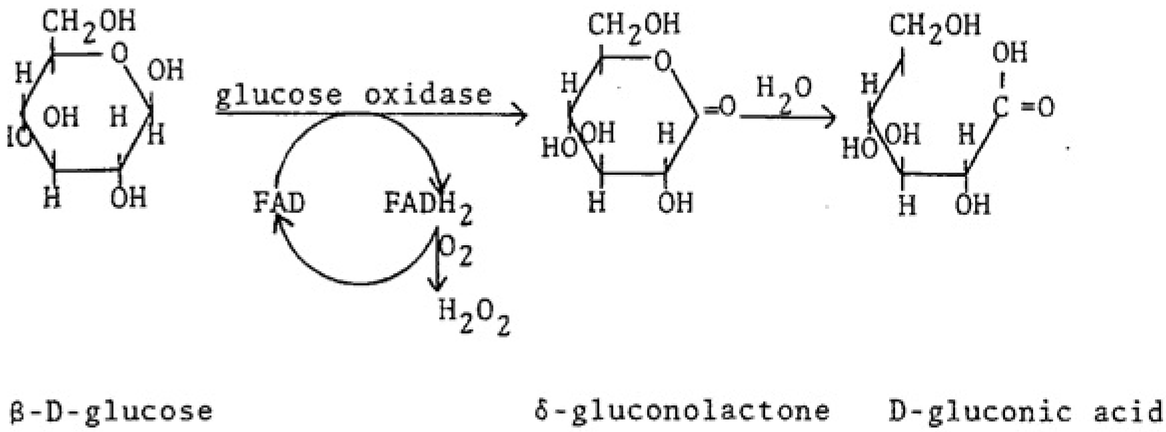
3.2.4 Conversion of Nectar to Honey

The conversion of nectar to honey requires two processes, the chemical changes and physical changes.

Chemical Changes to Nectar



The chemical change to nectar is the breaking down of the disaccharide glucose to its monosaccharide constituents, glucose and fructose. When nectar is brought back to the hive, the forager already starts to break it down in the crop, hydrolysing the sucrose to produce glucose and fructose:



The glucose may be further converted to gluconic acid. This happens in three steps:

- The dextro-rotatary isomer of glucose is converted to the laevo-rotatory version
- A co-enxyme FAD works with glucose oxidase to produce the ketone gluconolactone. What happens is that the glucose is oxidised with the parallel reduction of FAD (reduction is the inverse of oxidation), producing the reduced FAD-H_2.
- This ketone is then oxidised with the H_2 combining with oxygen to produce H_2O_2 (hydrogen peroxide). and hydrolysis break the ring, producing the organic acid gluconic acid.

Physical Changes to Nectar

The physical change is the evaporation of excess water in unripe honey to bring the sugar concentration up to 80%.

- A large amount of space is required as the honey is hung in empty or partially-filled cells, to increase the ssurface area for evaporation.
- Currents of air are distributed around the hive by the bees fanning, bringing in dry air and expelling wet air.
- As the water content reduces and the sugar concentration approaches 80%, the honey is moved and the partially-filled cells are completely filled and capped. Since Amm store the honey with a small air pocket under the cap, the wax appears white.

3.3 Pollen

3.3.1 Collection of Pollen

The colony needs a fertile queen and pheremone from open brood to stimulate foragers to collect pollen. Returning foragers recruit more forages by dancing to indicate the location of the pollen. The number foraging for pollen will vary depending on the needs of the colony.

- Average pollen load per bee: 12-30mg
- Average number of trips by one bee per day: 6-8
- Total collected by colony in 1 year: 50kg
- Anount needed to raise one adult bee: 70-150mg

When the bee lands on a flower, she bites the anther of the stamen with her mandibles to dislodge the polen grains. The pollen grains attach themselves to the plumose (feathery) hairs that cover the bee's exoskeleton. She then leaves the flower and hovers nearby to clean the pollen from her body and load it into her pollen baskets (corbicula):

- Front legs: Clean pollen from head and first thoracic segment (prothorax) using stiff hairs moistened by honey or nectar.
- Middle legs: Collect the pollen from the rest of the thorax and the front legs, passing it to the inner side of the basitarsi on the rear legs.
- Read legs: Clean pollen from tha abdomen, also gathering it on the inner side of the basitarsi. When sufficient pollen is collected on the basitarsus, this surface is "raked" by the pollen rake (rastellum) at the bottom of the tibia of the opposite leg. The pollen is forced (as a paste) onto the flat surcace of the auricle which is beveled upwards and outwards. THe tarsus is closed against the tibia, and the pollen is squeezed out onto the outside of the corbiculum (note the single hair acting as a pin through the load).

One full load of two pollen pellets represents approximately 100 flowers visited when there's a plentiful supply, e.g. dandelions when they're yielding well.

3.3.2 Storage of Pollen

When the pollen-laden forager returns to the hive, she selects a cell close to unsealed brood. She grips the cell with her front legs, puts her posterior on the opposite wall of the cell with her hind legs dangling into the cell. She uses her middle legs to push the pollen loads off her legs and into the cell. She then departs for another load.

A house bee then comes along and breaks up the pollen pellets with her mandibles, pushing it firmly into the cell. Honey or nectar is added to the pollen - it becomes darker, has a higher sugar content, and is known as *bee bread*.

All pollen storage is adjacent to the brood nest where it is required for use. Packed pollen can be fed to the brood or to house bees (to produce brood food), or the cell can be filled up with more loads, topped with honey and sealed with wax for winter stores.

After pollen is collected by the bee, it is no longer viable for plant reproduction.

3.3.3 Pollen and Nutrition

Pollen is the principal source of protein, fat and minerals in the honeybee diet. Around 50kg is required by a colony each year. The demand for pollen is related to the amount of unsealed brood. Bees cannot raise brood without pollen: nurse bees require pollen to produce brood food from the hypopharangeal glands, with 70-150mg required to raise an adult bee. Bees also use pollen to increase their fat bodies in preparation for winter.

Pollen is stored for use early in the year before a fresh supply becomes available.

Pollen is rich in protein, essential to growth and development and healing/repair. It stimulates the hypopharangeal gland and the fat bodies of the winter bees. Protein amounts vary by flower type - high protein pollen such as beans have ca. 35%. The important constituents of pollen are:

- Protein 5-35
- Lipids (fats) 6-15
- Amino acids 10-20

- Minerals 1-5

In particular the levels of each of the 10 essential amino acids (arginine, histidine, lysine, tryptophan, phenylalanine, methionine, threonine, leucine, isoleucine, and valine) vary from pollen to pollen. The bees discriminate pollen types by smell and colour, not by quality, so they can easily collect pollen with poor amino acid contents, resulting in less healthy bees. Willow and gorse provide good quality pollen.

3.4 Propolis

3.4.1 Collection of Propolis

Propolis is a gum produced from resin collected from trees and other plants. In warm weather, when the resin is softer, it is collected by the bees (with difficulty):

- A small piece of resin is bitten off using the mandibles
- This is kneaded and shaped
- The softened resin is transferred from the second legs directly to the corbicula
- The second leg pats it in place

When the forager returns to the hive, it needs the help of a house bee to unload, typically near where it is to be used:

- The resin is unlloaded by another worker bee.
- It bites and pulls the propolis off the forager an puts it in place.
- The cementing bee usually mixes some wax with the propolis.
- The forager pats the remaining load smooth again.
- The unloading process can take more than an hour, depending on its use in the hive.

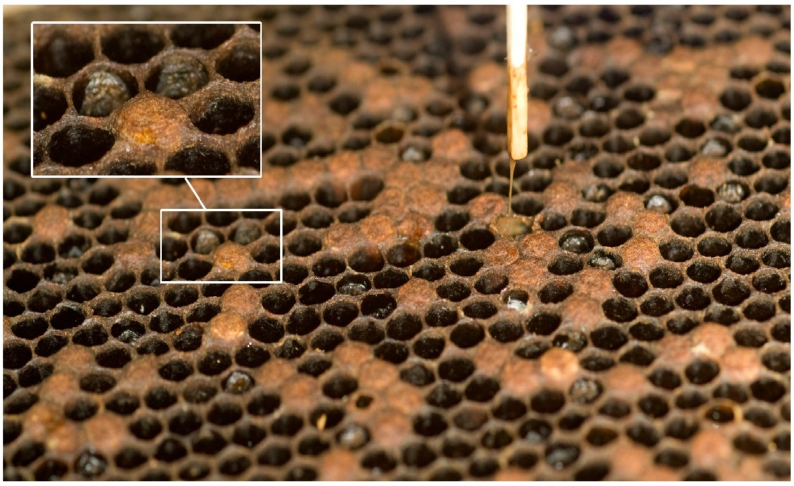
Generally only about 0.5% of foragers collect propolis.

3.4.2 Uses of Propolis

Propolis is generally used as a filler, a glue or a disinfectant:

- To fill cracks in the hive
- To reduce openings, e.g. building a curtain to reduce an entrance.
- To smooth the interior of the hive
- To varnish/polish the interior of brood cells
- To strengthen comb attachments
- To cover dead intruders that are too large to carry out, e.g. a mouse

Propolis is famously used by humans as a varnish, e.g. Stradivarius violins were coated with a propolis varnish.



4. Diseases & pests

4.1 Varroa

4.1.1 Varroa lifecycle

Varroa have two stages in their lifecycle, the phoretic stage and the reproductive stage.

Phoretic stage

During the phoretic phase, female Varroa feed on adult bees and are passed from bee to bee as bees walk past one another in the colony. They live on adult bees and usually can be found between the abdominal segments of the bees. Varroa puncture the soft tissue between the segments and feed on bee hemolymph through the punctures. Recent research indicated that they also feed on the fat bodies.

Varroa are well-adapted bee parasites:

- Their flattened shape allows them to fit between the abdominal segments.
- They have claws that allow them to grasp the bee and ventral setae that allow them to remain attached to the bee.
- The cuticle has a chemical pattern similar to that of the bee's, allowing it to escape notice.
- The cuticle is highly sclerotized, protecting it from bee aggression.

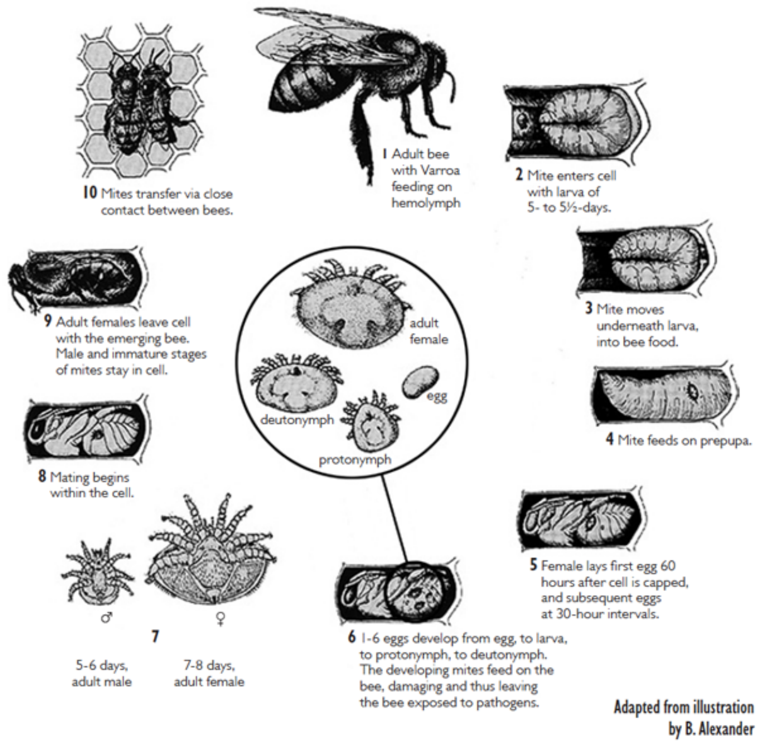
The phoretic stage of varroa is when the infestation spreads:

- The mites can move from bee to bee within the colony
- Then can be passed between colonies when infested bees drift into another colony, particularly between hives that are close together,
- Beekeepers who add bees or brood from another colony spread the mite.
- Beekeepers transport colonies from one area to another, facilitating the spread of Varroa regionally.
- Individual colonies swarm and move to a new location, spreading Varroa simultaneously.

- Mites may spread between colonies as bees from the colonies rob one another

The phoretic period may last 4.5 to 11 days when brood is present in the hive or as long as five to six months during the winter when no brood is present in the hive. Consequently, female mites living when brood is present in the colony have an average life expectancy of 27 days, yet in the absence of brood, they may live for many months.

Reproductive stage



- The adult female mite enters the cell containing a 5-day-old larva before it is capped.
- She initially feeds on the larval brood food, breathing through a snorkel-like peretrime.
- After the cell is capped the mite pierces the lower abdomen of the larva. It then feeds on the larva's haemolymph.
- The varroa mite lays the first egg 60 hours after the cell is capped. This egg is unfertilised and, as for bees, hatches out as a male). She lays subsequent eggs, all female, at 30 hour intervals after that.
- The eggs mature in around 6 days. The sequence of development is:
  - egg
  - larva
  - protonymph
  - deutonymph
  - mature adult
- When the adult bee emerges, the male mite along with any immature females all die.

The action of the mother mite in puncturing the larva leads to stunted, deformed and compromised bees.

- More important is that the varroa is both a vector and transmitter of viruses.
- The physical damage done by the varroa provides an entrance site for the viruses.
- Also the biting and enzymes activate the viruses to greater action or virulence.

- Viruses that enter by the alimentary canal or food route are not as virulent as those that enter via the varroa damage site.
- About 22 viruses have so far been discovered and characterised in the honeybee world.
- gives rise to Parasitic Mite Syndrome (PMS).
- The effect is a much reduced population of bees and also that other diseases become much more signigicant

4.1.2 Counting mites

- OMF - not very reliable since there are so many variables outside our control
  - Place a tray under the OMF for 3-5 days and count the mites that fall naturally, i.e. without treating.
  - The count depends on the time of year, and treatment is necessary if counts are greater than:
    - Jan-Mar: 2 mites/day
    - Apr-May: 7 mites/day
    - Jun-Aug: 8 mites/day
    - Sep-Dec: 8 mites/day
- Sugar roll - quite accurate and the bees are not harmed
  - Knock bees from a brood frame into a bowl/bucket, taking care not to include the queen
  - Scoop up 100ml (300 bees) into the sugar shaker and replace the lid
  - Sieve 2 tablespoons of powdered (icing) sugar through the lid
  - Roll the bees thoroughly in the sugar and leave for 10 minutes
  - Shake the sugar out over water in a white bowl/bucket: the sugar will dissolve and the mites will float
  - Count the mites = n
  - If there is no brood, the count is n/3%; if brood is present the count is 2n/3
  - If the infestation > 2%, treat

4.1.3 Queen trapping

This is particularly useful when it isn't possible to use other treatments, e.g. when there are supers on the hive. The idea is to trap the mites in sealed brood and remove it to prevent the new mites from emerging, causing a rapid reduction in the number of breeding varroa females.

This technique involves caging the queen for 9 days on three combs in succession, keeping these in the colony for a further 9 days while the Varroa enter the brood cells. The combs containing trapped mites in sealed brood are then removed and destroyed:

- Cage the queen on a frame for 9 days
- On day 9 repeat
- On day 18 repeat, removing the first frame which is now sealed.
- On day 27 release the queen, removing the second (day 9) sealed frame
- On day 36 remove the third (day 18) sealed frame.

This method is very time consuming and requires good timing: you can weaken the colony if not done correctly.

4.2 Foulbrood

Comparison of AFB and EFB

	AFB - American Foul Brood	EFB - European Foul Brood
1	Paenibacillus larvae	Melissococcus plutonius
2	Spore forming bacteria	Non spore forming bacteria
3	From food, affects all body tissues	From food, consumes food in ventriculus so larva dies of starvation
4	Colony must be destroyed: Kill bees, burn bees, wax & frames, & scorch boxes.	Can be treated with shook swarm if light infection, otherwise as AFB
Both of these are notifiable diseases		
The signs and symptoms of both AFB and EFB:		
1	Sealed brood affected - kills pre-pupa/pupa from septicaemia	Unsealed brood affected - kills larva, and often hygienic behaviour masks the condition
2	Domed cells become moist and darker in colour.	Larvae in contorted unnatural positions in cell - twisted not c-shaped.
3	Sunken cappings	Irregular brood pattern
4	Bees chew holes in the affected cappings - pepper pot appearance.	Larvae coloured dull cream, yellow, green or brown.
5	Poor brood pattern.	Uneasy wriggling of larvae in cells.
6	May be an offensive smell due to secondary infection.	Larva loses its segmentation.
7	Match stick test through sunken capping.	Distorted, discoloured larvae in cells (hard to detect if bees have removed them)
8	Ropey mucous 1 - 2 cm long	Contents of the cell porridge-like
9	Dried out remains form a hard black scale at base of the cell.	Dead larvae have meltdown appearance and dry to rubbery scale, loose.
10	Shine light into base of cell to see scale	Best time to check April/May when brood outnumbers adult bees.
11	Diagnostic on site test kit Vita-R	If find dead larvae around hive - investigate further.

4.3 Nosema

There are two types of nosema infections cause by *nosema apis* and *nosema ceranae*

Similarities:

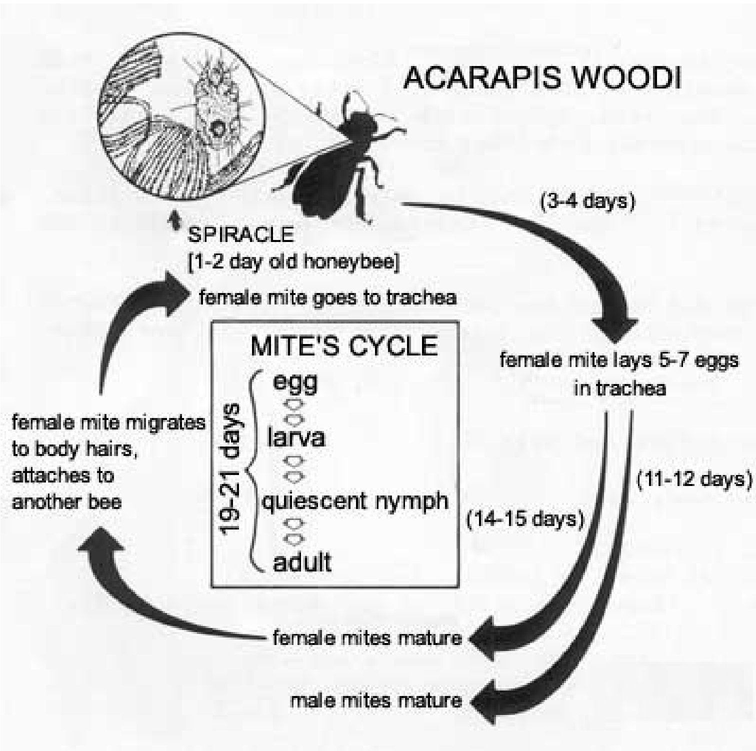
- Parasitic microspore fungus
- Invade the epithelial cells lining the mid-gut of the bee, multiply rapidly and fill cells with spores

- When the host cell ruptures, the spores are excreted by the bees, and can from there infect others
- Hive fails to thrive
  - Progressive reduction of number of bees
  - Decline in productivity
- Secondary infections - chalk brood, AFB
- Transmission
  - Contaminated comb
  - Crushed bees
- Diagnosis:
  - Spores appear as white/green rice-shaped under microscope
  - Precise diagnosis using DNA techniques (Polymerase Chain Reaction)
  - Scanning electron microscopy can differentiate folds on the spore
- Treatment
  - Healthy colonies can handle infection, so ensure good health
  - Clean frames - shook swarm/Bailey frame change
  - Requeen with resistant strain
  - Fumidil B, but no longer approved in the EU

Comparison of Nosema variants

Nosema apis	**Nosema ceranae**
Dysentry	No dysentry
Dead bees in front of hive	Bees die away from hive
Restricted to midgut	Also indications that it infects hypopharengeal glands, impacting brood food

4.4 Acarine



Tracheal mites, *Acarapis woodi*, are parasitic mites which invade and infest the respiratory system of adult bees. Infestations shorten the life of adult bees and symptoms vary, depending on the number of mites infecting a bee. Symptoms are noticed in early spring, when the colony slowly begins to dwindle. Adult bees infested with tracheal mites will cluster on the ground in front of the hive, appearing disorientated and unable to return to the colony. Large numbers of bees may also be seen crawling up stems of grass in front of the hive, although these symptoms are also associated with other paralysis viruses.

It can only be diagnosed by microscopy: healthy tracheal walls are normally whitish and translucent but become opaque and discoloured with blotchy black areas due to melanin crusts.

Control:

- Colonies with low infestations produce more brood, so breeding from these helps.
- Colonies should be headed by young and prolific queens because they lay more eggs, so that the proportion of infected bees is smaller.
- Breed from colonies that groom, since the mites can be dislodged when on the bees.
- Lay out the apiary to reduce drifting.
- Biotechnical methods to cause broodless periods cause drops in the mit populations.
- Apiguard and MAQS also work on acarine mites.

4.5 Chalkbrood

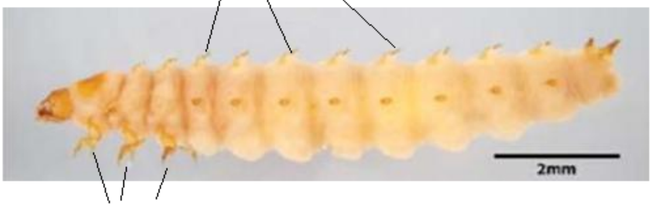
Chalkbrood is a fungal disease of the honeybee larvae caused by *Ascosphaera apis*. It rarely destroys a colony, but can prevent normal population build-up when the disease is serious.

Diseased brood can be found throughout the brood rearing season, but is most common in late spring when the brood nest is expanding, particularly in weak colonies and in nuclei. Chalkbrood mummies, once dry, are loose in the cells and are easily removed by the nurse bees. Occasionally these are visible on the ground at the entrance of the hive.

Larvae affected by chalkbrood may release millions of spores that all have a sticky coating, enabling them to adhere to combs and adult bees. Spores are the dormant phase and can survive for many years. Both the transfer of combs by the beekeeper and drifting bees can transmit chalkbrood spores between colonies.

There is no specific treatment, but apiguard helps. Requeening sometimes helps, and reducing any sources of stress to the colony helps too. Since the spores otherwise can live a long time, treating frames with acetic acid will kill the spores.

4.6 Small Hive Beetle

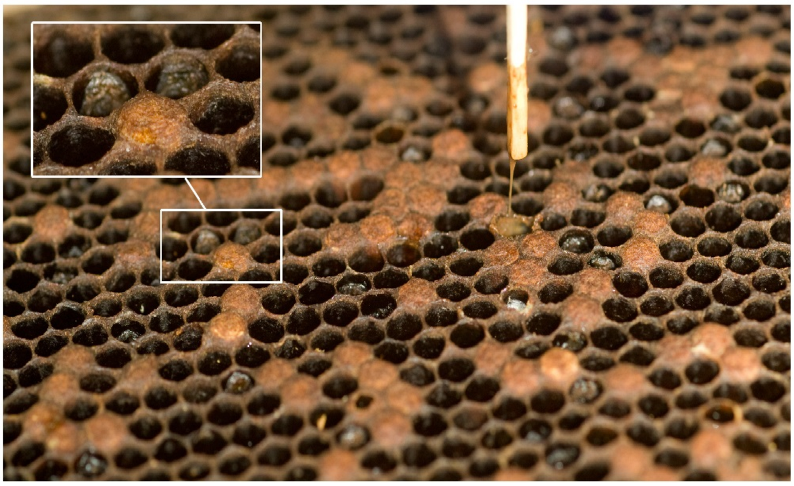


The Small hive beetle, *Aethina tumida*, originated in Africa and is present in North America and Australia, and has more recently been found in Italy. The beetle's characteristics are:

- Adult beetles
  - size: 5-7 mm
  - colour: black
  - behaviour: hides from the light
  - clubbed antennae
  - short wing cases
- Larvae
  - Larval stage lasts 10-16 days
  - size: 10-11 mm
  - colour: beige
  - spines on dorsum
  - 3 pairs legs at the head end, with an absence of silk webbing and droppings on combs
  - The larva eats brood, pollen and honey, and builds tunnels through the comb.
- Eggs
  - size: 1.5 x 0.25 mm (two thirds size of honeybee eggs)
  - colour: white
  - location: masses of eggs e.g. in hive crevices or hive floor

The fertilized female lays eggs in clusters in wood crevices or directly into brood cells, and can 1000-2000 eggs in the hive during their lifetime. Mature larvae pupate after 15-60 days. Pupation occurs in soil outside the hive, usually at a depth of 1 cm to 30 cm and within 20m of the hive. In rare instances larvae will crawl 200m to find suitable soil. Soft and moist soils and a temperature above 10°C are necessary for completion of the life cycle, although SHB may be able to survive at lower soil temperatures if of short duration (< 3 weeks). Adult beetles usually emerge after 3-4 weeks but can emerge anytime between 8 and 84 days depending on temperature. Adults can fly at least 10 km to infest new colonies. Adult beetles can survive for up to 9 days without food or water, 50 days on used comb and several months on fruit.

Spread occurs naturally as SHB is a good flyer, but it's enhanced by movement of package bees, honey bee colonies, honey bee swarms, honeycomb, beeswax or beekeeping equipment. Movement of soil, fruits, and alternative hosts (e.g. bumble bees) may also be routes for introduction.



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