Honey Bee Anatomy and Physiology

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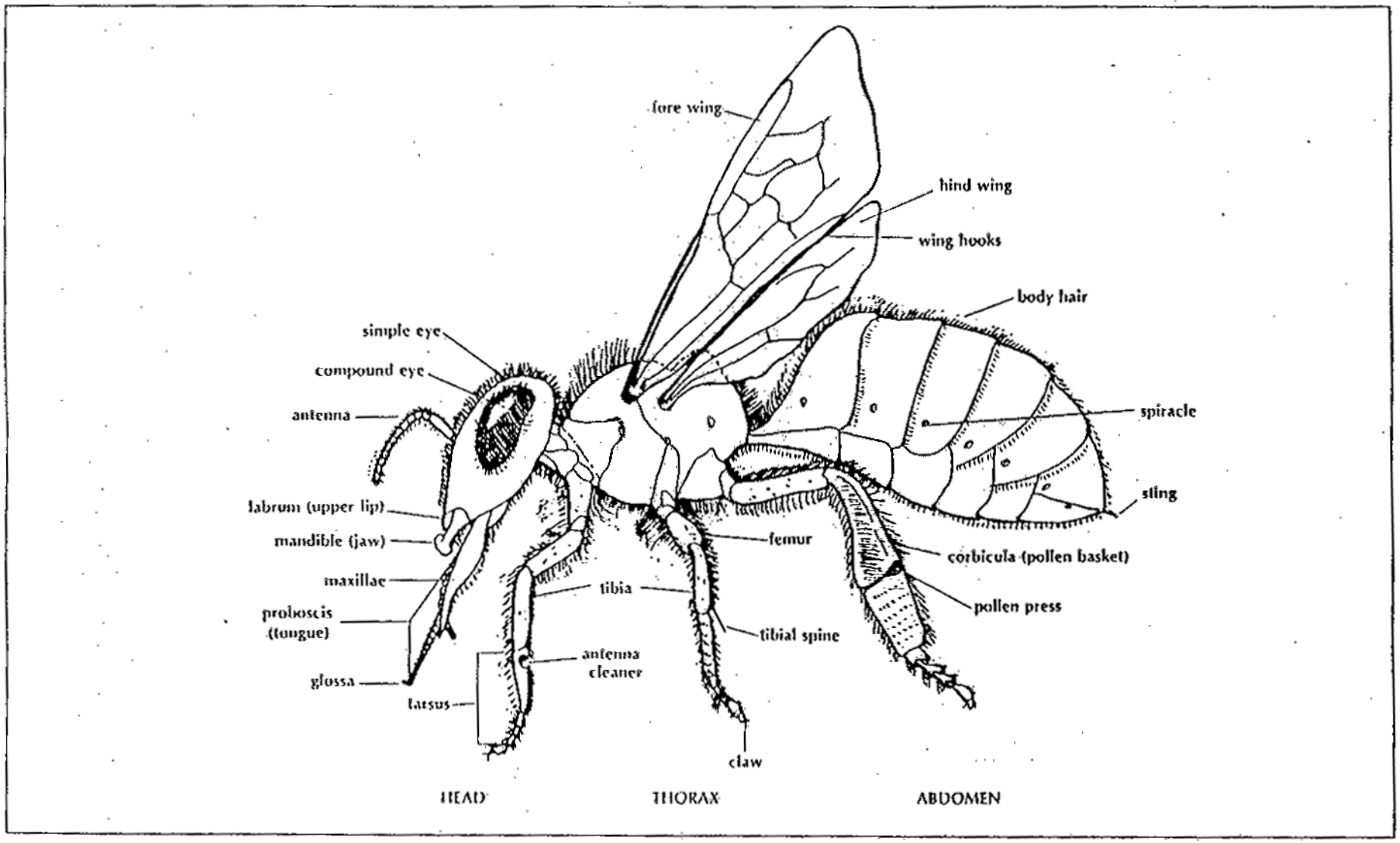
Lancaster Journeyman Class

2017

Worker Honey Bee

The Honey Bee



Morphology of a Worker Bee

Illustration by Diana Sammataro

High Level View

- Lack arteries and veins and their liquid plasm and blood cells circulate openly within the body cavity (**open circulatory system**). Blood carries food, hormones and cells to fight diseases but does not contain red blood cells holding oxygen.
- A separate transport system, the **tracheal system**, carries oxygen-rich air from the exterior to the body cells and gaseous carbon dioxide waste back outside. **Spiracles** are the openings on the exoskeleton. The body cavity tubes (the **trachea**) branch repeatedly to smaller tubes (**tracheoles**) throughout the interior.
- Lack kidneys and a liver; thin filamentous projects from the junction of mid and hind gut, termed **malpighian tubules**, cleanse the blood of nitrogenous cell wastes and deposit them as non-toxic uric acid crystals into the undigestible food wastes for elimination from the anus. There is no liquid waste in bees as their small body size makes water conservation a necessity.
- Internally a series of nerve cells extend from the brain to concentrations of nerve tissue in each body segment (**ganglia**) constituting a central nervous system. Nerves extend from brain and ganglia to send signals to body parts and structures to coordinate behaviors.

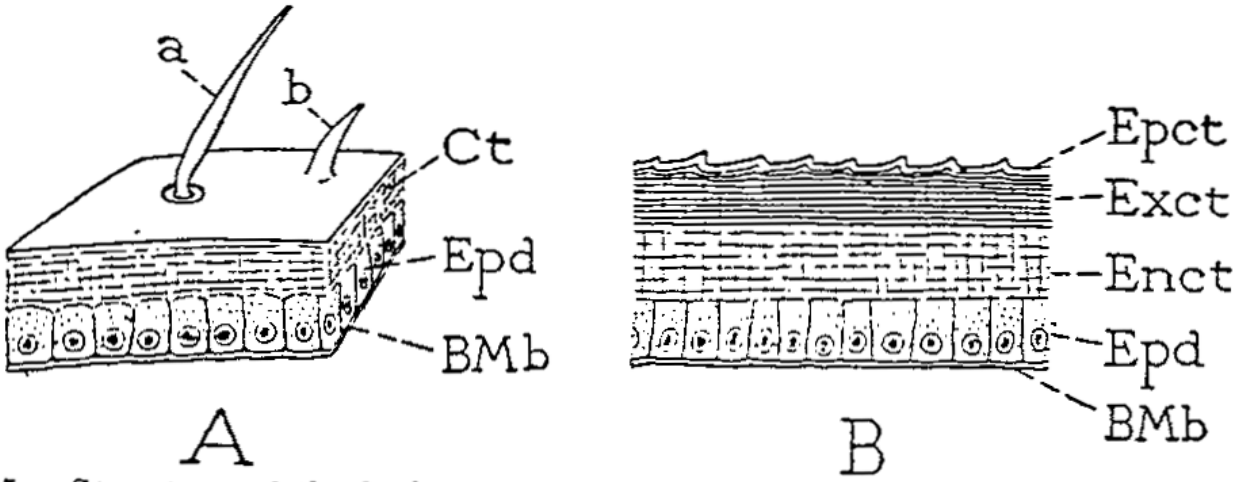


FIG. 25.—Structure of the body wall, diagrammatic. A, piece of body wall bearing a movable external process, or seta (*a*), and an immovable process (*b*). B, vertical section of body wall. *BMb*, basement membrane; *Ct*, cuticula; *Enct*, endocuticula; *Epct*, epicuticula; *Epd*, epidermis; *Exct*, exocuticula.

Honey Bee Wax Glands

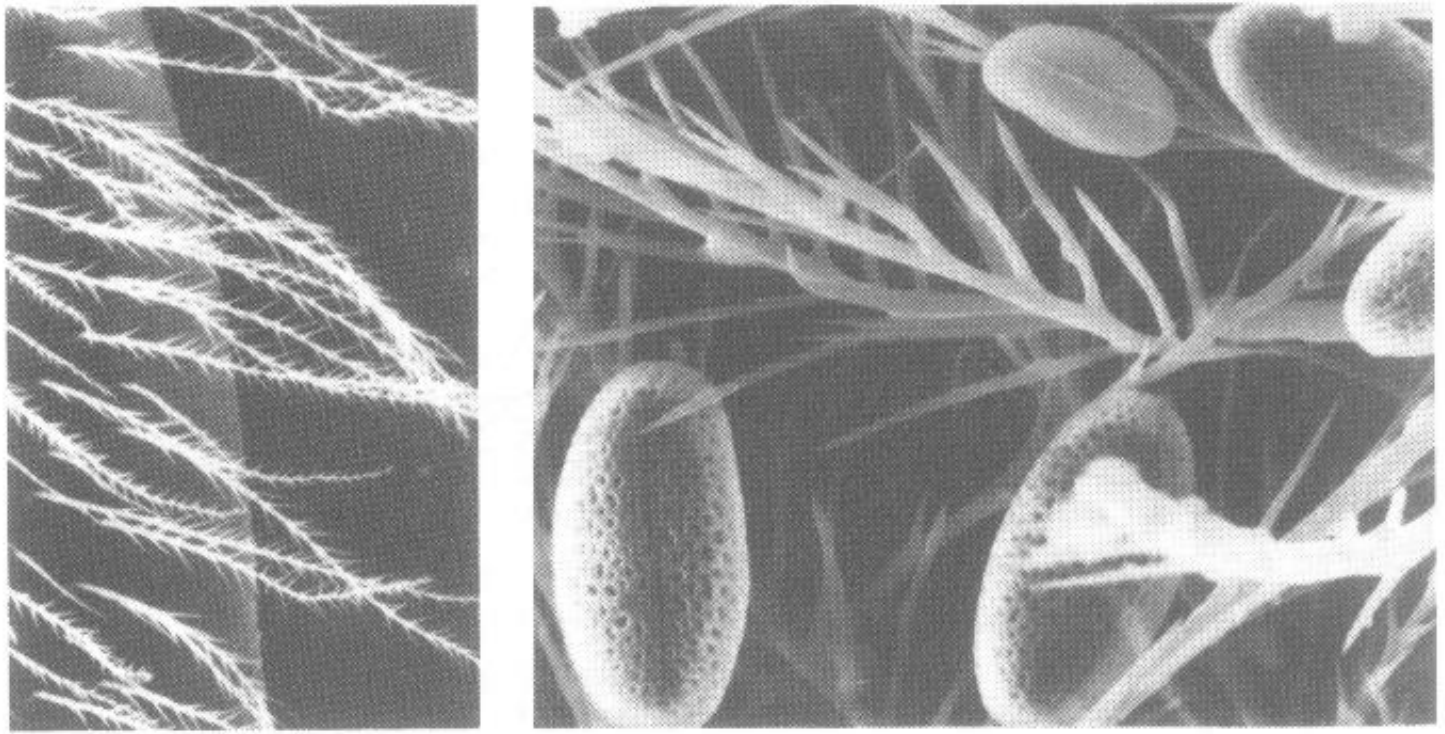
Wax

- Honey bees use wax to build comb that forms their nest and the intricate hexagonal cells that make up that comb. These wax cells are used to house the various stages of bee young (or brood) as they develop from egg to adulthood. In addition wax cells are used to store pollen and nectar.
- Wax is produced as needed by worker bees to form and repair comb and individual cells. The wax is secreted by these worker bees, from eight special wax glands situated on the underside of their abdomens (inside the protective plates or sternites of **abdominal segments 4 to 7). Worker bees produce wax most efficiently during the 10th through to the 16th days of their lives and this declines steadily from day 18 until the end of life.**
- When wax is required these workers fill themselves up with honey and then hang together in clusters to contain the heat generated by the metabolism of the honey in their muscles. This resultant rise in temperature allows the wax to be secreted from the bee's wax glands and this secreted wax then pours into special holders beneath these glands and solidifies.

Worker Bees Festooning

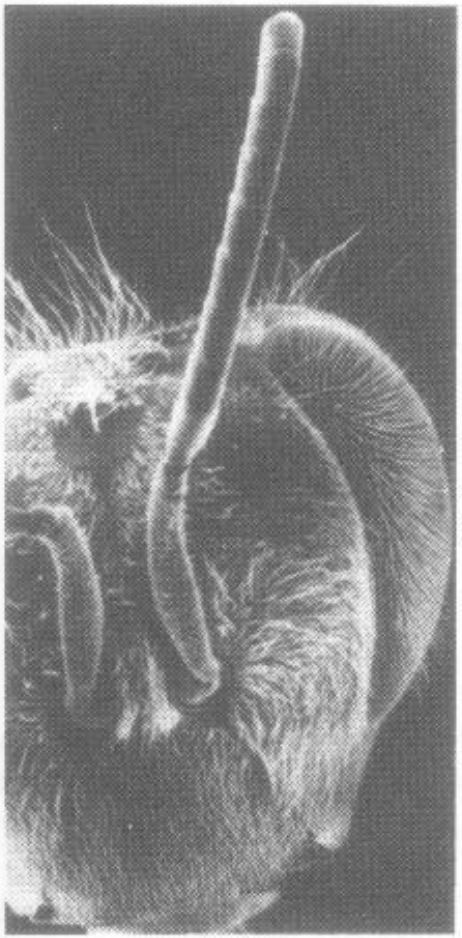
Fat

- Food storage occurs with the fat body.
- It is a layer of conspicuous creamy cells concentrated on the floor and roof of the abdomen.
- There are 2 kinds fat body cells; 1) “fat cells” contain mostly fat and some albumen (protein), and some glycogen, 2) oenocytes, thought to have functions associated with wax production, and the transport of molecules.

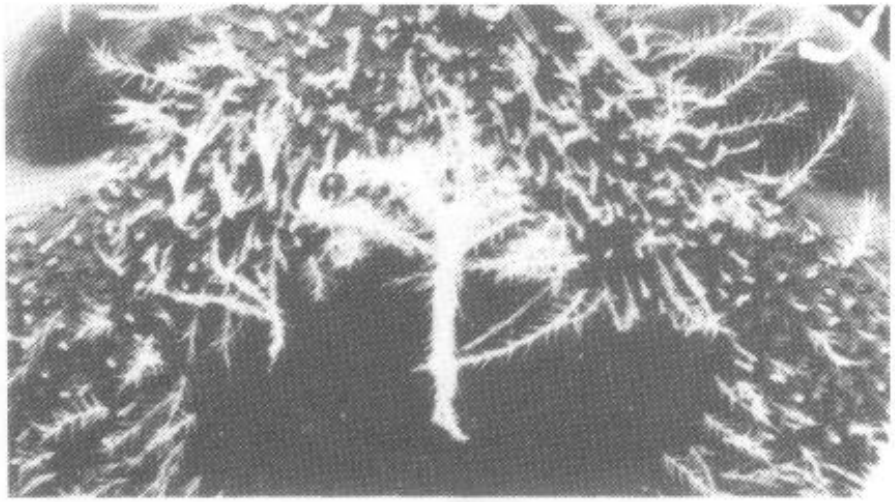


A B

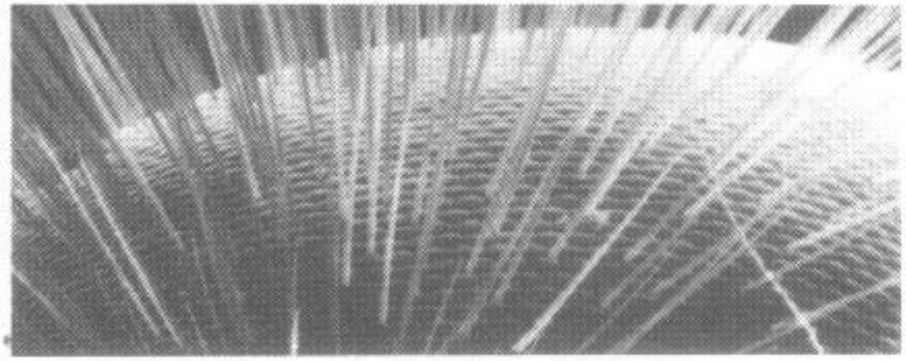
PLATE 3. A. Branched body hairs (X 85). B. Pollen grains in a tangled mass of hairs (X 750).



A



B



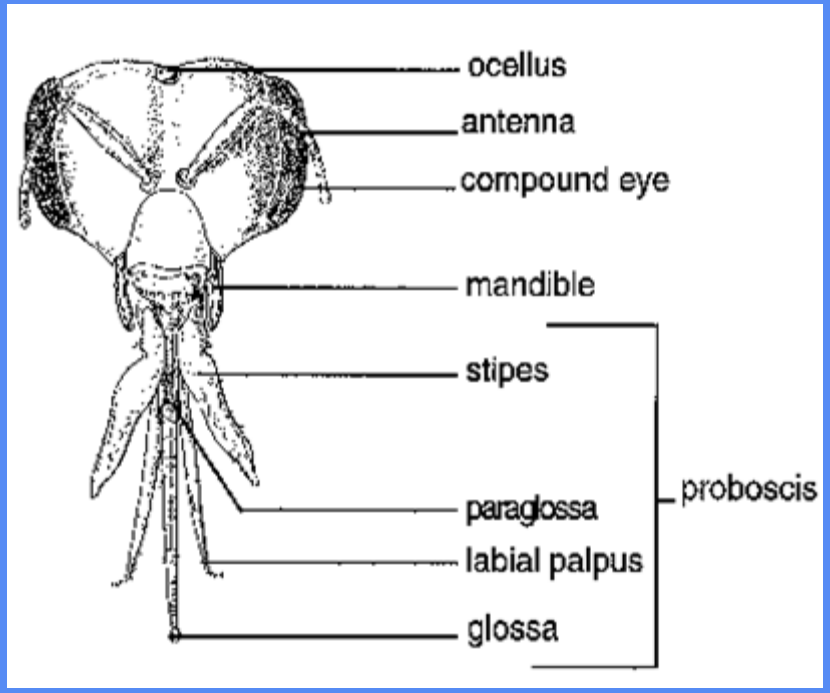
C

Plate 4. A. Worker face showing ocelli at the top between the antennae, and a large compound eye. Small black arrow points toward one of the two anterior tentorial pits (X 15). B. Close-up of the three ocelli (X 80). C. Close-up of the surface of the compound eye with its numerous facets and hairs (X 120).

Antennae

- Antennae receive and analyze highly volatile substances that are responsible for **odor and taste**. Antennae also perceive **vibrations and movement of air (, sounds, temperature and humidity . Aide in communication**
- **Johnston's organ** is a collection of sensory cells found in the pedicel (the second segment) of the antennae. Johnston's organ **detects motion** in the flagellum (third and final antennal segment). Johnston's organ can also **sense wind**.

Head External Features



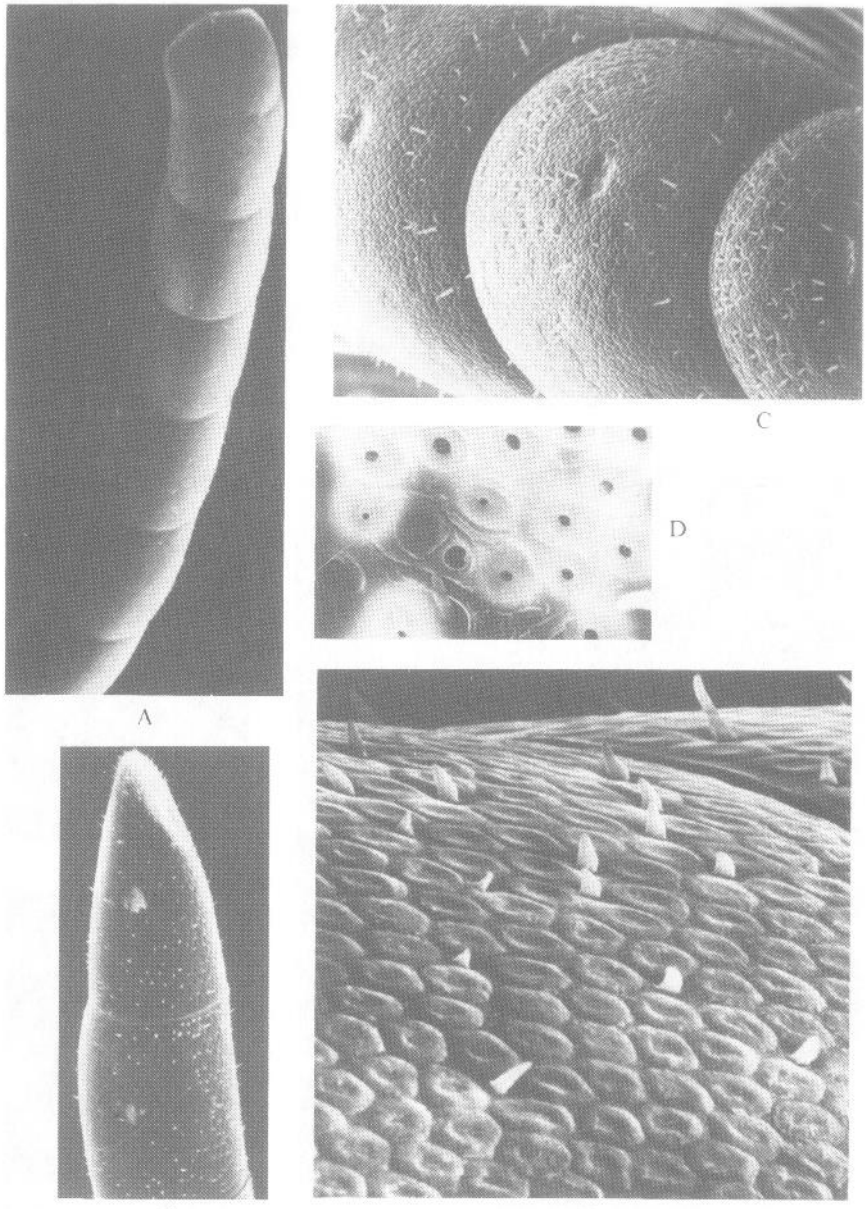


Plate 7. A. Drone antenna (top view) (X 60). B. Tip of a drone antenna displaying several sensory organs including clusters of pit organs (X 70). C. Enlargement of three antennal segments (X 210). D. Close-up of a cluster of pit organs (X 789). E. Close-up of the high density of plate organs on the drone antenna (X 1,015).

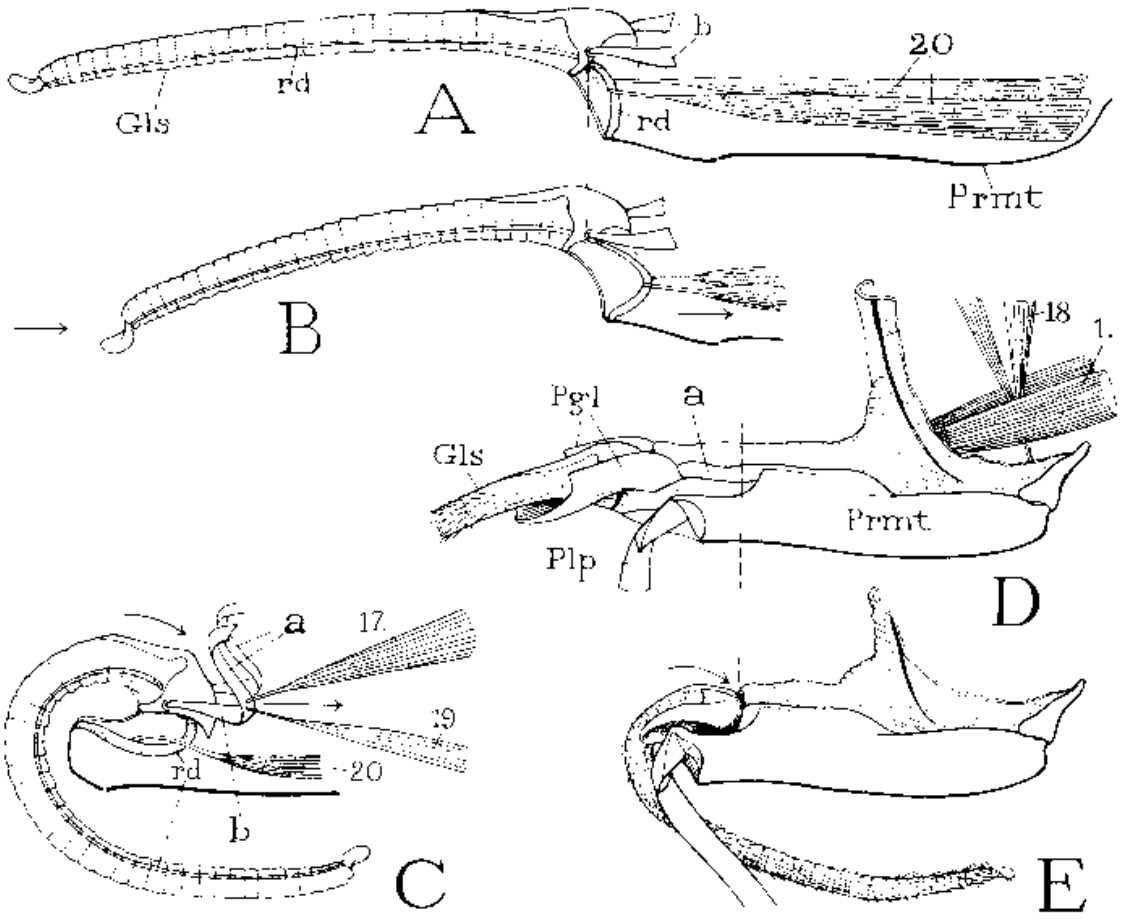


FIGURE 7. Mechanisms of the proboscis of a worker bee.

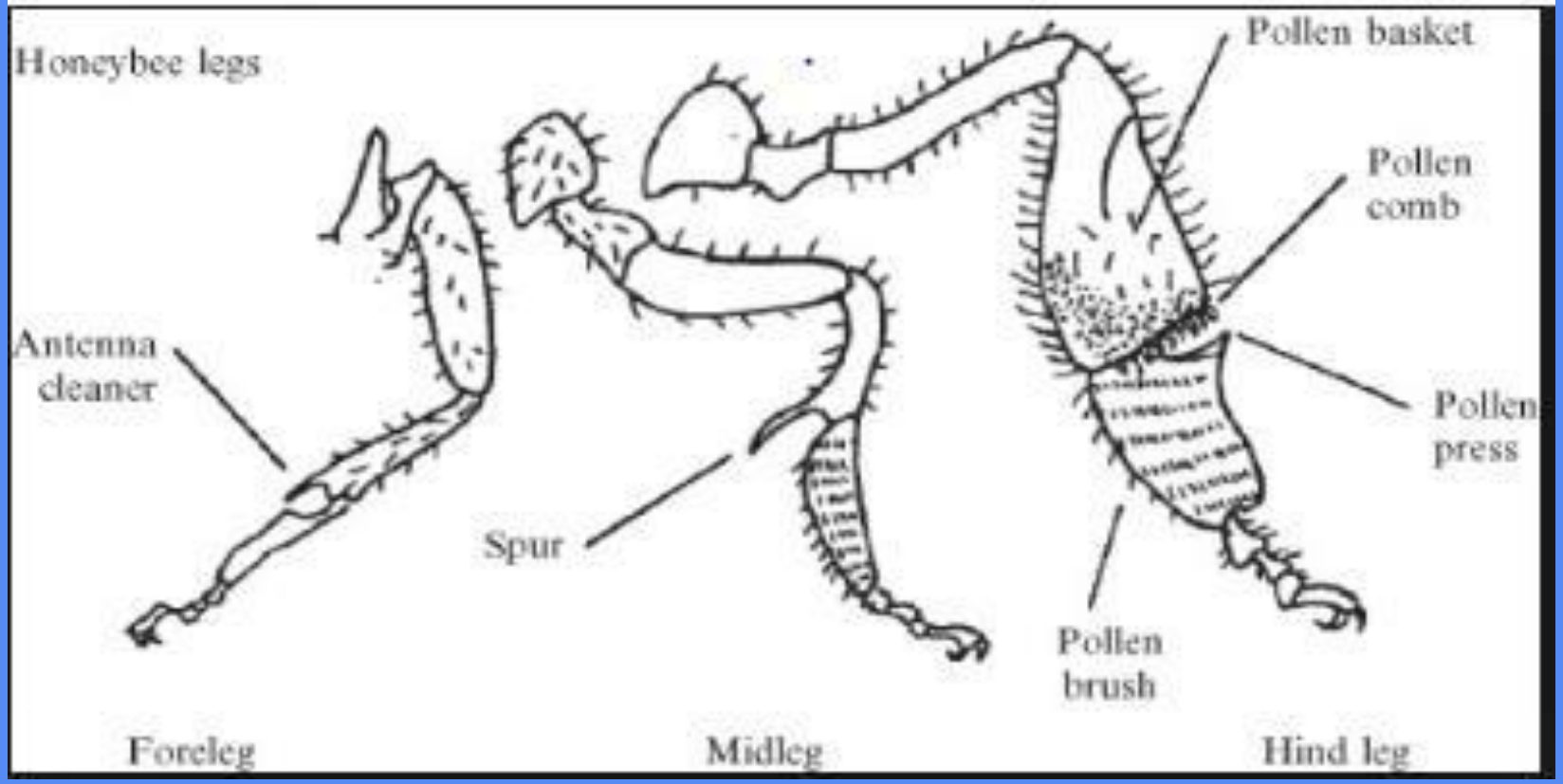
A, diagram of tongue extended from prementum, showing tongue rod and its muscles. B, tongue shortened by pull of muscles on base of tongue rod. C, tongue retracted and automatically curved backward by pull of muscles *(17, 19)* attached on supporting arms *(a)* of tongue base. D, base of labium, with tongue and paraglossae extended. E, same with tongue and paraglossae retracted and tongue curved back as at C.

a, supporting arms of tongue and paraglossae; *b*, pivotal supports of tongue; *Gls*, tongue; *Pgl*, paraglossae; *Plp*, labial palpus; *Prmt*, prementum; *rd*, flexible rod of tongue; *17, 19*, retractor muscles of tongue and paraglossae; *18*, adductor muscle of labium; *20*, muscles of tongue rod.

Worker Bee Taking Up Nectar from Flower Nectaries

Proboscis Inserted In Flower Nectaries

Honey Bees Legs



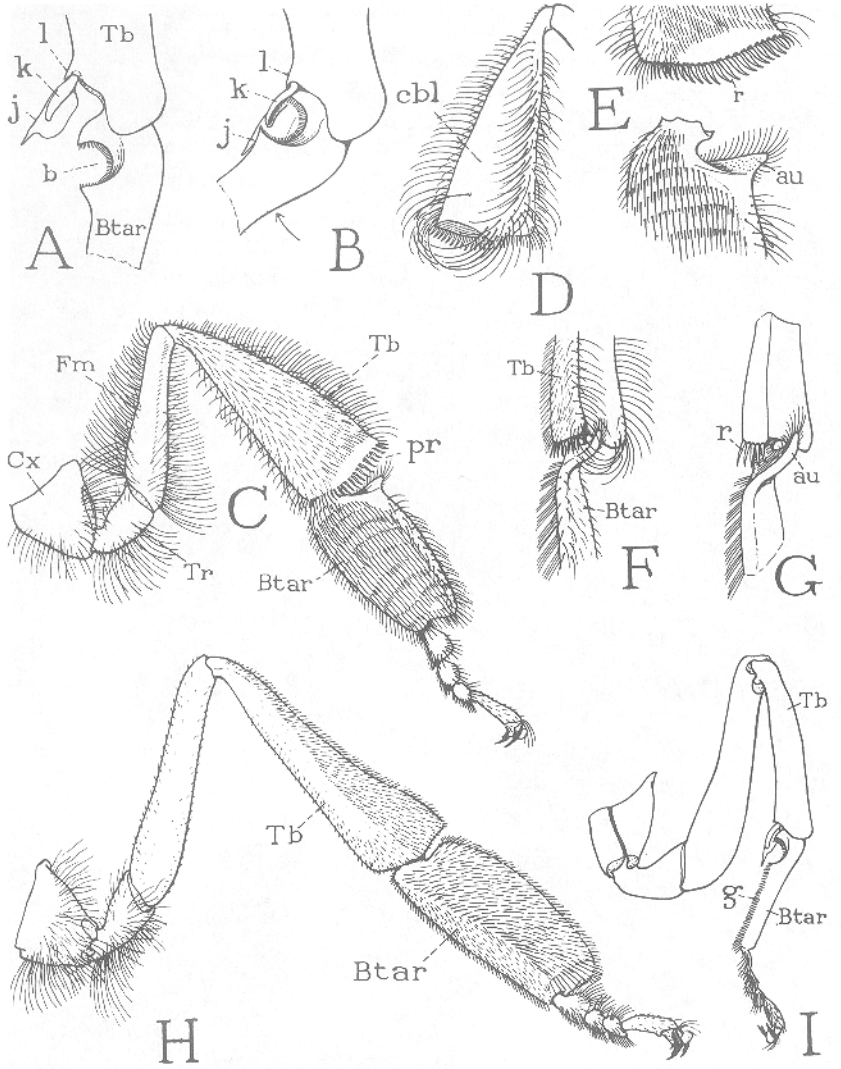
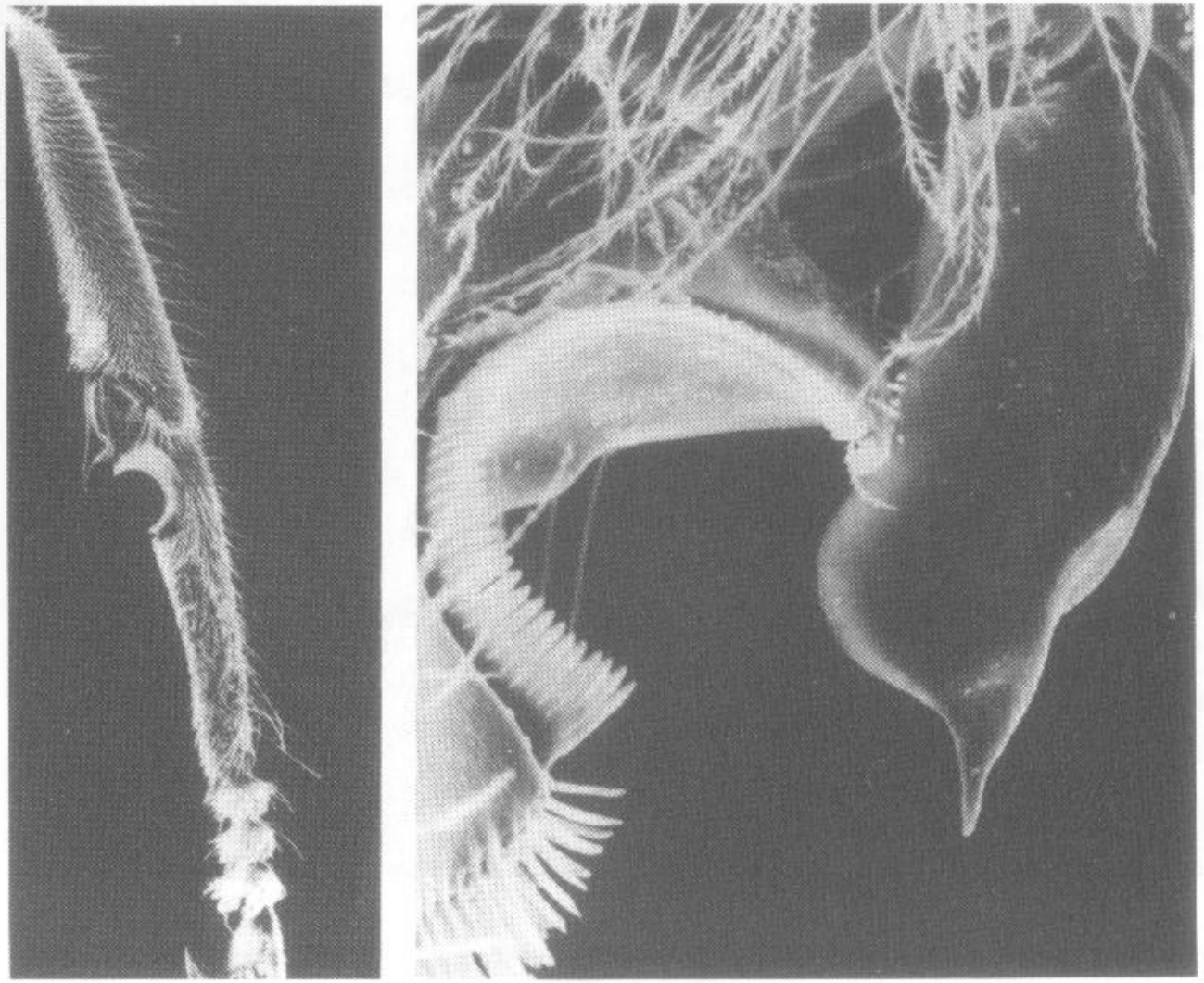


FIGURE 11. Special features of the legs of a worker bee (except **H**).

A, antenna cleaner of first leg, open. B, same, closed. C, hind leg of worker, inner surface, showing pollen-collecting brush on basitarsus *(Btar)* and pollen press *(pr)*. D, pollen basket (corbicula) on outer surface of hind tibia (C, *Tb*). E, end of hind tibia with pollen rake *(r)* and opposing end of basitarsus with auricle *(au)*. F, pollen press between tibia and basitarsus, dorsal view. G, same, better seen after removal of tibial hairs. H, hind leg of drone. I, first leg of worker, showing position of antenna cleaner.

au, auricle; *Btar,* basitarsus; *cbl,* pollen basket; *Cx,* coxa; *Fm,* femur; *g,* tarsal brush of first leg; *h,* antenna cleaner; *i,* notch of antenna cleaner; *j,* clasp of antenna cleaner; *k,* lobe of clasp; *l,* stop-point for clasp; *pr,* pollen press; *r,* pollen rake; *Tb,* tibia.



A B

PLATE 12. A. Drone fore leg with antenna cleaner (comb) (X 20). B. Comb close-up (X 152).

Ball of Pollen on Corbicula

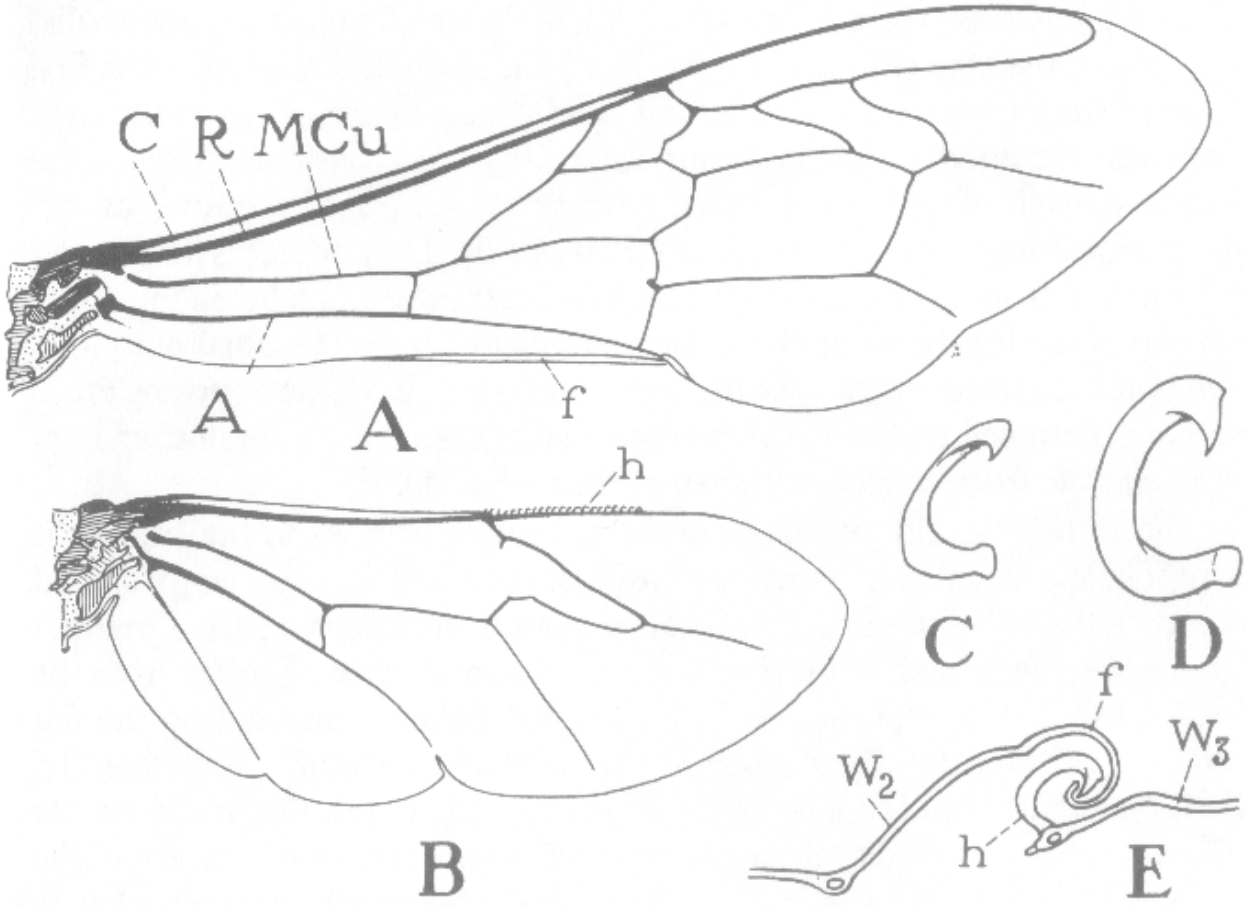
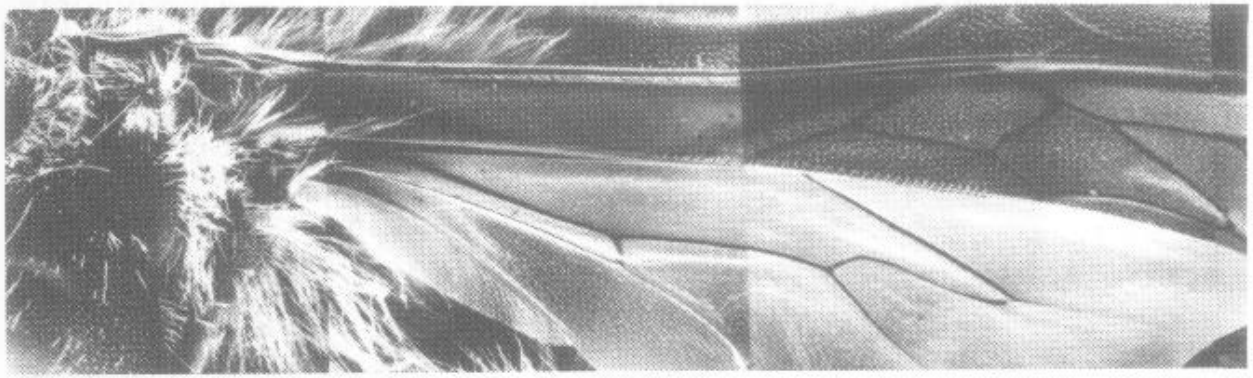


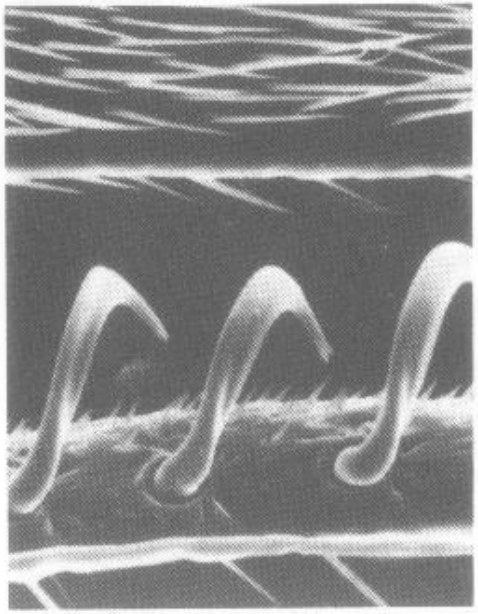
Figure 12. The wings of a worker bee.

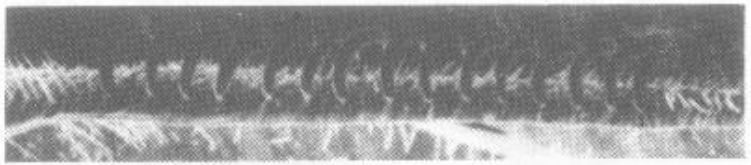
A, right fore wing of worker. B, right hind wing. C, hind wing hook of worker. D, wing hook of drone. E, section of fore and hind wings showing interlocking by fold and hooks.

A, anal vein; *C,* costal vein; *f,* marginal fold of fore wing; *h,* marginal hooks of hind wing; *R,* radial vein; *MCu,* median and cubital veins united; W_2, fore wing; W_3, hind wing.

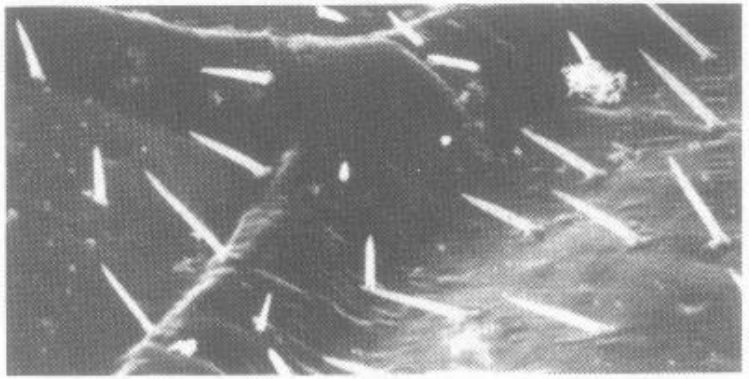


A





B



C D

PLATE 14. A. Undersides of the worker fore and hind wing showing wing veination and hooks on the leading edge of the hind wing. (X 13). B. Enlargement of the zone with wing hooks (queen) (X 285). C. Close-up of three wing hooks (queen) with opposing trailing edge of fore wing (X 81). D. Close-up of the queen wing surface showing veins and surface spines (X 242).

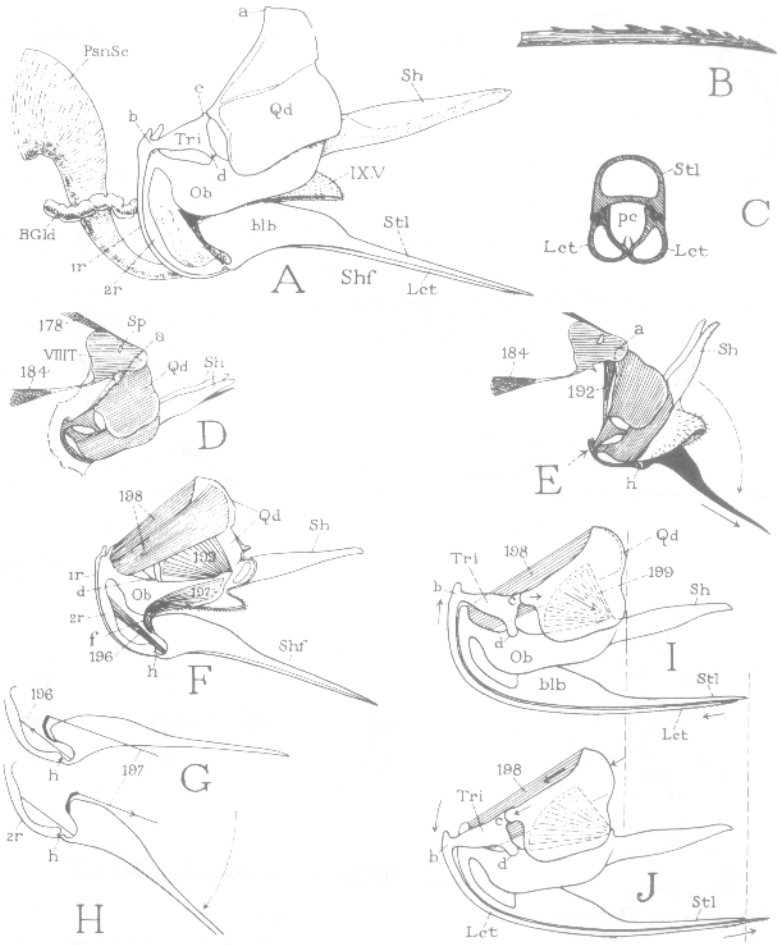


FIGURE 16. The sting of a worker bee.

A, entire stinging apparatus, left side. B, end of a lancet. C, cross section of shaft of sting. D, sting in position of repose, suspended from wall of sting chamber between spiracular plates *(VIII T)*. E, sting in position of protraction (arrows indicate the two essential movements). F, diagram of sting and its muscles. G, diagram of shaft of sting held in position of repose by muscle *196*. H, same, shaft turned down (as at E) by contraction of muscle *197*. I, J, mechanism of retraction (I) and protraction (J) of lancet.

a, attachment of quadrate plate with spiracular plate; *b,* apex of triangular plate continuous with lancet; *BGld,* "alkaline" gland of sting; *blb,* bulb of stylet; *c,* hinge of triangular plate on quadrate plate; *d,* hinge of triangular plate on oblong plate; *f,* forked rod (furcula) giving attachment to depressor muscles (197) of shaft; *h,* hinge of bulb with its basal arm *(2r); Lct,* lancet; *Ob,* oblong plate; *pc,* poison canal; *PsnSc,* poison sac (see Fig. 22C); *Qd,* quadrate plate; *1r,* basal arm (ramus) of lancet; *2r,* basal arm of bulb and stylet; *Sh,* sheath lobes; *Shf,* shaft of sting; *Sp,* spiracle; *Stl,* stylet; *Tri,* triangular plate; *VIII T,* spiracular plate associated with sting base.

Guard Bees

Drop of Venom on Stinger

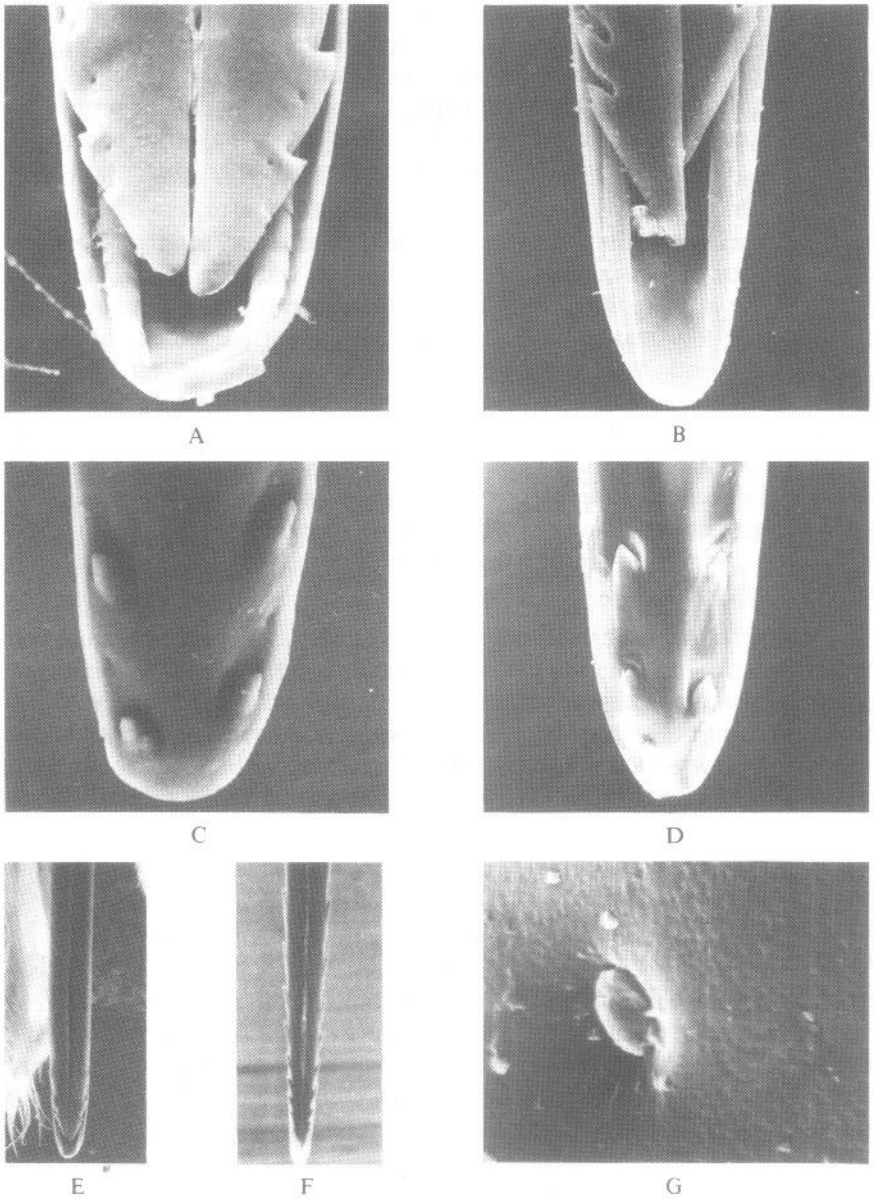
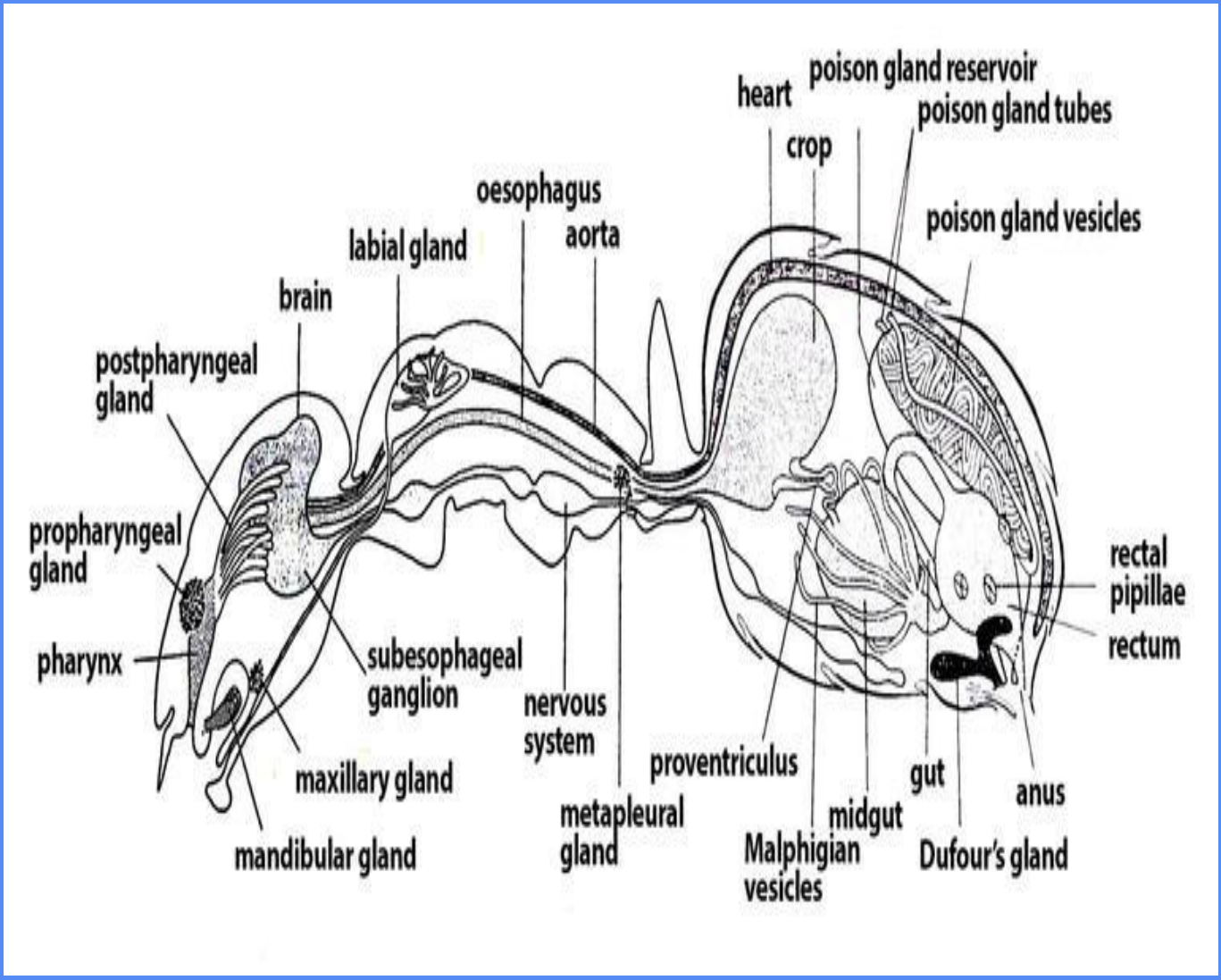


PLATE 21. Comparison of the stings of the queen and worker. A. Tips of the queen lancets (X 270). B. Tips of the worker lancets (X 270). C. Tip of the queen stylet (X 270). D. Tip of the worker stylet (X 270). E. Shaft of the queen sting (X 110). F. Shaft of the worker sting (X 110). G. Close-up of a sensillum for detecting pressure (X 7,615). Note that one of these sensors is associated with each barb on both the stylet and lancets.

Honey Bee Internal Organs



Circulatory System

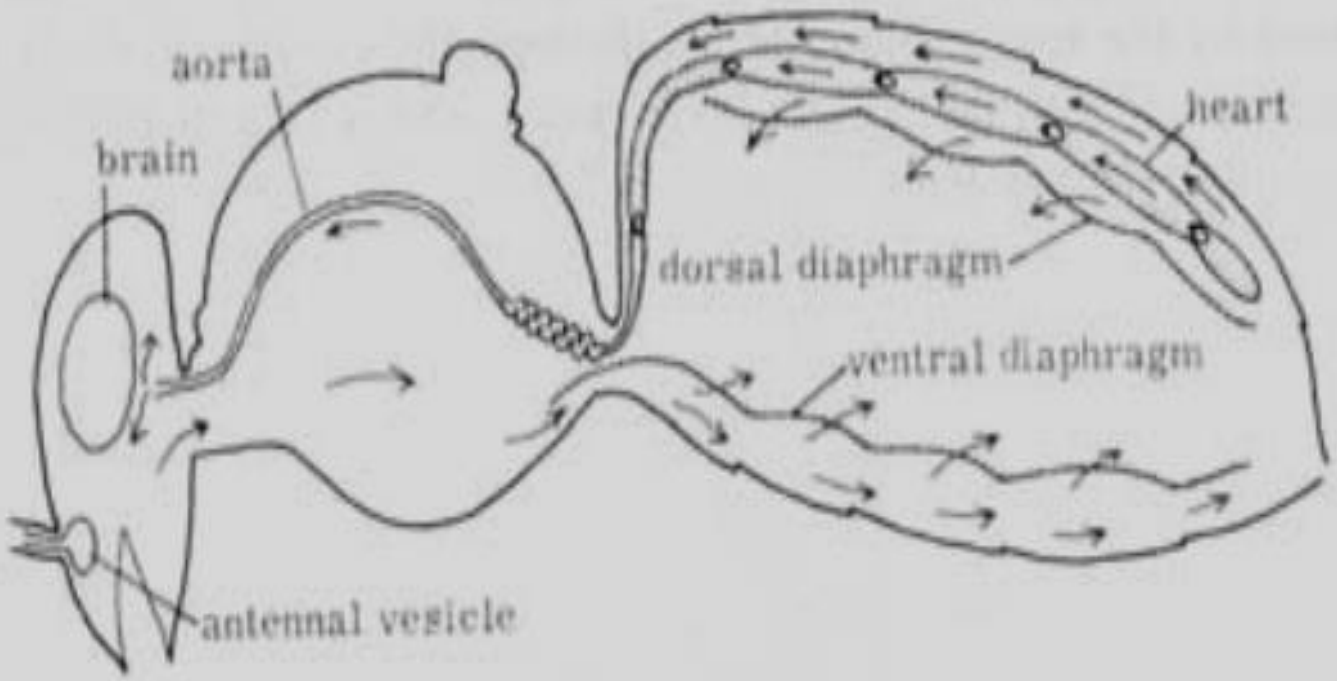
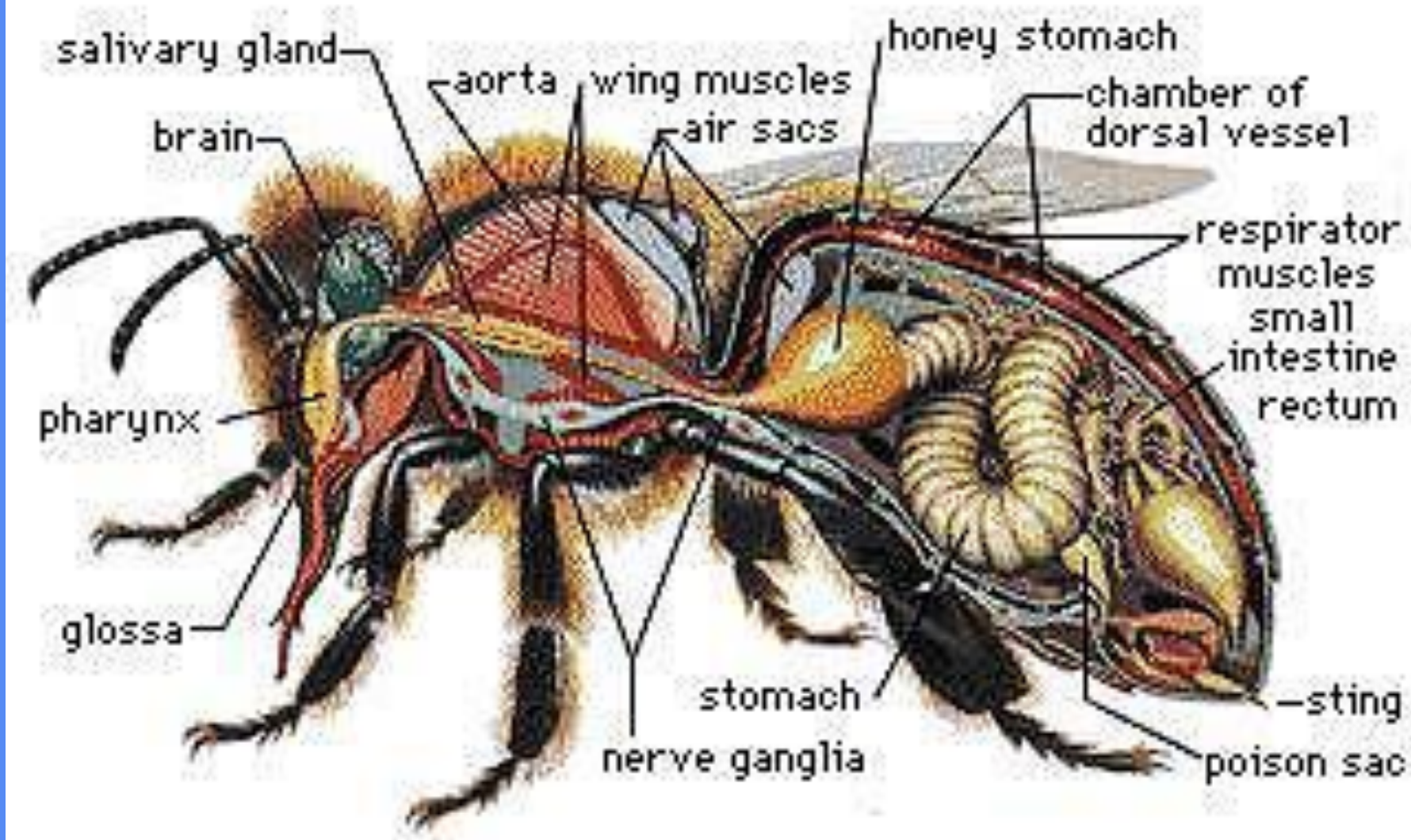


Fig. 20. Diagram illustrating the action of the heart and diaphragms.


salivary gland
aorta
wing muscles
air sacs
honey stomach
chamber of dorsal vessel
brain
respirator muscles
small intestine
rectum
pharynx
glossa
stomach
sting
nerve ganglia
poison sac

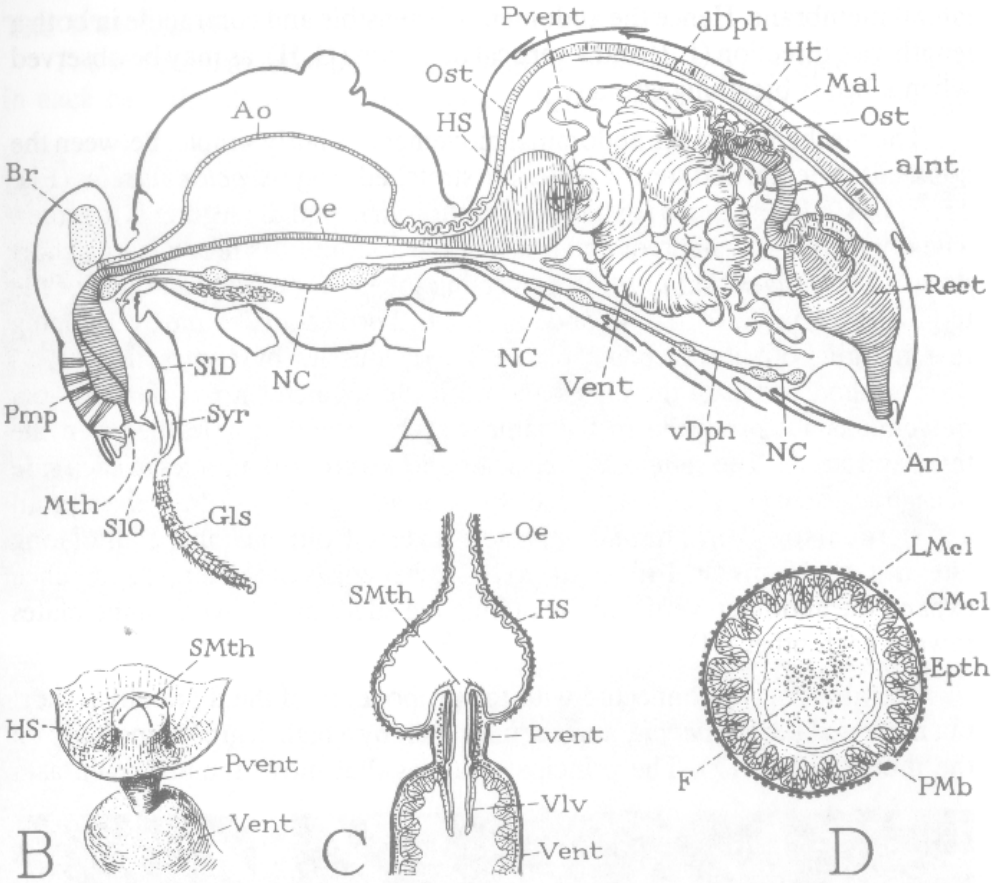


Figure 17. The alimentary canal and other internal organs of a worker bee.

A, lengthwise section of a worker bee, showing alimentary canal, dorsal blood vessel, diaphragms, brain, and ventral nerve cord. B, inner end of honey stomach cut open to show stomach mouth *(SMth)* at summit of proventriculus *(Pvent)*. C, lengthwise section of honey stomach, proventriculus and anterior end of ventriculus. D, cross section of stomach (ventriculus).

An, anus; *alnt,* anterior intestine; *Br,* brain; *CMcl,* circular muscles; *dDph,* dorsal diaphram; *Epth,* epithelium (cellular layer of stomach); *F,* food material; *Gls,* tongue; *HS,* honey stomach; *Ht,* heart; *LMcl,* longitudinal muscles; *Md,* mandible; *Mth,* mouth; *NC,* nerve cord; *Oe,* oesophagus; *Ost,* ostium; *Pmp,* sucking pump; *PMb,* peritrophic membrane; *Pvent,* proventriculus; *Rect,* rectum; *SlD, salivary duct; SlO,* salivary orifice; *SMth,* stomach mouth; *Syr,* salivary syringe; *vDph,* ventral diaphragm; *Vent,* ventriculus; *Vlv,* proventricular valve.

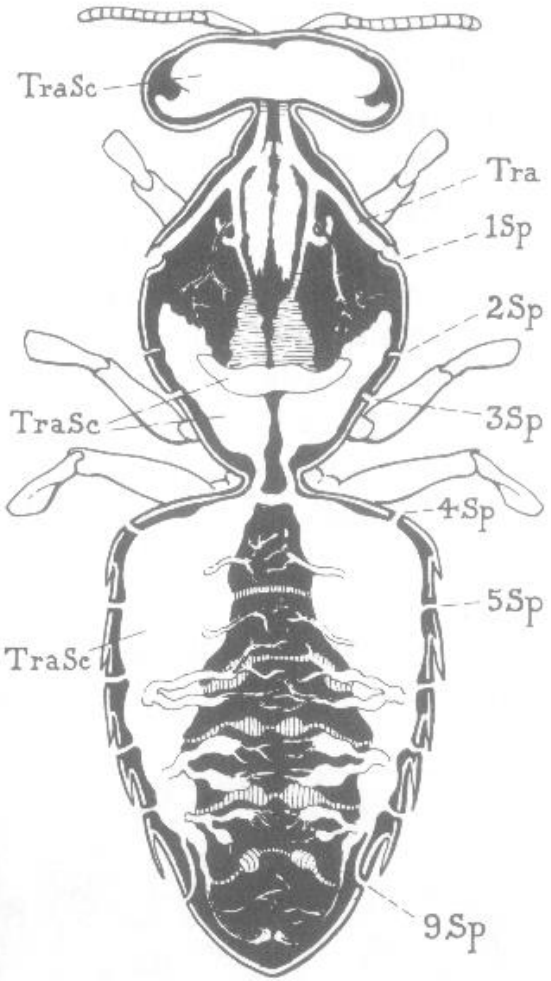


FIGURE 19. General view of the tracheal respiratory system of a worker bee, seen from above. *1Sp-9Sp,* spiracles; *Tra,* tracheal trunk from first spiracle; *TraSc,* tracheal sacs. Though not designated, the sixth, seventh, and eighth spiracles are the openings shown between the fifth and ninth spiracles.

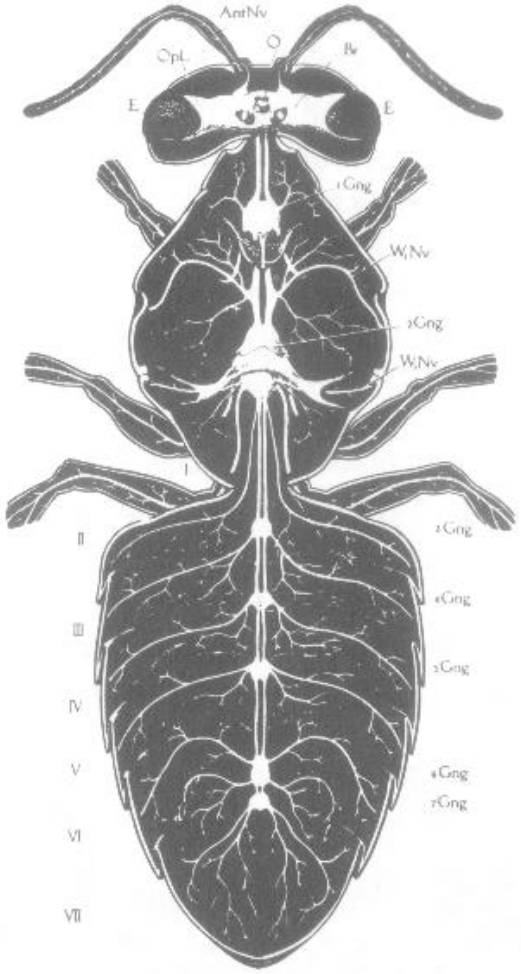


FIGURE 20. The nervous system of a worker bee seen from above. *AntNv,* antennal nerve; *Br,* brain; *E,* compound eye; *1Gng-7Gng,* ganglia of ventral nerve cord; *I,* propodeum; *II-VII,* abdominal segments; *O,* ocellus; *Opl,* optic lobe of brain; W_2Nv, nerve to first wing; W_3Nv, nerve to second wing.

RESPIRATORY SYSTEM

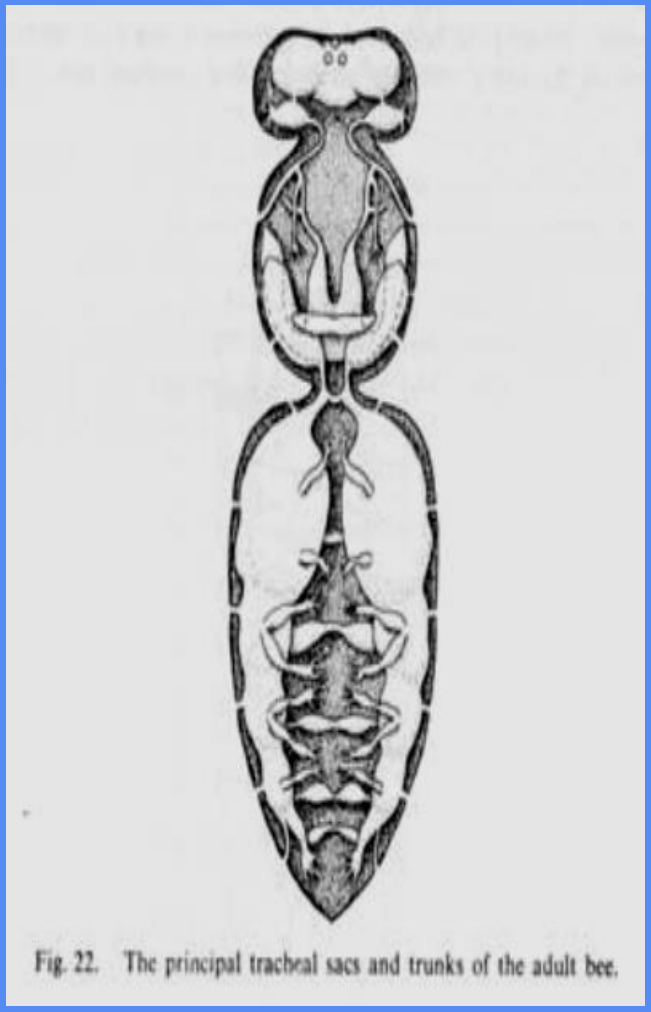


Fig. 22. The principal tracheal sacs and trunks of the adult bee.

- **Respiratory system**

- Insects have no lungs or centralized respiratory system.
- System of **trachea** which carry oxygen to and CO2 away from cells.
- Trachea are connected to the outside by a series of holes in the exoskeleton called **spiracles**.
- At rest respiration occurs passively by diffusion.
- Under stress, such as during flight, bees pump their abdomens to increase gas exchange and expand air sacs of the trachea like bellows, facilitating greater gas exchange.
- Though the blood contains no hemoglobin, muscles indirectly connected to the wings contain cytochrome, a molecule which enhances gas exchange.
- Insects are adapted to tolerate much higher concentrations of CO2 than humans.

Honey Bee Brain and Nervous System

- Honey bees like most insects not only have a brain in their head but several sub brains or ganglia (7 of these) spread throughout their bodies. There are 2 ganglia in the thorax and 5 in the abdomen. Ganglia function independently but can be controlled or over written by instructions from the main brain. They also send feedback to the main brain about the state of the environment in their particular area.
- Most locomotion is controlled by the ganglia, not the brain and in fact a beheaded bee can move it's legs and wings vigorously. A bee will be able to walk and sting for a while when decapitated, but not fly as its balance will be out without a head.
- An adult honey bee is one of the most advanced insects and is capable of a huge range of different complex behavior. Honey bees are capable of learning and have short-term memory.
- The actual main brain of a an adult honey bee is proportionately very large in comparison with its size. In the worker bee the brain consists mainly of the optic lobes, with the central part acting as a coordinating center and this central part is larger than in most other insects. Nerve fibers connect the brain to the 2 ganglia in the thorax and the 5 in the abdomen.

Honey Bee Brain and Nervous System (con't)

- Each ganglion has nerve fibers which connect it to sensory receptors on the outside of the body, to bring information back from the outside environment. The antennae are of course the main sites for sensory reception in the bee.
- The ganglia also each have fibers which bring information about the condition of the internal organs of the bee and those which send back regulatory information. Fibers also carry information to the muscles to control their actions.
- Much is still to be learned about why the bee is capable of displaying such complex behavior in particular its amazing ability to navigate to and from its hive, remembering and passing on detailed information about the position of food sources.

Glands

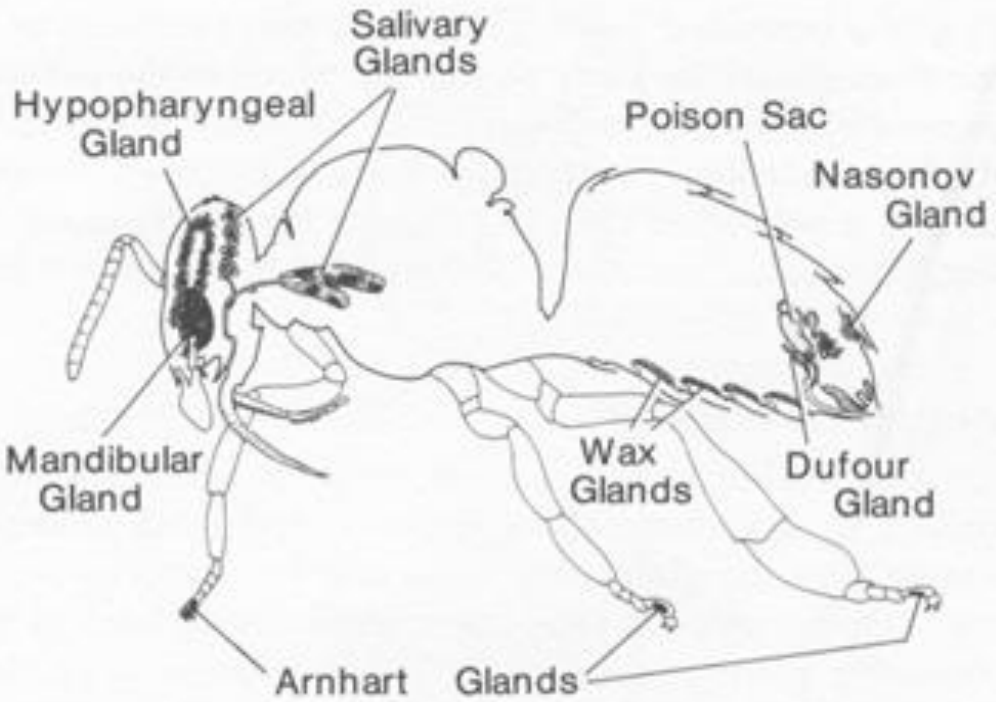


Fig. 3.19

The worker glandular system. (Redrawn from Michener, 1974.)

Honey Bee Glands

- wax gland produce wax in segments of abdomen
- nasonov gland orient swarm/hive entrance/flower attraction. produced in the last abdomen segment. dispersed by wing buzzing
- ***mandibular gland*** makes lipids for larval food/alarm pheromone '2-heptanone'/ and queen substance. produced in the head
- sting pheromone gland makes the alarm 'isopental'. produced in the stinger
- arnhart gland leaves the 'scented footprint' on flowers and hive. produced in the tarsal segment of legs
- ***salivary gland*** secretes invertase. produced in the mouth
- ***hypopharyngeal gland*** produces royal jelly, produced in the head

Glands

- Four basic functions
  - Wax production
  - Communication
  - Defense
  - Food processing
- Just inside the bee's mouth are the opening points of two very large hypopharyngeal glands. These glands are made up of a number of secretory cells clustered around a central canal. When the honey bee is young, in the first few weeks of its life, these cells are round and plump and produce brood food, a form of bee milk which is used to feed bee larvae. As the bee gets older and becomes a forager at about three weeks old, these cells become smaller and much reduced in size. The hypopharyngeal glands have now switched from producing brood food to producing invertase. Invertase is an enzyme used in the pre-digestion of sucrose. However if necessary for the needs of the colony the worker bee can switch back to producing bee food from these glands.
- In addition a pair of glands in the mandibles secrete a type of preservative which is mixed with the brood food as it is secreted from the hypopharyngeal glands, this has anti bacterial qualities which prevents the food from deteriorating.
- The mandibular glands also produce an alarm scent called heptanone which is used to alert other bees to danger. The mandibular glands in the queen bee produce a type of fatty acid which is called 'queen substance' which is used to ensure the workers are aware of her presence.

Glands (con’t)

- There are two salivary glands in the head and thorax, with openings on either side of the bee’s tongue. Their liquid secretion is used to dilute honey and dissolve sugar crystals.
- On the upper side of the abdomen of the bee on the last visible segment is the Nasanov gland. This releases a pheromone which is used to attract members of the colony who might have lost the location of their hive. Often you will notice bees at the entrance of a hive fanning with their wings to propel the airborne scent to the bees flying around, especially when the hive has been disturbed.
- Worker bees also have four pairs of wax glands on the underside of the last five segments of their abdomens. Wax is secreted into pockets underneath each gland and quickly solidifies into translucent white blobs which are then removed by mouth and worked on to use to build comb as required (see How and why bees produce wax).
- Finally there are two glands associated with the bee’s stinging mechanism. There is a long thin venom gland which produces the acidic venom which is contained in the venom sac. The second sting gland produces an alkaline solution which is thought to act as a lubricant for the stinging mechanism.

Pheromones of the Queen Honey Bee

- Pheromone — Source
  - Queen substance (QMP) — mandibular glands
  - Food-print — Amhart (tarsal) glands
  - Tergal — tergite glands (abdominal)
  - Feces — hindgut
  - Egg marking — durour’s gland?
  - Queen attract and scent — Koschevnikov gland
  - Queen cell — immature queen /cell
  - "The Dufour's gland seems to inform workers that queens have mated, while the mandibular gland seems to indicate the queen's mating quality,"

Pheromones

- **Alarm pheromone**, produced by workers, is a releaser pheromone that calls nest mates to help defend the colony from intruders. A sting, which also releases alarm pheromone, causes other bees to sting as well.
- **Brood ester pheromone** (BEP), produced by larvae, is a primer pheromone that, among other things, inhibits ovarian development in worker bees.
- **Drone pheromone** is released by drones and allows them to find each other and form a drone congregation area (DCA).
- **Dufour's gland pheromone** is not clearly understood except that it has something to do with interactions between queens and workers, and between laying workers and non-laying workers. The composition of the pheromone changes as a worker evolves into a laying worker.
- **Egg marking pheromone** allows worker bees to distinguish between queen-laid eggs and worker-laid eggs. At one time, scientists believed that the Dufour's gland pheromone marked a queen's eggs, but now egg-marking pheromone appears to be separate.
- **Fecal pheromone** is produced by virgin queens. In-hive squabbles between virgin queens, or virgin queens and workers, are sometimes resolved when virgins squirt feces on the aggressive bees. Workers covered in the pheromone-laced feces back off in order to groom, and virgin queens covered in feces are ignored by the workers.
- **Footprint pheromone**, also known as trail pheromone, is found in many social insects. Worker honey bees secrete the pheromone from their feet as they go about their daily business, and the odor is attractive to other honey bees. In theory, footprint pheromone is used for orientation and may aid the workers in finding the hive entrance or in locating a good food source, but the specifics are unclear.
- **Nasonov pheromone**, sometimes called the "come hither" scent, is produced by worker bees to attract nest mates to the colony entrance, a clustering swarm, or a food source. If you move a hive a short distance from its original location, you can see workers exposing their Nasonov gland (it lies between the sixth and seventh abdominal tergites) and fanning the scent into the air. Nasonov can also be used to attract swarms to nest boxes.

Pheromones

- **Tarsal pheromone** is similar to footprint pheromone but it is secreted by the queen. The pheromone is deposited on the surface of the comb and is believed to delay or prevent queen cell construction.
- **Tergite pheromone** is produced by all bees in the hive but the composition and amount varies with the type of bee. Virgin queen tergite pheromone is believed to be related to fighting among virgin queens.
- **Queen mandibular pheromone** (QMP) plays many roles in the hive, including regulating social behavior, swarming, mating, and suppressing laying workers. Often known as “queen substance” the pheromone is spread throughout the hive by the worker bees, thereby alerting colony members that the hive is “queen-right” and operating normally.
- **Queen retinue pheromone** (QRP) entices worker bees to groom and feed the queen, and causes a circle of attendants to surround and care for her.
- **Worker pheromone** (Ethyl oleate) is a primer pheromone produced by foraging bees that slows the maturation of nurse bees into forager bees. It is believed this pheromone helps to maintain a proper balance of nurse bees to forager bees in the colony.

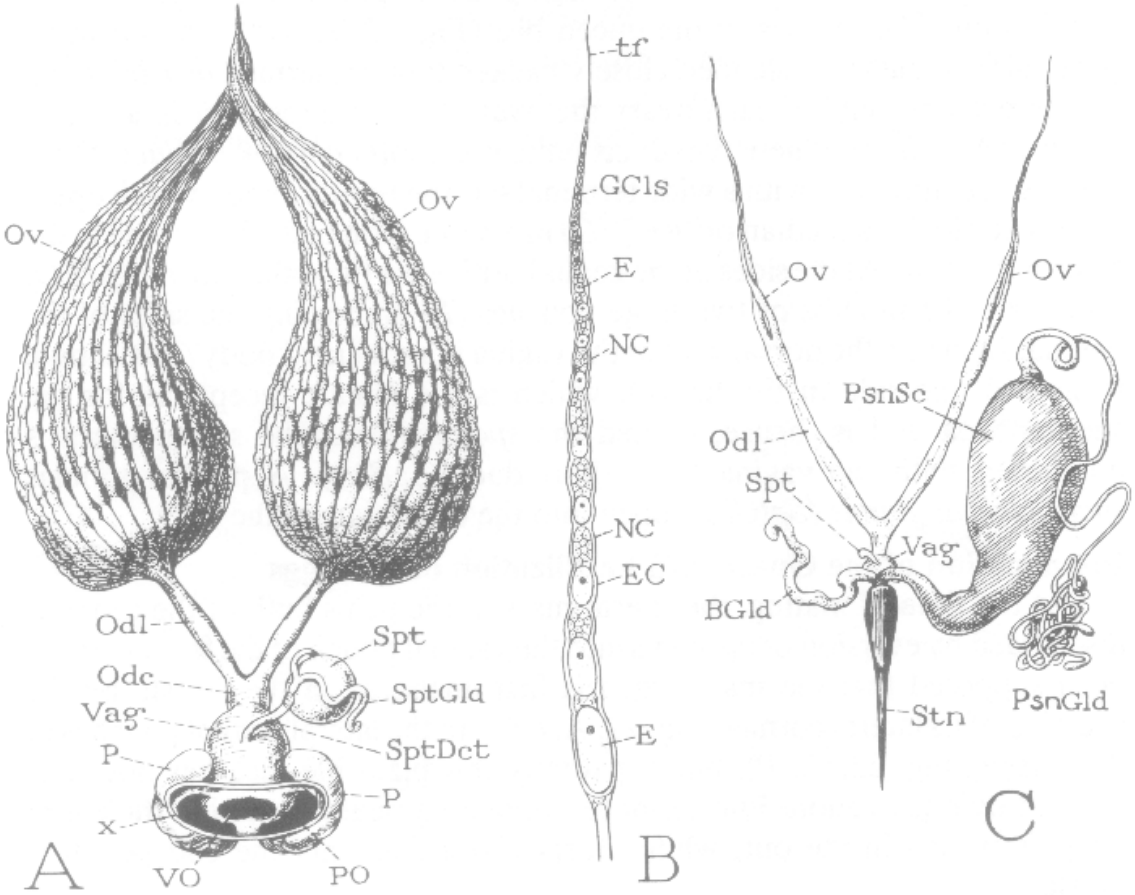


FIGURE 22. The female reproductive organs.

A, ovaries, genital ducts and genital pouches of the queen. B, single ovariole, diagrammatic, showing succession of egg cells and nurse cells. C, reproductive organs of a worker, together with shaft of sting, sting glands, and poison sac.

BGld, "alkaline" gland of sting; *E,* egg; *EC,* egg chamber; *GCls,* undifferentiated germ cells; *NC,* nurse chamber; *Odc,* common oviduct; *Odl,* lateral (paired) oviduct; *Ov,* ovary; *P,* lateral genital pouch; *PO,* opening of lateral pouch; *PsnGld,* poison gland of sting; *PsnSc,* poison sac; *Spt,* spermatheca; *SptDct,* spermathecal duct; *SptGld,* spermathecal gland; *Stn,* shaft of sting; *tf,* terminal filament; *Vag,* vagina; *VO,* opening of vagina; *x,* cut edge of body wall around genital openings.

DRONE MORPHOLOGY

- In immature adult males the majority of the abdominal cavity is taken up by testes which are white, bean-shaped bodies.
- Testes are composed of bundles of tubules in which sperm are produced and mature.
- At **sexual maturity (~12-13 days after emergence**), testes are greatly reduced to small, greenish-yellow tissue.
- Sperm and associated nurse cells pass to the seminal vesicles.
- The endophallus is everted on mating.
- A pair of copulatory claspers grip the queen during copulation.
- Once completed the endophallus breaks off and left in the queen.
- Drones mate only once in life, then die.