

# Honey Bee Biology

## Anatomy & Physiology

**BBE-Tech Apiary Services**

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*Should you be interested in becoming certified through BBE-Tech Apiary Services in Organic Beekeeping (after obtaining the Apiarist Certification) the written exams will be focused primarily on the material presented in this study guide.*

If you are taking a Honey Bee Biology class offered by Tony Sandoval, you will have the advantage of being able to ask questions, verify information, clarify information and extrapolate ideas as they may apply to your specific apiarist endeavors.

If you downloaded this study guide from the BBE-Tech website, I hope that this provides you with information to help you be successful. You may arrange a private consulting/coaching session with Tony or arrange for a private class to be offered individually or for a group.

This class assumes that you have already had some familiarity, education and/or experience with honey bee physiology and behaviors. If you have not, you may want to consider a private coaching session with Tony to become familiarized with this type of equipment.

Anatomy is the parts of the body. Physiology is what do they do and how do they work together. In this manual I will introduce both anatomy and physiology of the honey bee so as to help beekeepers and those who wish to understand honey bees and beekeeping better have a solid understanding and foundation in what the honey bee is, what it does and what it's needs are.

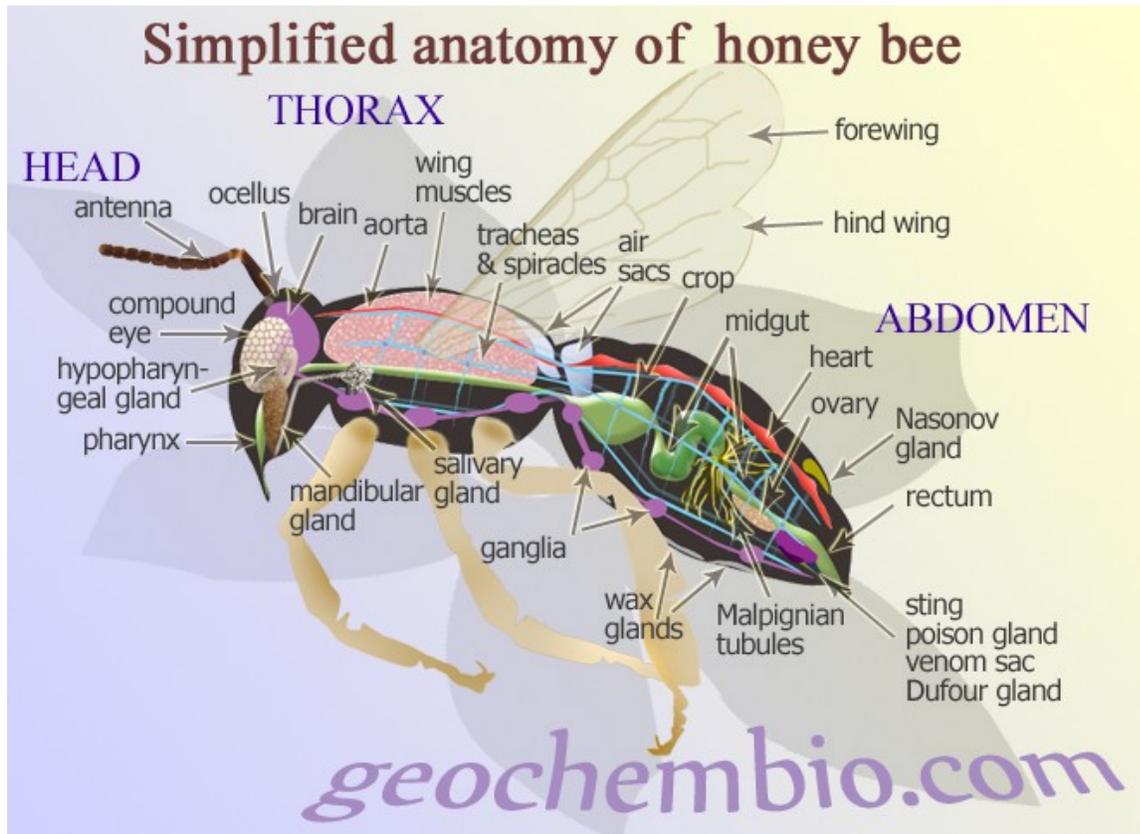
Being successful in beekeeping and facilitating the success of bees relies critically on understanding what the honey bee is, what it does, how it does things, and what it needs.

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## Anatomy

### Parts of bees in General



**Hemolymph** – The name for what we refer to as blood. Part of an open circulatory system, it fills in all the open spaces of the internal body surrounding everything inside. It functions to distribute digested food materials and transport of carbon dioxide but does not transport oxygen. Hemolymph is a pale amber color (kind of like honey, imagine that!?)

**Hairs** – The inside ends of the hairs covering a bee's body are connected to sensory nerves resulting in the sense of Touch when moved by air or contact is made with the hairs.

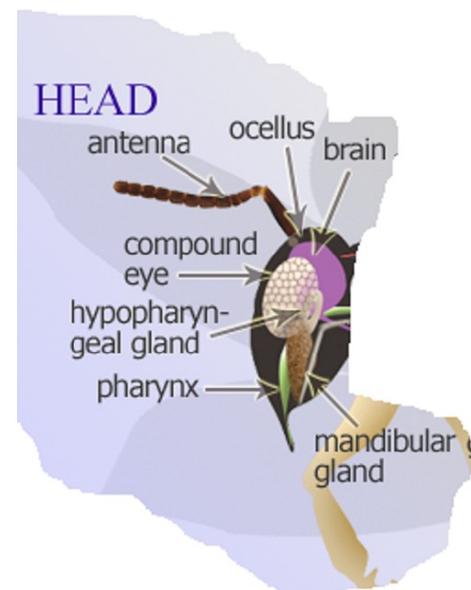
**Dorsal & Ventral** – The topside or back of the bee is the Dorsal side. The underside or bottom of the bee is the Ventral side.

## Head

The primary communications and intake part of a bee's body containing the:

- **Antennae** - multiple segments of 3 parts. Primarily used for senses of touch and detecting odor. Covered with hair and sensory structures. At least 13 specialized cell structures for detecting odor. 7 sensory organs on antennae (**sensilla**)
  - The "**Basal stalk**" (bottom area),
  - **Distal** (mid area has 3 segments), and
  - **Flagellum** (outer area has about 8 segments)
- *Mouth* consists of **Labrum** (upper lip)
  - **Proboscis** – multiple uses...
    - ingest liquid materials (nectar, honey, water...)
    - food exchange (transfer of nectar/honey to other workers, queen and drones)
    - licking pheromones from queen
  - **Mandibles** – used for multiple purposes...
    - collect/eat pollen
    - manipulate wax/build comb
    - clean hive/gather debris
    - fight
    - gather/work propolis
    - support proboscis
  - **Cibarium** – The “pump” (muscle sac) used to draw fluids via the tongue through the proboscis into the mouth.
- **Eyes** – adults have two types of eyes but larvae have no eyes.
  - **Compound Eyes** – main vision organs. Comprised of many individual units called “**ommatidia**” each having it's own lens.
    - Sensory hairs grow on compound eyes at junctions of ommatidia. Used for perception of air flow aiding flight and determining air flow or wind speed.
    - Forming visual images
    - color vision

- perception of light polarization plane
- aid in head turning responses
- detecting movement
- recognize shapes and patterns
- differences in light intensity
- **Ocelli (Simple Eyes)** – also light intensity detectors
- **Brain.** Part of the honey bee central nervous system. Information processing center. Connected to the ventral nerve cord. It contains the “Mushroom bodies” (*corpora pedunculata*) which are considered the seat of intelligence in an insect and have more direct relationship with learning and memory of scent and scent related activity.
- **Major Glands**
  - **Hypopharyngeal (brood food) Gland** – Produces Invertase enzyme to convert sugars in nectar. These glands shrink in “Summer bees” from disuse. “Winter” bees maintain large. Also produces “Brood Food” (with some material from Mandibular gland).
  - **Mandibular Gland**– Produces some substance mixed with liquid secreted from Hypopharyngeal gland for brood food.
  - **Labial (Salivary) Gland** – Produces Saliva which is used to...
    - dissolve or dilute sugary foods
    - clean surfaces such as brood cells or body parts
    - moisten chew-able substances



## Thorax

The primary motor center of the bee's body containing the:

### → *Wings*

- Honey bees have 4 wings in two pairs, the fore wings and the hind wings.
- The front and back pairs of wings can be connected with a series of upturned “hooks” (**Hamuli**) for flight or separated for other purposes.
- The wings of honey bees are membranous and two layered.
- They are fused extensions from the body.
- There are blood vessels called “veins” in wings that are thickened supporting structures for the wings.
- Wings are located on the mesothorax (fore wings) and metathorax (hind wings).



### → *Wing Muscles*

- Used to power flight of the bees.
- Used by bees to move wings when not attached for flying to create air movement for “fanning”.
- Bees can “shiver” these muscles while not moving wings at all to generate heat in their body.

### → *Legs*

- Three pairs of legs.
  - Fore legs. Connected to the Prothorax. Contain the “Antennae cleaner”.
  - Middle legs. Connected to the Mesothorax.
  - Hind legs. Connected to the Metathorax. Contain the Corbicula (pollen basket).
- There are 4 major parts to the legs of bees
  - Coxa, the basal leg segment connected to the thorax
  - Trochanter

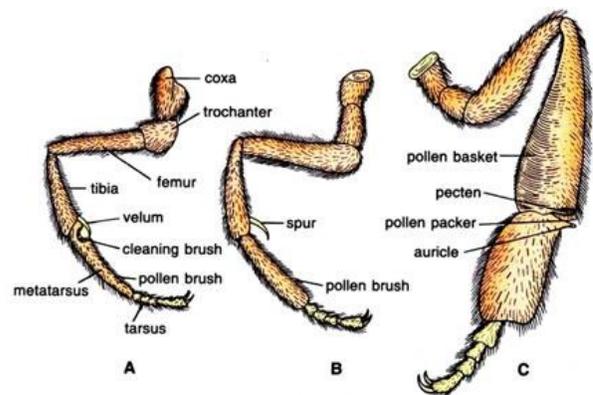
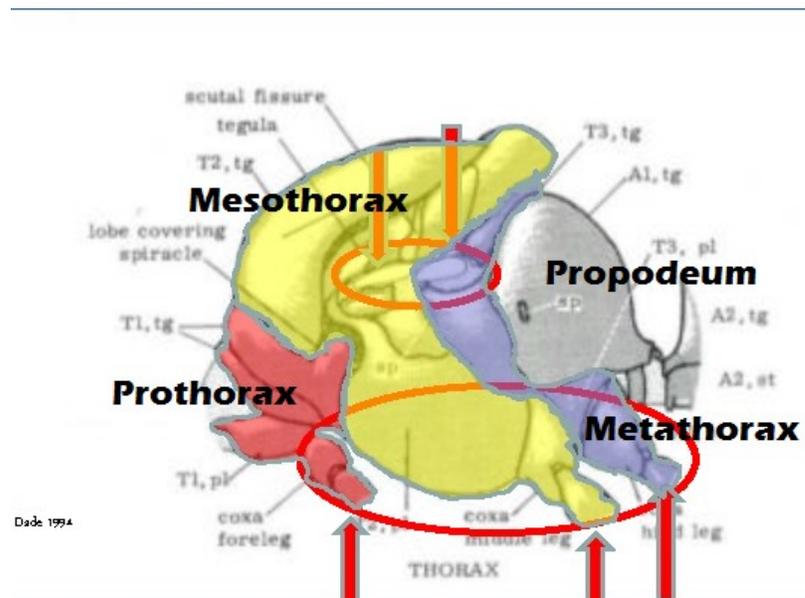


Fig. 77.5. Honeybee. Legs. A—Prothoracic leg; B—Mesothoracic leg; C—Metathoracic leg.

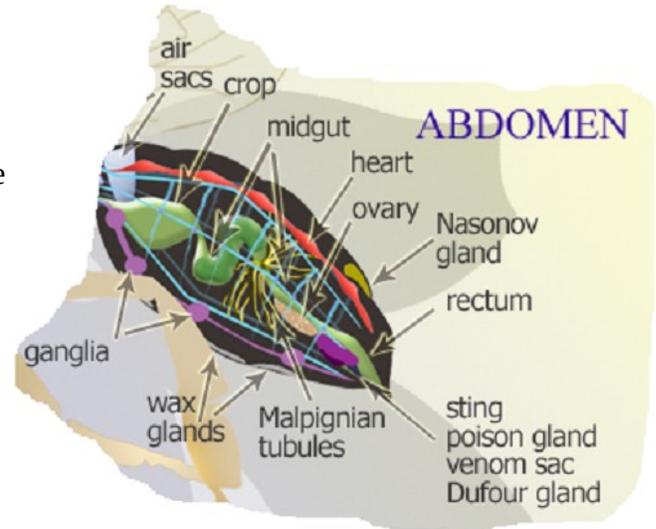
- Femur
- Tibia
- Tarsus - which can be broken down into the Metatarsus and the tarsus. The actual “foot” segment is the “basitarsus”. Also has the “Arolium” a pad-like structure between the foot claws and used for walking on smooth surfaces.
- The spur (tibial spine) on the middle leg is used to loosen pollen pellets from the rear leg pollen baskets.
- **Body**
  - Covered with branched body hairs that aid in pollen collection
  - Thorax divided into 4 parts; **prothorax, mesothorax, metathorax** and the **propodeum**.
  - Three pairs of Spiracles (respiration holes) in thorax connected to **tracheas**
  - Air sacs are at end (Propodeum) of Thorax. Air Sacs are mostly used to increase movement of air through the bees body during flight or other strenuous activity.
  - Salivary gland is contained in Thorax
  - The aorta, one half of the bee circulatory system, is contained in the Thorax. It is connected to the heart in the abdomen and pumps blood (hemolymph) to the brain.



## Abdomen

The primary digestive, reproductive and respiratory systems of a bee. Divided into 3 cavities by the dorsal and ventral diaphragms (used to circulate blood inside the bee body).

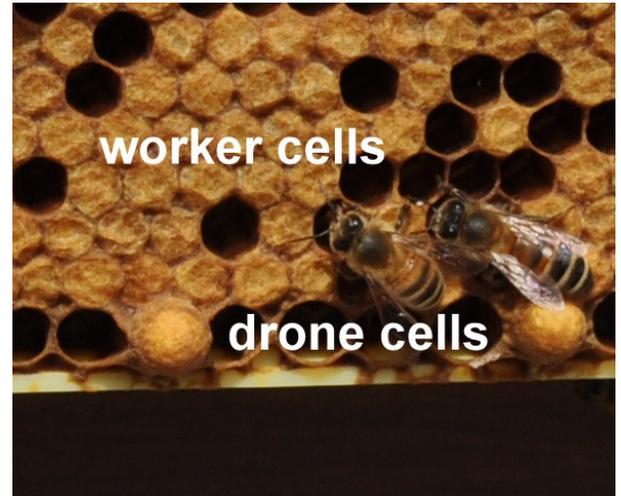
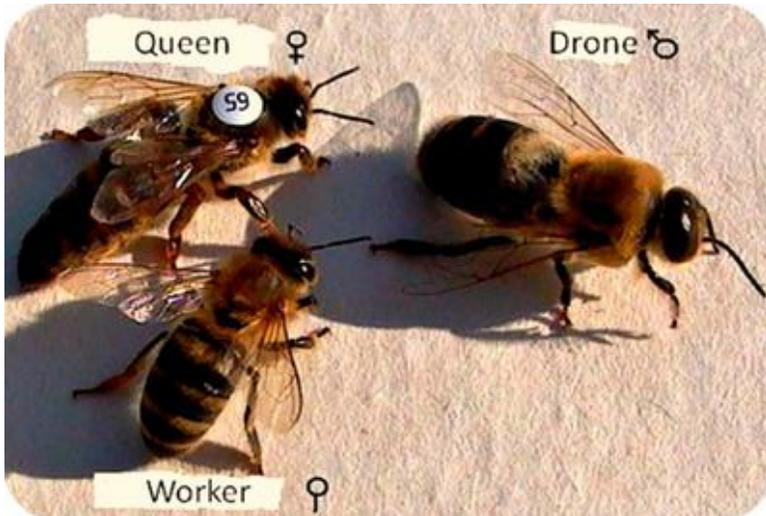
- **Crop**, a specialized expansive gland that can store forage to be transported to the hive. Leads to the **Proventriculus** which separates selected foods to go beyond into the digestive stomach.
- **Stomach**. AKA “Mid gut” and **Ventriculus**. The digestive stomach of the honey bee.
- **Spiracles**. Holes along the sides of the abdomen identical to those in the Thorax. These connect to **tracheas**, through which bees breathe.



- **Heart**. The other part of the Circulatory system in the dorsal area of the abdomen.
  - 5 chambers.
  - It pumps the blood (hemolymph) of the bee primarily to the aorta to the head of the bee. The blood completely fills all open spaces inside of the bee surrounding the organs.
  - Each chamber has a pair of slits (**Ostia**) allowing blood into the chamber.
  - Ostia prevent blood from flowing backward out of the heart.
- **Sting**.
  - The sting shaft itself is actually three pieces. A central stylet and two lancets.
  - It is actually a modified **ovipositor** which has a slight curve to it.
- **Venom Related Glands & Organs**.
  - **Venom Sac**. Storage for produced venom in preparation for defensive activity.
  - **Venom Gland**. Produces the venom related to the sting of of the bee.
  - **Alkaline Gland**. Produces an acidic secretion into the sting with the poison/venom. It's primary contribution to the mix is thought to be as a lubricant perhaps but research is still uncertain.

- ➔ **Nassanoff Gland.** Produces Nassanoff pheromone. It is emitted from a dorsal opening at the rear of the abdomen. Nassanoff pheromone is usually released away from the broodnest and is used for...
  - ➔ foraging for water
  - ➔ identifying nest entrance
  - ➔ coordinating swarm movement and cohesion
  - ➔ marking potential nest sites by swarm scouts
  - ➔ identifying a queen
  - ➔ identifying a non-flower sugar rich forage source.
- ➔ **Wax Making Glands**
  - ➔ 8 (4 pairs) glands exposed on the rear, ventral segments of the abdomen.
  - ➔ Factors regulating development of wax glands are; 1) the age of the honey bee, 2) the amount of nectar or honey in the Crop, 3) a present need for comb in the nest.
- ➔ **Reproductive Organs**
  - ➔ **Spermatheca.** The organ that stores sperm from drones and keeps it alive after mating.
  - ➔ **Spermathecal Gland.** Provide nutrients to stored sperm.
  - ➔ **Ovaries.** Located in the dorsal rear section of the abdomen. Each **ovary** contain 130-186 tubular **ovarioles** for up to about 360 total. Egg cells start development at the tips and continues as it moves down the tubes.
- ➔ **Various related glands, organs, and muscles.**
  - ➔ **Malpighian Tubes** – Remove metabolic waste products from the blood. Approx. 100 of them in the honey bee abdomen.

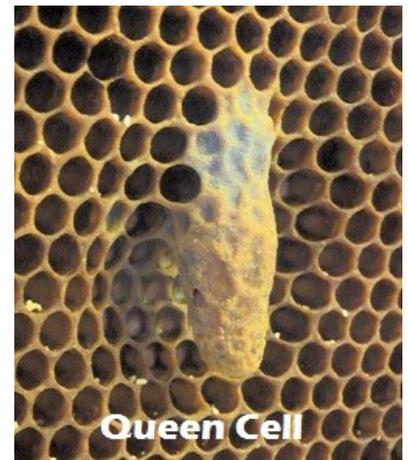
## Differences between castes of bees.



### Parts Unique to Queens

#### Head

- Antennae: has 12 segments.
- Mandibles are larger than worker mandibles
- Has smallest compound eyes made up of 4,000 ommatidia
- Only Queens produce Queen Substance in their mandibular glands. This is used to inhibit queen rearing by Workers.
- Queens have a gland on the rear abdominal dorsal surface which secretes a pheromone to attract attendant Worker bees to her.



#### Abdomen

- **Sting.** Used by the queen to place eggs specifically within a cell. More securely attached, longer and more stout than a worker sting. Curved with fewer barbs.
- Nassanoff Gland is undeveloped.
- Have up to about 360 ovarioles to produce eggs.

## Parts Unique to Drones

### Head

- Antennae: has 13 segments.
- Mandibles are smaller than worker mandibles
- Has largest compound eyes made up of 8,000 ommatidia

### Abdomen

- Sting. Drones do not have a sting as they are born without one.
- Nassanoff Gland is undeveloped.

## Parts Unique to Workers

### Head

- Antennae: has 12 segments.
- Compound eyes made up of 5,000 ommatidia
- Workers produce a secretion that is not Queen Substance in their mandibular glands that aids in preparation of wax, it is the principal component of larval food and contains some type of alarm pheromone.
- The Hypopharyngeal gland in Workers produces the enzyme Invertase which is used to convert sugars while nectar ripens into honey.

### Abdomen

- **Sting.** Workers have a sting which while still a modified ovipositor, it not used commonly to lay eggs as workers are generally not intended to lay eggs. Straight with multiple barbs.
- Nassanoff Gland is fully developed only in Workers.
- Wax glands are found only in Workers to produce beeswax.
- Spermatheca. Workers have a vestigial, non-functional spermatheca and are missing other reproductive/genital structures that the queen does have.
- Have about 20 or fewer ovarioles to produce eggs.

## Physiology

### Diet

Diet is critical to honey bee life and activity. Nutrition is key to performing very specific activities and the timing of them. They are natural vegetarians. Their sole nutrition comes from the consumption of nectar, honey and pollen. Nectar and honey typically provide the carbohydrates bees need. Eating pollen provides the fats (lipids), minerals, proteins and vitamins needed for development. Bees eat LOTS of pollen in their first two weeks after emergence. After about 14 days, they switch over to a diet primarily based on honey and nectar. It is notable that in those first two weeks, the Workers bees spend most of their time as nurse and attendant bees, caring for and feeding the brood and Queen.

Water is also critical to a colony. Water helps dissolve solid foods to be eaten as well as aids in food digestion and metabolizing. Water is also used to breakdown crystallized honey in cool weather and to help cool the hive with fanning in warm weather.

### Temperature

Honey bees are cold blooded insects. Temperature is key to life. In order to fly, it must be about **50° F** in order for bees to fly. The weaker the colony in terms of number of bees in the colony, the longer it takes for them to get started flying on cooler days. Weaker colonies may not normally start to foraging until it reaches about **60° F**. This is at least partly related due to that bees need to maintain a thoracic temperature of about **80° F**, that is, they must shiver their wing muscles to warm up their bodies until internally, they are at least about 80° F. When it's cooler temperatures outside, it is more difficult for lower population colonies to have bees get warmed up very rapidly as there are fewer bees in the cluster to maintain a higher cluster temperature. This means the individual bees have to work harder to warm up to start flying than bees in a larger, more populous colony.

The broodnest temperature affects worker bee development. Brood in the warmer center of the broodnest develop a bit sooner than those in cooler outlying areas of the broodnest. The more consistent and warm it is maintained, usually in the center, the better for brood development.

### Circulatory System

The Circulatory system of the honey bee is quite interesting. Bees have a 5 chambered heart pumping blood, (called **Hemolyph**) through the body. The **Heart** is in the Dorsal front part of the abdomen and connects to the **Aorta**, which is a pump that shunts blood to the bee's head. Hemolyph does not carry oxygen but it does transport Carbon dioxide. It is transporting nutrients and hormones mostly throughout the bee's body to the organs though it is collecting metabolic waste as well.

The Heart is connected to the Aorta as part of a continuous dorsal blood vessel that extends into the head. It pulls blood in from the body through the slits (2 in each chamber for a total of 10) called

**Ostia** which allow blood in but only inward, preventing it from “backflow” out through the Ostia. The heart then pumps the blood taken in and pumps it anteriorly toward the Aorta and head.

## Nervous System

I am going to discuss other sensory systems in this area as with honey bees, many of these are related or share anatomical traits. In general, Honey bees there is a **Central Nervous System** consisting of the **Brain**, and a ventral **Nerve Cord**. From the main nerve cord “trunk” are 7 nerve masses called **Ganglia** throughout the bee’s body. **Nerves** are running throughout the bee’s body, connected to various external receptors.

## Hearing

Honey bees don’t have any auditory sense receptors found so far. It is generally taken that bees can only “hear” via air waves vibrations felt through their feet and their bodies perhaps. Their legs do have special receptors to detect such vibrations.

## Vision

Having both two larger **Compound eyes** and three smaller Ocelli or “Simple eyes”, bees are able to see a great deal more than we are able to. Combine that with other sensory reception and you have the amazing Honey bee GPS system naturally built in. Their compound eyes allow for seeing images, and light quality as well as seeing the ultra-violet spectrum and polarized light. The **Ocelli** are capable of helping see the changes in light intensity. Bees have trouble seeing colors at the Red end of the color spectrum.

The compound eyes, being composed of thousands of segments each having its own lens (ommatidia) and having hairs growing from between the segments not only see when they are flying, but the combined sensory input allows them to adjust their flight for wind speed while they look for where they want to go.

## Touch, Smell, Taste

Believe it or don’t, most of these three functions are all combined into the sensory organs of the antennae. The honey bee’s antennae have 12 or 13 segments with various multiple sensory receptors built into them to allow for the sense of touch and sense and to a limited extent, even perhaps taste. The actual sensory receptors are found not at the base of the antennae but near the top of them.

Touch is also accomplished with the nerve endings attached to the ends of the body hairs that cover the bee’s body below the exoskeleton. When those hairs are moved by air or come into direct contact with something, it is part of how bees feel the sense of Touch.

Honey bees secrete a wide variety of chemical pheromones to communicate with. The sensory receptors in the antennae are attuned out picking out the specific scents and identifying them.

## Reproductive System

Worker reproductive systems are severely limited and not intended to allow Workers to mate or reproduce. All Workers and Queens have two **Ovaries** but only the Queen's are fully functional with a high number of **Ovarioles** to make eggs. Workers have radically fewer ovarioles, at least about 2 to 4 and as many as about 20 compared to the Queen's nearly 200 or more.

Queens that go to mate with Drones will store sperm obtained from those drones in the **Spermatheca**. There the sperm are kept alive and provided with necessary nutrients from the **Spermathecal Gland**. The eggs form in **Ovariole tubes** and as they move down, they continue to develop.

Queens use their **Sting**, which is actually a modified **Ovipositor**, to deposit the eggs specifically and carefully within the cell as she goes about the comb doing her maternal duties. The Queen's Sting is curved and long with a bit of a groove along it to allow the egg to "slide" precisely to where it needs to be placed and hold it there temporarily until it is firmly in place.

## Digestive System

Bees take various foods in both solid and liquid form in through their mouth,. They use the **Mandibles** for solid food like pollen and the **Proboscis**. The Proboscis made up of separate parts called the Maxillae and the labium, that when formed, acts as a sort of a piston with the tongue inside of it, drawing liquid up. The **Cibarium** then pumps it through into the liquid through the **Oesophagus**, which leads to an organ called the **Crop** or "Honey Stomach" (though it is not actually a true stomach).

The Crop acts as a storing area for liquids to be taken back to the nest. From the Crop, the **Proventriculus** sorts out solids, like pollen, from liquids and prevents liquids to be regurgitated for hive use from interacting with digestive content from the true stomach. (this is why honey is not actually "bee vomit", because vomit, medically speaking, includes digestive content from the stomach that is regurgitated.)

Once past the Proventriculus, it enters the **Ventriculus** or "Mid-Gut" for digestion by the bee. In the Ventriculus, there are digestive enzymes and juices that are produced by the cellular lining. The digested food moves through the small intestines and is dispersed into the body of the bee. The waste is moved to the **Rectum** where **Rectal Pads** remove water from the waste.

The **Malpighian Tubes** extract metabolized material from the hemolymph in the body of the bee to be eliminated as well. The Rectum can expand and retain waste for prolonged periods until the bee leaves the nest to eliminate the waste so as not to pollute the nest environment. From there, waste is eliminated via the **Anus**.

## Respiratory System

The Honey bee takes in oxygen through 10 pairs of holes called **Spiracles** along it's sides in the Thorax and Abdomen. There are tiny muscles behind the holes that can contract/close so the bee can essentially "hold it's breath" for short periods of time. The oxygen is carried through little tubes called **Trachea**. Trachea tubes have endings all throughout the bee's body are called **Tracheoles**. This allows air to be brought in and directly distributed to all the internal parts and organs within the bees body. It is the primary basis through which bees conduct exchange of oxygen, carbon dioxide and even some water vapor.

There are some Trachea that lead directly to **Air Sacs** located in the dorsal areas to the rear of the Thorax and the front of the Abdomen. The Air Sacs are instrumental in providing increased oxygen flow to the body and particularly the nearby wing muscles during vigorous activity by the bee such as when flying.

## Flight

I would be remiss if I didn't address how bees manage flight seeing as it is one of their most obvious activities. The large dorsal muscle mass, the Wing Muscles, is located entirely within the Thorax. The wings of the bee are connected to the muscles directly.

The legs by which the bees walk, climb, crawl and handle things are also entirely connected at the Thorax.

The wings on each side work together while flying. The two pairs are connected together (the Fore Wings and the Hind Wings) by a sort of "bee Velcro" called **Hamuli**. This coupling of the wings can be done at will by the bee either to connect the wings for flight or to disconnect the wings for other uses when not in flight.

Bees wings don't just "flap" up and down like a bird. They actually move at the tips in sort of a figure 8 formation during flight. They use a variety of movements of the wings going up and down, forward and back and even somewhat rotary or circular movement depending on the flight action of the bee. This allows bees not only to climb in the air to go higher or to descend but to hover in place as well.

## The Sting

The Sting consists of multiple parts and is not just one “needle” type part of the bee. It has 3 separate parts. These are the Stylet which a bulb shape on the inside end and comes to a pointed shape toward the bottom. There are two Lancets which connect to the bottom of the Stylet by some type of “sliding” attachment.

The Poison/Venom Gland makes the venom bees inject through the Sting. It connects to the Poison/Venom Sac which stores it to have ready. Alarm pheromone is created by cells lining the sting “chamber” in the abdomen. Another gland that is connected is the Alkaline or Dufour Gland. It contributes a secretion into the sting with the venom from the venom sac. Not much is really known about what the secretion really is for. It is usually taken that the secretion aids somehow as lubrication for the Sting. The Sting itself actually works in a piston or reciprocating saw fashion where the two lancets slide up and down, against each other while the venom sac squeezes and injects venom through the Sting.

## Wrap Up

In order for beekeepers to best identify what they are seeing in a bee or in a bee colony. In order to best try to anticipate progressive steps or actions by bees and bee colonies, it is absolutely necessary to know and understand as much as we can about what bees are and how they function.

This is important for all beekeepers but perhaps moreso for Organic beekeepers who are relying on more prevention and early intervention methods based on what the bees are doing and how they do it.