Beekeeping Basics

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Part 4:
Honey Bee Biology and Behaviors

Honey bees are living things, and they require some care and attention, just like pets and livestock and people, to keep them at their best and most productive. Scientists sometimes describe a bee colony as a **superorganism**. While made up of many thousands of individuals, the honey bee colony appears able to act and make decisions almost unanimously. Each bee will take turns doing different specific tasks in the hive, which typically change every few days as they age, following a general pattern of development, but allowing them to adjust these behaviors as circumstances dictate.

A honey bee colony cooperates to **gather food** and other resources as needed. Even though the spring bees will literally work themselves to death doing it, they labor tirelessly to store up surplus honey so that other bees will survive the next winter when flowers are not available.

Bees also cooperate to very effectively **defend** their home. When a hive is disturbed, numerous bees are immediately alerted to danger and respond by being ready to sting if necessary. Stinging is usually fatal to a honey bee, but individuals are more than willing to do so selflessly if it will protect their family and their colony as a whole.

And while only a mated queen bee can produce fertilized eggs to keep her colony going, the entire bee colony reproduces by splitting in half and forming a new colony. This is known as a **reproductive swarm**. It's a natural and normal phenomenon, that ensures the survival and the range of their species, but this is one behavior that beekeepers often try to suppress, because it can deplete the workforce in our hives at the beginning of the honey-producing season. So while beekeepers generally try to prevent swarming in the colonies they manage, they also usually welcome capturing a swarm they discover as a way to increase the number of colonies that they have.

Honey bees are **social insects**, and are highly dependent on each other. There are many solitary bee species, with individuals who create a nest, rear a few offspring and then die out each season. Those offspring spend most of the year dormant, and emerge for a short time to repeat the cycle. But by cooperating together, a honey bee colony with many thousands of members can accomplish a lot more. They can raise brood nearly all year round if the weather permits, and they can store up a large amount of surplus food, as long as resources are available. And the pollination service that bees provide to both agricultural crops and wild plants is practically immeasurable.

While some people may consider them to be livestock, honey bees don't really behave like other livestock does. You can't fence them in; they need to be able to come and go as they please to collect their food over a very large territory, in a radius of up to three miles or more from their hives. They take care of their own needs pretty well. They have been caring for themselves much longer than we have been trying to manage them. And most of the problems that honey bees are currently experiencing are a result of changes that humans have made to land management, agricultural practices, and the movement of plants and animals, including honey bees and their associated pathogens and parasites, around the globe.

We can convince bees to nest in the hives that we provide for them, and we can try to manage their activities, but we should remain aware that the honey bee is still very much a wild animal, and will often seem to make their own decisions that can be contrary to our own wishes. We can take a portion of their surplus honey as long as we leave them sufficient stores to survive the winter. Honey bees are highly efficient in everything they do. And successful beekeepers will learn to work with their bees, and help them accomplish their own instinctive goals throughout the seasons.

In the **spring**, bees respond to warm weather and abundant food by increasing their population to swarm, so that both resulting colonies can take advantage of the favorable conditions to build up their numbers and their food reserves to successfully survive the next winter. We can help them out by adding honey supers, to increase the volume of a hive for food storage. We can also split the colony, essentially creating an artificial swarm, so that each resulting half has a good safe, dry home, and can be immediately productive, which can curb their natural instinct to swarm. In the **summer**, bees need water to drink and to keep their hives cool. We can help them by ensuring hives are properly ventilated, but still secure from intruders, and by providing them with a clean water source nearby, to reduce the effort they must expend to maintain an appropriate temperature in their hive. In the **fall** we can make sure each colony has sufficient food, and that each hive is dry and solid, and ready to withstand the **winter** conditions in the local climate. And throughout the season we should continuously monitor all colonies for health and productivity, and be able to provide them with all medications (if necessary) or to correct other problems as quickly as they are detected. But all of our activities work best when we can try to anticipate and support what the bees already have in mind.

There are **three types of honey bees** in our hives: the **queen**, the **workers**, and the **drones**. Each is an important part of honey bee society, and each has its own role in keeping their colonies thriving.

The **queen bee** is a reproductive female. There is usually only one per colony. Occasionally a beekeeper might see two or more queens in the same colony, but this is not common. It is likely observed when the bees are in the process of replacing an aging or failing queen with a younger one (a process called **supersedure**). The situation is likely temporary, while the workers evaluate their sister as a new queen before getting rid of their mother. They do this to avoid being without a queen, and thus slowing the population growth in the hive or risk not being able to successfully rear a new one at all. Having multiple queens at once in a hive may be more common than we realize, because usually once a beekeeper spots a queen, they generally don't look for another one.

The queen honey bee is the **mother** of the entire colony. A bee colony can have anywhere between 20,000 and 60,000 members, but they are all her daughters! A queen bee can lay more than 1000 eggs every day. Some estimate even 1500 or more. In order to maintain such a high level of egg production, a queen must eat a lot! She may consume many times her own body weight each day, and will eat only a single food for her whole lifetime. This food, called **royal jelly**, is secreted by the worker bees from special organs called **hypopharyngeal glands**. This jelly is a highly nourishing, energy-rich blend of proteins and amino acids, carbohydrates, vitamins and other nutrients. Workers must consume a lot of **pollen** in order to metabolize this special food. They also feed a similar jelly to each young larva. This is done primarily by young workers called **nurse bees** whose job it is to tend (or "nurse") the queen and developing brood. A well-cared-for queen bee can last for several productive years. Some beekeepers anecdotally report having good queens for up 5 years, but queens are generally replaced by a colony after no more than two or three years – often without our notice. Some beekeepers choose to replace their queens each year, to maintain healthy young egg-producers, but this is not really necessary. Your bees usually know when it's time for a change. Although if you detect a colony does has a failing queen, replacing her can certainly help the colony begin to thrive again.

Besides eggs, a queen bee also produces a number of important **pheromones**. These are chemicals that convey specific messages and are passed from the queen to the workers as she is fed and groomed by them. These workers, in turn, transfer these pheromones to additional bees. Worker bees constantly share food with each other, and with drones, throughout the colony. As this food is shared, these pheromones are passed around from bee to bee, eventually reaching every member of the colony. These compounds convey to other bees some important information about the status of their queen and her health. Through this interaction, every bee in the hive will take on the distinct odor of their queen. Her pheromone is actually a complex blend of multiple chemicals, the precise makeup of which varies slightly in each individual queen. So while they may all appear the same to us, the sensitive antennae of a honey bee can recognize a distinct difference between two queens. And because the worker bees smell like their queen, they can recognize whether another bee belongs in their colony or not.

The aptly named **worker bees** are all females, and they do essentially all necessary tasks in the bee hive. These workers do all the housecleaning. They remove dead bees and other debris to keep the hive clean and sterile. They also clean individual brood cells after a new bee has pupated and emerged, to make it ready for the queen to deposit another egg. The workers tend to all the brood, feeding them almost constantly during their early development. The workers feed and groom their queen bee as well, dispersing her pheromones throughout the hive. These bees also metabolize flakes of beeswax from special glands on their abdomens, which they use to build and repair the honey combs. Worker bees also regulate the temperature in the hive, keeping the brood nest just right for incubation – around a constant 93°F (34 C). Only these female worker bees will visit flowers to pollinate, and bring home the nectar and pollen, water, and propolis that a colony needs. They also work hard to transform the nectar they collect into honey. And if you have ever been stung by a honey bee, that was also a female. Workers bees are the only ones equipped with a **stinger**. A queen bee does have an **ovipositor**, an egg-depositing structure, which she can use to defend herself, but hers is smooth and is not fatal to her if she does use it. The ovipositor of a worker bee has been modified to become a barbed stinger – a very effective weapon for colony defense with which beekeepers may become very acquainted.

Male honey bees are called **drones**. They have thicker bodies and larger eyes that meet at the top of their heads, and wrap around to their chins. Their appearance is very distinct from their sisters, and some new beekeepers may mistake one for the queen. Drone are all potentially reproductive, although the vast majority of drones will never have the opportunity to successfully complete the only job nature has assigned them. The male bees don't participate in any tasks inside the hive.

They don't clean, don't tend brood, don't produce beeswax, don't pollinate, and don't forage for food. These drones can't even sting to defend the colony. Their only purpose is to mate with a new queen bee, providing genetic diversity for the honey bees' society. Those drone that are successful in mating will die immediately afterward. Those that aren't can try again hopefully each day, but will eventually be expelled from their hive as winter approaches, and soon die as well. The workers refuse to feed and care for those drones during the cold months, but a healthy colony will begin producing more drones again in the spring, as soon as temperatures are warm and flowers become abundant.

A queen honey bee looks similar to the workers, but with a much longer abdomen, which may often lack distinct stripes. She can be hard to spot, because she is elusive, preferring to hide from the light, and is often covered up or surrounded by workers. A colorful dot of paint makes a queen much easier to notice.

Beekeepers actually have an **international queen marking color code** that tells us how old a particular queen is. The color corresponds to the last digit of the year in which the queen was mated, and the five color repeat every 5 years, since it's unlikely that a queen will survive that long. These paint marks are pretty durable, but they do wear away slowly. If you are diligent in keeping your queens marked, and suddenly find an unmarked one, you have likely had a **queen event** happen in your hive – this means that the colony has replaced her with a new queen. They usually do this because they detect that she is aging or otherwise failing in her duties to the hive. Or, perhaps your queen was in excellent condition, and was so prolific that she left the colony with a swarm after initiating the process of rearing a daughter queen to take her place.

There are numerous devices you can purchase to capture and hold your queen carefully to mark her. Many people simply pick her up, mark her, and put her back down. This is best done with bare hands, and should not be attempted with thick leather gloves. You must handle a queen bee very gently. If you injure her, she may become useless for egg laying, and the colony will quickly supersede her. If you don't feel comfortable handling an individual queen bee, practice with drones. They are easy to spot on the comb, and can't sting you. And there are usually plenty of drones to spare.

Workers will generally not rear a new queen bee in a colony that has a healthy egg-laying queen. The workers constantly evaluate their queen based on the amount of pheromone she is producing, and they are receiving from her. A healthy young queen produces a lot of queen pheromone, or queen substance, but an old or failing queen produces far less, and is more likely to be replaced. A poor queen may produce enough pheromone for a small colony, but in a more populous colony, that amount of pheromone becomes more spread around, so that each bee receives a progressively smaller share as the colony gets larger. And this can ultimately lead to the production of a new queen.

New queen bees will be reared in distinct vertical cells rather than the usual horizontal brood cells in the honey combs. These cells are usually between one inch to an inch and a half long, although sometimes the whole cell may not be easily visible. They tend to have a bumpy texture on the outside similar to a peanut shell. These cells can be found anywhere on the comb, but they are often built along the bottom or sides of a comb, near the brood nest, but they may occur anywhere the comb has been damaged or poorly drawn out, and comb edge is visible. Their location can sometimes give us a clue about why the bees are rearing queens.

New queens are only produced under certain circumstances. If the queen is perceived to be failing, workers will rear a new one to replace her. This is known as **supersedure**. In this case, the population usually does not build up too large because the queen herself is producing fewer eggs. Recognizing that she is doing a poor job, the workers locate brood cells with very young larvae and provision them with ample royal jelly. They also add beeswax and elongate these cells out from the surface of the comb, and then draw them down, transforming them into vertical queen cells. These may be found anywhere within the brood nest. Once a new queen has emerged, mated, and proved herself by beginning to lay eggs, the workers will surround and kill their old queen, with no interruption to the brood cycle. Hopefully, the colony will soon thrive with a healthy new queen in place.

If the hive has a good queen, who is laying abundantly, then population can increase quickly. This usually happens in the spring when flowers begin to bloom, and the workers can bring home copious amounts of fresh pollen. They are able to feed the queen a rich, nutritious diet of royal jelly, and she responds with increased egg production. If the queen begins to run out of empty cells to lay in, she will seek out **queen cups**. These are small shallow cells that are naturally found on the bottom edges of a comb, where it rounds over to the other side. They may also be found on the sides of combs, or anywhere a comb has been damaged and rebuilt, or poorly constructed to start with.

If a queen deposits an egg into one of these queen cups, which are oriented downward, instead of horizontally, the workers will automatically respond by trying to rear these larvae as new queens. They will elongate the cells and supply them with abundant royal jelly. You can often observe a number of these cells at different stages of development. As the first of these new queens nears maturity, the colony prepares to **swarm**. The old queen will typically leave the hive with up to two-thirds or more of the worker bees, and some drones. They will seek out a suitable cavity in which to build new beeswax combs and found a new colony. The daughter queen will emerge and inherit an established colony, still full of brood and food and numerous workers to serve her. Over the next few days, she will leave the hive briefly to mate, then she will return and begin producing her own eggs. She will never leave the hive again, unless she eventually departs with a future swarm as well.

In the event that a queen bee suddenly dies or disappears – either naturally or because of beekeeper activity – then there will be no other bee in the colony capable of producing **queen pheromones**. Amazingly, within a little as 4 hours, the workers can recognize the sharp decline in queen pheromone level within the hive. They respond to being queenless by selecting a number of young larvae, which have only been fed on royal jelly so far, and enlarging their cells and feeding them more. These are known as **emergency queens** and represent the only chance for this colony to produce a new queen and continue their livelihood. If they don't succeed in producing a viable queen within a few days, all the brood in the hive will soon be too old to raise as queens, and the colony population will begin to dwindle away to nothing.

Beekeepers can also use these natural instincts of the bees to encourage a colony to rear queens on purpose, and in any number, by presenting a queenless colony with suitable larvae in a downward orientation. Recognizing that they are queenless, these bees will be eager to rear a new one before it is too late. They will often rear multiple queen cells at once, to ensure success, even though only one, usually the first to emerge, will typically kill all her rivals.

Raising quality queen bees is a good skill for beekeepers to master for its own sake. Queens sometimes need replacing, and can be expensive to purchase, and may not always have them available. If you can raise your own, you can replace those your colonies have lost, you can use them to split colonies, and you can also provide them to other beekeepers. Queen breeding takes practice and must be done on a precise schedule that matches their biological development. But good queens are usually in high demand all season, and selling them can be a good side business for extra income. Good queen producers should always try to improve their stock by breeding from their strongest, healthiest colonies, and continue to select for the best traits over successive generations. For specific and detailed information on queen bee production, download a free copy of the publication **MP 518 ("Rearing Quality Queen Bees")** from the University of Arkansas Cooperative Extension website.

Mating and reproduction in honey bees was poorly understood for many years because it happens outside the hive, far away, and high in the air. On sunny days, **drones** spend a good part of their time visiting sites called **drone congregation areas**. These sites are somewhat mysterious. Scientists are still not completely sure why these areas tend to develop in specific places. But these sites collect drones from multiple colonies around a given area, and seem to have very distinct boundaries. The drones leave their hives almost daily, to fly around and around in these congregation areas, hoping to encounter a newly emerged queen bee. If they do not, they will return to their hive to eat and rest and may try again later the same day or the next. Drone bees live only one season, but next year's drones will be instinctively attracted to these same locations, and will repeat the same patterns of behavior.

Young virgin queens put themselves at substantial risk to avoid inbreeding. After emerging from their pupal cells, they may spend a few days in the hive eating and getting stronger, but will soon take one or more mating flights. A **virgin queen** will fly to a drone congregation area, which she will also instinctively know how to locate. Drones typically stay within a half mile or closer to their colony, but a queen will seek out a more remote congregation site, up to a mile or more away, to reduce the possibility of encountering one of her own brothers as a potential mate. This may seem unfair, but it take far less honey to fuel thousands of drones on short daily flights, and send a new queen on a few long-distance flights to avoid them, than to have a virgin queen take a few short, safe trips while making many drones fly much farther every day. Just as foragers and drones face many hazards every day, a new queen risks being eaten by a bird or other predator, or sometimes simply gets lost returning home.

While their journeys are perilous, most new queens do survive, and will take one or more nuptial flights to these drone congregations areas over the course of several days. They will usually mate repeatedly during these trips, with different drones each time. For drones, mating is a one-time occurrence, and they will die quickly afterwards, having actually lost a significant piece of their anatomy in the mating process. The queen stores the genetic contributions from each of her drone suitors in a special organ in her abdomen called the **spermatheca**, which actually mixes the drones' semen and keeps the spermatozoa alive and viable for several years. This allows the queen to continually produce eggs, and fertilize them as needed, without having to go back outside the hive and take more risky mating flights.

A queen bee may mate successfully with only a single drone, or with as many as 40, but the average is around 15 times. This promiscuity can actually be highly beneficial for a colony by ensuring genetic diversity in the queen's offspring. While the many thousands of colony members descend from their mother, the queen, there are usually numerous patrilines in the colony, with slight genetic differences that may go unnoticed during favorable circumstances, but may be highly beneficial to the colony if it is challenged by pathogens or other environmental conditions. Having a portion of the colony that is resistant to disease or more tolerant of mites or better able to withstand other changing conditions can give the bee colony an advantage that helps it to survive adversity and ultimately thrive.

If we compare a worker bee and a queen bee, they are fairly similar in size except for the abdomen. This is the part that contains most of their internal organs. And in a queen bee, the abdomen is filled largely with her well-developed ovaries. As she lays an egg, the queen bee can release sperm from the spermatheca to fertilize the egg while it is being deposited in a cell. Amazingly, a queen bee is able to choose somehow whether to lay a fertilized or unfertilized egg. A fertilized egg will develop into a female bee – usually a worker, but potentially a new queen. However an unfertilized egg can also develop – into a drone bee. This means that drones are "**haploid**" – they have half the number of chromosomes as a "**diploid**" worker. As a result, a drone has no father, but he does have a grandfather. Because his mother, the queen, did have a father. This is known as **haplo-diploidy sex determination**. It sounds strange, but it's not uncommon in insects and some other creatures.

Honey bees all follow a similar **pattern of development**. A queen deposits a single egg in a honeycomb cell, which will hatch in about 3 days. The larva then feeds almost constantly for the next 6 days, molting (shedding its skin) about once a day during that time. All honey bee larvae are fed exclusively on nutritious jelly for the first three days. After that, most will be switched to a diet we call **bee bread**. This is a mixture of pollen and honey that the bees store in cells around the brood nest. Sometime on the 5th day of their development, the nurse bees will pack in some extra food and seal the cell with a wax lid called a **capping**. The capped larva will spin a cocoon and undergo complete **metamorphosis**. Over the next 12 days, the larva will grows wings and legs, eyes and antennae, and all kinds of other useful parts. Then, about three weeks after the egg was deposited by the queen, a new adult worker bee will chew a hole in the capping of her cell and emerge, ready to begin her life and career as a productive member of the honey bee colony.

If the workers continue to feed a female larva with ample royal jelly after the third day, instead of changing her diet to bee bread, she will automatically develop into a queen bee. There is no genetic difference between a worker bee and a queen. But different genes are turned off and on during their development, all controlled by the quality of the diet the larvae receive. So every female egg has the potential to become a new queen bee if it's treated like royalty. However, most female eggs will simply develop into more workers.

It takes 21 days for a worker bee to develop from an egg. And she will live for only 4-6 weeks in the spring or summer. All the work she does, particularly the flying and foraging, simply wears out her body. She literally works herself to death. A winter bee can live for 4-6 months because they don't spend all their time flying. They remain mostly in the hive, taking turns keeping each other warm.

If the bee is a drone, he follows a similar developmental pattern, but he will remain in the pupal stage for about 15 days, so it takes him a total of 24 days to reach adulthood. This may not seem significant, but it can be important when we consider the number-one enemy of the honey bees: the **varroa mite**. These mites are parasites that feed directly on the honey bees, and can reproduce only in sealed bee brood cells. The mites enter the cells just prior to being capped, where they remain hidden and protected, and their feeding causes particular damage to developing pupae.

Because drones remain in the capped pupal stage for 3 days longer than their sisters, these varroa mites are able to have more offspring if they enter a drone cell than a worker cell. For this reason, the mites are particularly attracted to drone brood, which they recognize by keying in on odor cues. Beekeepers can use this behavior against them by trapping the parasitic mites in the sealed drone cells. We'll explore this in more detail in a later lesson on hive pests. Drone bees live for one season – anywhere from a few weeks to a few months. If they are successful at mating, they die immediately, if not, they may be eaten by a predator on one of their many daily flights. Otherwise they are usually ejected by the workers in the fall. They not usually allowed to stay in the hive, consuming honey, throughout winter. But a healthy colony will always begin producing more drones in the spring when food is more abundant.

Queen bees develop very rapidly, completing the entire cycle of development from egg to adult in only 16 days. They are fed a very rich, highly nutritious diet that speeds up their growth. Also, if the colony needs a new queen, they want to produce one quickly, to minimize the break in brood production. Beekeepers should also be acutely aware of the development cycle of the queen, in case they need to raise new ones. Queen breeders must learn to separate capped queen cells into separate colonies – often called mating nucs – at the right stage, otherwise a single queen that emerges early is likely to kill all the other developing rival queens. A healthy queen is said to be able to live up to 5 years, but 2-3 years in one hive is still an excellent career for a queen bee. Queens are probably replaced through swarming or supersedure more often than beekeepers are aware.

When workers emerge as adults, they tend to follow a predictable pattern of chores in the hive. The youngest bees are **nurse bees** and they remain close to the safety of the brood nest, cleaning brood cells for a day or two is usually one of their first jobs. They also begin to feed bee bread to the older larvae, and probably consume quite a bit themselves. This is why a bee colony stores bee bread around the brood area – so it will be located conveniently for the nurse bees. Consuming this rich diet stimulates their **hypopharangeal glands**, which produce the **royal jelly**. Once these glands have become active, the workers will shift their duties to tend and feed the youngest larvae, and the queen, who all need this food. As they get a little older the bees begin to do other chores inside the hive, and are sometimes referred to as **house bees**. They accept the nectar from foragers, and help to process and store it in honey cells. They also begin to secrete beeswax, which is used to construct or repair the wax honeycombs. They will soon begin taking brief orientation flights outside, staying near the hive. They also spend time near the entrance as **guard bees**. Their job is to intercept bees trying to enter the hive. They can recognize their nest-mates because every bee in their hive should smell like their queen, while bees from other hives smell like a foreign queen. Their job is to prevent strange bees from entering the hive. They should also try to keep out other insects and predators. Larger animals, such as skunks, badgers, bears, and even beekeepers are first met by these guard bees. These bees give off alarm pheromone, which alerts other bees that there is potential danger, and they may sting to drive off the intruder, even at the peril of their own life. The final job for the worker honey bee is that of **forager** or **field bee**. These bees will keep this job for as long as they last, which is usually less than a couple of weeks. It's a physically strenuous job, and there are many dangers outside of the hive. Most of these bees will fly out one day and simply not return. Those that do return every day only to die in the hive eventually will simply have their bodies dragged to the entrance and unceremoniously tossed outside before it can become a source of contamination to the colony.

If we take a closer look at a worker bee, we can really begin to appreciate what a remarkable creature this truly is. You may have heard the phrase "the bees knees" in reference to something that is really cool or interesting. And honey bees do have some pretty cool knees and other parts. A honey bee is kind of like a Swiss army knife… everywhere you look on a bee, you can find adaptive features that functions as useful tools. Each pair of their 6 **legs** is different; each are modified with special structures to help them accomplish various tasks in and out of the hive at different times.

Most insects have two pairs of **wings**. Honey bees have a large pair of **forewings** and a slightly smaller pair of **hind wings**. On bees there is a special row of tiny hooks called **hamuli** on the hind wing that latch onto a groove in the forewing, hooking them both together and creating a large flight surface. But the bees can also unhook their wings and fold them back out of the way when at rest. Bees are very efficient, graceful fliers. Their wings can beat over 180 times a second, crating the familiar buzz that they are famous for. And they can easily fly faster than 15 miles per hour. If you ever thought you out-ran a bee, you've been kidding yourself. You simply moved far enough away from the bee or its hive that it was no longer concerned about you. Bees really have no interest in stinging us unless they feel threatened or provoked. They are, of course, ready and willing to stand up to another creature many times their own size if they feel they need to defend themselves or their colony, but they would rather intimidate us into leaving than to sting, which is usually fatal to themselves.

Bees, like most insects, have large compound eyes. Each of these eyes is composed of an estimated 6,700 individual lenses called **ommatidea**, which wrap around their heads and give them a very wide-angle view of the world – about 280 degrees (humans, by contrast, see about 120 degrees in our field of vision). Having compound eyes mean that bees don't focus their attention on a single point the way we see the world, but their eyes give them a mosaic view of their surroundings, relating a tremendous amount of information at once, and giving them a good sense of depth, color and movement. Honey bees can see all the colors we can except for red – their eyes simply don't detect that wavelength of light. Red flowers are more often pollinated by butterflies or hummingbirds, but not bees. However, bees can see a color that we cannot see: **ultraviolet**. So their range of vison is simply shifted down the scale of visible light from what we can detect. We don't know exactly how the world appears to honey bees, but we can detect their spectrum with special cameras, which shows us that most flower petals actually have patterns of UV-reflecting pigments, called **nectar guides** which stand out brilliantly to bees, and help them to spot flowers in the landscape more easily, as well as creating a bulls-eye on the flower that directs the bee to the nectar reward. So, while honey bees can't detect red, they can see these UV patterns on red flower petals, and may be attracted them to visit some plants with red blooms after all.

Honey bees must navigate long distances to and from their hives every day, and they use the position of the sun as a reference point. And because ultraviolet light can pass through clouds, bees can navigate even on a cloudy day. Honey bees even have the ability to detect the plane of polarization of ultraviolet light, which helps them to stay on course when on a long flight away from their hive.

Honey bees also have three simple eyes in the middle of their foreheads called **ocelli**. These small eyes don't focus on an image, but do detect light intensity, and probably help a bee to orient in relation to a light source, such as the hive entrance, or perhaps to the sun while in flight.

While vision is important, Bees and other insects use their **antennae** to provide all kinds of sensory input. A bee's antennae can be used to feel things in a dark environment, such as their hive. But they are also highly sensitive to odors – which are a very important part of the bee's world. Bees use a complex and efficient language of pheromone smells to communicate with each other in the hive. They are able to distinguish their own queen by her particular pheromone scent, which also permeates the entire hive and effectively labels all the members of her colony as belonging to her. Bees use their sense of smell to find food in the world outside the hive. And differences in brood pheromones tell nurse bees exactly what, and how much, to feed each of the larvae in the hive, and when to cap cells for pupation. The surface of the antennae are packed with highly tuned microscopic sensory cells that can pick up even faint traces of aromas in the air or on the surfaces of things they touch. They can even have fine hair-like mechanoreceptors able to detect airborne vibrations at close range, allowing them a very limited sense of "hearing."

A bee's antenna has a long first segment, with a distinct "elbow" joint where the rest of the flexible antenna attaches. The tiny **Johnston's Organ** is located here, in a small segment called the **pedicel**, and is believed to help perceive vibrations related to dance language, may help detect wind speed in flight, and may even help the bee to perceive weak electric fields generated by flowers and other living things. The antennae can also detect temperature and humidity, carbon dioxide levels, and help to orient the bee to gravity. A whole lot of the complex information that a honey bee perceives about the world around her comes in through these two thin filaments.

Because her sense of smell is so important, honey bees must keep their antennae clean. Nature has equipped them with a special notch built into the back of each front leg we call the **strigillis**, or antenna cleaner. A bee can clamp her antenna between this notch and a spur that extends from the adjacent leg section, and when she draws her antenna though, it cleaned off like a squeegee or a windshield wiper. It is named for a similar device, the strigillis, which ancient Romans used to scrape oils and dirt from their skin before soap was widely used. But the bees invented it first!

A worker bees secretes small flakes beeswax from a set of eight **wax glands** on the underside her abdomen. This is a metabolically intense process, and so the bees need to consume a lot of honey or other sugars in order to produce a relatively small amount of wax. If you are starting a new bee hive, or you have given your bees a lot of empty foundation to draw out, providing them with ample sugar syrup will supply them with the resources they need to create that wax. Also, a large volume of syrup or nectar coming into the hive stimulates them to build more comb, so that they will have a place to put all that new food. Worker bees collect these flakes and chew on them with their mandible, making them more malleable, and adding them to the work of other bees, to build and repair the honey combs.

The bees' mouthparts are very complex and versatile. They use their strong **mandibles** to soften and shape the wax into perfect honeycomb cells. These tough mouthparts open sideways, and are attached to relatively strong muscles inside their heads. Their mandibles are used manipulate wax, carry bee bread to the brood, to bite intruders in defense of the colony, and to carry out dead bees and other debris to keep the hive clean. There are also several glands associated with the mandibles that produce important pheromones and enzymes.

Behind the mandibles the bee has a long and complex looking **tongue**. When not in use, it folds back under what you might consider to be the bee's chin. The tongue is composed of several intricate parts, and has a lot of surface area that can help to lap up liquids like nectar, honey and sugar syrup. Colorful, sweet-smelling flowers are an attempt by plants to attract bees for pollination. The plants reward visiting bees with nectar, but this is usually hidden in the bottom of a flower, so bees must probe deeply with their tongues to find it. This puts them into contact with the flowers' anthers, which transfer pollen to the bees' bodies, and some of which will be hopefully be deposited on the receptive stamen of the next flower they visit.

A honey bee collects nectar from many flowers on each foraging trip, which will be transported in her **honey crop** or **honey stomach**. This is not a true stomach, but more of an elastic pouch at the bottom of her esophagus. A tight valve keeps the nectar from moving into the bee's actual stomach. No digestion takes place in the crop, so it is absolutely false to say that honey contains "bee vomit" as some people have wrongly claimed. The honey crop is a storage tank for the nectar, and more. It can also be a fuel tank for bees on long flights. If they need the energy, they can release some of the nectar into their actual stomach, the **ventriculus**, to digest and sustain their activity. When bees depart their hive when swarming, they will fill their crops with honey before they leave. They are effectively packing their lunches. The swarm is temporarily without combs of stored food, so they store it inside their bodies. Some bees will scout the area for a suitable home, but most of them remain fairly inactive, conserving their energy and resources, and sharing food with each other from their crops as needed.

The crop is separated from the stomach by an intricate valve called the **proventriculus**. This "gate" seals off the crop, but also actively strains out solid particles, such as pollen and even some bacteria, from the nectar. The solid pollen can be filtered out and pushed through into the **true stomach** and digested, leaving the liquid nectar in the crop very clean.

Food that enters the bee's true stomach, or **ventriculus** is digested for nutrients and energy. Anything that is not digested here will pass to the **hind gut**. This is analogous to a large intestine in mammals, and is where wastes are stored before getting rid of them. During warm weather, bee can do this regularly when they are out foraging. But honey bees must sometimes remain in their hives for weeks or even months during wintertime in cold climates. On sunny days bees might emerge from the hive to take a quick "**cleansing flight**" and empty their hind gut, but will immediately return to the warmth of the hive.

During warm weather, the older foraging bees return home loaded with nectar and distribute the contents of their crop to a group of younger bees still working in the hive. Their job is to receive the incoming nectar and begin processing it into honey. This division of labor efficiently lets the experienced foragers return with food and then leave again quickly to get more. Meanwhile the house bees "work" the nectar for several minutes, starting the process of chemically converting the nectar into honey. They will alternately move a droplet of nectar back and forth between their crop and holding it between their mouthparts. This accomplishes several things.

Honey bees carry beneficial bacteria in their crop, which are added to the nectar and help to keep it from fermenting while it is being turned into honey. The bees also add an enzyme called **sucrase** or **invertase**, to the nectar. **Sucrose** is the primary sugar component of nectar. Through a chemical process called **hydrolysis**, the enzymes break a chemical bond in the sucrose sugar molecules into two smaller sugars. This complex "**disaccharide**" sugar is broken into two simpler "**monosaccharides**" – **fructose** and **glucose** – which are the two main sugars that make up honey. The final step is to remove excess moisture. Fresh nectar contains a high percentage of water – perhaps up to 80%. The bees attempt to bring down the moisture level to below about 20% water.

Remove this water reduces the total volume of the liquid, so stored honey takes up much less space in the hive than freshly collected nectar. But more importantly, when the moisture level is kept below about 18.6%, naturally occurring yeast cells cannot become active, and cannot cause the honey to ferment, and it can remain stable in the comb for a very long time.

Some water evaporates as the bees work the nectar droplets, but they will soon concentrate it into honeycomb cells and finish the process by fanning their wings, creating air currents across the ripening honey, further drawing out additional moisture. Eventually, when they perceive that the moisture in a cell of honey is just right, and they will cap off that cell with a beeswax lid. The bees have invented canned food! The resulting stored honey is very stable, and has a long shelf life. During times when there are no fresh flowers in bloom, such as winter, or even during a period of summer dearth, the bees can open these cells and feed on the stored honey.

Honey is low in moisture, making it very **hydroscopic**. If the bees did not seal the honey in capped cells, it would soon begin absorbing moisture readily from the humidity in the air until it reached a point where it would begin to ferment. Beekeepers should only harvest honey from sealed combs, and store it in sealed containers as soon as it has been processed.

It has been estimated that an individual worker bee may produce approximately 1/12 of a teaspoon of honey in her whole lifetime. But bees in a hive work together, and by cooperating, a healthy colony might produce well over 100 pounds of surplus honey under good conditions.

So the next time you are enjoying a spoonful of delicious golden honey, you might think about how many times that spoonful has been in and out (and in and out and in and out…) of hundreds of individual bees before it ever reached your table. Or maybe you'd rather not think about it?

On the outside of a bee's abdomen are bold stripes. We think of honey bees as being yellow with black stripes, but there are actually many genetic variations of honey bee color patterns from yellow to reddish brown to dark brown, to gray and silver and almost black, but most do have visible stripes on their abdomens. These contrasting colors make them highly visible, and nature has put them there as a warning to say this creature is armed and dangerous! A honey bee is equipped with an effective weapon – the stinger. Other bee species, as well as wasps and hornets, have a smooth stinger which they can use multiple times. The stinger of a honey bee, however, is different. It's barbed, like a fishhook or a harpoon, and is designed to go into skin easily, but not come out. This may sound bad for you, but it's much worse for the honey bee. She will be literally ripped apart in the process. When a worker bee tries to pull away, her stinger stays put in your skin, along with the tip of her abdomen and a few of her internal organs. The sting apparatus is much more than a pointed weapon with which to stab. There is an attached **venom sac** which is tiny, but holds enough bee venom to cause a significant reaction in people. For most, this is a simply a **histamine reaction** the body's natural defense against the presence of foreign proteins in the blood stream. It typically causes immediate pain and swelling, with significant itching for several days. But for a small minority, it can result in a rapid and severe allergic reaction that can be fatal if not immediately treated with an epinephrine shot. If you are one of these people, then beekeeping is, unfortunately, not for you. Although beekeepers try their best to avoid it, by working with their bees as gently as possible and wearing appropriate protective clothing, we all get stung occasionally. And it will hurt. It's supposed to. This is the bees' way of letting us know that we did something wrong, and to not do it again. Sensible people listen and stay away from bee hives. And then of course… there are beekeepers.

Within the sting apparatus that the honey bee leaves behind is a muscle that pumps the bee venom down through the shaft of the stinger and into your skin. If you look closely, when you are stung by a bee, you can clearly see that this muscle continues to work, even though it has been disconnected from the bee's central nervous system. Don't stare too long though, because it is continuing to pump it's venom into you, which will increase the severity of your reaction. To minimize the painful reaction, you will want to remove the stinger as quickly as possible. Do not attempt to grab it and pull it out unless you have a pair of very fine-tipped forceps. If you squeeze the venom sac, you will effectively inject the remaining venom right into your skin. Your best course of action is to **scrape** the stinger out sideways. You could use a long fingernail, or any flat, thin surface, such as your library card, driver's license or a credit card. If you are standing at your bee hive, you likely have a hive tool in your hand. Use it to immediately remove the stinger, then puff some smoke onto the same spot to mask the scent of alarm pheromone that the bee has also left on your skin. This bee's stinger is actually a very sophisticated and highly effective defense. For a lot of people, a single sting in childhood is enough to create an intense aversive fear of bees, wasps, and many other flying, striped insects that can last a lifetime. While it would be painfully fatal to this individual worker, she is willing to sacrifice herself if she happens to be present when she senses danger to her colony. She may die, but her family and home – and in many cases her entire species – are protected from further danger.

Most bees are adorably fuzzy. All insects have hairs on their body – many species utilize them to better sense their surroundings. But the hairs on bees are different. Each individual hair is branched and feathery. And many types of pollen grains have rough or spiky textures, which readily cling to the **plumose hairs** on a bee's body. This helps the bees to efficiently transport pollen grains to another flower, where some deposited, and more are picked up, to be moved to yet another flower. This pollination happens automatically as the bees probe each flower for nectar.

Bees will stop their work periodically and groom themselves. Their front and middle legs are equipped with long bristles called **pollen combs**. They literally comb their hair – and comb the pollen grains out. Pollen is a valuable commodity to the bees. It is highly nutritious and an important part of the colony's diet. So the bees pack the pollen grains onto a section of their back legs called the corbicula, or **pollen basket**, to bring it home to their hives. This part of the leg is wide and flat, and somewhat concave. It's surrounded by long bristles that really do form a kind of basket. The bees may a drop of nectar, from their crop, to help make the pollen grains stick together for transport. Beekeepers love to see their bees returning to the hive with these colorful loads on their hind legs. This assures us that our bees are finding a good, rich diet to support themselves. More pollen being brought into the hive means the colony can support more brood, which will soon lead to more adult bees, and a larger population can produce more honey.

After returning to her hive, a pollen forager will seek out a cell near the brood nest to deposit her load. She will kick the pellets off and use her head to pack the pollen down flat, to make the most efficient use of the space. If you were to cut a pollen-filled comb apart you would see layers of colorful pollen stacked up like pancakes. The bees also add some honey to the cell, which contains live bacteria from the honey bee digestive tract, and are also naturally found on flowers themselves, and presumably on the pollen grains. These **lactobacilli**, as they are called, produce a chemical called **lactic acid**. As these bacteria multiply, the lactic acid builds up in the pollen storage cells. Through a process called **lactic acid fermentation** this pollen is essentially sterilized within a few days, killing off other microorganisms, and eventually resulting in the death of the lactobacteria too, just as yeasts produce alcohol during wine fermentation until the level is high enough to kill off the yeast cells. The fermented pollen we see in the cells around the brood nest is now called **bee bread** and can remain in the cells for a long time without spoiling.

Honey bees are very adept at maintaining a constant temperature inside their hive, especially in the brood nest. The ideal temperature to incubate bee brood is right around 93°F (34 C). The mere presence of many active bees is often enough to keep the brood warm, but if necessary, the workers can actively heat or cool the hive if needed. In the winter, honey bees will cluster together around their queen to keep her warm. By vibrating their thoracic wing muscles, each bee generates a small amount of heat (similar to the way our muscles shiver when we are cold, in an effort to warm us up). Thermal imaging of bee colonies has shown that the center of this cluster can remain as warm as 90°F or higher. The bees on the outside of the winter cluster are a little cooler (down to 60°F), but they don't remain there for long. These outermost bees are resting, and while doing so they form an important insulating layer, that keeps the heat inside the cluster. They can also open a sealed cell of honey, and fill their crops. This honey can be held here, and digested as needed, or shared with other bees who might need a bite to eat. Later they will return to the center of the cluster and warm up, and they will take another turn generating heat, using the energy in the honey they have just fed upon. After a while, they will be replaced by other bees, and they will slowly move away from the center of the cluster, eventually returning to the outside to rest and feed again. If the temperature begins getting too warm, the bees will spread apart slightly, allowing warm air to chimney up and away, bringing in cooler fresh air from below. If the temperature drops, the cluster will tighten together again to conserve heat. The whole process is very dynamic, and the will bees remain active in the cluster all winter long, continually responding to changing conditions. The whole cluster, meanwhile, also slowly migrates through the hive, usually moving upward on the combs, as heat rises, and onto more cells containing honey. This is why the bees tend to store their honey in the upper part of the hive.

During warm weather, bees also maintain a fairly constant brood nest temperature. You may see a large number of bees gathered on the front of the hive on warm summer nights. This is called **bearding**. The population in the hive is very high, so some bees stay outside to reduce the amount of body heat indoors. This can suggest to a beekeeper that the hive could use some ventilation. Honey bees will also line up together, facing the same direction, and actively fan their wings, creating air currents that help to blow fresh air into the hive, and move stale air out. When the temperature outside is above what the bees prefer in the brood nest, they will actively bring home fresh water in their honey crops, and place droplets of water around the hive. As they fan their wings, this water evaporates, and effectively cools down the hive. Yes, honey bees invented air conditioning! This same process of moving air across the surface of honeycomb cells helps to remove moisture from the ripening honey. When the moisture level has been reduced, the bees cap each cell with a wax lid, otherwise the honey would reabsorb moisture from the humidity in the air.

The honey bee is an amazing creature. And working together, the bees in a colony can do some amazing things. In our next lesson we will explore how these thousands of individual hive members can communicate with each other to get things done.