Beekeeping

Reference text for a MOOC course

beeB
beekeeping bridges

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English language editors:
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Media type: ebook
Edition: 1st edition
Publisher: Instituto Politécnico de Viseu/Norwegian Beekeepers Association
ISBN: 978-989-97584-5-2
Concept by: Beeb – Foster for beekeeping bridges through innovative and participative training
Project financed by the Erasmus+ programme

beeB Project

Foster for beekeeping bridges through innovative and participative training

October 2022
Book published in 7 languages: English, Portuguese, Spanish, Italian, Croatian, Estonian, Norwegian
The project has been funded with support from the European Commission.

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Proj No: 2019-1-PT01-KA202-60782
beeB - Foster for beekeeping bridges through innovative and participative training

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1.1

A History of Beekeeping

A reproduction of an image found on a cave wall in the Cuevas de la Araña, in Valencia, Spain. Dated 8000 BCE.

Honey gathering 8000 BCE

The oldest image we have of humans and bees together comes from an area close to Valencia, Spain, about ten thousand years ago. This cave painting (left) depicts a honey hunter, a gatherer that harvests comb from wild honeybees. Honeycomb was filled with sweet honey and nutritious bee brood that benefited early human societies, but it was sometimes dangerous to acquire, as the bees lived very high up in trees or on cliff faces, and their stings were just as painful.

The first beehive, 7000 BCE

The next step to developing honey gathering was to try and get the colonies into a more accessible place. It was discovered that if the queen stays in one location, the colony will build the nest around her. Evidence of bee colonies being kept in pottery vessels was found in the middle east, dated to about 7000 BCE. The first hives were made of logs, bark, woven straw, and pottery. Generally, these hives were used only once and had to be destroyed to harvest the honey and wax, and the bees would leave soon after and had to be collected from the wild again. In Egypt's old kingdom, we see depictions of some of the first hives and of people using smoke to gentle the bees and take honeycomb. This is when humans began to develop the art of beekeeping. It was much easier to take honey from a man-made hive, which was close to the ground and could be approached safely. Traditional hives are still used today in places where modern hives are not affordable, or where the bees' behaviour does not lend itself well to staying in one place. African bee subspecies tend to abscond, meaning that if they are disturbed, they will likely leave their nests. Some subspecies even migrate to escape dry climates.

Modern Honey Hunters

Honey hunting is still a practiced tradition in a few places around the world. In Nepal, beekeepers harvest honey from the giant honeybee, *Apis dorsata*. These bees make open nests high up on cliff faces, and honey gatherers must climb 30 meters or higher on thin bamboo rope ladders. The job is very dangerous but lucrative for the people in the area. It is a tradition that is dying out as many believe it is too dangerous to continue.

Large-scale beekeeping, 900 BCE

Once humans made the discovery of keeping bees in man-made structures, however, beekeeping as an industry began to take off. There are many examples of mass keeping of bee colonies all across the old world.

Ancient Egyptians were some of the first to keep bees in man-made hives, and bees were considered divine in origin, being the tears of the sun god Ra.

3000 years ago, in the Jordan Valley, Israel, hives were kept in neat rows and stacked three hives high. This operation likely housed about 100 hives and produced products for local markets and perhaps even long-distance trade. Greece had a booming honey industry, and the participants were wealthy enough to have beekeeping scenes depicted in gold. Ancient China developed different techniques to keep bees, putting them in wooden boxes (though without movable frames like in modern beekeeping). Even in pre-colonial America, bees were kept by the ancient Mayans: stingless bees (*Melipona*) that made smaller, upright comb, but the products were much the same.

Modern hives, 1870 AD

The invention of movable frames in a hive box was the thing that revolutionized beekeeping. Throughout the Middle Ages, beekeeping was developed by many different people: monasteries commonly kept bees to make mead and produce wax for candles, but the hives were always destroyed in the harvesting process--until a new kind of beehive was conceptualized in the 18th century. Thomas Wildman, an Englishman and a beekeeper, designed a new hive that looked like a skep hive but had wooden frames on which the bees could build comb, and a top that could be opened for easy access to them. This was the first top-bar hive--and though it was an improvement, the frames were not designed to move. François Huber was the one to start on the theory of movable frames, but his frames were designed to open like the pages of a book, still too difficult to use quickly and efficiently.

A skep hive made from straw or grass. This type of hive required the destruction of the hive to harvest honey, and beekeepers could not monitor the health of their bees.

The final form of this innovation came almost one century later, invented by a man named Lorenzo Langstroth. Lorenzo, reviewing previous research done in the 18th century, realized that there was a very specific distance between comb that bees would not build in. This was called “bee space”. Using this information, he created wooden frames set into a box from the top that accommodated for bee space and found that bees would build comb *on* the frames and not between, leaving the frames free to be moved in and out of the hive easily, one by one.

From this design, many different types of hive developed, all presenting the movable frame design that Langstroth had created.

The spread of the Western honeybee

Not all subspecies of *A. mellifera* have been regularly used in domestic beekeeping. Over time, and with the innovations in Europe, the European honeybee (or Western honeybee) has been selected as the global favourite. They have many traits that lend them well to a wide range of environments:

1. Their prolific honey production
2. Their tendency for gentleness
3. Their reduced tendency to swarm or abscond
4. Their large colony sizes
5. Their resistance to many diseases
6. Their ability to survive long periods without food
7. Their ability to survive extreme cold or extreme heat

The European honeybee includes many subspecies ranging from all over Europe and some parts of North Africa. The most common subspecies are *A. m. ligustica, A. m. carnica, A. m. mellifera*, and crossbreeds between these and a few others, which are given the blanket name "Buckfast". Bees have moved with humans since we developed the ability to contain them in artificial hives, and it is difficult to estimate just how often and how far these subspecies were brought; however, in recent centuries we know that European honeybees have been established on every continent save for Antarctica. Due to the qualities with which they have been bred, they are the only choice for large-scale production.

Industrial and globalized beekeeping

Throughout the modern era, beehives with movable frames have allowed us to expand the practice of beekeeping to an industrial scale. Now thousands of hives can be kept by just one team of a few people, but with so many beekeepers (and more hobbyists every year), questions of sustainability are being raised. Colony density in areas is increasing, and thanks to the globalization of markets, international transport has spread new pathogens and pests, creating real problems for apiculture as a whole. If we are to keep beekeeping sustainable, we must understand bees and their environment together, and make good choices within our own operations and as members of a growing international community.

1.2
Honeybee biology

Honeybees are in the order of insects called Hymenoptera, one of the youngest clades of insect. As insects, they have their hard body structure on the outside, called an exoskeleton, and soft and delicate insides. They have six legs, two antennae, and two pairs of wings. Honeybees are eusocial, which means they live in large colonies with only one reproductive bee: the queen. Honeybees have a very complex life, and in this chapter, we will introduce you to their basic biology, behaviour, and how they live in our world.

The anatomy of a bee

A bee's body is made up of three main parts: The head, thorax, and abdomen. They have specialized hairs all over that can help regulate their body temperature or collect pollen. Their wings are paired, two wings a side (four in total) and built for fast flying. Their internal biology is built around a special diet of pollen and nectar. Because of their colony life and caste systems, worker bees, drones (the males), and queen bees all have slightly different anatomies. In this section we will discuss the anatomy of a worker bee.

Head

The bee is highly specialized to collect nectar and pollen. A bee has five eyes: two main multifaceted eyes that take up almost 30% of the head's surface area, and three small ocelli used only for detecting light intensity rather than shapes and colours.

The antennae are paired as well and covered in odour receptors. Using both antennae in tandem, a bee can zero in on scents from a very far distance. Bees use their antennae to tell friends from foes, find food, and find home again when they need to return to the apiary.

A bee's tongue is made up of several parts that can be folded down under the head. The most important part is the proboscis, a hollow tube-like structure that draws up nectar from flowers.

Thorax, legs & wings

The thorax can be broken down into three distinct segments. Each segment houses a pair of legs, and the final segment holds the wings as well. The thorax contains the muscles used for flight and several nerve bundles to control wing movement. The thorax in drones is enlarged due to the competition drones must go through in order to mate.

The wings are not actually limbs; rather, they are extensions of the exoskeleton, specialized to move in many directions using complex

What is an insect?

Not all creepy crawly things are insects. Insects are a specialized class of animals in an invertebrate phylum called Arthropods. Arthropods have segmented bodies, exoskeletons, and jointed legs. They include things like shrimp, centipedes, and spiders. Insects distinctly have six legs and nearly all insects have wings at one or more stages of their lives.

Bee or wasp?

Bee **Wasp**

How can you tell the difference between a bee and a wasp? Simple: Bees are fluffy!

Nearly all species in the family Apidae (bees) are covered in soft, branched hairs. They have these hairs all over their body, including their legs and head. Wasps may have some hair, but it will never be as much as a bee.

joints. They are strengthened on the leading edges to withstand rapid movement, and the fore and hind wings can be locked together in flight to increase the surface area of the wing.

The legs of a bee are specialized for pollen collection. The rear-most pair have segments that are flattened and curved, with special hairs on them to collect and hold pollen. These flattened segments are called pollen paniers. The ends of the feet are tipped with small claws to help the bees climb on honeycomb and on flowers.

To bee or not to bee?

This insect is not actually a bee! It is a fly mimicking a bee to protect itself from predators. Bees can give a painful sting, and it pays to put on the disguise. The large eyes, short antennae, and single pair of wings give it away.

Abdomen

The abdomen contains most of the bee's organs, including the stomach, gut, and heart. It is also home to the fat bodies, responsible for storing protein and fat. The abdomen is made of chitinous segments held together by elastic membranes which allow the abdomen to expand when the bee takes in nectar. It also permits the bee to expand and contract the abdomen to increase oxygen circulation. The stinger in a worker bee is a modified ovipositor, made to inject as much venom as possible into a potential predator. When a bee stings, the portion of its abdomen containing muscles around the poison sacs tears away to continue to pump venom into the attacker. This increases the intensity of the sting and works as a better deterrent. The bee, however, dies soon after.

Respiratory & circulatory systems

Like all insects, bees do not have lungs; their respiratory system is made of tiny tubes called trachea that run all throughout their bodies. The openings of these tubes, called spiracles, run along the sides of the bee. Bees do not have blood vessels to carry oxygen to the cells. Instead, the blood, or "haemolymph", of a bee surrounds the cells and brings oxygen to them freely. The haemolymph is pushed about the body via a long, flat heart that runs along the top part of the abdomen, and a central aorta that carries oxygenated haemolymph to the thorax and head.

Nervous system

The brain of a bee is located in the head, and though it is the central unit for decision-making and coordinated movement, there are seven nerve centers that control movement and passive body functions in the bee. These ganglia are located in the thorax and abdomen, which is why a bee can still move its entire body even after the head has been lost.

Digestive system

The crop, or honey stomach, is the holding area for nectar and pollen after it has passed through the head and thorax via a long esophagus. The crop allows bees to store water or nectar and then return with it to the hive or use it to replenish their own energy reserves. Pollen is filtered into the midgut; the tough grains are broken down so the bees can access the nutritious proteins inside, and husks and other wastes are excreted.

Glands

A honeybee has many glands that serve various purposes such as excreting pheromones, producing larva food, and creating venom and wax.

Wax glands are found on the underside of the abdomen and are most active in younger workers. Wax is produced in small flakes and shaped by the bees' legs and mandibles to build comb.

Glands in the head and mandibles are responsible for producing the milky-white brood food that is fed to developing bees. These are the hypopharyngeal and mandibular glands respectively.

There are several glands associated with a bee's stinger. Some make the venom for the sting, while others produce alarm pheromones to alert fellow bees that danger is nearby. Still more glands near the end of a bee's abdomen are used in homing and territorial communication.

Bee flight

Bee flight is a form of powered flight created by the strong flight muscles in the thorax and the unique, aerodynamic shape of the wing. The flight muscles of bees have a special orientation that minimize the energy needed for movement. Their resting positions are either fully up or fully down, and it takes just a small amount of energy to switch between these two positions. This allows the bee to beat its wings about 230 times a second. The movement of the wings is not simply an up and down motion, but a figure eight shape, sliding diagonally up and forward and then down and back. This pattern creates an updraft which increases the amount of lift a bee can generate and permit it to fly quickly, even with a crop full of nectar.

Giants and dwarves

Honeybees come in a few shapes and sizes. They exist all over the world, and in some places like Asia, there are different species of wild honeybee.

Apis Dorsata is the giant honeybee. It builds honeycomb in the open, on tree branches or cliff faces, and these 3cm long bees guard their nests very well.

Apis florea is also known as the dwarf honeybee. This little bee is only 1cm long. Neither species is used in honey production, but they are close relatives, and we can learn a lot from their behaviour and biology.

Species of honeybee

Like everything in the animal kingdom, honeybees have a wide variety of species and subspecies that exist in different places all over the world. *Apis cerana*, the Asian honeybee, is the closest relative to our domesticated bee species *Apis mellifera*, but there are many subspecies of *Apis mellifera* (nearly one for each region in Europe and several in Africa too!) Each subspecies is uniquely adapted to its own environment, which is why you must be careful when importing new bees to your area. It is always best to include local bees in your stock to keep a strong, locally adapted population.

Bee castes and colony structure

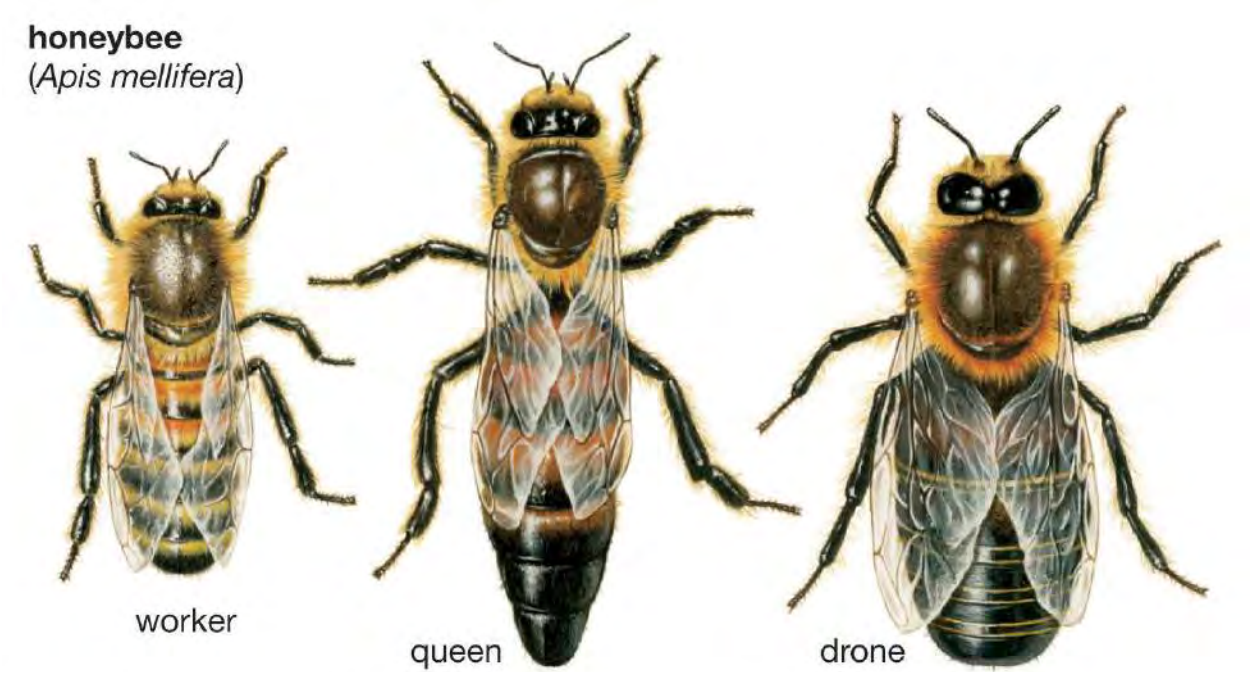
Honeybees are eusocial colony nesters. There is only one reproductive female, the queen, that produces all the bees that build the colony. No other bees will reproduce, and every other individual in the colony is the offspring of the queen. The workers are also female, but they have neither the reproductive physiology nor the pheromone control a queen has. It is possible for a worker to lay eggs on very rare occasions, but these eggs will always be male, and this is generally not tolerated in a colony with a healthy queen.

Queen

Because she is fed a large amount of special brood food by the workers when growing, queen bees have a much larger abdomen than worker bees to hold a fully developed reproductive system. They have special pheromones that keep the worker bees calm and happy, and when mated, they can lay up to 2000 eggs per day. A virgin queen must first be mated before she can take control of a colony. Virgin queens fly out when they become sexually mature (four to six days after hatching) to special mating congregations where drones from other colonies are waiting to compete for them. A queen will mate with multiple drones to obtain enough sperm to lay eggs for an average of three years. Mating with multiple drones increases the genetic diversity in a colony and makes it more resistant to threats like disease and food scarcity. On average, a queen can live between three to five years but is often replaced by the beekeeper after one to two years.

Drone

Drones are male bees. They are haploid, meaning they are born from unfertilized eggs laid by the queen and have just one set of chromosomes. Drones have large eyes that meet at the top of their heads, long and sensitive antennae, and large thoraxes to house powerful flight muscles. All these adaptations are used to find, chase, and mate with queens. They are produced during summer when the colony is strong enough to begin swarming.



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Drones do not work in the hive. After emerging, they spend two weeks being fed by workers, strengthening their flight muscles so they can fly out to compete for queens. Once a drone has mated with a queen, it will die. In the autumn, a colony will no longer tolerate the drones, as they are a drain on colony resources, and the remaining drones are killed or driven out of the hive. Drones generally live an average of one month.

Worker

Worker bees make up the entirety of the functioning force of the hive. They perform all functions outside of reproduction, keeping the hive clean, brood comb intact, and resources like honey and pollen stored well for later use.

Workers are the smallest caste of bee. They have specializations that allow them to complete their tasks: glands in their heads to produce brood food for larvae, pollen paniers on their legs to collect large quantities of pollen, and large honey crops in their foregut to hold nectar. They care for the queen, drones, and all of the brood. The workers are the force that collectively decide when to replace the queen, when to rear drones, and when to grow or shrink the colony size to match the season. They respond to a very complex array of signals from their environment to make these choices, and we still do not understand everything about this process.

The average lifespan of a worker bee in summer is between four and eight weeks; however, just before winter, the worker bees are reared slightly differently, and they become “winter bees”. Winter bees have larger bodies to store more nutrients and fat, and they can live up to eight months to see the colony through a long period without food.

Worker task partitioning

Workers are responsible for nearly all tasks within a hive. They must work efficiently to maximize fitness so they can successfully compete against other colonies and survive. The structure of the worker force is built upon maximizing efficiency, which can be categorized under two priorities:

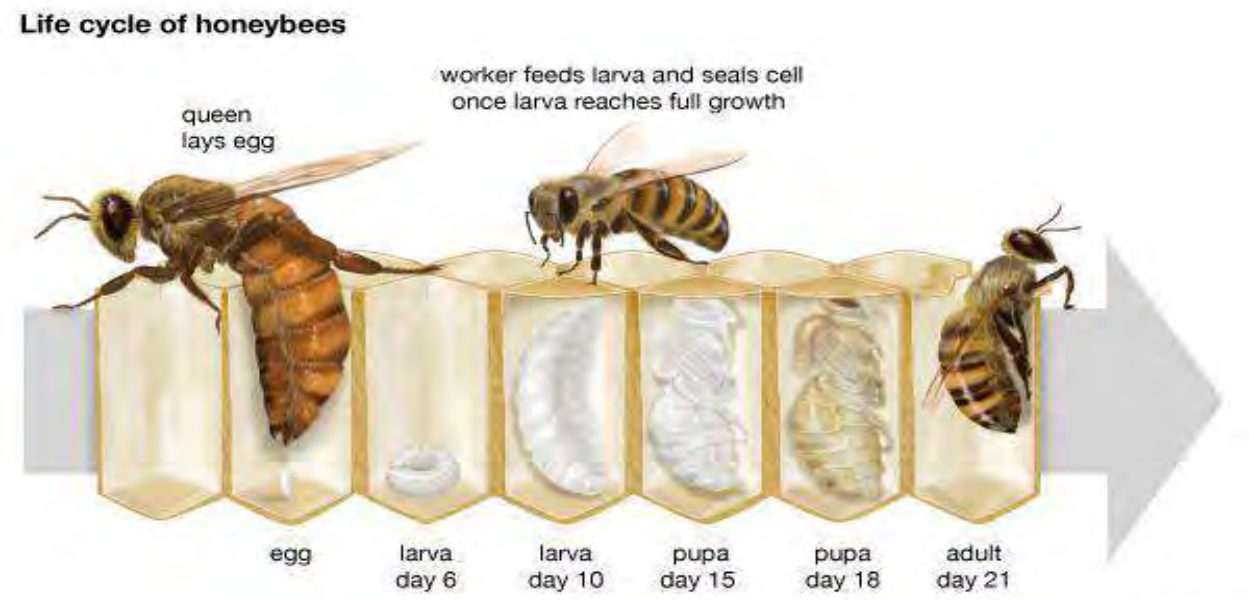
1. Reduce risk

   Tasks performed outside of the hive are much more dangerous than tasks performed inside, therefore the older bees are the ones that work outside. The older workers are the foragers, guards, and undertakers, while the younger bees build comb, nurse larvae, and look after the queen. Older workers take risks in the outside environment and work with dead or diseased bees. If a worker becomes injured or sick, oftentimes it will fly away from the colony, so as not to spread pathogens to its siblings.

2. Task affinity

   Mating with multiple drones creates genetic diversity in the colony. Workers with different drone fathers are slightly different, and some display more of an affinity for certain tasks. Worker bees generally do what they are good at, so bees from the same drone fathers tend to do more similar tasks.

Life cycle



The lifecycle of a worker honeybee. The queen lays an egg which is cared for by workers until the larvae is old enough to pupate. The cell is then sealed with wax and the larva metamorphoses into an adult bee. The entire process takes approximately 21 days.

All honeybees are reared in the brood cells of their hive. Without the constant, careful nurturing from the nurse bees, the larvae will die.

Eggs are laid by the queen at the bottom of the comb cells. After three days, the eggs hatch and the nurse bees will begin regular feedings, placing brood food around the larvae at the bottom of the cell. The brood food changes depending on whether they are rearing a worker, a queen, or a drone. For a worker bee, feedings are stopped, and the cell is capped over at about 10 days after laying. The larva finishes the rest of the food in its cell and spins a thin silk cocoon to pupate.

Pupation completely restructures the physiology of the larvae. Legs and wings are developed, and the internal organs and muscles are formed. After 11 to 12 days in a capped cell, the worker emerges fully formed, 21 days after the egg was laid. The process of creating a drone takes slightly longer, about 24 days, but queens develop the fastest of all at approximately 16 days. This is likely because when multiple queens are reared at once, the queens must compete, and the first queen to emerge will have a large advantage as she can kill her sister queens when they are still in their cells.

Communication & Behaviour

A queen attended by workers. The queen communicates with her daughters mostly through pheromonal signals, but there are several auditory and behavioural cues used as well.

Honeybee behaviour is not typical of other insects. Honeybees are highly social and rely on complex decision-making to ensure the survival of the hive as a unit. This often means the sacrifice of the individual for the benefit of the collective, which can lead to altruism-like actions taken by single bees. Example: stinging a predator in hive defense.

The worker bees are generally not reproductive, and due to the bees' special genetic system, they are actually more related to their full siblings (bees with the same father) than they would be to their potential offspring, so they have an evolutionary tendency to maximize the fitness of the colony. The word used to describe this particular type of behaviour is "eusocial".

Communication

Because they are eusocial, honeybee communication is very complex, and relies on a vast number of cues from nestmates and the queen. Most communication happens in the colony in almost complete darkness, so visual communication is at a disadvantage. Instead, honeybees use acoustic vibrations created by their buzzing, or chemical communication in the form of pheromones and other scents. Even the bee dances, which we define visually, are actually used to send vibrations throughout the comb for other bees to read. In this section, we will briefly cover how a bee might experience their world and communicate with their thousands of siblings.

Auditory/mechanical

Honeybees can make a wide range of sounds, changing the pitch and timber of their buzz to communicate different things. Not only does buzzing make an audible sound, but it also sends vibrations throughout the wax comb that can be detected by a large number of bees at once. The queen uses this type of communication frequently during emergence, making short, high-pitched bursts of sound called piping. Other queens that have not yet hatched will answer this call, even though it means the emerging queen will find them and likely kill them. It is possible that this trait evolved to reduce risk and damage to the new queen, because the death of more than one queen in a fight would fundamentally be a loss for the colony as a whole.

Workers use acoustic communication very frequently, and these signals can have very large changes in the behaviour of the entire colony. During a large nectar flow, workers will use a dance to communicate that there is food readily accessible. The intensity of the dance is directly related to the amount and quality of the food. If the colony needs nectar, these dances will recruit many foragers to go out and collect it. The dance produces both vibrations across the comb and sounds in the air to help relate specific information on distance, direction, and quality of food. Alternatively, when the colony's honey cells are becoming full, the bees taking nectar from the foragers release a vibrational signal to indicate that the foragers should reduce the number of bees going out.

Sometimes, workers can pick up parasites on their foraging trips, and they will perform a different dance to ask their sisters to groom them. This dance, called the tremble dance, also relies on vibrations to attract other bees to the task.

We still have not decoded all the subtle forms of audial and vibrational communication that bees use, and there is likely still a lot we do not know. An experienced beekeeper can tell a lot about the state of a colony by simply hearing the buzz of the bees, so it pays to stop occasionally and just listen.

Chemosensory

In the world of a honeybee, their sense of smell is vital. Much of their collective decision-making relies on pheromonal cues emitted by the queen and each other. Even the larvae and pupae give off pheromonal signals to tell the nurse bees what they need.

Queen pheromones can have the largest visible effect on worker bees. When you place a queen in a small cage, workers from that colony will flock to her. Removing a queen from the colony sometimes has instant effects on the behaviour of the bees. They can become noticeably louder and their movements more erratic. Queenless colonies, or those with virgin queens, can be more defensive than colonies with a healthy, mated queen. Queen pheromones predominately inhibit queen rearing, swarming behaviour, and most importantly, strong queen pheromones inhibit the development of worker ovaries. When a colony becomes too large for its space, the queen reduces the number of eggs that are laid

A worker bee fanning homing pheromones from the Nasonov gland. These pheromones help bees find their colonies, a new swarm, or needed resources.

and potentially decreases movement, limiting the spread of pheromones. The lack of pheromones around the edges of the colony may be what triggers the workers to begin producing swarm queen cells.

Queen pheromones also play very important roles in mating congregations where drones can detect these pheromones from up to 60 meters.

Lastly, subtle differences in queen odour allow bees to distinguish between their queen and a foreign queen. If you want to introduce a new queen to a colony, you cannot simply switch her for the old queen immediately. The colony must be permitted to live without a queen for a few days, to dissipate the scent and pheromones of the old queen; otherwise, when the foreign queen is introduced, the workers will not accept her and usually the new queen will be killed. Pupating queens will also produce queen pheromones, so it is a good idea to remove developing queen cells too, before the introduction of a new queen.

Workers use a wide array of pheromones, and often they are combined to communicate different things. Homing pheromones emitted by glands at the back of the abdomen (the Nasonov gland) can be controlled in intensity to communicate how badly the colony needs a resource. An example of this would be using this pheromonal cue to help foragers collect water (a resource that does not have a scent and may be visually hard to find). If the colony has enough water, however, the chemical signals from workers at the water source will be weaker than if the colony was in great need.

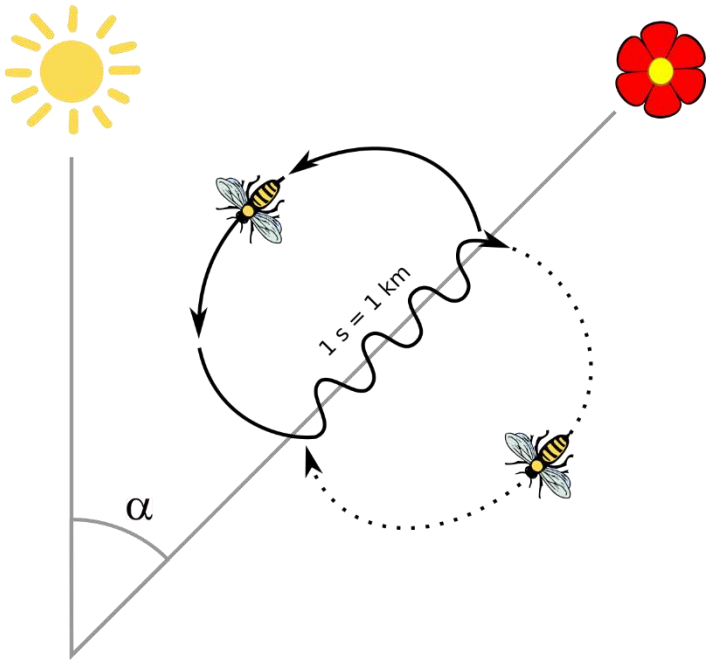
Decoding the waggle dance

Possibly one of the most famous forms of bee communication is the dance. When a large food resource has been found by foragers, they will return to the colony and begin a very specific series of movements that communicate distance, direction, and quality of food. But how is all this information packed into such a simple form?

Karl Von Frisch was an Austrian ethologist and the first person to decode the waggle dance that bees perform. From the entrance to the hive, draw a straight line to the position of the sun on the flat horizon. When the dance is performed in the hive, that line becomes a vertical line from the bottom to the top of the frame. The dance is looped, with the bees circling around and coming up in a central line while wagging their abdomens. That line will be at a specific degree distance from the top of the hive. This communicates the direction of the resources. The duration of the “waggle” part of the dance communicates distance, roughly 400 meters per second of waggle.

This information was published in 1927 in Von Frisch’s book *The Dancing Bees*. There are other dance movements bees perform; for example, if there is a resource close to the hive (between 50 and 100 meters) the bees perform a “round dance” which does not relay distance or direction.

A bee's world is filled with a lot of sensory information that we are not used to interpreting. Learning to imagine the world how a bee experiences it will likely give us a lot more understanding and insight into the lives of these tiny but extraordinary creatures.



Social immunity

Living in an enclosed space with so many individuals is a recipe for illness. Pathogens and parasites can spread very quickly, leading to outbreaks that the bees must control in order to keep the hive healthy.

This gave rise to the evolution of social immunity, which is a series of behaviours the bees perform collectively to help minimize illness in the hive.

Collection and use of resins in propolis

Honeybees collect resins from specific trees that contain antibacterial properties. They do not eat these resins but mix them with beeswax to cover hive surfaces. Propolis kills bacteria and may also remove some viruses, preventing more bees from becoming sick.

Undertakers and self-isolation

Minimizing contact with sick bees is another way the colony keeps itself healthy. There are special undertaker bees which are tasked with removing sick or dying bees from the hive. These bees generally do not move into the brood nest or have much contact with other bees. They are usually older, allowing the younger bees to take on less risky jobs. If a bee does become sick and they have the capacity to leave, often they will crawl or fly from the hive themselves, reducing the risk to their sisters and the queen.

Grooming

Grooming is a strategy used by nearly all community-living animals, and bees are very good at it. They can groom themselves (autogrooming) or ask nestmates to groom them (allogrooming). Grooming removes dirt and parasites that could make bees sick. If a colony is infested with parasites, this may provoke an increase in grooming behaviour across the entire colony, and bees may become more sensitive to foreign objects on their bodies.

Defense

Colony defense is a very important component of bee behaviour. Bees are well-equipped to deal with large threats, but only if they work together in a coordinated attack. This requires a series of colony-wide cues that will raise the alarm and signal many bees to emerge and drive off a would-be predator.

The first line of defense is found in the guard bees. These are bees that stand at the entrance to a hive or fly very near to it to scan for potential enemies. If something disturbs the hive, these guards will emerge and begin investigation flights to assess the danger. If the guard bees are provoked, they will begin bumping into the animal (or human) that has aggravated them. This is a warning. A full out attack is expensive, and bees will usually send a clear message to “back off” before they are driven to it. If the warning is ignored, the guard bees will begin to release an alarm pheromone. This is an acidic substance that to some smells like bananas. That is the signal for the bees to begin an attack. Pheromones play a very important role in coordinating hive defense. There are a series of pheromones involved, however the alarm pheromone is the most recognizable, and mimicking just this pheromone is enough to trigger bees to begin an attack. All bees can be provoked into this state; however, centuries of domestication has made this response very difficult to trigger in commercial bees, and working with a colony in good condition will generally not make them angry.

1.3
Honeybee Ecology and the Environment

Honeybees are completely dependent on their environment. It is the responsibility of the beekeeper to make sure the bees are kept in conditions that can sustain them. With current landscapes changing so

quickly due to agricultural intensification and changes in climate, it is challenging to find a consistent habitat for your bees to thrive in. It is crucial for beekeepers to be aware of what is around their apiaries and how it changes over the seasons. In this section, we will talk about the habitat needs of your bees, their foraging habits, the most common habitats in Europe, and some risks that can be associated with them.

Honeybee foraging strategy

Early spring build-up needs

A honeybee collecting pollen from the flower of a subspecies of *Salix*. In many areas in Europe and North America, this species provides a large amount of early spring pollen.

Pollen pollen pollen! In early spring, honeybees need pollen to develop the brood that will be the workforce gathering honey in later spring and summer. The amount of pollen they can collect will dictate their growth rate much more than nectar at this time. In many habitats, the bees will collect pollen in autumn when it is plentiful, but early spring pollen is still crucial. In colder climates, this pollen is often only available for very short periods, but in warmer climates, the season for good pollen collection may be longer; however, this will always depend on your local area and what resources are available. Many beekeepers choose to feed their bees a little pollen or pollen substitute in spring, especially if the area does not have many flowering plants that give pollen when the bees are building up. Pollen or pollen substitute is often sold as a paste mixed with a bit of sugar so the bees will take it faster.

Over a great area in Europe, *Salix* subspecies are the most common early pollen plants that bees can collect from. They flower within a short time in spring and are one of the earliest flowering species.

Burst-crop pollinators

Honeybees are generalists, meaning they can collect nectar and pollen from a very wide variety of plants; however, they are also burst-crop pollinators, and this means that they tend to target flower species that bloom all at once over a very short period. Honeybees usually limit their foraging to only a few plant species at a time that happen to have an abundance of flowers. This is how they maximize the number of resources gathered while minimizing the time they need to find them. This fact about their foraging biology is very important, because it means they are very well-suited to monoculture crop pollination. It also means their foraging is very targeted, and this can often be marketable in the form of different flavoured honey. For keeping your bees happy and healthy, this means that you must be aware of the mass-flowering plants, both wild and domestic, in your area and when they will be flowering.

Flow and dearth

Flow

A honey flow is a period in which a multitude of flowering plants produce nectar, and the conditions are favourable for bees to go and collect it. Often, the flowers belong to the same species in burst-flowering events, but not always. At these times, bees can bring back a large amount of nectar very quickly, and they can fill a super box entirely in only a few days.

A honeybee collecting nectar and pollen from a species of the *Rosacae* family. *Rosacae* includes many fruiting crops like apples, pears, cherries, peaches, and plums. This family can be grown all across Europe and they are burst-flowering crops--perfect for honeybees!

Flows usually occur around the same times each year, in line with the flowering phenology of the burst-flowering plants, but the precise timing is often dictated by a period of rain, and then a few days of warm and often humid weather. The weather after rainfall must be warm in order for bees to fly out in large numbers.

There are many weather factors that may limit a flow, even if there are abundant nectar resources. Strong wind, for example, can limit the foraging ability of bees. In more arid climates, weather may be too hot for bees to forage for long periods. Flows will depend greatly on rainfall, unless the flows come from domestic crop plants that are watered artificially.

Honeyflows in more northern regions last for a shorter time, but the days in summer are generally longer than in more southern latitudes, so flows may be much more important to beekeepers in northern climates. During a good flow, a strong hive can collect between 4kg and 10 kg of honey in a single day. Beekeepers must know when the flows in the area can be expected. Usually, they prepare for flows by putting extra honey supers on their hives just before it will begin, so colonies do not overfill their brood box and thereby prevent the queen from laying eggs. Giving the bees more space will also reduce the risk of swarming.

It is not easy to predict precisely when a flow will occur. Most beekeepers will put boxes on at the earliest date a flow could occur while also making sure the weather is not too cold for the bees to manage the extra boxes.

Predicting a flow is best done by watching your bees. If the bees are flying out in large numbers, chances are there is a large floral resource currently producing nectar.

Dearth

A dearth is a shortage of nectar-producing flowers. The most obvious dearths would be in northern winters, when the weather is too cold for flowers to bloom, and also in southern summers, when there is too little rainfall. An unpredictable summer dearth can cause much more damage than a hard winter, as the colony is the largest in summer and has the most energetic demands. Dearth outside of cold winters are often linked tightly to rainfall. Droughts can cause dearth, and beekeepers should be watching how and when the rain falls so they can determine if their colonies will need a summer feeding. Catching a dearth could mean the difference between saving or losing the hives.

Consider this:

A dearth can be very hard to spot because the landscape may still look green and lush, and there may actually be flowers dotting the sides of the road you are driving on; but without water, plants cannot produce nectar. The nectar flow does not need to stop completely, it only needs to be reduced to a point where your bees are losing energy trying to find it. Monitoring the behaviour of your bees is the best way to tell when a dearth is happening, and it allows you to do something about it quickly! A hive scale can also be helpful to follow a gain or loss in weight.

Oftentimes, bees can prepare for a dearth by collecting honey and storing it; however, if that honey is being harvested, the beekeeper must make sure the bees not only have sufficient food to survive it but also to make sure their numbers are strong enough to catch a new honeyflow so that they may continue brood rearing. If bees do not have enough resources to survive a dearth, it may lead to robbing. In order to survive or thrive, honeybees will steal nectar resources from weaker colonies. Most often it is the closest hives, which will be the weaker colonies in the beekeeper's own apiary. This can lead to loss of colonies and the spread of pathogens and parasites like *Varroa destructor*.

When feeding your colonies in summer, make sure the super boxes are removed to keep the bee feed out of your valuable honey, and try to feed all colonies in the apiary at least a little to reduce the risk of robbing. You can reduce the entrance size while feeding to help the bees protect the food you have just given them. It is often better to feed close to evening, so the bees have a chance to take most of the food before the next active period starts.

There are several signs you can use to tell if your bees are experiencing a food shortage, some physical, some behavioural. Different bee species can behave differently, and oftentimes the behaviours are complex and vary between breed and location, but in the event of a dearth these signs are the most common:

1. A hive will be considerably lighter to lift than it was in the past.
2. The queen will slow or stop laying eggs (there are many reasons for a queen to do this, however).

3. Bees will often become louder when they lack food.
4. Bees can sometimes become more aggressive.
5. Bees will re-visit the same flowers or visit species they normally avoid.
6. Bees will try to rob your honey house and any sugar that is left outside.
7. Bees will often change their flying patterns, becoming more exploratory and flying lower, diving or swooping, and will be attracted to any promise of sugar.

Decision-making in foragers

There are many things bees must consider when going to forage. A colony's survival may depend on the decisions the foragers make and where their workforce is directed. Bees have a limited time to collect a large number of resources that will get them through food shortages.

Simply because a resource is close and abundant does not mean the bees will prefer it. Oftentimes, the structure of the flower and the quality of the nectar it provides will factor into their choices.

One thing that beekeepers can count on is that bees will make the most profitable choices. They will maximize resource gain while minimizing energy loss in flight time and processing.

Studies done by researchers like Thomas Seeley revealed that there are scouting foragers that evaluate floral resources within a few kilometers and return to the hive to communicate their findings. A communal decision is then made based on the distance of these patches from the hive, the patch size, and the quality of the resource. The best patches are then chosen to be exploited.

Resource quality in and of itself has a few principal components to consider:

1. The amount of nectar a flower can produce.
2. The sugar content of the nectar, both in type and concentration.
3. The level of harmful volatiles that some plants can produce.

Wild habitats vs human-mediated habitats

What flowers are bee flowers?

Honeybees are generalists, which means they can take nectar from almost anything, but there are some flowers that are made for certain species or genera that either cannot be accessed by honeybees or do not have the nutrition the bees need.

These mango flowers (above) are best suited to small flies, and even though some mango farmers rent bee colonies, bees will prefer almost anything else, which does not make them effective pollinators for this crop.

This white clover however, which can be found in many hay meadows to produce food for cows and other farm animals, is much beloved by honeybees and they will prefer it over many other flowers.

There is a large difference between wild habitats and agricultural habitats, and this changes the strategy of the bees and may require a change from the beekeeper as well.

Wild habitats

These habitats are very diverse--wild spaces often have hundreds of interacting species and numerous microhabitats to promote the growth of rare and unique species. Because of this, they may not have as many resources to give all at once, but they can provide more consistent flows throughout the active season. There will always be some species of flower growing, unless conditions are unsuitable. The diversity of a wild habitat also lends strength to the nutritional value the bees receive in the resources they collect.

Bees are generally burst-crop pollinators, and they will collect on the most abundant resources present at the time, but they are also opportunists and can collect on a diversity of plants simultaneously.

Human-mediated habitats

Human-mediated habitats have a wide range of quality for bees. Not all human-mediated habitats are suitable to keep large numbers of bees, and some of these habitats can actually be fairly barren for honeybee food for the majority of the year. Cities, for example, have a very limited number of resources, and oftentimes can only support a few rooftop hives among a group of hobbyists.

Agricultural habitats are the most common form of human-mediated habitats that bees are placed in, often dominated by large areas of monoculture crops which may or may not have a flowering that benefits bees. Often there are flowering verges and small patches of wild or semi-wild habitats. Beekeepers can move their bees to different flowering crops to take advantage of different flowering times, and often they are hired and paid for the pollination services their bees provide. Beekeepers should always be aware, however, that resources can be scarce in these environments, and should be mindful of what resources their bees have access to at critical periods. The bees may require feeding at certain times of the year if there are no crops to provide needed food.

A good beekeeper will take advantage of all the habitat types they can access to provide the best nutritional opportunities for their bees, and the best honey crops for themselves.

EU ban of dangerous pesticides in 2018

On May 30th, 2018, the EU implemented a ban on the outdoor use of three active components of a group of pesticides collectively called neonicotinoids:

- Imidacloprid
- Clothianidin
- Thiamethoxam

Neonicotinoids attack the nervous system of insects, and they are very effective. So effective, in fact, that even in tiny quantities they can affect the performance of honeybees.

With a growing need for food globally, agricultural systems are stressed to find more effective ways of generating higher yields, and beekeepers should always look out for new

Environmental risks

Agrochemicals

In most areas, it is nearly impossible to avoid exposing your bees to harmful chemicals. We use pesticides on our crops for every serious problem in the agricultural industry, from insect pests to fungal diseases, and even the artificial fertilizers may have some impact. Though most agricultural chemicals are not even targeted at flying insects, they can still do a lot of harm to your bees.

Research has concluded that no one pesticide can be held responsible for colony disruption, and it is likely a synergistic effect of many chemicals that can weaken the bees and leave them more open to risk from diseases and harsh weather. A beekeeper must be knowledgeable of the types of chemicals used in their area, and when and how they are applied. Sprayed pesticides are likely much more harmful than fertilizer chemicals placed in the soil, and chemicals sprayed during the flowering periods of plants likely create the largest risk.

If your operation is going to be organic there is a specific distance, generally set by EU or country-level regulations, that your hives must be from any crop or large area of managed land that use conventional, non-organic pest control and non-organic fertilizers. This is to minimize the amount of chemical residue in your bee products that the bees will bring in from the environment. It is unfortunately not enough that you, as a beekeeper, do not use conventional pesticides to manage threats like Varroa in the colonies.

Neonicotinoid pesticides

These pesticides are some of the most effective chemicals in killing insects in cropland. They are used widely to control a variety of destructive herbivorous insect pests. They are systemic pesticides, meaning they are usually applied on a seed coat and taken into the plant itself, appearing in very small quantities in leaves, stems, pollen, and nectar. They are designed to kill pests that consume the plant, however, amounts of the toxin can be collected by bees.

Neonicotinoids affect a part inside an insect's central nervous system that is unique to insects, so these toxins are much less harmful to other animals like mammals and birds. In a veterinary setting, these compounds are safely used in combatting parasites like fleas.

There is a considerable amount of evidence that these pesticides can affect the orientation and learning of bees, and if sprayed directly they can cause mass die-offs. Most types of neonicotinoids have been banned in many countries in Europe

Colony density

Another growing risk to honeybees is the number of colonies in an area. The closer bee colonies are to one another, the higher the chance they can spread harmful pathogens. In the autumn, or in periods of food stress, colonies within a few kilometers of each other have the potential to rob other colonies (or

to be robbed themselves). This is not only destructive for the colonies getting robbed, but it can also have the potential of transmitting parasites or diseases to a strong colony, putting the robber at risk, too. In a later module we will discuss the various pests and diseases that pose risks to honeybees. Most countries require beekeepers to register their apiaries and the number of hives they keep so they can monitor how many bees are in an area and mitigate colony density. A beekeeper needs to be aware of how many hives are in their area, both the ones that belong to them and also the ones that belong to other beekeepers close by. Speaking to your local beekeeping association is a good way to get to know beekeepers in your area and share the space fairly.

Predation

Not every region must worry about predation, but there are many animals that are fond of eating bees and their honey. Most domestic bees are much more docile than wild bees, and it will take them much longer to ramp up their defence pheromones and attack. Bears and some species of badger are common hive predators. Smaller predators include species of birds, shrew, and ants, which will take advantage of the bees in colder climates when they are clustered for warmth. Most of these predators only take a small number of individuals, but ants may kill an entire colony in a few days. Threats like bears can be deterred using electric fences, which may be a good idea to install to avoid attracting bears to the area where you work.

Theft

Animals are not the only sentient threat; in many countries there is a market for stolen hives. As they are often in remote areas and unguarded, some apiaries can be the target for theft. Thieves will often operate at night, when the bees are not flying, but they have been known to take hives in broad daylight. There are programs that offer to install a GPS tracker in your hives (oryou can do this yourself), however, the pricing of these methods can be high, and generally, theft is not a large enough threat in most areas.

Roads

Another risk to your bees is busy roads. Placing your hives next to a major road can significantly reduce the number of active foragers in your hive, especially if there is a coveted resource across the road. Always be aware of where your bees are flying and what obstacles they need to overcome to make the journey safely.

Climate change

Weather patterns have been measured over many years and the trend is that the climate in many areas is becoming more volatile and the weather harder to predict long term. Periods of heavy rain may drown flowering crops, and droughts can cause dearths in unusual seasons where they can last for much longer than normal and remove crucial water resources from the landscape. Shorter winters may allow

more parasites to survive in the colonies, and it only takes one very harsh winter to raise the mortality rate of your bees. Though you can treat the symptoms of climate change (feeding, putting water out for your bees, etc.), this threat is impossible to change alone, and only pressing the government for firmer restrictions on greenhouse gas emissions will yield any meaningful effect. Collectively, however, there are many efforts one can engage in to reduce your personal carbon footprint and help make a difference on a smaller scale.

Organic landscapes

Organic beekeepers must be very conscious of the environment their bees are using. There are a number of very strict regulations set by each country in order to maintain the organic status of honey and other bee products. Wild ecosystems are often low risk in terms of chemical residues, however there may be limited resources of said ecosystems and possible competition with wild pollinator species. The best scenario is likely an agricultural setting that is managed organically, such as orchards or fields that can provide resources to your bees and that meet an organic standard of their own.

Extra Resources:

https://ec.europa.eu/food/plant/pesticides/approval_active_substances/approval_renewal/neonicotinoids_en

1.4
Choosing the Right Bee

Depending on your type of operation, you will need specific traits from your bees. Honeybees are not like other domestic animals. They have unique adaptations to maximize their genetic diversity, which means their traits are often harder to predict and maintain.

There are many honeybee subspecies and races to choose from, each with slightly different performances in the traits they are required to possess to make them good domestic livestock. A race of bee is what we call a different breed, all races are generally from the same species: *Apis mellifera*. Depending on where you live, and what you need from them, you will have to choose which bee is right for your operation.

Genetic history of the domestic honeybee

The European or "Western" honeybee is native to Europe, Africa, and Western Asia. Wherever it exists outside of this range it has been introduced by humans. Human history is linked very tightly with the evolution of the domestic honeybee, and we continue to adapt and manage our bees to provide us with honey (and now, more importantly, with the pollination of 30% of our global food crops).

In Europe, there are 13 different subspecies of honeybee. These subspecies belong to several different evolutionary lineages that separated 150, 000–350, 000 years ago. Most of these subspecies originally had a limited geographical distribution, but with the help of beekeepers, a few have expanded their ranges and are now found in large parts of Europe and even on other continents. The Italian and the Carniolan bee are the most popular races of bee and have been widely exported all over the globe.

Table of European subspecies of honeybees and subspecies imported to Europe

Subspecies name	Common name	Original distribution
Apis mellifera adami	The Cretan honeybee	Crete
Apis mellifera carnica	The Carniolan honeybee	Slovenia, Bulgaria, Poland, Austria, Croatia, Bosnia and Herzegovina, Serbia, Hungary, Romania
Apis mellifera carpathica	The Carpathian honeybee	Ukraine, Bulgaria, Romania, Moldova
Apis mellifera caucasia	The Caucasian honeybee	South Russia, Turkey, Georgia
Apis mellifera cecropia	The Greek honeybee	Greece
Apis mellifera cypria	The Cyprus honeybee	Cyprus
Apis mellifera iberiensis	The Spanish honeybee	Spain, Portugal
Apis mellifera ligustica	The Italian honeybee	Italy
Apis mellifera macedonica	The Macedonian honeybee	Bulgaria, Greece, Macedonia, Ukraine
Apis mellifera mellifera	The European dark honeybee	Europe North of the Alps
Apis mellifera rodopica	The Bulgarian honeybee	Bulgaria
Apis mellifera ruttneri	The Maltese honeybee	Malta
Apis mellifera siciliana	The Sicilian honeybee	Sicily

There are several traits that are desirable in a bee that will be used for production:

- Good build-up and large size
- Good honey production
- Low swarming rate
- Gentleness
- Disease resistance
- Low propolis production
- Food stress tolerance

Though most beekeepers can assess what they need, choosing the right bee is a little more complicated than filling out this list; in many cases the environment will dictate the success each bee species might have at any of these traits, and the best performances are always in an environment to which the species has been adapted.

Honeybee trait guide

There is a lot of variation between different bee races and also between different stocks within a race, and it can be difficult to choose the right bee for your operation. Below is a list of the most important factors to think about when choosing your bees while also taking the environment into account, followed by a chart that categorizes these traits in the most common races of honeybee used in Europe.

1. **Build-up**: This defines how quickly a colony can build up a large force of bees when they begin in spring. Having a slow build-up is not necessarily a bad thing, however. Whether it is for pollination or honey production, if the bulk of the target flowers only open in mid-summer, then bees with a fast build-up may require feeding before the flow. Having a fast build-up time is good for climates where flowering peaks late spring to early summer, and often in climates with mild winters.
2. **Honey production**: If the focal product of your operation is honey, then you need bees that can produce large quantities in the right conditions. There are many factors that contribute to a high honey production, and this can include build-up speed, environment, flowering time, flow season activity, colony size, etc. Many bee races can produce large quantities of honey, but some will only peak in their performance in an environment they have adapted to.
3. **Swarming**: Swarming can halve the size of your colony, and often it is difficult to catch, resulting in the loss of bees. Naturally, beekeepers want colonies that are not prone to swarming; otherwise, you will want colonies where swarming can be managed by giving the colony more boxes. When colonies prepare for swarming, they also stop collecting nectar, which results in a reduced honey crop. It is best to avoid swarming if possible.
4. **Gentleness (docility)**: This is likely the most important trait for managing honeybees. You need bees that tolerate being worked with, bees that will stay calm and still on the frame and that cannot be antagonized easily. An agitated hive will result in more bee deaths when moving frames or boxes. More dead bees can increase the spread of disease and force the rest of the colony to become aggressive. Having gentle bees will keep you and your bees safe and healthy.
5. **Disease resistance:** This is one of the hardest traits to measure, and it varies greatly depending on where the bees were bred and where they are kept. Generally, bees brought to an

environment they are not suited for will have more problems with disease. There is no good measure for a bee race's ability to resist disease in general. Some races may be good at resisting one type of pathogen but may be susceptible to another. The best way to secure disease resistance is via local adaptation and selective breeding for your specific area, and to be mindful of the density of colonies within it—however, the best way to prevent disease is through good management practices!

6. **Propolis**: Propolis makes the frames sticky. It stains badly and gets stuck on your tools, gloves, and anything else it comes into contact with. For this reason, many beekeepers select bees that create less propolis; however, propolis is what bees use to clean the hive and decrease disease within the colony. The benefits of having less propolis versus a hive that has an easier time cleaning itself must factor into your decision when choosing a bee. If propolis is one of the products you wish to produce, then obviously having a bee that creates an excess of propolis is ideal for you.
7. **Cold-resistance:** Some bee stocks are just not well suited to overwintering in cold climates. They are less active at lower temperatures, resulting in lower honey production and starvation. Honeybees can be more susceptible to diseases brought about by the cold and damp. If you have long, cold winters, it is better to choose a bee that matches your environment and is adapted to the cold.
8. **Food stress:** Many areas are subject to drought or periods where there are few resources. A colony that is not good under food stress can eat up all the honey that would have been collected by its beekeeper, and in the worst case, colonies can starve before the beekeeper is able to go out and feed them. Having a bee that can resist food stress means you have more time to save your bees and your honey when you are hit by a dearth. An experienced beekeeper who knows their stock well does not have a large issue with food stress as they know when to provide their bees with food, but for beginners, having a species that deals well with food stress is important.

	Build-up	Honey production	Swarm	Gentle	Propolis	Cold-resistance	Food stress
The Buckfast bee (traits are variable)	fast	high	low	good	low	good	good
The Carniolan (grey) honeybee	fast	high	low	good	low	good	medium
The Carpathian honeybee	fast	high (local)	medium	good	low	very good	good
The Caucasian (Georgian) honeybee	slow	high (local)	low	good	high	bad	good
The European dark honeybee (Norwegian brown, British black, German dark etc.)	slow	Medium (high on late season flows	medium	medium	low	very good	good
The Greek honeybee	fast	high (local)	low	good	high	bad	good

The Italian honeybee	fast	high	low	good	low	good	bad
The Spanish (Iberian or Gibraltar) honeybee	fast	medium	high	bad	high	very good	good

Depending on where these bees are kept, whether they have been under systematic selection, and how different their current environment is to the one in which they were bred, these traits may vary. For example, the Caucasian bees are generally disease resistant and can produce a lot of honey when flows peak in mid-summer. But in colder climates, they are prone to a fungal disease called *nosema* which can kill overwintering colonies, and if the flows peak earlier than mid-summer, you will not get a good honey crop out of these bees. During recent years, there has been an increasing effort to improve the traits of the more neglected races of the European honeybee through selective breeding.

Common breeds of domestic bees used in commercial beekeeping

-  Carniolan
-  Italian
-  The black, brown, or dark bee
-  Buckfast

Though the list of honeybee races is expansive, there are only a few common races used widely for professional beekeeping. This is because these races have been the most dependable in nearly all categories that are needed for a good domestic bee stock.

Why the gold bees?

When asked, many beekeepers who breed Buckfast or another mixed type of bee say they prefer a more yellow or gold bee colouring, but is it really just the aesthetic of a lighter bee? Oftentimes, in early domestication breeding experiments, coat colour was used as a measure of docility. Whether or not this is true for all animals has not yet been scientifically established, but it is possible that in some types of bee, a lighter colour could be more associated with a gentler bee.

Carniolan bees (*Apis mellifera carnica*)

This bee is one of the most popular bees in Northern Europe. They have a good cold tolerance and an early spring build-up. If they have space in their hives in early summer, then they can often be discouraged from swarming. The colonies are large and very active in collecting honey and they can be very prolific pollen collectors. They generally have a low propolis production, and when the colonies are strong, they are fairly resistant to brood diseases like chalk brood. They can be susceptible to drought and long periods without nectar flow, so consider having bee feed on hand for lean times.

This breed is more inclined than others to stop brood production during the absence of nectar flow, and this can lead new beekeepers to think that the colonies may have become queenless. Very frequently, they do have a queen, and waiting for a few weeks or feeding a little when there is no flow will make the queen reappear on the comb. This also means they overwinter in small numbers, allowing for better use of stored honey. These bees are best suited to areas with strong spring nectar flows and early flowering crops.

Italian bees (*Apis mellifera ligustica*)

This bee is one of the most prolific honey producers. The colonies of Italian bees can become very large very quickly and generally stay active as long as the weather is favourable. They are also remarkably gentle and calm on the frame and disinclined to swarm if given the right amount of space. For these reasons, they have been a favourite both for export and for hybridizing throughout modern beekeeping history. They can produce a lot of wax and are fastidious cleaners, which contributes to disease resistance. They tend to flourish in warmer climates, and pure-stock Italian bees fair less well in cold climates with long winters as they tend not to reduce their worker force as much as more cold-tolerant races. This can to an extent be solved with extra feed, but they may also be slower to build-up in spring.

Because the colonies are large and active throughout the entire collecting season, they may starve out more quickly than other races during a dearth, so it is very important that beekeepers know when to feed. These bees have been known to drift more than other races, so if colonies are placed in a line facing the same way, the colonies on the outer edges will collect the workers from your other colonies,

potentially causing weakness, robbing, and higher rates of disease transfer. Placement and direction of the hives is important for this species. These bees seem best suited for a commercial rearing on monoculture crops or areas with large blooms and may be best suited to pollination services, especially in more southern countries.

Black, brown, or dark bees (*Apis mellifera mellifera*)

These bees are the native race to Northern Europe and have historically occupied the northern most limits of the honeybee range. There are many variants in this race, but all share similar characteristics: They are dark in colour and slightly larger than other commercial bees. The colonies often do not grow as fast or as large as other races; they can be more restless on the comb and irritable when worked. Some unselected populations are also inclined to swarm, but they are the masters of cold tolerance and can forage in lower temperatures, making them a good breed to keep in northern climates. They are very resilient to long periods without food and have brood cycles that are tied to nectar flow. They are slightly more vulnerable to disease in general, however, and this coupled with their smaller colony size and tendency for aggression has not made them widely favoured as a commercial bee.

In many countries, the local black bee race has been considered a heritage breed and is conserved very carefully, sometimes with funding available for beekeepers who wish to keep them. These bees are very effective at collecting nectar from late season flowers like heather.

Buckfast bees (*Apis mellifera ligustica x mellifera mellifera or another race of bee*)

The Buckfast bee is one of the few races of bee that was not based off a single pre-existing subspecies of honeybee—they're mixed-race bees. These bees hail from the Buckfast Abbey in England, where a man known as Brother Adam crossed the favoured Italian bee with the local British Black bee. The eventual result was a half-gold bee with a well-balanced mix of all the desired traits for that region. Currently, the term "Buckfast" generally applies to any bee cross that is lighter in colour, though there is an established trait profile maintained by the Federation of European Buckfast Beekeepers. These bees are quick to build in spring, the colonies are large, they are prolific foragers, and swarming can be controlled well. They can be more resistant to pests and diseases than other races, and they generally build comb neatly with little bridge comb between frames.

Buckfast bees are more suited to colder climates than their Italian relatives as they can reduce their brood at will and spend resources carefully. Not all bees that bear the name Buckfast come from these well-preserved lines, however, and when buying Buckfast, beekeepers may want to become better at breeding and maintaining traits within their stock. Being a crossbreed means that traits can be more

variable and may shift across generations, but this variability may also give them a much better potential for resistances to pests like Varroa mites. These bees can be adapted to a wide range of habitat types, and it is a good idea to look for a local Buckfast stock if you choose this bee. Be mindful that in some areas, conservation rules have been placed preventing people from keeping these mixed-race bees.

Regional adaptation

Honeybees have several strategies to maximize their genetic diversity, and though this makes desirable traits harder to manage, it also gives them a stronger resilience to unforeseen threats. The many subspecies of honeybee in Europe are each adapted to their own specific habitat type. But adaptation does not stop there. Honeybees can adapt to a specific locality even within their subspecies, which can make buying local bees a more stable and reliable option than importing stock from afar. Environments for honeybees can be extremely varied, and to maximize their survival, bees must be able to use their specific habitat to its maximum potential. Whether this adaptation is more behavioural or genetic, we do not know; however, we do know that honeybees tend to do much better in nearly all regards when they are raised in a habitat that their origin stock has been bred in.

Where to buy bees

Like any livestock, purchase can require careful thought and thorough research. Buying stock from a reputable beekeeper is always the safest option but tends to be more expensive than buying from a small time or hobby beekeeper. The seller should allow you to visit their operation and examine some of the colonies to assess the health of the stock. Buying bees is very much a seasonal activity, and oftentimes you must speak to a beekeeper well before you need your bees, so they know roughly how many queens or swarms they must produce for the active season. The more advanced notice you can give a beekeeper, the better the swarms will be. Be aware that there might be local or regional regulations on trade and transport of honeybees.

Rearing your own queens

Queen breeding is one of the most complex, labour-intensive, and sensitive activities in beekeeping, but for those that put in time and patience, it can be very profitable. Rearing your own queens means that you are not dependent on buying new queens every time you require one, which can become expensive if you need to buy emergency queens for a swarmed or queenless colony. You can also begin producing queens to sell to other beekeepers, and if your stock is productive, they may be in high demand. If your goal is to become a successful queen breeder, you must know the traits of your bees very well, and you must always select your stock with the aforementioned beekeeping traits in mind while also maintaining enough genetic diversity in your colonies to keep your bees healthy. It takes many years to become a good queen breeder and is generally only recommended for people who have become comfortable working with bees.

1.5
Anatomy of a Colony

Honeybees are eusocial organisms that live in large groups of 10, 000 to 60, 000 related, non-reproductive worker bees and 1 queen. They are cavity nesters, which means they must make their nests in an enclosed space that is protected from the elements. They c comb made of a special wax called beeswax and create thousands of hexagonal cells. These cells store all of their food as well as new generations of bees. In this chapter, we will look at what makes a honeybee hive. You will learn how the colony is structured, how to distinguish between different types of cells, and the components of a good domestic bee hive.

The right housing

In the wild, honeybees usually nest high up in the hollows of old trees. This keeps them protected from wind, rain, snow, and many different predators. Bees generally prefer cavity spaces of around 50 litres. Too big and it can be too hard to control the temperature--too small and they might not have enough space to grow during the summer as well as not enough space to store honey for the winter. During brood production, a honeybee nest is kept at a near constant temperature and humidity by the worker bees, about 34.4°C with humidity at about 50%. Honeybees fan air through the hive and collect water to help with this process. This keeps the young developing bees warm and hydrated and prevents the honey from crystallizing.

Honeycomb

The wax comb that bees use to build their nests is called honeycomb. Bees produce wax from special glands on the underside of their abdomens and using this wax they build the cells that will house honey, pollen, and honeybee brood (eggs, larvae, and pupae). The brood is usually kept in the centre of the nest, where the temperature and humidity are most stable. Honey is stored on the outer comb and at the back of the hive, furthest from the entrance, so it can be better guarded from predators and robbing bees. In summer, pollen is stored in a ring around the brood so it can be accessed easily by nurse bees that need it to make brood food for the developing larvae. In winter, pollen can be packed solidly into a frame for storage so it can be extracted when the queen begins to lay

Why a hexagon?

There are several theories as to why honyebees build their comb cells in a hexagonal pattern. It is the shape that conserves the most material while at the same time being structurally sound.

Wax is costly!

Wax costs sugar, and bees need to consume at least three kilograms of honey or sugary bee feed to make half a kilogram of wax!

Brood bath

Developing larvae are fed more brood food than they can eat. In open cells it looks like they are floating in a milky-white bath. A good sign of pollen is when the young larvae seem dry or are sitting in an empty cell.

eggs for the coming spring.

Where are the bees in the hive?

Workers, drones, and the queen all have their preferred places in the hive: Workers can be found everywhere, however the younger workers will generally be in the centre of the colony with the brood. The older workers tend to be foragers and they can usually be found in the outer comb and with the honey cells. Cells of developing worker brood are always collected in a central brood nest.

A swarm cell on the side of a frame. The queen that emerges here will likely take control of the colony while the older queen will fly out with a portion of workers to find a new home. This process is called swarming.

Drones can be found all over the hive once hatched, and it is the size of the cell that dictates whether the laid egg will become a worker or drone. They depend on the workers for food. Drone brood is usually made at the bottom of the comb, and only in spring and summer. A beekeeper can control where the drone brood is laid by putting in one frame without a foundation, or one with the foundation of a large, drone cell size. The worker bees will build the empty space on this new frame into drone comb and the queen will lay drone eggs. This process can be very helpful when controlling pests like Varroa mites that much prefer to reproduce in drone cells.

The queen will nearly always be in the brood nest in the centre of the colony, laying eggs in empty cells. The cells of developing queens can be in two places depending on what the queens are being raised for: Swarm queen cells will be made on the edges of the brood comb, and usually in groups. If a colony has lost their queen or is trying to replace her, however, they can build cells anywhere on the brood frame. Usually, emergency queen cells like this are only found on one or more frames.

Honey

Honey is a mixture of sugars and water that bees have made from the nectar collected from flowers during the day. Gradually, most of the water is fanned away, leaving the thick, sugary syrup. It can contain traces of pollen and propolis, which give it a golden-yellow colour. Honey that has been completely processed is capped with a fine layer of beeswax to preserve the moisture content. Bees produce and store honey to feed themselves in times of food scarcity. Only adults will eat honey exclusively, and they need no other food to survive.

Pollen

Pollen is a grainy substance made of tiny particles that contain the male gametes of a plant. These gametes are protected by a tough outer pollen coat which can be broken down in the bees' digestive systems. Pollen is rich in protein, and the bees need these proteins to feed their developing brood and keep the queen laying eggs. Young workers digest pollen and convert it into a protein jelly using special glands in their heads. This jelly comes in different ratios of proteins, sugars, and fats, and depending on the quantities of these substances, they use it to feed developing workers, drones, and queens. Pollen is generally stored close to developing brood, and in a healthy hive it should encircle the developing brood almost completely.

Propolis

Propolis is derived from the Greek words *pro* meaning "before" and *polis* meaning "city". Ancient Greeks observed bees putting this substance at the entrances to their hives. Propolis is not made by the bees but collected from specific plants. It is mainly made from sap and resins that contain antimicrobial properties. The bees use propolis to clean their hives. This is part of something called social immunity, where the bees in a colony work together to keep their home disease-free. They line honeycomb with it to prevent the spread of bacteria and viruses to brood and use it to block and seal small holes in their nesting space or brood box. A lot of propolis can be annoying as it hives hard to open. Propolis is very important for the health of th where the bees put it.

A good pattern

Assessing whether a colony is healthy or not is one of the mos beekeeper. There are a lot of factors that can affect colony health, b will tell you if your colony is doing well. One of these signs is the pa the brood box. If the brood patch on the frame is full, with few er few larvae were removed, which is a good indicator that there is lit the queen is healthy and laying well. If the colony can collect eno surrounding the brood patch in an uninterrupted ring. If they ha honey in the outer cells of a frame. When inspecting your colonies have enough honey and pollen, or the bees may not be able to incr summer is very important for a good honey crop.

Honey and pollen surrounding brood on a frame. This pattern generally means a healthy, well-fed colony.

Colony basics

Your colony needs a few basic things to be happy and healthy:

1. **A weatherproof box**
   A good-sized box that is insulated, with a cover that will n necessary for maintaining a healthy colony. The entrance must be large enough for many bees

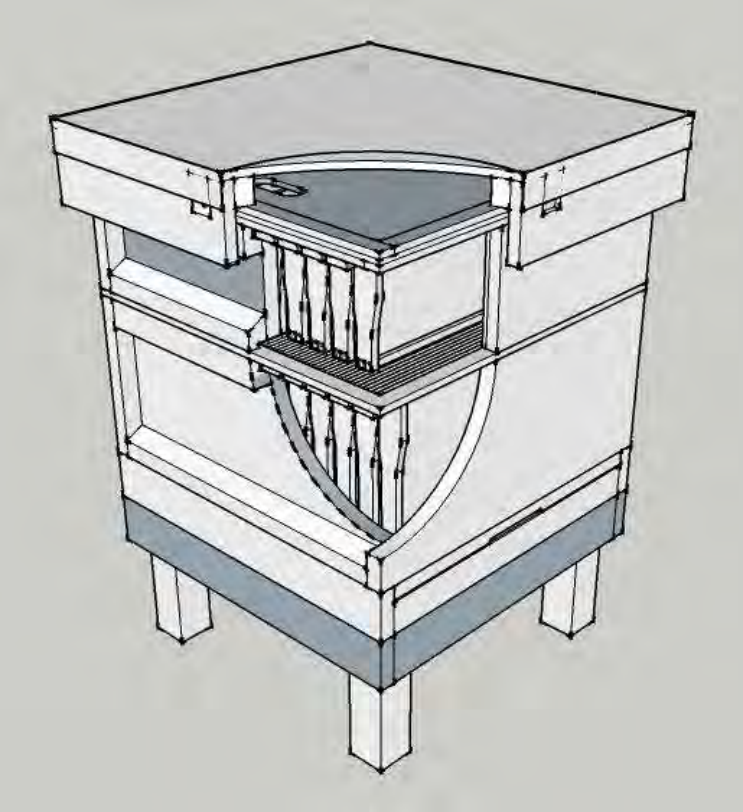
to pass through at once, but not large enough for small animals to get in as well. Usually, this is a thin slit at the bottom of the front side of the hive, just tall enough for your bees to fit through. They need to feel safe in their space and sure that no predators can get in.

2. **Good ventilation**

   A wire mesh floor is a good way for the bees to get enough air circulation while preventing other bees or animals like mice from coming in to steal their resources. The bees must be able to regulate the temperature of the hive effectively in hot or cold weather, or they will risk killing their brood.

3. **Enough food**

   Honeybees will always need honey to work. It is the primary food source of all adult worker bees. If bees are food-starved they can get aggressive, and often cannot work to run the colony. If there is a period without flowering plants, you should consider helping your bees with a little sugar syrup. Pollen is very important too; without it the colony cannot make more bees. Always check to make sure your colonies have the pollen they need to grow big at the start of the season.



A standard modern hive with a base board, brood box, queen excluder, super box, inner cover, and roof.

The modern hive

4. **Access to water**

Water is crucial for regulating temperature and humidity in the colony and when producing brood food. Bees will fly out and collect water just like they collect nectar. They must have access to water every day they are active. If water is scarce in the landscape around your bees, consider putting out a water trough. Float a wooden lattice or gate on top of the water so the bees can perch on it, or use it to climb out of the water if they fall in.

The modern hive was designed to make honeybee management easy and simple. Here we will cover all the different parts of a modern hive and the purpose of each, starting from the bottom and working our way upwards.

The base board (bottom board)

This is usually a wood frame with a wire mesh set underneath. The wood frame will meet with the bottom of the first box to create a sealed seam all the way around save for the entrance at the front. The wire mesh is usually very fine, with holes that are too small for bees to come through. This means the only way into a colony is through the proper entrance, which can be guarded much more easily. Often times, these bottom boards are designed to hold a metal or wood tray underneath the wire mesh to collect falling debris from the colony. These trays are good tools to use when monitoring your colonies for parasites like Varroa.

The boxes

The boxes of a hive are traditionally made of wood, but in colder climates they can also be made of Polystyrene (styrofoam). The boxes can be painted bright colours or have different coloured panels set above the entrances to help bees differentiate and find their own hives. They should be sealed, with no holes save for a space at the bottom which serves as the bees' entrance to the hive.

The brood box

This is a box usually set with full frames that serves as the primary living box for the bees. The queen and all the brood should be kept in the brood box at the bottom of the hive, separated from the boxes above. In summer, it is not uncommon to keep two brood boxes to house the bees that will collect your honey. Generally, a colony should be given no more space than the bees can handle; too much space and it becomes hard for them to control the hive temperature and protect their honey from robbing bees. If in spring or summer, however, they become too big for their brood box, the bees may decide to swarm. Keep a close watch on your bees in spring when the colony is growing and see if they need more room.

Hot or cold?

Which way should your frames be turned relative to your hive's entrance?

Why does it matter? There is a lot of debate in the beekeeping world about which way to turn your frames.

Setting them to hang perpendicular to the hive entrance creates more air flow and allows the hive to be cooled faster. This is known as the "Cold" way.

Setting them parallel to the hive entrance reduces airflow and may help the bees keep the hive warmer. This is known as the "Hot" way. Colder climate beekeepers tend to like having their frames the "Hot" way, while in warmer climates the "Cold" way is favoured. Ultimately, though, whichever way you choose should be the way you stick with. The bees like consistency above everything else.

The queen excluder

The queen excluder is usually a barred metal grate with spaces between the bars just big enough for your worker bees, but too small for a mated queen (and drones) to fit. This grate is placed between the brood box and your honey supers to keep the queen from putting eggs in with your honey. On occasion, an unmated or a newly-mated queen can slip through the bars, so in summer if you can't seem to find the old queen this may be why.

The super boxes (honey boxes)

The super boxes are structurally the same as the brood box, though they can be half as deep, with half-frames that are much lighter to carry than full frames when filled with honey. A colony can fill several supers in just a few short weeks if the conditions are right. If the colony does not have enough supers during a nectar flow they could swarm, or begin to put honey where the brood should be. In both cases it will reduce the number of bees in the hive, and reduce the amount of honey you will get for the rest of the season. In warm climates a second entrance for the bees in one of the supers will help the bees to ventilate the hive.

Comb & framesFrames are made of untreated wood, usually pine, and are threaded with metal wire with two connection points for a current which will melt the wax sheet in place. Wax foundation can be bought printed with the hexagonal pattern in a standard diameter of 5.3mm for worker cells (6.5mm for drone cells). The wax foundation encourages the bees to build comb quickly and gives them a little material to start with. You can also find plastic frames with the printed comb pattern made in the plastic base instead. Though these are less work to prepare, it is harder to see the brood and eggs and make judgements on your colony's health.

A BIG Question:

Why does a hive need to be kept off the ground?

A honeybee colony should NEVER be placed on the ground. The ground is cold, often wet, and can contain a lot of things that are bad for your bees. Aside from that, the colony drops a lot of debris, from diseased brood to old wax and waste. Oftentimes, this debris can make your bees sick if it stays too close to your hive. Keeping the hive off the ground by placing them on stands or pallets makes sure your bees can get rid of waste and regulate hive temperature easily.

Covers and roof

The inner cover of the modern hive is made to insulate the colony and help temperature regulation. Oftentimes, this is polystyrene or pressed wood pulp or even solid wood with a plastic sheet between it and the bees to prevent the bees from chewing and damaging it. Some types of inner covers are made with one or more holes in the top so that the roof can be taken away and top feeders can be placed on the colonies.

Entrance

The entrance to the hive is typically at the bottom-front of the

hive box. The bottom board willl have a slight dip in the front so that when a box is placed upon it, it provides a bee-height space for the bees to come and go. In colder temperatures, or when the bees are robbing, the entrance can be partially blocked to control heat escape as well as protect the hive from invading bees. The hive entrance should only be completely closed when you are going to move a hive or euthanize it. If the bees cannot leave the hive they can starve in just a few days depending on the resources they have saved.

There are many parts in a honeybee hive and all of them are very important. To take care of your bees in the best possible way you must know what they need and why they need it. Good shelter is the most important thing you can give your bees. Not all equipment is created equal, so make sure you do your research and thoroughly examine the quality of the parts you are looking to purchase before you buy them.

1.6

Beekeeping Equipment

Like any business, a good set of equipment is going to make work efficient, safe, and cost-effective. In beekeeping, there is a very large variety of things you can buy for your operation, but not all of it is necessary to make a successful business. This section will cover the most essential equipment, its diversity, and its function.

The hive

We now know that the beehive provides your bees with controlled shelter from the elements. Bees naturally nest in cavities, and they are most comfortable in enclosed spaces with narrow entrances. We covered the basic parts of a hive and their function in section 1.5; in this section, we will discuss hive diversity, detailed components of the hive, and its materials.

Hive types

There are a wide variety of hive types available, and it is very important you know which type you are buying as many have fundamental differences that will dictate the rest of the hive equipment you need. For example: The standard Langstroth hive has variants that differ in the dimensions of the box. The dimensions of the box will control the size of the frames you will need in both length and depth, as well as the number of frames per box. This will also force you to buy or make wax foundation of that specific size, or else risk having foundation you must cut to fit, which can take a lot of time and wastes wax. Generally, countries will have either one or several standard hive types that are preferred by most

beekeepers, and therefore equipment for this hive type will be much more available (both new and second hand).
For beekeepers who intend to create a successful business, moveable frame hives like the Langstroth are a must, especially since other types of hives, like the top bar, can be hard to find. The top access and movable frames are crucial for quick and easy management, and they are the least disruptive to your bees.
The frames must also be kept at precisely the right distance apart (the space between them is called the "bee space"), between 6mm and 9mm from the top of the cells. Too little space and the bees will not build comb properly, too much and they will build comb in between the frames (called bridge comb). Both cases will reduce the efficiency of your hive.

The super (honey box)

This is a box placed on top of your brood box with a queen-excluding mesh between them. The box is half the height of a brood box because, when full of honey, the box can be extremely heavy. A half-box super can weigh between 15kg and 20kg, while a full box can weigh between 30kg and 40kg, depending on the material of the box.

The inner cover

Usually this is made of wood and has a lip to allow a bit of space between the cover and the tops of the frames. This allows the bees to move freely overtop of the frames and allows for necessary airflow. If you choose to use bucket feeders, which are placed on top of the hive, some inner covers have small holes in them to allow the feeder to be placed on top while protecting your bees in colder climates, there can be a layer of insulative material between inner cover and the roof.

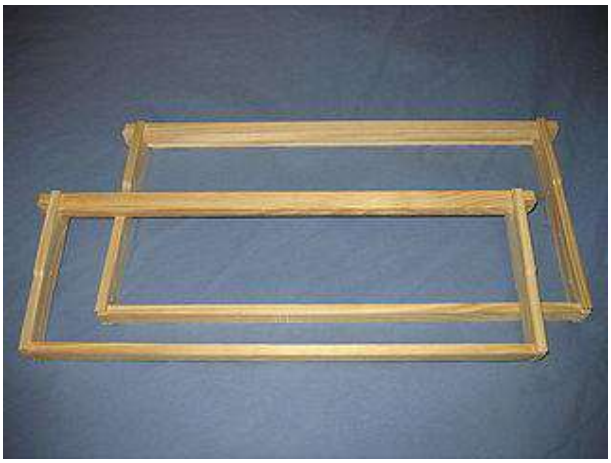
The roof

Generally made of a waterproofed material, this part of the hive should be slightly larger than your box, with slanted edges to keep rain from seeping into your colonies. Wet colonies can collect mould and decrease the vitality of your bees, so it is very important that the hives are protected from the elements.

Use caution when buying used equipment

Beekeeping equipment can be very expensive and sometimes you might find a good deal buying things from another beekeeper; however, there are certain diseases like European and American foulbrood that can stay in wax and wood for a very long time. These diseases can destroy your operation. It is important to buy from dependable sources and ask questions about the history of the equipment. Inspecting it personally will help reduce the risk of buying worn out or damaged equipment. There will alsways be a risk to buying equipment second hand, however. If you want to avoid that risk, it's better to buy it new.

The frames



All frames are reusable, and many beekeepers replace the wax foundation of their frames after one or two years in the brood box to let the bees build new comb, rotating old and new frames so bees always have new comb to rear brood on. This helps reduce the risk of brood disease and the effects of pesticide poisoning. The size of your frames will depend entirely on the hive boxes, and generally the frames will carry the same name as your hive type. It is crucial that the frames be the right size for the hive or they will be completely unusable. Frames are simple wood, usually made of a softwood like pine, with the top part of the frame slightly elongated on either side so it can sit and slide into the hive box grooves. Frames are bought with metal wire threaded through them so that wax foundation can be laid directly into the frame and melted in place using an electric embedder (electrodes and a battery) to gently heat the wire. It is important to get a low voltage battery for your electric embedder as the melting point of beeswax is very low, and you can risk cutting your foundation to pieces if the wire becomes too hot. Often, the wire is straight and smooth, but crimping the wire can make the wax foundation much more stable in the frame. A special tool called a wire tensioner can be used to do this. Sometimes frames can come without wire, but they usually have holes and nails so you can wire the frame yourself. Standard wire diameter for threading frames is 0.4mm and is often made of stainless steel or galvanized iron.

Some frames are plastic and have a plastic foundation guide built in. These are easier to use and more durable, however they are often not favoured by the bees and must be coated with beeswax to encourage the bees to build on them. Plastic frames cannot be placed in a wax melter to extract the wax that you can recycle or sell.

Wax foundation

Blank wood frames require wax foundation, printed with the comb pattern in the diameter you would like your cells to be. Generally, the standard size for a worker cell on a commercial wax foundation sheet is 5.3mm. Wax foundation is the best way to get your bees to build comb straight on the frame, and it avoids cross-building or bridge comb, where bees build comb between frames and thereby prevent the frames from being moved without damaging the comb and leaking honey. Though wax foundation makes the hive boxes much neater and easier to manage, you do not require wax foundation. A wax “starter”, usually a flat wood stick dipped in beeswax or a strip of foundation fixed lengthways under the top part of the frame, is enough to encourage the bees to build the right way. This

method can guarantee the source and therefore quality of the wax you produce, but you will not be able to control the size of cell your bees make, and this can often lead to drone brood being produced in quantities you do not need or in places you do not want.

Feeders

There are many ways to feed your bees, and a type of feeder for each way. The most important thing when choosing a feeder is to make sure it does not encourage robbing among your hives. Feeders must be tightly attached to the hive and fixed so that access to the food is inside the hive and nowhere else.

Never feed your bees in open air. It will trigger robbing and fills the area surrounding the hives with bees, which can create large problems for you when working them, and for any other people nearby.

Top feeder

The top feeder is the most popular type of feeder for large operations. It allows a large quantity of sugar syrup to be given at once. It is roughly the size of a super, with an open trough and a narrow passage on one side so bees can crawl up and over the lip of the trough to take the sugar. Top bucket feeders can also be made from making a small hole in your inner cover (4-5cm in diameter) and upturning a closed bucket filled with syrup, with pin holes (2mm) poked into the lid. This method relies on liquid pressure and having too much syrup or having pin holes too large can flood your hive with syrup which makes a mess and can induce robbing.

Frame feeder

This feeder has the dimensions of one or two frames and can be placed in the colony the same way as a frame. It is a deep container you can fill with sugar syrup, likely with a mesh grid overtop to help the bees out if they fall in. The volume of sugar that can be fed is much smaller than the top feeders, however these are entirely internal feeders which can be best guarded from robbers.

Entrance feeder

These feeders are usually the smallest kind and consist of a glass or plastic bottle fixed to a special bottom that can be inserted into the hive entrance. These feeders have the benefit of letting you see how much food is consumed, however the nearness to the entrance can encourage robbing in lean seasons.

Queen excluders

These are metal or plastic grates with spaces wide enough for worker bees to fit through, but not wide enough for mated queen bees and drones. The queen excluder is placed above the brood box but underneath your honey boxes to keep out unwanted drones and to make sure the queen does not put eggs in the frames you want to take honey from. It is very important to make sure there is always a queen excluder between your brood box and your honey boxes, or you risk getting bee brood in your honey, which will not only change the flavour, but it might also make your honey unsellable.

Bee boards

Also called escape boards, bee boards are special boards with entrance excluders. These boards are placed under your honey boxes but above the brood box and queen excluder during harvest time. These boards permit bees to come down out of the honey box, but prevent them from going back up, emptying your honey box of bees, and making it easier to take. Brushing bees off each frame is time consuming and can damage your bees. The bee board is only used after a honey flow, as using it during a honeyflow will prevent your bees from putting honey in their honey boxes, and they will flood the brood room instead. To encourage the bees to go down, a feeder can be placed between the bee board and the brood box (above the queen excluder).

The tools

Veil

The bee veil is the most important piece of protective equipment you can have. Even if there is no risk of allergy, apitoxin (bee venom) can still be dangerous when you are stung in any area with an airway, like your face and throat. It is highly recommended to always protect these areas. Even if your bees are docile, accidents can happen, and it is much better to be cautious.

The veil is usually made of thick cotton and a malleable plastic mesh to prevent bees from getting through. The veil should be maintained well, and holes in the mesh should be repaired before working bees again. There are many types of veil, and the styles are often left to personal preference. It is a good idea to get a veil that offers protection from the sun as well as bees, as much of the bee work is done during the day and for long periods.

Suit

The bee suit is another important piece of equipment. Made of a thick, breathable material like cotton, it works to protect the beekeeper from the worst of the bee stings one might encounter. The suit is full length but can also come in the form of just a jacket, and it is elasticated at the wrists and ankles to keep bees from crawling in. A zipper will usually attach the veil securely to the suit, but not always. Under normal circumstances, you will not be at risk of being attacked by domestic bees, but if an accident occurs (like a dropped colony box in the field or during transport, or an animal attack on your hives) you could be walking into a situation with very aggressive bees. In this context, it is necessary to have as much protection as you can. Tall boots or thick socks are good ways to protect your ankles and feet below the suit, and you should always have a pair of beekeeping gloves handy.

Gloves

When working with bees, stings are inevitable, and the most common place to be stung is on your hands. Crushing bees under your grip on a frame is almost always the reason why you will receive a sting. Beekeeping gloves are made of leather, thick enough to block most stings but supple enough that you can move and grip things without much difficulty. The leather can be made of pig or deer skin, and the gloves should extend up to the base of the elbow, though only the hands need to be made of leather. The ends of the gloves should be elasticated to prevent bees from slipping into your suit. Even if you do not like working with gloves, you should always have a pair close in case a colony becomes aggressive.

Keeping the hive clean

Throughout the season, bees will eventually put comb where they are not supposed to, and a build-up of propolis on the frames and between boxes can make your job much harder. Using a hive tool to scrape away excess material is a good way to keep the hive clean and easy to work with. If bees are building a lot of comb on top of the frames and filling it with honey, they may have run out of room and will require another box. It is very important to give bees enough room duirng a flow or you will risk making your colony smaller by preventing the queen from laying

Hive tool

The hive tool is the most used tool in beekeeping. It is crucial in moving frames and boxes and is specially designed to make these tasks smooth and easy. Though simple, nothing can substitute it for function. One end is bevelled and sharp to slide between boxes and act as a lever to pry apart the propolis seals. It can also be used to cut plastic, excise pieces of comb, and scrap off debris and burr comb that keeps the hive tidy and clean. The other end is hooked to catch the top part of frames and pry them up out of the box. You should not start your beekeeping day without it on hand.

Smoker

This is another essential tool, though there are some beekeepers who work without one. The smoker has a chamber to hold burning material that produces smoke which will take advantage of the natural behaviour your bees have in response to signs of fire. The bellow at the rear of the smoker allows you to stoke the embers within and push smoke where it is needed. When bees sense there is a fire nearby, they rush to consume as much honey as they can to save it if they must flee their home. While they do this, they become more docile and permit you to work the hive without rousing their predator defence response. The smoke also acts as a repressor for the detection of their alarm pheromones which will trigger aggression. Bees will move away from the smoke, and you can keep them off the parts of the frame you touch to reduce the potential number of bees killed. Killing bees while you work releases large amounts of alarm pheromone, and the bodies of deceased bees increases the risk of disease spread. Once the smoke is gone, honeybees will replace the honey and go back to their normal routine.

The types of material used in the smoker varies, but it is generally wood-based and can burn for long periods while producing cool smoke. It is important not to light a fire that is too hot, or you risk burning your bees. Avoid chemical starters or gases as they are volatile and can produce fumes which can harm not just your bees, but you as well. Using some form of gentler, be it water or smoke, is generally wise, as it reduces aggression as well as the amount of alarm pheromones that get onto your gloves and tools.

Brush

A bee brush is used when you need to move a large number of bees off of or onto a surface. The most common use is during the honey harvest to clean the honey frames of bees so you do not take half your bees home to the honey house. The bristles must be soft, or you risk injuring your working bees and breaking honey cell caps which can leave a mess and

attract more bees. Most brushes are made of wood with soft plastic bristles; traditionally, bristles were made of horse or pig hair and those materials still work well today.

Pest control

Depending on the area where you live, there are many pests that plague honeybees. The most common and most devastating is *Varroa destructor*, a small, parasitic mite that can spread disease amongst your bees. Section 4 covers pests and pathogens in depth and discusses some of the tools you will require to trap, measure, and treat for them. It is very useful to research the problem species in your area before you buy bees, and to create a plan to deal with outbreaks.

The honey house

The place where honey is extracted is called the honey house. It keeps all the equipment and storage space needed for the extraction, filtration, processing, and packaging of honey and other products. The space must be clean and often must adhere to country-specific standards to produce approved products. Oftentimes, smaller beekeeping operations can rent the extraction and processing equipment of a producer or a larger beekeeping operation, so you do not necessarily need to purchase this equipment yourself; you will, however, need it if you wish to extract products in quantities and qualities you can sell. Bee-tight

The building must be bee-tight, which means it must have closable doors and windows to prevent hungry bees from getting in and relaying to all their sisters the wonders of the honey house. A honey house full of bees can be disastrous for the quality of honey you can produce, not to mention it can be complicated and dangerous to navigate a room full of bees.

Water-tight sealed floors or thick, plastic floor cover

The floors must be washable, as honey and wax are bound to get everywhere. You can also use plastic sheeting to make the floors easier to clean. Floors should be sealed in concrete or linoleum with a lip that extends a short distance up the wall. Wood floors are not recommended.

Temperature controlled storage for un-extracted frames

Pending on the nectar sources and sugar composition in the nectar, honey tends to crystallize at cooler temperatures, and the type of nectar the bees have collected will change the time of crystallization. As a rule, you should keep the honey boxes in the colonies until one to three days before extraction but having a heated storage room can slow the crystallization process and give you more time. If the honey crystallizes in the frame, it will be impossible to extract, and even the bees may have a hard time cleaning out the cells. In cold and humid climates, there is a risk that the water content in the honey is too high. Water content is best measured with a refractometer. A dehumidifier in the storage room can reduce the water content in the honey before extraction.

Honey extraction and processing

As you might have guessed, there are many different tools for extracting and processing honey. Below we will discuss the most common and likely most important tools you will need.

Thermometer (best with humidity gauge)

It is always a good idea to maintain a constant temperature in your honey house to make the crystallization process consistent and predictable. As stated above, crystallized honey in the frames means a loss of product.

Food safe tools

Because honey is a food product, health and safety standards dictate that all tools used to contain and process honey must be food safe. There are many types of metals and plastics that meet this requirement, and any tools manufactured specifically for honey processing should already have a certification.

Capping fork, heated knife, or machine

The best quality honey is honey that the bees have decided is ready. They tell you this by capping the finished cells with a fine layer of fresh beeswax called a wax cap. To extract the honey, you must remove these caps from the cells. This can be done manually with a capping fork or heated capping knife, or automatically with an uncapping machine. Leaving capped cells results in the honey in those cells staying on the frame. A capping fork is the cheapest option and usually the most efficient, but it is time consuming. Capping knives and machines are much faster, but more honey is lost and not all cells may be cut, meaning you may have to go over the frame more than once.

Capping basin

Once the cells are uncapped, honey will begin to escape. You can catch this honey in a capping basin that has a holder placed over the basin, holding the frames as they wait to be placed in an extractor. This honey can be added to your holding tank with the rest before it is filtered.

Honey extractor

This machine is fundamentally a spinning barrel that holds frames in a circle and at the precise angle that

will draw the honey out using centrifugal force. Honey extractors come in many sizes to fit all scales of operations and can be hand-spun or built with a motor to automate the process. There is a spout at the bottom that will pour the honey into the holding tank. It is very important the barrel not become overfilled with honey, or you will risk breaking the machinery. While the frames are being spun, the spout must be open with the tank in place.

Honey strainers

Honey, when it is first extracted from a frame, will contain pieces of wax, propolis, and hive debris. Due to its very high sugar concentration, honey is very resistant to harbouring most bacteria, so a filtration process to get rid of debris is usually all the processing that is required, though country standards do vary, and some do require the honey to be pasteurized before sale. Honey strainers are fine wire mesh strainers that can be single or double meshed, and these are generally sufficient to produce clear, smooth, and debris-free honey. Depending on the water content of the honey, the process may be quite slow, so pay attention to the honey flow through the strainer and make sure you do not flood it. It is wise to have a few strainers on hand, as they may need to be removed and cleaned throughout the process.

Settling tank

Once extracted, honey generally contains a lot of air in the form of tiny bubbles, which can form foam at the top of a jar if bottled too soon. Letting honey sit allows the bubbles and any remaining wax to float to the top of the settling tank and leaves you with good quality honey to bottle and sell. The settling times vary depending on the temperature of your honey house, the water content of the honey, and the type of nectar the honey was made from.

Honey pasteurization machine

Some countries will require honey to be pasteurized before it can be sold on commercial markets. Pasteurization is a process that heats the honey, killing bacteria and preventing the crystallization process. There are machines that can do this, though the specifics of the process are dictated by country regulations. In other countries, pasteurization is not even permitted, as it reduces the enzyme activity in the honey.

Jars, pots, buckets, or bottles

Honey is usually packaged by gram weight and can be sold in bulk using large buckets, or in small, personal or family-sized jars for direct consumption. Most beekeepers have a variety of packaging for direct sale as well as sale to a producer. Attractive glass jars are good for direct sale, while producers generally ask for honey in bulk buckets of 10kg or more. Whatever packaging you use, the container that will store the honey does not need to be sterilized.

Other product tools

Wax melter & Foundation sheet maker

Beeswax is the second most popular product after honey, and bees produce a lot of wax over the active season in the form of wax cappings on honey frames and old frames you replace in the brood nest. That wax can be very valuable, both for your operation and to sell as a product, but first it must be melted and filtered.

A wax melter is basically a steam room with frame holders and a mesh floor that traps debris and permits melted wax to filter through into a collection container (usually a bucket with cold water). For extra purity you can add another filter. Once you have the filtered, clean wax you can begin making products like candles, wax polishes, or skin products, or you can re-work it back into a new wax foundation.

New wax foundation can be made with a wax foundation printer. This can be as simple as a manual hand-worked printer, and as complex as a machine that also heat treats the wax before forming it into a thin sheet and printing it. Heat treating may be a necessary step in the making of frame foundations, as it prevents the spread of bacterial diseases that can be very harmful to your bees. You should check your local regulations before producing wax foundations to sell.

Pollen and propolis traps

Other products that are now gaining in popularity are pollen and propolis. Pollen is often used as a dietary supplement and is collected using a special trap placed at the front of a hive, or it can be integrated into the bottom board and will carefully brush the pollen from the pollen paniers on the bees' legs. It does not collect all the pollen, however. You should be careful when and for how long the trap is placed on your colony, as the bees require pollen to rear brood.

To collect propolis you must take advantage of the bees' natural behaviour: Propolis is a good antibacterial agent and bees line their nests, fill small holes, and clean with it. There is often a lining of propolis at the front entrance of the hive so entering bees must walk over it and "clean their feet". To collect propolis all you need is a plastic sheet that looks very similar to a queen excluder, but the slits are too small for any bees to pass through. Once bees discover they cannot get through the holes, their

instinct is to block the holes with propolis. The bees' motivation to seal the holes with propolis can be increased by having ventilation over the sheet, creating drafts they will want to block. When the trap has been filled, freezing it will make the propolis brittle enough to collect.

Queen rearing

There is a lot of specialized equipment used in queen rearing, though most of it is not expensive. Queen rearing requires you to remove capped queen cells that have been produced in a special "queen breeding" colony, and care for them in an incubator. The process must be timed so you are present within 4 hours of their emergence to mark them and place them in cages with workers who will feed and care for them.

The incubator must have a humidity and temperature control, and the frames and queen cups used to graft larvae are specially made for the task.

Grafting tools are made specifically to collect the delicate young queen larvae without damaging them.

Specialized incubator cages are built to encase queen cells so the queen can emerge but be contained and thereby prevented from killing the other new queens. More details on queen rearing, and an in-depth look at the tools and processes required, will be covered in section 5.

2.0

Beekeeping Through a Year

There are many different methods to keeping bees, and beekeepers develop their own techniques over time. Seasons look very different depending on which region you live in--lowlands or mountains, Mediterranean or Baltic, arid or wet--and this changes the timing and method of the tasks. Honey and other product collection will rely precisely on the major nectar flows in your area, and these can be different, even in similar ecotypes and countries, depending on the landscape and the weather. There are a few main elements that are common for all operations, however, and we will cover the very basics of what you must do season by season to keep healthy and productive hives. Keep in mind that though some tasks will be set to one season, the tasks must be brought forward or pushed back depending on the area, weather, and environment, so the timing of these events covered in this course section can vary.

The role of the beekeeper

As a beekeeper, your role is to give your honeybee colonies the best conditions possible so they stay healthy and productive. The honeybee colony goes through several phases in a year, and it is important that the beekeeper understands this cycle to be able to perform the right tasks at the right times. The difference between success and failure as a beekeeper is often related to timing, and this depends on the situation in the colonies, not on the date of the calendar. For this reason, a good understanding of honeybee biology will make it easier for you to succeed.

2.1 Winter/spring

Pre-season preparation

Clean and organize your equipment

Before the bee season starts, it is a good idea to clean and sort all of your equipment, so it is organized and ready to use when the bees begin to be active. Once spring is truly under way, you may not have much time to dedicate to this task, and you will need the equipment. Scrape off old propolis and wax, paint, or re-paint boxes, and make an inventory. Organizing what you have makes it much easier to see what you need.

Make new frames

Whether you are buying wax foundation, making it yourself, or using plastic frames, you must make sure you have all you need plus a little extra. Bees benefit from having new wax in their brood room because

old brood frames can carry pathogens like *nosema* and chalkbrood, and bacterial diseases like European and American foulbrood.

You will also need frames for your super boxes. The number of frames replaced in the brood box each year depends greatly on the beekeeper and their preferences, but it is recommended at least half the frames be replaced each year to keep your bees healthy. It is a good idea to prep your honey supers and stack and cover them to protect the wax from pests like wax moth. Depending on the area, the race of your bees, and the honey flow, it is beneficial to have about two to seven half-box supers prepared for every hive. Not all colonies will produce honey, but some will produce much more than others. It is also a good idea to have a stock of frames and wax foundation so more frames can be made as needed.

Prepare bee feed

Not knowing what the season will bring is one of the difficulties of any land-based business. Prepping some bee feed to have on hand in case you need to rescue starving colonies or help your bees through a lean spring will save you a lot of trouble in the long run. In some areas, it is common practice to feed the bees every spring to help give them an early start so they can grow the colony before the first honey flow. Bee feed can come in two forms: a paste or a syrup. The paste can be bought, and sometimes it is mixed with pollen to give colonies a protein boost in areas with low levels of spring pollen. Oftentimes, the syrup is the cheapest option and can be bought in bulk or mixed yourself. Generally, there is a 50:50 ratio of kilograms of sugar to litres of water, but many beekeepers change this ratio based on time of year. In spring, it is common to make the syrup a little thinner to entice the bees to start the process of foraging and honey making. You should prepare enough feed in spring to feed your colonies at least one to three kilos of bee feed. They may not need it all in spring, but they might need it later!

Mix solid sugar with room-temperature to cold water (never hot water). Store the excess sugar feed in closed containers and in a bee-proof building. During times of food stress, bees can be excited very quickly at the thought of an easy meal and you can have masses of bees collecting in your honey house or bee yards if things are not kept closed and clean.

Create a spreadsheet for your colony records

Writing things down can save a lot of time and effort. It is a good idea to create a spreadsheet that can be printed out and written in as you work your way through the hives.

Having things like queen status, colony temperament, frames given, food given, colony size, and parasite counts can really help you keep track of the health of your individual colonies and help you make informed decisions on what to do in a given situation. Almost every beekeeper has their own system, and you must find out what works for you. Whatever system you use, it is good to have it ready to go before the bee season really begins.

Early Spring inspection

When is it the right time?

Like most things in beekeeping there is no calendar date for a spring inspection. Checking your hives for the first time is completely dependent on when the conditions are favourable enough for bees to begin to fly out and start their spring build-up. The temperature will factor into when to do your inspection; opening the hive for a thorough check in cold temperatures could risk your vulnerable cluster losing needed heat and may even kill your colony. A good sign of the right time to check up on your bees is when they are actively flying out for most of the day. Once a colony is active, it will begin to use resources faster, and your job as a beekeeper is to make sure they have those resources.

Remove deadouts

Looking at which colonies have flying bees is also a good way to find deadouts. A deadout is a hive that died over the hibernation period, and it is advisable to close the flight entrance and remove these hives as soon as they are detected. If the colony died of disease, hungry foraging bees from healthy colonies could invade these empty hives for left over sugar and bring the disease back with them. Once the hives are removed, melt or discard the wax, and if your equipment is made of wood and metal, you can use a gas torch to scorch the equipment and remove any trace of most diseases. Washing equipment is also an option, and there are disinfectants that work well on pathogens like *nosema*.

Food

When you decide to do your spring check you will be looking for several things:

1. Do the bees have enough food to last them until the honey flows begin?
2. Do the colonies have a well-laying queen?
3. Do the bees have sufficient pollen stores to begin brood rearing?
4. How much brood have they begun to rear?
5. How many frames are the bees occupying, and how much of the colony died off during hibernation?
6. Are there signs of disease? Mould? Pests like mice, ants, or shrews?

A well-wintered colony should have good honey and sugar stores that will last them until the spring flows, but some colonies, especially from races that overwinter in large numbers, may have gone through their stores before any spring flowers appear. Simply lifting each hive from the bottom and weighing it by one edge in your hand will tell you if the colony has sufficient honey or sugar. If the bees have ample pollen but are not producing brood, it could be an indication that the colony does not have enough sugar. This is when it is important to feed your colonies. For the colonies to take the food, it must be consistently warm enough during the day that they can get to the food safely. Bees leaving the cluster to fetch sugar are at risk of freezing, and the cluster shrinks, increasing the chances you could lose your hive. It is unwise to do any work like frame changing or combining weaker colonies at this time, as you cause stress and may risk losing your colonies.

In dry climates, it is always important to make sure your colony has access to water when it is warm enough for them to fly out. Colonies are at just as much risk of dying from thirst or heat as they are from the cold.

Pollen & Brood

Most bee races are very good at building up pollen stores in fall to begin brood production over winter before spring pollen is even available, but if your colony has gone through all their pollen, the beekeeper can add a pollen pack, which can be bought at most bee supply stores. Pollen is the best protein source for the bees, but it can be swapped with other sources like brewer's yeast, soy-based supplements, and some animal-based supplements if necessary. You should always make sure you know the source of the protein, and it is good to make sure it is produced sustainably. There are many different protein supplements on the market, but pollen remains the best for the health of your bees. Be aware of possible regulations set on the use of bee-collected pollen harvested outside your own operation, as there is a risk of contamination with pathogens.

Colony size

It is natural for some bees to die off during a period of hibernation due to the heat or the cold, and the colonies will commonly be smaller in spring than they were in the autumn. Too many dead bees, however, may indicate several different problems with the hive: disease, a lack of food or water, or that too many of the bees were already old when they began hibernation in the fall. Usually, dead bees will fall to the bottom of the colony and will be removed by the living bees slowly as the colony builds, but you can help your bees by cleaning out the bottom board for them, so they can spend more energy foraging and are less exposed to disease from contact with dead bees.

It is important to make sure the bees have only the amount of space in the hive that they can control, so if your cluster has shrunk considerably over winter, it may be a good idea to remove some frames and add insulators, and to only expand the hive again with wax foundation frames when the colony size increases. In spring, the size of the colonies will often vary within a bee yard. To have a smooth-running operation, however, it is advisable to make all colonies more or less the same size. You can achieve this by moving frames with capped brood and young bees from strong colonies to weaker colonies. This can reduce the chance for swarming in the more robust colonies and make the weaker colonies strong enough to collect honey or any other product you need for your operation.

Disease

Module 4 discusses pests and disease at length and provides training on recognizing and dealing with these types of threats, so we will only briefly discuss them here:

Checking for disease is important in spring. This is when many of the diseases will be most apparent. Fungal pathogens like *nosema* or chalk brood cannot be treated, but they often do not last past the spring, and adding a few healthy bees from a strong colony may give a needed boost when the weather is favourable.

Some diseases are much more serious. European and American foulbrood can affect colonies at any time of year, but it is most common in weak colonies and in cold, damp conditions, precisely the conditions that you are faced with in spring. These diseases must be dealt with swiftly and severely according to the national regulations. It often includes euthanasia of affected colonies and the burning of all hive equipment associated with the infected hives. Most countries will also require you to report the outbreak to local beekeeping regulators.

Signs of pests are also most common in spring when many animals are waking up hungry. There is little to do to prevent these attacks apart from moving your hives. Some ants may be deterred by removing their chemical trails up the legs of the hives, and this can be done by rubbing the legs with vinegar or by placing the hive stand legs in small buckets of water (keep in mind that these buckets can drown thirsty bees too).

Mid-late spring

Pollination

Some regions are well-suited for growing fruit and other flowering monoculture crops that honeybees are experts at pollinating. Honeybees can increase not only the amount of fruit produced, but the size and quality of the fruit set as well. Pollination service is a very large business for some beekeepers, and on rare occasions, it can replace honey and other products completely. Crop producers will often rent honeybee colonies during the flowering time of their fields or orchards. If pollination is a service you wish to provide, you must know your market and how many colonies you will need to have ready for the flowering times, which often only last a few weeks. You must be aware of what sort of chemicals are used in the fields and how this will affect both your bees and any potential honey you could collect from your hives.

In some regions, contracts are used to secure bees for pollination, and it is the responsibility of the beekeeper to do research and make sure the contract is fair. If a crop producer will not divulge what is used on the crops in terms of pesticides, fertilizers, or fungicides, this could be a red flag, and you should avoid operations with little transparency. Many insect-pollinated crops flower early in the season, and beekeepers need to build their colonies strong in spring to be able to provide professional pollination services

Add frames & supers

When the colonies begin to build up in a new season, they will of course need more room to do it, or you will risk encouraging your colony to make swarm queens. Adding fresh wax foundation to the brood room gives new wax for the queen to lay on and helps reduce brood disease. The question of when to add supers (honey boxes) can be tricky; putting them on too early risks the hive being too large for the bees to heat, which may result in dead brood. Put them on too late, and the colony will become honey bound, reducing the brood room and the growth of your hive (or you could lose half your bees to swarming). The best time to add a super depends on the weather, on flowers blooming, and on the race of your bees. Bee races that are fast builders will need a super earlier than slower builders, and the

climate temperature needs to be consistently above zero for a super to be placed on the hive. It is very important to stay ahead of your bees when adding supers. When the season's flow begins, a strong colony can easily fill a half-box in just a few days. As long as the supers remain on the hive and there are enough bees to heat it, the honey will be kept in a liquid state, and more supers can always be added if your colony is happy to grow.

Keep empty hives handy

When drones begin to appear, some swarming is inevitable; this is the main way a hive can reproduce, and the better the conditions, the more chance of swarms. The inclination to swarm varies between and within races. Thus, choosing a stock of bees that are less inclined to swarm will save you from a lot of extra work. Keeping some empty hive boxes (free of sugar or honey) in the apiary is a good way to catch escaping swarms and may help you keep some of your escaping bees. If your bees do escape, there may be a chance that they choose to rest somewhere nearby; in that case the swarm will be close to the apiary, and your equipment will be there waiting for you.

Drone watch

To be ready for the swarming season you must be aware of when your hives begin to produce drones. The brood is easy to see on a pulled-up frame, but some beekeepers leave a small, 4cm gap between the wax foundation edge and the top of the frame. This open space encourages bees to build drone cells at the top of the frame, so you can see them by simply opening the hive.

Splitting and swarm control

Use of drone frames

Many beekeepers use a special drone comb to encourage the colony to make drones. This is a frame without wax foundation that can be split into two or three sections by adding vertical wooden mouldings. In spring and summer, the colony will usually build drone cells on this frame. The drone frame can serve several purposes: First, it can be used as a biotechnical method to fight Varroa mite by removing the sections of capped drone brood that are preferred by the Varroa. Second, if the bees build the drone frame as expected then this is a good indication that there is no ongoing swarming activity. Otherwise, it is advisable to do a thorough check of the brood nest for swarm cells.

The ideal situation for most beekeepers is to control swarming before it happens. This reduces the risk of losing half your colony (and your marked queen). It is most often the old queen that will fly out with a swarm, though sometimes you may get a virgin swarm, where multiple virgin queens will emerge and fly out with your bees. The first thing you must do is make sure your bees have enough space to grow, but if you find clusters of queen cells about the edges of your frames and the colony looks like it will swarm despite the space, there are some more things you can do:

1. Cut away swarm cells

The first thing you need to do is go through your colony and remove every swarm cell you can find. A determined colony will swarm with just one capped queen cell, so it is important to find all of them. This will prevent immediate swarming, but it might not deter them completely. The bees will continue to make swarm cells until you miss one and they get a queen. A colony will also not collect honey while they are preparing to swarm, so you will lose honey production as long as they stay in this state.

2. Split the brood room

Alternating a brood frame with fresh wax foundation gives the bees the impression that they have much more room for their brood. By mid to late spring these frames are usually built very quickly, and this can reduce the chance of the colony making swarm queens. You can add another deep box to the brood room or donate the brood to a weaker colony. Both ways allow you to keep the majority of your bees in the same hive and keep its size for the honeyflows.

3. Split the hive (creating an artificial swarm)

In some cases, despite all other efforts, the hive will not be discouraged, and creating an artificial swarm is the only thing left to do. This method is referred to as “splitting” and is also used by beekeepers who make a business out of selling nucs (small starter hives) and swarms. One of the later modules will go

into more concise detail on the many ways you can produce a split hive so we will only touch on the topic briefly here.

Splitting will require a separate hive, normally a smaller box to start, but if the colony is large you may benefit from using a full hive. The goal is to create in this new box the environment a colony would be in if it had just swarmed. Catch the old queen and shake a portion of bees from the swarming hive into a box with frames and some new wax foundation. It is important not to transfer any brood. All of the brood must remain in the old hive, which will now either have one of the remaining swarm cells, or will remain queenless for a few days to await a new queen you will choose yourself.

Splitting can also be used to grow your operation or replace a deadout hive you may have lost during a dearth or during winter. If you need to "split" and the hive is not showing signs of wanting to swarm, you can split by leaving your queen in her own colony and introducing a new queen to the nuc you create. A strong, brood-filled colony may be much less likely to take a new queen than a broodless split. To give your new split a bit of a boost, you can also add one or more frames of capped brood, but it is important that all the brood on the frame is capped or just about to be capped. Transferring eggs into your split may make the colony much less likely to accept the queen you will introduce, as they will have the means to make their own queen.

When making a split, it is a good idea to asset the location of the new hive more than 3km from the original place of the hive. Otherwise, all the foraging bees from your split will return to the original hive they came from. If you do not have another yard, you can try the following options: 1. Add lots of extra bees to your split so the bees lost will not result in an empty hive; 2. Put the split in place of the original hive and move the original (with their own queen) to a new place. The young bees and all of the emerging brood will stay with their own queen; 3. You can also choose the age of bees you add to the swarm by shaking bees off of brood frames. These bees are most often young bees and have not had the chance to fly out of the colony and learn its location; 4. Reduce the entrance size of your split to minimize the number of bees that can fly out at once. This generally decreases the number of bees that try to fly back to their original colony.

These are the principal tasks that are generally done in spring. Depending on weather and region, you may need to adjust when in the season and to what degree you take up these tasks.

2.2 Summer

Summer is often the time when nectar flow is at its peak. Depending on the region and the type of habitat available, flows can last anywhere from a few weeks to over a month and can be burst-flows or flows that are slow but continuous. Drone production is in full swing, and swarming in early summer is very common. In dryer regions, it is very important to watch for periods of dearth and make sure your colonies have access to enough water.

Dearth can also increase the rate of robbing, so be mindful of that during summer. This is the time when colonies are often at the height of their strength, and it is a good time to produce swarms and sell queens. The first honey harvests are often done in summer, after significant blooms.

Add supers

The region will dictate this timing, but you should keep an eye on how quickly your bees' super boxes are being filled and add boxes as necessary. If the colony becomes honey bound, it could reduce brood production and therefore the size of your hive, which could reduce the second, late summer-autumn harvest. It may also prompt your colony to swarm.

First harvest

Late-spring to summer is often the time when your first honey harvest should be coming in, and your honey house should be clean and ready to use. Depending on the fructose and glucose ratio in the nectar collected by the bees, the honey will either start to crystallize or it will stay liquid. For honey that crystallizes quickly (e.g. rapeseed (canola) honey with a low fructose to glucose ratio), it is important to harvest the honey as soon as it is ripe (when the bees have covered the honey with wax cappings), and it should be extracted within a week after harvest. Honey that stays liquid or crystallizes slowly can be stored for weeks before extraction. Once the extraction process is finished, the honey should be bottled shortly after and prepared for sale. By harvesting the honey after every major flow, you can collect honey from different nectar sources with their distinctive tastes and properties.

Checking queen performance

Summer is also a very common time for queen supersedure. If the queen is old or not mated properly, the colony may try to replace her. Supersedure cells, unlike swarm cells, are often only made singly on a frame and are commonly in the centre. Watching the behaviour of your bees is the best way to tell if you have a defunct queen. A queen can stop laying in mid-summer for many reasons, such as if the colony is preparing to swarm, if the area is going through a dearth, and if the colony is under food stress. It is very important not to jump to conclusions and try to replace a queen that the bees have not tried to replace themselves.

If something about the performance of the colony is undesirable to you as a beekeeper, however, summer is a good time to replace a queen. Most often, a queen should be replaced if the colony is consistently aggressive, if the laying pattern is patchy or small, or if the colony is consistently trying to swarm. None of these traits are good for your stock, and you will want to reduce the chances of this colony passing on its genes. Summer is a very good time to evaluate the performance of your hives and, if you plan to breed you bees, select the queen breeder colonies you will use both this and next year.

Making swarms for sale

Swarms can be made throughout the active season, from late spring to late summer, and splitting the stronger colonies can reduce the risk of uncontrolled swarming. Producing swarms is a very good way to earn money from your bees as well as to replace lost colonies and grow your operation. A strong colony will recover from a split very quickly in peak active season, and it is important to time the splits to one of those peaks so your bees have the resources they need to grow. Prices of swarms vary by country, bee race, and the size of the swarm, usually measured either in the number of frames of bees, or the kilogram weight of the swarm. It is important that the swarms that are produced have a size that enables good over-wintering. The later in the season the swarm is produced, the stronger it must be.

Queen rearing

Queen rearing can begin as soon as the colonies start to produce drones for the active season. Queen rearing is a very good way to make your operation self-sustainable, and it can allow you to improve your stock within a local context. The full process of queen breeding will be covered in detail in a later chapter, so only the basics will be discussed here.

To make queens successfully, you will need to create broodless splits from the stronger colonies in your operation. Do not put a queen in these splits. It is the absence of a queen that will make these bees produce queen cells for you. Once they have settled and you are sure no brood can be found in these splits, you can select a frame of very young larvae laid in another colony of your choice.

Depending on the size of your operation and the number of queens you want to produce, you can choose between simple or more advanced queen rearing. A much-used technique of queen rearing is to graft young larvae into queen cups, which can be set into a special queen frame, and to then set this frame into your queen breeder split for the worker bees to rear. It is very important to know the precise timing of capping for the queens, because you MUST either cage the queen cells in the rearing colony (small operations) or relocate the caged queen cells into a special incubator (large operations). The capped queen cells are added to queenless splits one to two days before the queen will emerge. Queens left to emerge in the rearing colony or in the incubator can be marked by the beekeeper and added to small mating boxes so they can begin their mating flights. Queens can be sold or added to colonies as virgins, but mated queens have a much higher rate of acceptance, and they can begin laying straight away.

Parasite control

In many regions, a good time to apply necessary parasite treatments that will control pests like Varroa is after the first honey harvest. By measuring the infestation levels, for example, by counting the natural fall of Varroa mites on an insert in the bottom board, you will better know the need for Varroa treatment. Treatments should be applied when there are no honey supers on the colony, and depending on the type of treatment used, there is usually a waiting period relative to the treatment when supers should not be placed. Alternatively, to summer treatments, and again, depending on region and weather, treatments for Varroa can also be applied in early spring, to reduce the starting mite

population, and also in autumn, after the last harvest, so no treatment residue appears in your honey. Keeping on top of Varroa is one of the best ways to keep your hives healthy and get them safely through the winter. The regulations on what can be used as a mite treatment varies by country, but if you are aiming for an organic operation then your options may be limited to organic acids like formic and oxalic acid. Treating for mites can be a delicate process and you must not overuse the treatment, or you risk damaging or killing your bees.

In spring and summer, the longevity of worker bees is short. However, successful survival during the winter relies on a sufficient production of worker bees in late-summer and fall. In Northern Europe, the bees in the winter cluster are produced from mid-July until early September, and they must survive until a new generation of worker bees are produced in April of the following year. In Southern Europe, the winter is much shorter, and the winter bees are produced later in the season and replaced by a new generation earlier in the following year. As a beekeeper, it is important to see that your bees continue brood rearing during the period when the winter bees are produced.

Migration

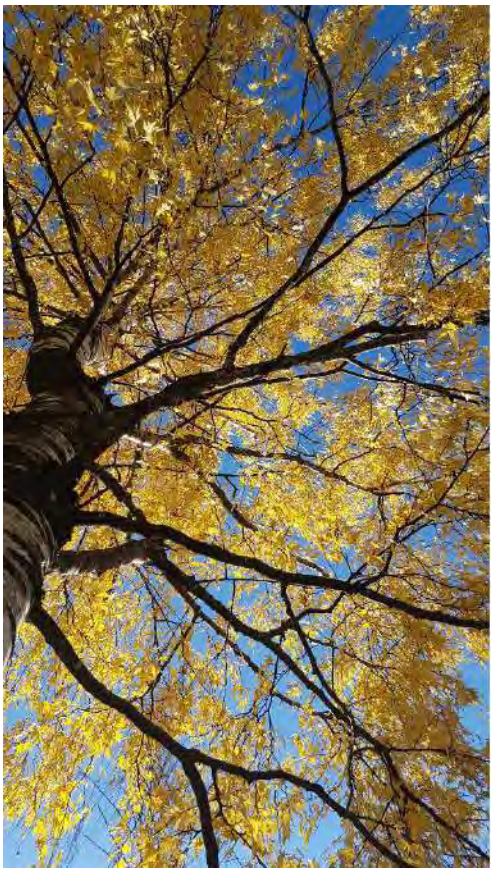
Many areas require nomadic beekeeping tactics to follow the blooms and collect money from pollination services provided to crop farmers, or else collect enough good quality honey to sell. For example: the Italian markets for professional beekeepers often rely on nomadic tactics to turn a profit. Even small-scale beekeepers can benefit from shorter migratory beekeeping to produce several varieties of honey.

Migratory beekeeping to provide pollination services often requires a lot of bees, and it is generally a practice done only by professional, full-time beekeepers, though as a hobbyist or small beekeeper you can rent your hives to local farms for a little extra money. Many places rely on contracts signed by beekeepers and crop farmers to bring bees to a specific area for their pollination service, and this requires good preparation and planning on the part of the beekeeper. You must have the right number of colonies and make the most efficient routes between cropland if there are multiple crops to pollinate in one season. Weather can have a very large impact on the profitability of a trip, especially if it affects the flowering and, if you rely on honey, the nectar production. Crops will not bloom at the same time each year, and a migratory beekeeper must be flexible and constantly aware of the flowering of their target crops. A beekeeper must weigh the cost and benefit of making a trip with the bees and choose the right contracts that suit their operation.

Migratory beekeeping requires a talent for making strong splits and building bees up quickly, so you have the volume year to year to fulfill migratory contracts. It is important to mix enough feed for the bees, as generally they are placed in whatever crop they will be pollinating before the blooming period begins (when only about 10% of the flowers have opened) and they must have resources to live off of until the flowering peaks. You must also know the pesticide schemes for each field and agree with the crop farmer to remove your bees before the chemicals are sprayed on the fields. Many crop chemicals can be very harmful to your bees and will contaminate any products you hope to collect.

Migratory beekeeping is not advised for those just starting out with bees, and at least a few years of beekeeping experience is needed before a migratory strategy will be profitable.

2.3 Autumn



In many locations around Europe, the growing season is long enough that there may be several honey harvesting periods, the last one being in autumn. This is the time when you must remove the last supers from your hives and make sure your bees have enough resources for the winter. Colonies will be reducing the number of bees in a colony for the dormant period, and in many cases, colonies will produce special, long-lived bees called winter bees, to get the colony through until spring. Winter bees are essential for a good overwintering, and you must make sure your colonies are relatively disease-free before putting them away for the dormant period or you risk losing them.

Autumn is often the time of year where floral resources are scarce and, as a result, bees will engage in more robbing. This is a problem for your bees as well as for your honey collection, as bees are more likely to flock to any source of sugar to try and exploit it. Making the hive entrances a little narrower can protect your hives from being robbed by other bees, and when harvesting, you must work quickly and in short sessions to avoid stressing your bees too much.

Feeding

It is very important to check the amount of food the bees have in the brood room when you remove the last super. Often you can do this by lifting the hive and checking its weight. Some bee breeds are good at keeping at least a little honey in the brood room, but many will not have enough and must be fed directly after you pull the last honey box off. You must not feed the bees before you have removed all the supers from the hive or you risk contaminating your honey with sugar syrup, which will hinder the quality of honey and decrease the price you can sell it for. Generally, a healthy colony will take several kilograms of sugar over the weeks just before winter. If the temperature is too cold (below 10°C in the day), the bees may cluster, and they will not take food down into the colony as quickly (or at all). You must not leave feeding too late or the bees may not be able to take enough food to last them through the dormant period.

Reducing the hive space

In many areas, the temperature can drop significantly in the dormant period, and the bees reduce their colony size to save resources until spring. Reducing the number of frames to just enough for the bees to cover can have a large impact on how well they survive the winter. Closing the rest of the hive space with insulating blocks will help them conserve heat and use less food. Generally, a healthy hive will overwinter on 8 frames in a 10-frame box, however this number varies with race, area, and weather, and it is up to the beekeeper to know what a healthy state is for their own bees.

Weatherproofing and checking hives

If the colonies will be left alone for a long time during a dormant period, it is very important to make sure the hives are secure and weathertight. Many beekeepers add tightening straps on their hives at this point so the lids do not blow away, and if the colony is knocked over during a violent storm, it will stay together and allow the bees to better control the hive temperature until you find it. In colder climates, an inner cover insulator is added, usually polystyrene or felt, to keep heat in. Colonies must be waterproof, as water inside your colony leads to mould and a significant loss in temperature, both of which can kill your bees. If you did not narrow the entrances in the early autumn to prevent robbing, you may want to do it now, as it helps preserve heat.

Checking on the apiary

Even though the bees are not active, it is a good idea to go and check the apiary. You should avoid opening your hives in cold temperatures (below 10°C) unless it is absolutely necessary (e.g. For Varroa treatment or for adding food to a starving colony), but making sure the hives are still standing after an intense storm may save some hives.

2.4 Winter

Clean equipment, storage space, and honey house

There is nothing to do with your bees during a dormant period, so in times like these it is prudent to clean and organize your equipment, so it is ready for use in spring. In some areas where diseases like foulbrood are common, it may be a good idea to sear wooden equipment with a fire torch. Scoring the wood with flames melts wax and propolis and can drastically reduce the risk of catching and spreading harmful pathogens.

Making sure your honey house is clean and sugar-free will reduce the risk of attracting insects like wasps and ants in the spring and stacking and taking inventory of your equipment will allow you to know exactly what you have to work with in the coming season. You can order replacements for broken equipment and items for the production and packaging of the products you will make.

Craft from products: wax, propolis, etc.

Honey may require processing and packaging quickly due to its crystallization, but other products can be processed more slowly when the beekeeper has time, like wax and propolis. You can make your own products to sell at local markets, or replace the wax needed for frames with your own if you have access to a wax foundation printer. There are many different craft materials and craft products that can be made from material harvested from your bees, and whether you make it yourself or simply sell the material, these items can be sold for good prices at fairs, markets, and online.

3.0

Honeybee Products

Honeycomb

In the hives, honey is put inside the comb sealed with a thin layer of wax.

Honey in the comb contains small amounts of pollen, wax, propolis and possibly also bee venom. The amount of these substances depends on how long the honey is left in the comb; however it is rare that these trace amounts trigger allergic reactions in people and normally, honey is safe for

Bee products have wide-ranging uses in human diets, industry, and medicine. Honey and beeswax are by far the most recognized of these products, but there are many others that also have dietary, medical, and cosmetic applications. The use of bee products to promote human health is called apitherapy, and there are some distinctions among cultures in the level of interest and acceptance of this and other alternative uses of honeybee products. Regardless, each of the products discussed can be marketed and sold in a beekeeping operation and are therefore, worth discussing in this section. It should be noted here that any product that is made for human consumption must be handled, processed, and stored using food-safe materials. It is imperative to do research on the standards of food-safety and material requirements before investing in the production of any of the substances discussed.

To increase income and stability as well as access to healthier products, this chapter will provide information on the characterization, obtention, and uses of primary beekeeping products.

3.1 Honey

What is honey?

Honey is a sweet viscous liquid food, golden in color, produced by honeybees. Bees store honey in the comb in a beehive and use it as a food source in times of scarcity and for overwintering.

How do honeybees make honey?

The honey is made from nectar, a sugary liquid produced by plants in structures called nectaries, often found in flowers. The nectar composition is variable depending on plant species and environmental conditions. In general, it is composed of water (60-70%) and sugars.
Honeybees extract the nectar from the floral nectaries and store it in the honey stomach (crop) for transport back to the hive. In the honey stomach the nectar is mixed with enzymes (diastase and invertase) secreted by the salivary and hypopharyngeal (head) glands and begins its chemical transformation into honey. With the honey stomach full, the honeybee returns to the hive where the foraging honeybee regurgitates the contents and transfers it to another honeybee. This honeybee mixes it with more enzymes. The process will be repeated until the last honeybee deposits the honey in the honeycomb. The honey stored in the honeycomb is dehydrated by the constant beating of the honeybees' wings. When the honey contains less than 20% water the honeybees cap the cell with wax. This is what we call “ripe honey”, and it is ready for harvest.

Chemical composition

Honey has a very complex chemical composition that varies depending on the botanical source. Honey is mainly composed of water and sugars (fructose, glucose, sucrose and other sugars) with trace amounts

minerals, vitamins, amino acids, organic acids, phenolic acids, flavonoid and aromatic substances (Table 1)

Table 1- Chemical composition of honey.

Constituents	Percentage*	Range
Major constituents		
Water	17.9±3.16	13.2-26.5
Fructose	39.4±2.1	37.1-42.7
Glucose	28.2±5.7	18.2-32.1
Sucrose	3.2±3.8	0.36-16.6
Other sugars	8.5± (n.d.)	0.1-16.0
Protein	1.1±1.2	0.2-2.9
Minor constituents		
Minerals	0.36±0.18	0.11-0.72
Acids (as gluconic acid)	_	0.17-1.17
Vitamins, enzymes, aromas	<0.1	
Phenolic compounds	0.1	0.02-0.2

* Mean ±SD; n.d.- not defined

The honey composition can and can be influenced by the storage time and conditions. Moreover, due to its unique composition and chemical properties, honey could be stored long-term, often for years without losing quality.

As mentioned before, honey is a strong supersaturated sugar solution that usually contains more than 80% sugars and less than 20% water. These sugars will eventually crystallise and the product acquires a more solid form. A relatively high concentration of glucose compared to fructose will make the honey crystallise sooner. This can impede collection so it is important to know the nature of the honey that will be collected from the available flowers in your area and plan collection accordingly.

Properties and uses of honey

Nutritional

Honey has very little nutritional value on its own. The diverse sugars it contains may make it a better alternative to cane sugar (only sucrose) and the trace amounts of plant oils give each honey a unique flavour which can add to many culinary dishes.

Medicine

Honey can be used as a medicine. It has been reported that honey has antibacterial activity, and inhibitory effects in some species of fungi and viruses when used topically (on skin or wounds). Traditionally, honey is used in the treatment of eye diseases, bronchial asthma, throat infections, tuberculosis, fatigue, dizziness, hepatitis, constipation, worm infestation, piles, eczema though scientific backing for these claims is very limited. One of the most studied and most effective uses of honey is found in healing wounds. Medical honey is treated to clear it of all bacteria, and applied to a wound, The low moisture content of the honey changes the environment so that bacteria cannot grow, and the body's natural processes can work more effectively to close cuts and sores.

Single-flower honey and mixed flower honey

Honey is generally classified into two groups related to the origin of the nectar: monofloral and multifloral (polyfloral). When honey is collected mostly from a single flower species, it is called monofloral honey. If the honey is comprised of decent portions of more than one species, this is called multifloral honey. Honeys from different floral types can vary in flavour, texture and sugar composition, and therefore they vary in price, so it is important to be aware of what your bees are collecting so you can market it appropriately. Multifloral honey is generally sold as "summer honey" or "wildflower honey" depending on the flowers available in the area.

Honey Harvesting

Generally, special boxes called supers (section 1) are placed above the brood box of the hive, and separated from the brood by a queen excluder, a metal grate that allows workers to go through but not the queen. These supers allow the beekeeper to collect honey without risking the safety of the queen or brood. Once the honey is capped in the super, it is "ripe" and it is time for the harvest.

The beekeeper must approach the beehives from behind and use a smoker around the entrance to calm the bees. Proper beekeeping protection is highly recommended as in warm weather, when honey is collected, the bees will be very active. It is generally not a good idea to harvest without some form of bee calmer, because the exposure of honey can excite the bees and cause them to swarm around the resource as they try to rob it. The roof should be removed from the top of the super and the inner cover should be removed with the help of a hive tool, as the bees tend to seal it with propolis. Smoke should be applied to force bees into the lower parts of the hive. If no queen excluder was used, it is necessary to inspect the honey frames for brood. The frames with brood should not be taken, as they can contaminate your honey and their loss will weaken your hive. Remove the honey frames and verify that most cells are sealed, and the honey is "ripe", then you can brush off the bees and put the frames in a box to transport to the honey house for extraction.

Often, beekeepers like to use an escape board a few days before harvest, a cover-like piece placed between the super and the brood box that allows the bees to go down out of the super but it prevents them from traveling up. This makes sure there are almost no bees in the super when you come to collect it, but it will also keep the honey warm enough, so it does not crystalize in the comb and prevent harvest. You should only put an escape board under supers you intend to collect shortly afterwards, unripe honey will not be capped after the board is placed.

Fig 1: Frame full of honey and with all cells sealed
(Source: https://www.instructables.com/Honey-Harvest-and-Extraction/)

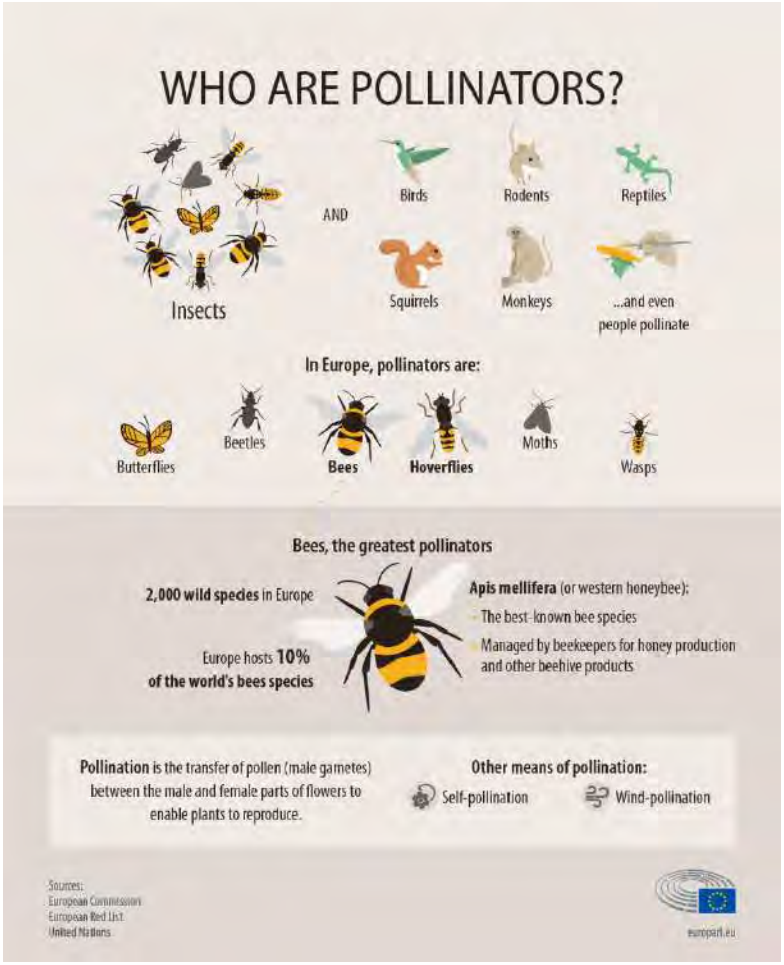
Honey extraction and processing

It is imperative that you extract the honey within 2-3 days of removing it from the hive, or else have a heated room to keep the honey from crystalizing. Honey that crystalizes in a frame is a loss, it cannot be saved. In the honey house, the frames should be removed from the super and the combs should be uncapped, using an uncapping fork or knife to remove the thin beeswax covering off the honeycombs. Uncap the cells over a capping tray or capping basin, to catch falling honey and wax and keep your honey house floor clean. The best temperature to uncap and extract honey is 21-27^{o}C. Above 32^{o}C the wax is too soft and below 18^{o}C the honey is stiff and is hard to extract.

The uncapped frames are put into the extractor (Fig 2), the lid should be closed, and the honey extractor turned on. The barrel will spin and the honey is flung against the sides to trickle down into a funnel catcher and then poured in a stream out of a nozzle at the bottom. It is very important to familiarize yourself with the specific working of the extractor you are using. These machines are powerful and can harm you if not used properly.
Fig 2: Put the uncapped frames into the honey extractor
(Source: https://www.instructables.com/Honey-Harvest-and-Extraction/)

After extraction the honey should be strained using a sieve to filter the wax and impurities (Fig 3). Often honey is strained twice to make sure no large debris will get into your final product and reduce the sale price.

Fig 3: Honey filtration
(Source: https://www.instructables.com/Honey-Harvest-and-Extraction/)



Once strained, the freshly extracted honey should go into a decanting tank. Honey generally contains a lot of air in the form of tiny bubbles and this process allows the bubbles and any remaining wax to float to the top. Bubbles can contain moisture that might begin to ferment your honey and reduce its quality. After settling, the foam and solids from the surface of the honey should be removed. The honey can then be stained once more and bottled, labeled and stored.

Fig 1 - Infographic on pollinating animals Source: https://www.europarl.europa.eu/

3.2 Pollination

What is it?

Pollination is one of the most important benefits bees provide to humanity, and one of the most lucrative services you can sell if you are a beekeeper, depending on your region. According to FAO (2018), pollination is a fundamental process in natural and human-managed terrestrial ecosystems, where it contributes essentially to plant propagation and food production.

Since plants cannot move in search of sexual partners, they use intermediaries to transfer pollen grains from the stamens to the stigmas of the flowering. These intermediaries can be wind, water, gravity or living creatures like bees (Fig 1). About 80% of flowering plants are pollinated by other organisms. It is estimated that about 90% of wildflowers worldwide and 75% of cultivated plant species depend on insect pollination (FAO, 2021).

Pollination services

The most used species in pollination services is the European honeybee (*Apis mellifera*), because it can form large colonies and is a generalist forager, happy to collect pollen and nectar from many plant species.

Honeybees are considered the most effective agricultural pollinators in terms of ease of keeping, transport, population growth and working efficiency. They can begin collecting as soon as the temperature is above 10^{o}C with a force of about 50,000 individuals on average, from the first minutes of the morning to the last minutes of the day. Due to the hairs on a bee's body, pollen grains adhere very easily and can reach the stigmas of several other flowers.

Fig 2 - Economic Impact of Pollinators
Source: https://www.europarl.europa.eu

Unlike other many other pollinators, honeybee colonies can be transported to places where pollination services are needed, such as orchards, vegetable fields, forage pastures and forest areas. Due to their instinct to collect and store provisions, even in times of floral abundance, honeybees collect food in quantities far exceeding the daily needs of the colony and this makes them highly effective pollinators.

A beekeeper can be contracted by plant farmers to supply a number of hives to orchards and fields for a set period of time. The number of hives used will depend on the size of the field and the type of crop that needs pollinating.

Economic value of pollination

The economic importance of pollination can be assessed for wild species and cultivated species. It is not easy to assess the economic value of pollination by honeybees in wild plants, but its ecological value is recognized for the service provided in pollinating most species present in forests and fields. Honeybees are known as ecological drivers, increasing fruit set and seed abundance that provides plants with reproduction and other animals with plentiful food sources.

In the context of cultivated areas, it is estimated that the value of the domestic bee pollination represents EUR 15 billion of the annual agricultural production of the European Union. Bees pollinate crops for direct human consumption, and crops that provide feed to the animals we keep.

The use of pollinating bees increases the quantity and quality of agricultural production by a significant amount (about 10-70% depending on the crop and the habitat surrounding it), and if the crop can be pollinated by bees, it is generally very lucrative for land-based farmers to purchase pollination services. As a beekeeper, it is important you know how much you may charge for pollination services in your area, and make sure your colonies are clean and healthy before they are transported, with a little food stored to feed them until the crop flowers.

3.3 Beeswax

What is it?

Beeswax is a substance that is secreted by honeybees and used for the construction of the honeycomb. It is solid below temperatures of 60^{o}C and cannot be dissolved in water.(Fig 1).

Fig 1 - Beeswax Block
(Source: beesweet.pt, 2021)

Beeswax is secreted by eight identical glands, located two by two, on the underside of the abdomen, between the fourth and seventh segment. The pure wax is white, and the final staining will depend on the presence of pollen and propolis. It is produced by worker bees usually aged between 12 and 18 days. Much of the wax sold is intended for use in beekeeping, but beeswax has a wide array of uses in many different industries
like cosmetics, cleaning products and polishes.

How is beeswax produced?

Worker bees must collectively consume 7Kg of honey to produce 1Kg of wax.
Over time, the color of the wax in the comb darkens with use; it changes from white to yellow to almost black as the cells are cleaned with propolis and reused. It is important to replace these dark, old wax frames with new wax frames. This is done to avoid swarming and keep workers and the queen healthy. Even wax that darkens with age, when extracted, comes out an attractive yellow, and once it is free of debris, can usually be sold for a high price or reused to build new foundation in your hive.

Fig 2 - Bee producing the wax blades
(Source: Abelhas da Beira, 2021)

Chemical composition

The composition of beeswax is very complex, mainly consisting of a mixture of lipids and esters.
Beeswax contains hydrocarbons (14%–16%), free fatty acids (12%–15%), linear wax monoesters, hydroxy monoesters (35%–45%), complex wax esters (15%–27%), free fatty alcohols (ca. 1%), and exogenous substances that are mainly residues of propolis and pollen. Beeswax has a wonderful fragrance, and it is a highly desired, natural wax for artisanal crafting.

Collection

There are several methods to extract and purify beeswax: the hot water system, steam system and solar wax melting system. Wax can be taken from the melting of older frames you clean from your hive, or from the fresh wax cappings removed during the honey harvest process.

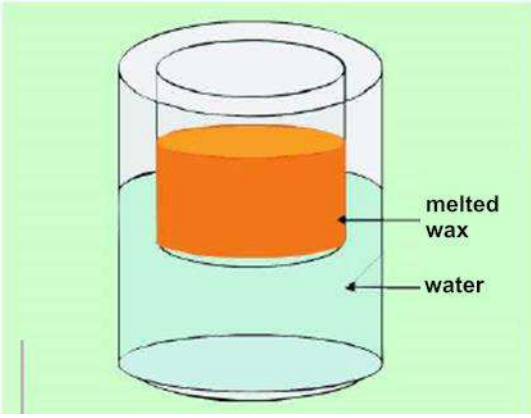


Fig 4 -Representation of the wax extraction method by hot water system
(Source: Correia Oliveira, 2019)

Hot water system

The wax can be placed in a container or in a bag. If a container is used, it should be placed in a larger container with water (Fig4). While the water is heating up, the wax melts and the melted wax is then removed and strained through a cloth. In this method there are relatively large losses, as the wax solidifies as soon as it drops below 60°C and catches in the strainer.

Steam system

A steam system is a more efficient method and can service a larger number of hives.
In this method, the wax is placed on a metal grid inside a vat. In the boiler there are two concentric vats open at the top, where the space between them is filled with hot water, generating steam (Fig 5). This steam ensures a uniform temperature inside the boiler. The impurities are retained inside the vat and the clean wax flows through the grate in the vat floor, being collected in a container with cold water, so it floats and solidifies. Sometimes an added strainer is placed at the spout of the vat to filter more debris from the pure, melted wax.

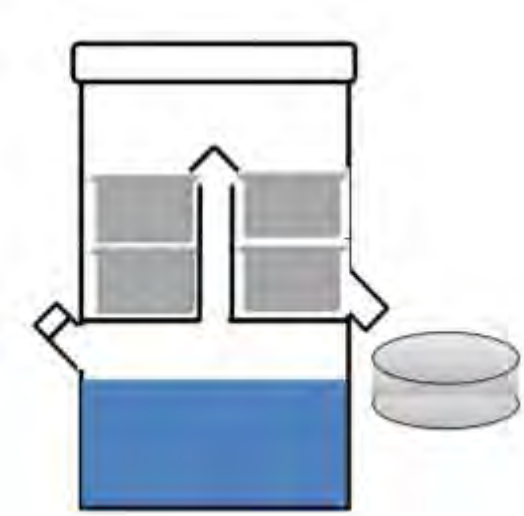


Fig 5 - Schematic representation of the inside of a steam boiler
(Source: Barros et al, 2009)

Solar Wax Melter

This is a simple system, consisting of a box painted black, with two glass plates (4 to 5mm thick) for a better use of solar energy (Fig 6). It should be placed at an angle of 45° so that the sunlight falls perpendicularly on the glass and the melted wax can trickle out.

The wax, old comb and other scrapings from the hive are placed on a slanted (usually metal) tray inside a box. The box is then covered tightly with a glass top and oriented toward the sun. As the temperature rises inside the box, the wax melts, and drips off the tray into a collector pan. This pan usually has slanted sides, facilitating removal of the wax block once it hardens.

This method is only used on very sunny days (summer) and

by beekeepers with only a few hives, since it is very slow. The advantage is that it does not require any power to run.

Fig 7 - Solar wax melter
(Source: https://www.latiendadelapicultor.com/, 2021)

Wax purification

To reuse or sell the wax, it must be melted and filtered.
Though beeswax melts at 60^{o}C, the temperature used should be around 80^{o}C to obtain good quality wax. In filtering, the wax is separated from impurities like hive debris. The filtration techniques may vary depending on the method of obtaining the wax, and may include the use of linen bags, linseed, and filters in the boilers. After these processes the melted wax is transferred to another container where it solidifies. Wax can also be treated with chemicals to reduce chances of pathogen spread, if the wax will be reused in new frame foundation.

If the treatment is done using hydrogen peroxide, the molten wax will have to be treated with activated carbon for the removal of peroxides in the final material, in chlorine-based treatments, the resulting ceras have low color stability and have chlorine retention, providing a lower quality product. It is important to do research on the specific requirements for wax production in your country and area. Some countries require all wax used in new foundation for honeybees be treated at high temperatures to remove harmful bacteria like foulbrood.

Wax molding – wax foundation for new frames
Wax printing or molding is a process that prints the wax into sheets for use in the hive. This is a very useful skill to learn as it will reduce the cost of your beekeeping by recycling wax produced by your own bees. Small hand-powered or electric printers can be purchased, but they are not always consistent and can be difficult to use. The machinery for professional sheet printing is often expensive, it is recommended that beekeepers in an area work together and pool their resources for the initial purchase, then split the maintenance and use of the machine between them.

1 - Pre-laminate molding
In this method the wax is placed on a smooth metal roller that rotates slowly forming a wax sheet about 3mm thick. This roller is cooled and lubricated with soap and water to prevent wax adhesion. The cut sheets are subsequently bathed in 40^{o}C water and then printed using a comb-pattern print roller.

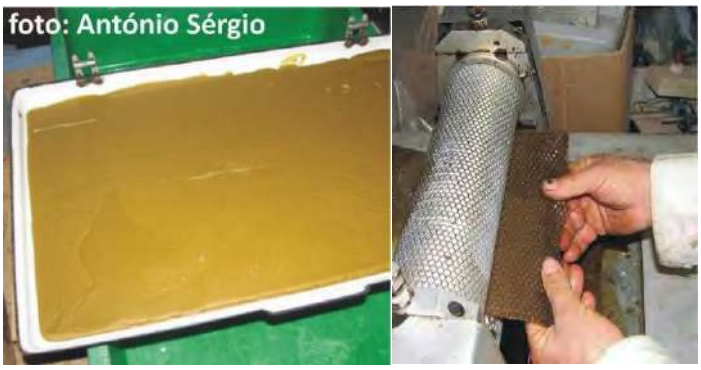


Fig 8 - Pre-laminate molding
Source: Monte do Mel 2021

2 - Direct molding

The casting wax falls directly into the molding rollers lubricated with soap and water. Due to the sudden change in temperature these sheets are more brittle at low temperatures but are more resistant to deformation.

Fig 9 - Direct molding

Conservation and storage

Foundation should be stored in a covered place, with enough ventilation, or in well-covered, free of gaps to prevent infestation by wax moth. These moths can digest the wax and reduce the quality of your product to the point where it cannot be sold or the bees in your hives will reject it.

Uses

Beeswax is highly valued and can have several applications. Among the many utilities, we can highlight the following:

1. Wax foundation for new frames in beehives
2. As a base of ointments, creams, balms, and other topical health products
3. In high-quality cosmetic products
4. As a wood or leather polish
5. In candle making. These candles do not drip, smoke, and have an unmistakable smell of honey not being toxic or harmful to health

Beeswax can be sold in bulk, but for smaller operations, creating artisanal products like candles and creams can be a great way to earn money outside of pollination and honey.

3.4 Swarms and colony splits

What is swarm?

A swarm is a group of worker bees and usually the old queen that split off from an existing colony to form a new colony elsewhere. Swarming is the natural process of reproduction for a hive; it happens when the colony is overpopulated, and the queen no longer has enough space for egg-laying. Swarming

can happen as soon as the colony is fit enough and there are drones available for mating, which is usually around late spring to early summer. Generally, it is very difficult to prevent a colony from swarming, the easiest way to deal with it is to create a split before the colony swarms. A split is a second colony that can be used or sold for a good price. Sometimes, swarming colonies cannot be found before the swarming event and the swarm must be caught to prevent loss of bees and your old queen.

Capturing a swarm

The beekeeper must know the approximate season for swarming in their region. In Mediterranean climates, they start at the end of winter and swarming can last until June, in more Nordic climates, swarming begins around mid to late May and ends in mid-summer.

Making an annual swarm register helps predict the apiary swarm time. Usually, there are one to two weeks at the beginning of the season where swarming is very common, followed by about a month of occasional swarming, longer if the climate is warmer.

Six weeks before the likely swarming period, it is advisable to place empty hives in the apiary or split your strong hives in advance of swarming. It is important that bees recognize these empty hives as good sites for the construction of a new nest. To make the empty boxes attractive, place built frames at the edges of the box and fill the remaining space with empty foundation frames. Old and very dark waxes should not be used, to prevent the spread of disease.

Fig 1 - Swarm-hunting in cores, wooden box and cardboard box

Hive splitting

This should only be done to strong colonies with enough brood to survive the process. There are a number of ways to split a hive and one method is covered in section 5: self sustained beekeeping. Details will be kept brief in this section.

The basic concept is to split the hive (sometimes splitting the brood, sometimes keeping all of the brood in the parent hive) and providing either the parent colony or the new split with a new queen, leaving the old queen in charge of one of the two resulting colonies. Keeping the brood in one hive will encourage the bees to remain with it in the box. The split without brood should be moved to a different apiary so the bees to not return to the parent hive. Whichever hive will receive a new queen must be left

queenless for a period of time (2-7 days depending on the season) so the pheromones of the old queen dissipate, and the new queen can be readily accepted. There is much debate about the precise period: some beekeepers choose to add a new queen right away and risk her being killed. Others choose to leave both hives with brood and have the queenless colony make their own queen.

Allowing the bees to produce their own queen increases the chance of an aggressive hive and it is recommended that the beekeeper choose at least a portion of the queens for the operation.

From a swarm or a split, the result is two smaller colonies, the parent colony and the nuc. These nucs are starter colonies that you can use to grow your operation or sell off to other beekeepers. There are some businesses that focus almost exclusively on nuc production as a business, along with queen breeding, and those beekeepers who master this technique can create a lucrative business, depending on the demand.

3.5 Queen Rearing

The honeybee queens

The honeybee queen is the only reproductive female in the colony. The main function of the queen is laying eggs. A queen lays, 2,000 eggs a day on average in the peak of the active season.

Good quality queens can be sold or used in your own operation and the breeding of queens has many benefits, but it is a delicate process, and a lot of time and experience is needed to make it profitable. Most beekeepers buy their new queens from a dedicated queen breeder but becoming one of those breeders can offer a good income if done well.

Origin of the Queen

The quality of the queen is often associated with her reproductive ability. After two to three weeks from the start of laying, a high-quality queen should: look big and strong, with a fully developed abdomen: this likely reflects proper feeding and proper mating; she should be symmetrical and be free of damage or deformation.

The queen should be fertilized by several drones from different hives, resulting in a high genetic diversity of the colony. The more drones she can mate with, the stronger your colony generally is, and the longer the queen will last.

How to choose a queen mother colony?

Choosing the queens should be done by evaluating the performance of her colony and there are several traits to focus on:

- Productivity

Productivity is expressed in the storage capacity of nectar, pollen or propolis, or other product bee products, depending on the purpose you are breeding for. Generally, a high yield of the target product is an indicator of a good queen. Most beekeepers measure this in kilogram weight of honey produced.

- Low tendency to swarm

Colonies with a low tendency to swarm are most desirable for beekeepers as it significantly reduces the work they must do in summer. A swarming colony will take their old queen with them, so older queens in your operation that have stayed in their boxes might be good candidates to select for low swarm rates. Swarming should always be recorded when it happens, and if possible, a recording of the queen in that hive.

- A good brood pattern

The appearance of brood combs is an important indicator of colony and queen health. A high-quality queen will exhibit a consistent and abundant pattern of brood. A large, uniform circle of brood should be observed in a tight pattern with few skipped cells: the oldest brood in the center and younger brood radiating outward. On the periphery of the brood, pollen or bee bread is typically stored with honey or nectar often found on the outside edge of the frame. Estimates for this parameter should be taken in the height of bee activity in summer. In autumn brood pattern decreases in quality even in fit hives.

- Free from evident disease

A colony chosen for queen breeding should be healthy. Evidence of diseases like chalkbrood or deformed wing virus should weigh into your decision to breed from that queen. Some beekeepers have opted to reduce treatments for parasites like Varroa and breed from the queens that have low mite levels despite not being treated. Pests and diseases should always be kept under control however, and stock should be consistently selected to reduce the number of hives that are noticeably susceptible to pathogens.

- Docility

The most important trait is docility, the bees should be gentle and calm, sit still on the frame and not be quick to anger when worked. Allowing aggressive colonies to remain in your population, even if they are productive, is an invitation for trouble: agitated bees sting more, become stressed and ill, and create more opportunity for disease as many more bees are killed when the hives are worked.

Producing queens

There are many different ways to produce queens, from choosing your own larvae to graft into specialized queen production cells, to allowing your bees to choose and rear their own queens. Detailed methods on the process of queen breeding are covered in section 5: self sustained beekeeping, but the process explained is by no means the only one and may not be best suited to the tools and resources you have in your own operation. It is important to do local research and make sure you are well-informed before attempting to make queen breeding part of your operation.

In order to produce queens, a healthy colony should be made queenless and broodless, with enough food resources to sustain them for several weeks. It is imperative the colony have no eggs or brood, or the bees will refuse to build queens on the cells you graft for them. Larvae of the beekeeper's choice can be inserted into special frames which will make the bees build them into queen cells, else, a frame of eggs from the colony of your choosing should be put into this colony, and the bees will choose their own larvae from that frame. The queen cells must be isolated from each other before they emerge, or they will fight with and kill one another. Once isolated and hatched, they can be marked and placed into a small colony so they can fly out and mate. Queens will almost always return to the colony they have been put in, provided they are the only queen there.

Marking Queens

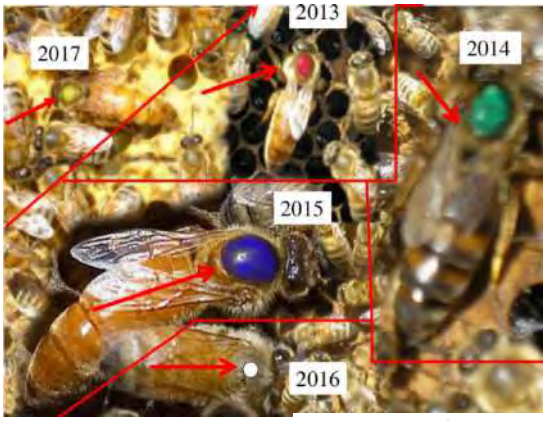
The marking of queens is a very common practice with a universal colour code system. This system allows you to know the age of your queens as well as find them much more easily in the hive. It will also tell you when a queen has been replaced, via swarming or supersedure, as the new queen will bear no mark.

Newly emerged queens are the easiest to mark as they are slower, weaker and can be restrained more easily than a mature queen. Gently take the sides of the queen's thorax between forefinger and thumb, with great care not to damage the wings and place a dot of paint using a nail polish brush or paint brush. The pigment should be quick-drying cellulosic ink and special pens and inks have been created specifically for queen marking that are sold at any beekeeping equipment shop.

This marking is based on a color system depending on the end of the years.

Colors	Years ended in
	1 and 6
	2 and 7
	3 and 8
	4 and 9
	5 and 0

Table 1 - Queens marking colors



(Source: (https://pt.slideshare.net/JeffersonBandero/biologia-das-abelhas)

Queen transport

The most common way to transport queens is in small cages (Fig 12) accompanied by 6 to 8 young nurse bees, with a sugar paste called “queen candy” in the designated compartment. This way of transport can keep your queen alive for weeks as the workers will sacrifice themselves to keep the queen hydrated, fed and clean.
These small cages can be dispatched by the courier services and endure very long journeys, more than 3 days. Shipping queens through the post always comes with risks as temperatures that are too high or too low can damage your queens. The best method of transport is in full nucs, or having the buyer come and fetch the queens directly.

3.6 Pollen & bee bread

What is it?

Bee pollen is a mixture of different flower pollen grains accumulated as pellets in pollen baskets on the rear legs of the honeybees (fig.1).

Fig 1. Bee pollen in pollen baskets of a worker honeybee

Pollen is the only protein source used by the bees and it is essential for the production of brood. It is consumed by the workers and broken down to create a nutritious secretion called royal jelly which is used to feed not only queens, but all developing bees in the hive.

Bee pollen is collected from flower stamens, packed on specialized hairs on the hind legs and transported to the hive by foragers. In a single trip, collecting bees visit between 1 and 500 flowers and make on average 10 to 15 trips per day. The pollen is collected from a wide variety of plant species within a flight of up to 1500 meters (in times of food shortages can travel longer distances). Honeybees usually forage on only one kind of flower during any single trip. Pollen can come in a variety of colours (fig.2) and flavours, depending on botanical origin.

Fig 2. Several colors of bee pollen collected

Pollen foraging behavior is dependent on the amount of uncapped brood (eggs and larvae) relative to the amount of pollen stored in the hive. The presence of eggs and larvae, in particular older larvae, stimulate pollen foraging. A low amount of stored pollen limits the breeding capacity of the colony, and therefore the population of adult bees. Any restriction on the amount of pollen brought into the hive can have dramatic consequences on colony survival, particularly winter success in temperate climates.

Pollen Collection

Bees cannot maintain a healthy colony without pollen, so pollen collection should be done carefully, safeguarding the needs of your bees.
A pollen trap is a device specifically created to remove pollen balls from bees returning to the hive (fig. 4). This device is gentle and does not injure your bees. These traps can be placed either in front of or underneath the hive entrance. When forager bees return to the hive with pollen, they walk through a metal or plastic mesh to enter the hive. The mesh is sized such that the foragers can get through it, but large pollen loads are scraped off the bees' legs and fall into a storage tray (fig.5). This storage container must have a good airflow to prevent moisture from building up and degrading the pollen. The storage tray, it is sectioned off from the bees using a fine mesh, so the pollen cannot be retrieved by foragers.

Pollen traps should be placed out only when the weather conditions are favorable (no rain) and when there is an abundance of pollen to collect. Traps should be placed for only a short time to avoid taking too much from the bees at critical periods, and pollen should be collected regularly to avoid a buildup of mold.

Depending on the type of trap, hive equipment, pollen supply, and the duration of trapping, reducing the colony pollen income for your bees can have unintended negative consequences on the ability of the colony to rear brood, so it is important you monitor how much pollen is going into your hive when the trap is placed.

*Fig 4 - Pollen-capture (*Source: FNAP)

*Fig 5 - Drawer and external screen pollen collector (*Source: Hervatin, 2009)

Transportation and Processing

To ensure the quality and conservation of pollen it should be dehydrated. First, pollen should be filtered through a fine mesh to remove colony debris. The pollen should then be stored frozen until processing.

When it is time to process, the pollen is thawed at room temperature for 3 to 4 hours and is dried using a forced circulation oven or dryer (fig. 6) at temperatures below 40 for°C for a period of 12 to 48 hours. The trays in the dryer should be periodically rotated (change the lower and upper trays to the centre and rotate the trays, to ensure even drying. After drying, a final cleaning should be carried out manually, with tweezers, or using forced ventilation. Once dried, pollen is packed and stored in a dark, dry place.

*Fig 6 - Pollen dryer (*Source: FNAP)

It is very important that pollen collected by the beekeeper is properly handled and stored so that there is no unwanted fermentation or growth of mold.

One of the most important processes for good pollen conservation is drying or dehydration. When this is done poorly, and the pollen has a water activity (AW) higher than 0.6 (limit in which the food is classified as dehydrated), pollen can become an excellent substrate for the growth of mold and production of mycotoxins. Mycotoxins, when ingested by humans can lead to health problems.

Pollen properties and uses

Since antiquity, pollen has been considered a good source of nutrients and energy, described by the Egyptians as the "powder that gives life". In ancient Greece there was a drink called "Ambrosia", a mixture of honey and pollen, which was seen as the drink of immortality and an inexhaustible source of power for organisms.

Today we know that not all the nutrients contained in pollen can be absorbed by the human body, we lack the enzymes needed to break down the thick pollen capsules like bees can, but some of the proteins, vitamins and minerals can be taken up, making pollen a decent food supplement, however the amounts of these beneficial nutrients vary widely with plant source, so the nutritional value of pollen cannot be standardized.

Among the many prophylactic and therapeutic properties of pollen some have suggested the following: antiatherogenic, anti-anemic, antitussive, diuretic, digestive, cardioprotective, hepatoprotective, renal function protective, immunomodulator, ulcer healing (leading to better tissue recovery), anti-inflammatory, antioxidants, antimicrobial potential against pathogenic microorganisms. It also has important effects on desensitization of allergies.

Although some scientifically backed evidence exists for some of these claims, pollen is by no means a cure-all and should not be treated as such.

What is bee bread?

Bee bread is a product of the hive obtained from pollen collected by bees, to which they added honey and digestive enzymes and subsequently stored in the combs, starting a lactic fermentation which increases shelf life considerably.

How is bee bread made?

Once pollen is brought into to hive, workers pack the pollen inside comb cells. The cells are packed about half full, with bees adding honey and digestive enzymes with each layer of pollen. During storage, the heat of the hive, sugars from the honey and enzymes begin a fermentation process that preserves the proteins, so the pollen retains its nutritional value. This is called bee bread.

Fig 1 - Collected bee bread
(Khalifa *et al*., 2020)

Bee bread composition

Bee bread chemical composition, like pollen, varies with the flora of the region and the time of collection by the bees. Bee bread is more acidic than pollen because fermentation will increase the lactic acid content causing the pH value to drop. Despite being a more processed version of pollen, bee bread still has a high moisture content and requires adequate drying for long-term preservation. Like pollen, bee bread is rich in carbohydrates, proteins, lipids, micronutrients such as vitamins, minerals, and polyphenols (flavonoids, flavonols, phenolic acids) and essential amino acids.

Bee bread harvesting

Collecting bee bread is not as popular as harvesting fresh pollen simply for the cost of the equipment and the difficulty of extraction, however, it can be done. The process for extraction of bee bread consists of gathering combs, drying, cooling and then separating the bee bread granules from the wax. Bee bread must be extracted from the comb directly and the process does destroy the comb in which the bee bread is stored. It is necessary to gather the combs free of honey and brood to provide a smooth segmentation process. Bee bread can be harvested from full frames, or cut away from honey frames, depending on where the bees have stored it.

Bee bread can be collected by hand without damaging the comb using a special coring tube sized to fit a single cell at a time, but for commercial harvesting there are special machines for bee bread collection (Fig 3). The commercial methods require the destruction of the comb, though the discarded wax can be melted and recused. First, the combs should be placed in the freezer at a temperature of -18 °C to -20 °C for about 16 hours. Then the combs are cut into small pieces. The pieces are put into a collector machine, and they are crushed and filtered. The wax and bee bread come out separately. Before final storage or packaging, the bee bread must be dried. Drying process must be carried out carefully to prevent loss of its nutritional properties and keep the product fit for human consumption. The maximum temperature drying should be done at is 40°C, just above the natural temperature inside the beehive.

Fig 3. Bee bread collector and wax separator

Bee bread properties and uses

Bee bread is consumed as a food supplement, to flavour drinks or to be put on top of cereal or muesli. It has the same benefits and uses as fresh pollen, though due to the fermentation process, it may have slightly more nutrients available for human consumption. This has not yet been supported with research.

3.7 Propolis

What is propolis?

Propolis, as also known as 'bee glue', is a strongly adhesive natural substance with antimicrobial properties. It is made from resin collected from the buds and new stems of trees and plants and mixed with pollen, salivary enzymes, and beeswax. It is water repellent and tends to stain any porous surfaces like wood, leather, and fabric.

How do honeybees collect propolis?

Plant resins are collected by worker honeybees and carried back to the hive on their hind legs precisely where pollen is stored. The worker bees cannot unload the propolis by themselves because it is so sticky so they must have another bee unload it for them. Different types of resins are collected based on the needs of a colony and they can change their preference depending on factors like pathogen outbreak or elevated humidity and risk of fungal buildup. The resin is mixed with wax, and enzymes and applied all throughout the hive.

What do bees use propolis for?

Propolis is prepared by the honeybees to seal cracks, smooth walls and to keep moisture and temperature stable in the hive. Honeybees also use propolis as an antiseptic to clean comb and protect larvae and honey and pollen stores from harmful microbes.

Composition

Propolis composition varies with the flora of a given area and the needs of the hive. The main components of propolis are resin (50%-70%), oil and wax (30%-50%), pollen (5%-10%) and other chemical compounds including: amino acids, minerals, sugars, vitamins B, C and E, flavonoids, phenol, as well as aromatic compounds.

How is propolis harvested?

The best time to harvest propolis is early fall, when bees want to seal and prepare their hives for winter. A trap can be used to harvest propolis: the trap consists of a flexible plastic screen with slits (Fig 1) that is placed on top of the hive, under the hive cover, replacing the inner cover. The slits in the screen are

too small for bees to pass through, so they are seen as a structural fault. The bees will seal the slits with propolis. When the trap is full (Fig 2) it is removed and placed temporarily in a freezer – the propolis, which is soft and sticky in the warm hive, will quickly become brittle in the temperatures below zero. Flexing the screen will crack the brittle resin off and it can be collected.

Fig 1. Propolis trap
(Source:
https://www.fao.org/teca/en/technologies/8703)
Fig 2. Trap full of propolis
(Source:
https://www.fao.org/teca/en/technologies/8703)

Raw propolis can be sold, but you can also clean and refine it yourself to make tinctures and creams for sale. Cleaning propolis is fairly simple, as it resists water; it can be rinsed thoroughly with cold water to clear it of any hive debris.

Propolis properties and uses

Propolis has been used as a medicine since ancient times. It was also used for cosmetic purposes, and wound healing. Propolis contains antimicrobial components that come from the plants from which the resin was collected, and can be used to help heal topical infections or treat sore throats. Not much research has been done on the effects of propolis, and many of the claims for this product have little scientific backing.

Nowadays it is widely employed in cosmetic formulations and pharmaceutical products and is one of the most widely used natural products. It is commonly used in oral and dental preparations as toothpastes and mouthwashes. It is also used in creams, drops, dietary supplements, gels, cough syrups, powder, soap, chewing gums, tablets, shampoos, chocolate bars, skin lotions, and antiseptic mixtures.

3.8 Royal jelly

What is it?

Royal jelly is a white, creamy, protein-based substance secreted from the head glands of the young nurse honeybees.

What is used for?

Royal jelly (or brood food) is the main larval food given to all developing bees, from queen to worker. The amount and composition of brood food changes with bee caste (worker, drone or queen), it being limited in worker cells, but given freely to queens. It is a very pure form of nutrition and allows the larvae to develop with very little waste, as they cannot leave the comb cell until they are adults.

Composition

Royal jelly has a complex chemical structure with a vast number of proteins. It is acidic, the pH of fresh royal jelly ranging between 3.6 and 4.2.

Royal jelly is mainly composed of water (60-70%), proteins (15-20%), carbohydrates (7,5-15%) and fats or lipids (7-18%). The flavour is generally unpleasant, and it must be mixed with other foods to be palatable.

Table 1. Royal jelly composition

Water (%)	60-70
Ash (%)	1,5
Lipids (%)	7–18
Proteins (%)	15-20
Sugars (%)	7.5–15
Phenols (mg GAE/g RJ)	23.3 ± 0.92
Flavonoids (mg QE/g RJ)	1.28 ± 0.09
Prolina (mg/100g)	58.76
Cystine (mg/100g)	21.76
Aspartic acid (mg/100g)	17.33

How is it produced?

Royal jelly can be collected in small quantities by creating a series of artificial queen cells, provided with larvae and given to a queenless colony for them to rear, but removed before the larvae becomes too large.

Strong colonies can have the queen isolated to a single box, and the absence of the queen in one box should prompt workers to begin rearing a new queen. The two brood boxes, separated only by a queen excluder, should have enough pollen and honey to sustain themselves. The royal jelly production box should include several capped brood combs (no open brood and no eggs), placed in the middle of the

box with pollen combs on each side. The royal jelly production frame should be inserted between two brood combs or between a brood comb and a pollen comb.

There are five steps to follow for the production of royal jelly: preparing the queen cups and frames, grafting the larvae, inserting the royal jelly production frames, supplementary grafting, and harvesting:

1. Frame preparation: Queen rearing frames consist of a square, wireless comb frame and two removable, horizontal wooden bars set with removable plastic or beeswax-based queen cups. Place the assembled frame into the colony for cleaning and to increase acceptance (12–24 h). These production frames are the same frames you would use for regular queen grafting.

2. Grafting: You can choose any larva laid in a worker cell for this process. Do not use larvae laid in the larger, drone cells. The larvae should be 12–18 h after hatching, not more than 3mm long. At this age, larvae have a croissant-shaped body and are bathed in royal jelly (not enough to harvest however). Gently remove the larvae from the cells and set them on their side (the same side they were lying on) into the grafting cups. The cup frame should then be set so the open end of the cup is facing down within the frame. Queen cells are always built and provisioned with the opening of the cell facing down, and this is how the bees know they must create a queen.
   The grafting of larvae is the most important step for producing royal jelly. The grafting action must be gentle and fast and should be completed in a single lift-and-insert operation to avoid damaging the larvae and having the bees remove the cell instead of filling it with royal jelly.

3. Royal jelly production: Insert the production frame into the hive box that does not contain the queen. Generally, a colony with 8–10 frames can support one or two royal jelly production frames, and a colony with more than 10 frames can have two or three production frames. Open the hive 3–5 h after grafting or the next day to check the acceptance of queen cells. You can regraft if the frame was rejected, and the larvae removed. If a larva in a queen cell has been accepted, it will be surrounded by nurse bees, and the queen cell will have fresh royal jelly secreted by workers.

4. Collection: The royal jelly production frame can be collected from the hive 68–72 h after larvae grafting. Gently shake the frame to get rid of the bees (the royal jelly will not fall out) and brush it to remove the residual bees. Use a food safe, stainless-steel queen cell cutting blade to cut off the protruding part of a queen cell and remove the larvae from the queen cells using tweezers. Collect royal jelly from queen cells using a specialized scraping bar and transfer the royal jelly into a bottle for storage in the freezer.

Properties and uses

The claimed effects of royal jelly are many, and there is a large market for the substance as a health supplement, but very little of the health benefits attributed to royal jelly have scientific evidence supporting them. Producing small amounts of royal jelly with a locally produced brand may provide a bit of income, but royal jelly is mass-produced in countries like China, which can drive the price down. It is important to research local demand before you invest in producing royal jelly.

3.9 Apitoxin

What is it?

Apitoxin, also known as bee venom, is a liquid produced in the poison glands (acid glands) of worker bees and queens. It is stored in the poison sac located at the base of the stinger. Bees excrete the venom, through their stingers, when they feel threatened. It is used to deter predators from attacking the hive. The stinger is designed to pump as much venom as possible into the wound and as a result, the entire apparatus can detach from a worker, usually killing the bee in the process, but the muscles continue transferring the venom after detachment.

Apitoxin is a transparent liquid, soluble in water and has a bitter taste. It is characterized by inducing allergic reactions in a wide range of animal groups, from other insects to mammals like humans. These reactions can take place in the skin, the respiratory tract, the cardiovascular system, and the gastrointestinal system. Severe anaphylactic shock is possible for people with allergies to bee venom, or in people who have received a very large quantity of venom. It is possible to gradually develop a sensitivity to bee venom, and caution should always be exercised when working with live bees.

Apitoxin can be collected by an automated process in which the bee is stimulated to sting using through small, non-lethal electric shocks. This causes no harm to the bee and so does not result in a detriment to the colony.

Composition

Bee venom is an acidic liquid (ph 4.5 to 5.5) made of 88% of water. A drop of bee venom has only 0.1 µg of dry venom. It is known to contain many active components including peptides like melittin, apamin, mast cell degranulating (MCD) peptide, and adolapin and enzymes, all of which contribute in some way to make the sting a memorable experience.

Apitoxin collection

Apitoxin can be collected by stimulating bees with an electrical current. Modern devices for collection of bee venom employ this principle. The advantage of this method in addition to generating greater quantity and quality of apitoxin for collection is that it does not cause damage or death to the bees (preserving the stinger).
A specialized collection apparatus can be placed just outside or in the hive. It consists of a glass plate, fitted with a thin fabric and an electrical circuit.

Fig 1 - Apitoxin collector inside the hive
(Source: Modanesi, 2012)

When the bees enter the colony and land on the glass plate, they receive an electrical shock that stimulates them to sting and release the venom that is

deposited between the glass and the protective material of the equipment. Subsequently, this venom dries (dehydrates) and is scraped off in the form of a white powder to be stored for later sale. When the device is placed inside the hive (fig 1), the whole colony becomes stressed, work is interrupted, and the temperature inside the hive increases. This could be very harmful during summer, so an external collector is recommended if you wish to keep the hive healthy (fig 2).

Fig 2 - Apitoxin collector at the entrance of the hive
(Source: Modanesi, 2012)

Uses

Melitin, the main constituent, when used in small doses exhibits anti-inflammatory properties, however in large quantities it causes pain, itching and inflammation. Because there are so many different proteins in bee venom, and some have beneficial effects while others have quite damaging effects, its use in medicine, despite having a long history in Asia, is debated scientifically.

Apitoxin therapy or bee venom therapy is the medicinal application of bee venom, often for the treatment of rheumatic diseases. This strategy has been used in alternative medicine for more than 5000 years. It can be applied indirectly, through extraction of bee venom, followed by injection into the patient's body, via acupuncture needles or directly through the sting of bees. The idea of using bee venom in the medicinal field was raised from the belief that beekeepers hardly suffer from rheumatism or joint problems, though no scientific studies have been able to confirm this in humans.

Apitoxin has been widely used in the treatment of some inflammatory diseases such as tendonitis, herpes zoster, psoriasis, rheumatoid arthritis, multiple sclerosis, osteoarthritis, among others but it is still considered a form of alternative medicine and is not used in mainstream practices. If the process can be streamlined, bee venom can be sold at high prices by gram weight and is used in cosmetics and for research.

3.10 Novel products (edible larvae)

There is an emerging market for the refining and consumption of insect proteins. Insects are numerous, easy to breed and can consume a wide range of materials that are inedible to other animals. The carbon footprint of insect production is also extremely small. Commercial use of insect protein has begun in the petfood industry and as delicacies in restaurants, but the culture of eating insects has existed longer than human civilization. Bee larvae contain pure a form of protein, they are soft, with no hard to pointed carapaces and are considered the more palatable of insect species.

Drone brood composition

Bee brood is very rich nutritionally, with a protein content similar to beef and a richness in vitamins and minerals, like vitamin A vitamins B3 and B5, and D. Their flavour has been likened to a mild, nutty taste or that of some types of mushroom.

Production of bee drones

The honeybee drones are most commonly produced for consumption. They are large and made automatically by the colonies during the breeding season, and their loss does not reduce the function or health of a colony.
Queens start producing drones in the early spring. Their number varies from a few hundred to two or so thousand in each colony, depending on bee race, colony size and the number of resources. Drone production at any one time is limited by the amount of drone comb cells present in the colony. During drone production season, drone foundation frames or empty frames can be placed in the colony to increase the number of drones produced.
Drones develop from unfertilized eggs laid by the queen in the larger, drone cells that have been built by worker bees. Drones take about 24 days to develop and reach their maturity, but larvae are harvested well before then.

Collection of drone brood

Though highly seasonal, drone production can be initiated through feeding and good queen selection, it can be promoted further by providing drone size comb or foundation in the colony.
In certain regions of the world, drone brood removal has become part of regular hive maintenance by beekeepers as a strategy for managing populations of the varroa mite (*Varroa destructor*). This practice makes drone brood a by-product, resulting in a possible abundant source of farmed insects with untapped potential and economic advantages.

Drone brood should be harvested before the pupae's eyes become pink, about 0–160 h after the cells have been capped with wax. This is the time when the larvae have pupated and are firm enough that they can be extracted but have not yet developed tough chitin that would make them unpleasant to eat.

Very limited research has been performed so far considering the removal of drone pupae from the comb cells and it is considered messy and difficult, several methods are briefly described below:

Shake method: The cells are uncapped with a fine, serrated and preferably warmed knife, and the larvae and pupae shaken out onto a clean surface. If the brood need not be whole, a fork with very long, fine prongs (as also used for honey uncapping) can be used to uncap and retrieve the larvae. Since larvae defecate just before pupation, larvae and pupae should be washed in clean water before further processing.

Removal can also be done by using a small jet of water cold water from a laboratory wash bottle to remove individual larvae from their cells. The author of this method had reasonable success flooding one side of an uncapped comb. All the cells were filled with clean water, and then the larvae and pupae were shaken out. This may lead to an excess of water in your harvest, which, depending on how many larvae have been damaged, could reduce your production.

Freezing the comb for harvest is another option, leaving the collected frames at -20 ºC for a few hours before extraction. The wax becomes brittle, and shatters and the more robust frozen brood can be sorted out and kept frozen for sale.

Many beekeepers choose to specialize in just one or two of these areas, with most beekeepers harvesting honey as their principal source of income. If you have the time to commit to mastering another product however, it can be quite lucrative if there is a demand in your area not being filled. Part of the start to a good business is doing research to find out the most needed commodities in your local area and design an operation that caters to them.

4.0

Pests and Pathogens

Honeybee pests come in many shapes and sizes, from large mammals like bears, to minute viruses and bacteria and there are many of them that can cause a lot of harm to your bees. Not only are there threats native to your areas, but there are also many invasive pests as well, either established or on the move within Europe. This chapter will outline some of the most common threats, provide a little information on how to diagnose them and how you, as a beekeeper, can treat them.

4.1 Parasites

4.1.1 Varroa mite

The varroa mite is a tiny, oval-shaped mite about 2mm wide. It has a deep, glossy red colour. They hang onto the back or the abdomen of adult bees and bite them, like ticks on a dog. The varroa mite (*Varroa destructor*) switched successfully from its native host (*Apis cerana*) to the European honeybee (*Apis mellifera*) in the early 20th century. It is currently the most devastating parasite plaguing domestic honeybees worldwide because it is invasive and European bees have no natural defenses against it. Varroa mites can damage honeybees in several ways: Adult Varroa females feed on the fat bodies of adult bees, reducing their protein storage, which can increase their chances of death over winter (3). Secondly, when mites feed on bees, they are simultaneously vectoring different viruses into the bee body. This process becomes extreme when the Varroa reproduce in the capped brood cells of the bees, and the pupae are exposed to the viruses before emergence. Highly infected larvae can display various deformities upon emergence as adult bees, like stunted abdomens and deformed wings. The most important condition however is the shortened lifespan, which reduces the colony's ability to survive winter hibernation. There is a list of different diseases that can be associated with the presence of varroa mite in honeybee colonies (deformed wing virus (DWV); chronic bee paralysis virus (CBPV); Black Queen Cell virus (BQCV); Sacbrood virus (SBV) etc) (4). In addition, colony collapse disorder (CCD) has been linked to high varroa infestation rate, likely because of its ability to vector DWV.

Varroa mites (female) use foraging bees (and drones) to spread from one colony to another. When strong colonies begin to rob weaker colonies in autumn, this process can increase the spread of Varroa by a huge amount.

To reproduce, female mites enter a honeybee brood cell just before capping. Because they can produce at least one more offspring in drone brood due to the longer development time, they are 12 times more likely to choose a drone cell in which to reproduce. Approximately three days after the brood cell is capped for pupation, the female mite lays her first egg (a male) and she continues laying eggs at 30 hour

intervals (all female). The foundress (mother) mite keeps a feeding site open on the pupae for the entire pupation period, and this is when virus transfer is at its highest. When the young bee emerges from the brood cell, so does the female mite and her mated daughters (5). The male mite cannot survive outside the cell and dies shortly after bee emergence.

Counting and treatment

Varroa treatment is now essential in almost any honeybee operation. Most country recommendations advise a blanket treatment for all colonies at specific times of the year, but if you aim to reduce the amount of product used in your operation, you should count mites on a regular basis. Mites are easy to identify with the naked eye. They are deep red and glossy and almost perfectly oval. They are all nearly uniform in size, about 2mm wide. There are some common ways to count mite numbers in hive. Sticky boards are used to measure natural mite fall daily or the effectiveness of treatment. This is a flat, metal or wood tray that can be placed under the brood boxes, designed to catch debris. The boards must either be coated in a special adhesive or else coated with oiled kitchen paper to prevent other insects from eating the mites and biasing your count. The boards are left for 5-10 days, and mites are counted and averaged to give a daily drop rate. Generally, a rate of more than 10 mites falling per day will require the colony to be treated. Another quick and effective way to count mites is to perform an alcohol wash; this requires a small container with a mesh top: approximately 300 bees (~2.5dl) are taken from the hive and submerged in a container filled with a solution of rubbing alcohol (ethanol) or methylated spirits (25% alcohol). The bees and mites are killed as you swirl the cup and after a minute or two, the cup can be up-ended, mesh-side down, over a strainer and the bees rinsed a few times to get all the mites off. The mites can then be counted. A similar method that does not kill the bees is the sugar shake method: the bees are placed into a mesh-topped cup and coated with icing sugar, the cup is shaken to coat the bees and the mites slip off. The cup can then be up-ended, mesh-side down over a basin of water and the sugar will melt away, revealing the mites in the bowl and can be counted (6).

There are several ways to treat varroa mites. Synthetic pesticides like tau-fluvalinate, amitraz and coumaphos (7) have been effective in the past, and tau-fluvalinate is still approved and used in the EU, however these chemicals are not approved for use in every country and mite resistances to these chemicals are increasing so they may not be viable for long (8,9). As an alternative, organic compounds like oxalic acid and formic acid have seen no adaptive resistances from the mites (10) and, if used properly, can be quite effective. If you aim to run an organic beekeeping operation, these acids are acceptable forms of treatment under most organic certifications. No substance treatment should be used while there are honey boxes on your hive. The products can contaminate honey and devalue it or make it unsellable entirely. Treatments are usually done before or after the honey boxes are placed on the hives. Other methods for control include beekeeping tasks that can be done at any time: Drone cutting is a process where a frame of drone foundation is used to encourage drone production in a single place. These frames attract mites, which enter the brood to reproduce, and the capped drone brood is then cut away before the drones emerge. A beekeeper may also remove worker brood in a highly infested colony or split the hive into two to reduce mite loads, though these last two treatments will reduce the colony's ability to produce a good honey crop for that year. Unfortunately, there is no method for varroa control that is 100% effective. Many beekeepers have been trying to breed bees that

have resistances to this parasite and some have been effective (11), but the methods are still under investigation, and no clear path to resistance has been found yet. Still, it may be worth asking your local community about resistance breeding initiatives and join forces with like-minded beekeepers to help advance this technique.

4.1.2 Tracheal mite

The tracheal mite (*Acarapis woodi*) is spread almost all over the world (except Australia). This small mite (125-175 µm in length) spends its life in the trachea (respiratory system) of a single host. Tracheal mites (adults and larvae) attach to the walls of the honeybee tracheal system and feed on bee hemolymph (blood). Female mites can jump from one adult bee to another, newly emerged bee to start reproducing. It has been noted that mite populations increase during the winter, probably due to winter bees increased longevity and the fact that bees are still, and more closely packed. Tracheal mites are known to affect the flight muscles of bees and can affect flying (foraging) and the bees' ability to heat or cool the colony. Honeybee colonies that are highly infested with tracheal mites show lower honey production and thermoregulatory disorders, which may lead to increased colony mortality.

Identification and treatment

Tracheal mites can only be detected by a microscope. To treat tracheal mites, menthol vaporization and chemical miticides can be used similar to Varroa treatment, and also only when the colonies are free of honey boxes (12).

4.1.3 Wax moth

Wax moths are small, beige-grey moths, the larvae of which have adapted to use bees wax as a form of food. Wax moths are parasites specialized for honeybee colonies but are usually cleaned out by healthy hives. They can wreak havoc in weak hives or on frames that have not been stored correctly in a honey house or barn. Wax moth can cause very costly damages. There are two main species in Europe: the greater wax moth (*Galleria mellonella*) and the lesser wax moth (*Achroia grisella*). In both species, eggs are laid in unoccupied wax comb or cracks and crevices in hives. Once hatched the larvae tunnel through the wax comb, leaving silk and frass (poop) in their wake. The tunneling usually prevents removal by worker bees, and larvae can consume nearly anything they encounter in the hive, depending on the species.

Identification and treatment

The larvae can look very similar to small hive beetle, but the silk and frass trails left in wax comb are very obvious. You should be wary if you notice grey-brown moths flying about your frame storage area, and check frames carefully for wax moth larvae. Adult moths have their wings folded against their backs and are about 1.3cm (Lesser wax moth) to 1.9cm (greater wax moth). Pupal cocoons are often gathered on the bottoms of abandoned frames and are lined with silk.

The best way to treat wax moth is to keep strong hives and make sure stored comb is sealed in boxes with no cracks for moths to squeeze through. Never leave stored frames uncovered, always keep them elevated off the floor of your storage area and place a separator (a sheet of newspaper will do) between

stacked boxes. If you find wax moth in hives or your storage house, remove the affected frames and melt them down or freeze and discard them. Do not simply throw them out untreated, the pupae can still hatch, and the adults can fly back into your storage area.

4.1.4 Small hive beetle

Small hive beetle (*Aethina tumida*), or SHB, is an insect, which spends most of its life in honeybee hives and feeds on bee brood, pollen and honey. The damage of SHB is recognizable by riddled combs with honey dripping onto the hive floor, where it mingles with the faeces of the beetle and debris of the comb. As a result, the honey in combs will ferment, making it totally unusable for both bees and beekeepers. The SHB can also vector honeybee diseases like sacbrood virus or American foulbrood (13,14).

This beetle originates from Africa, where the local honeybees *Apis mellifera scutellata* have behavioral adaptations to manage with the pest. Bees abscond from the hive when the number of beetles has grown too high. European honeybees *Apis mellifera mellifera, carnica, ligustica etc*. do not readily abandon their hives and if they escape, they leave larger amounts of resources behind. This kind of behavior supports the SHB population with plenty of food resources (15).

The adults live approximately six months and inhabit the whole hive, often near the brood area or in the debris on the bottom of the hives. A single female can lay up to 2000 eggs (16), which are placed in empty comb cells in clumps of 10-30 eggs. They can also deposit the eggs into capped brood comb, chewing holes into the walls of empty cells. After 3-6 days the eggs hatch. The larvae feed on pollen and honey, damage combs, and require about 10–16 days to mature. Last instar larvae leave the hive and pupate in the soil under the hives. The pupation lasts up to 4 weeks and newly emerged adults look for new hives where they mate and start a new cycle. The newly emerged adults can fly 5-10 km to find a new host hive.

The spread of SHB occurs naturally from apiary to apiary. The beetles can fly and disperse themselves over large distances. In addition, the beetle spreads with help of human activities – selling full size or small nucleus colonies, migratory beekeeping, trade of used beekeeping materials, but also transportation of fruits and horticultural products. The adult beetle can survive by eating any kind of sugars – fruit can fill this purpose. While SHB pupates in the soil around the hives (up to 200 m radius), the soil of flowerpots in the area may contain the pupae.

The SHB has now established in some Southern countries of Europe. It was first discovered in Portugal; however the infected colonies were exterminated. The beetle was then discovered in Southern Italy. To prevent the introduction of SHB into other parts Europe, the import of honeybees is strictly regulated by the European Commission, Regulation 206/2010. Italian beekeepers are under obligation to report new discoveries of SHB to the veterinarian board. Infected colonies may not be transported to any other region. Around every infected apiary the potentially infected ground area has a radius of 20 km and a monitoring zone is established with a radius of 100 km. Within the monitoring zone, the officers of veterinary board do regular random examinations. The adult beetles are able to survive up to two months without any feeding. The beekeepers are obliged to exterminate the infected colonies and

equipment and the soil around the apiary must be treated with pyrethroid insecticides. The beekeepers of the infected apiaries must also supply the hives with traps to catch larvae when they leave the hives before pupation.

Identification and treatment

The insect is on average 5.7 mm in length and 3.2 mm in width, which is approximately 1/3 the length of an adult bee. The small hive beetle is dark-brown and oval-shaped with clubbed antennae.

Beetles can often be seen running from the light when a hive is opened. Though SHB larvae look similar to wax moth larvae, they and be distinguished by their tendency to cluster on the frames or in the corners of the hive. Older larvae are attracted to light.

A key factor in the control of this pest is the cleanliness of the beekeeping areas, including storage and the strength of the kept colonies. While strong colonies manage better with the beetle, one should not split the hives infected with the SHB and not add many supers, since these enlarge the inspected territory for honeybees and can result in beetle larvae in your honey boxes. Another preventative measure is to make sure the substrate underneath colonies is sandy and dry, avoid mulch, leaves or anything that can remain damp for long periods of time. Never store boxes or frames on the ground, they should always be elevated, ideally on man-made flooring (stone, concrete, linoleum, or wood). SHB generally prefers shaded areas and colonies sitting in shade, setting your colonies in direct sunlight might deter invasion at least in part.

As chemical control, coumaphos strips have been used in the hive. When the soil (2 m radius around the hive) is infected with the pupae, it must be treated with pyrethroids like cypermethrin or tetramethrin, but these chemicals are also highly toxic to honeybees and any chemical treatment leaves residues either in the hive or out in the environment. Pyrethroid residues can be found inside the hives after soil treatments, and these will affect many other organisms also. Soil chemical treatment is not applicable in organic farms, groundwater protection zones, natural parks and in forests so for these regions, and for organic operations, non-chemical methods are suggested. Because this pest is relatively new to Europe, there are very few tested methods for controlling it. Some insecticidal fungi like the *Aspergillus* species, *Metarhizium* and *Beauveria* isolates have been found effective (17), there is evidence that the beetles probably do not survive pupation in soils below 10 ˚C or above 35 ˚C or a low soil moisture content. Hence any method or climate that provides temperature or humidity extremes as deep as 20 cm inside the soil could kill the pupae.

Apart from insecticides, there are a variety of traps available to help control the beetles: small hive beetles love small, tight crevices, and sugary substances and these are the bases for many traps: they provide spaces just large enough for the beetles to crawl into, and attractants to lure beetles in. The traps can either be removed and disposed of or contain something like an oil that drowns the beetles quickly and can be refilled. External lantern traps are made to catch newly emerged beetles. These are catch containers with special tops built to hang in nearby trees, allow beetles entrance and then trap them inside. These traps are baited with water and honey or fermenting sugars and oil that drown the beetles that fall in. You can trap larvae as they leave the colony to pupate by placing the hive stand in a

box lined with sandpaper and a mesh bottom (<1mm mesh holes) (18). When the trap remains dry, it prevents escaping of the larvae.

As methods are tested, they become more successful, so it is likely the information provided here may become outdated. It is important to check with your local beekeeper's association on the best management strategies if SHB is in your area.

4.2 Bacterial diseases

Bacteria are everywhere, and as clean as honeybees are, they can still contract bacterial infections both as adults and as developing larvae. The two most dangerous bacterial infections for your bees are two types of foulbrood: different bacterial species that kill developing brood and are highly contagious.

4.2.1 American foulbrood

American foulbrood (AFB) (*Paenibacillus larvae*) was first described in 1903. AFB is considered one of the most severe brood diseases. Usually, infected brood will die. AFB can infect honeybee workers, drones and queens as well, and can be spread on contact, and contaminated equipment. AFB is prevalent worldwide, causing severe economic damage to beekeepers. AFB spores are approximately 1,3 x 0,6 µm in size and cannot be seen with the naked eye, only the symptoms are apparent. It has been documented that *Paenibacillus larvae* spores are resistant to heat and melting the contaminated wax or scorching the wooden hives will often leave active spores behind. A common way for AFB spreading is via trophallaxis (food sharing) between honeybee workers and larvae. The bacteria multiply in the gut of the bees, and at a specific larval stage (approx 234 h) it becomes lethal. The dead larvae are then cleaned by nurse bees and spread to healthy cells.

Identification and treatment

The most common clinical symptoms of AFB are a very patchy brood pattern, in addition to sunken and dark honeybee brood caps and a very distinct, sour or rotting smell. The brood turns yellow-brown, falls to the bottom of the cell and turns into a sticky, stringy or ropey pulp when disturbed. The pulp sticks to something like a matchstick and can be drawn up out of the cell in a string-like consistency.

To prevent AFB distribution in your apiary, keep your hives, tools and storage very clean (disinfecting equipment, proper wax circulation and keeping healthy colonies). Nowadays AFB can be detected using special samplers. Due to its severity and its ability to spread very quickly, AFB is considered one of the most severe diseases worldwide and it is controlled very strictly. In many countries, all equipment and hives are burned if the symptoms of AFB are found, as it can rapidly destroy a large number of hives very quickly and spread to neighbouring beekeepers (1).

4.2.2 European foulbrood

European foulbrood (EFB) is caused by the bacterium *Melissococcus plutonius*. Like AFB, EFB is distributed worldwide, causing severe economic damages for beekeepers. *M. plutonius* needs carbon dioxide for growth and this pathogen targets and kills larvae in unsealed cells– the older the larvae, the

less likely it will be affected). Infected larvae become yellow or grayish black. A very sour smell cooccurs with infection and the brood pattern will also become very patchy. Colonies become susceptible to EFB when nutrition is poor, the climate is wet and cold, or the bees have been subjected to elevated levels of stress. It is important to combine or cull weaker colonies to make sure they do not contract infections like foulbrood and pass them to your healthy hives.

Identification and treatment

Like AFB, the EFB can also be detected before symptoms occur using special sampling techniques. In addition, using microscopic examination is also effective. These methods require samples to be sent to a lab for testing. EFB can be treated using antibiotic oxytetracycline hydrochloride (OTC), which inhibits the multiplication of the EFB causative agent (2), however chemical treatments are often strictly regulated in many countries, and some substances may be difficult to get. Several countries also have euthanasia and burn policies for EFB as it is also highly contagious. The best treatment for either foulbrood, therefore, is preventative and it done by keeping healthy bees.

4.3 Fungal diseases

There are not many fungal diseases that can cause serious harm to your colonies, however in the right conditions, or in addition to other problems, they can get out of hand. It is important to recognize symptoms and take preventative measures to minimize the chance of these fungi spreading in your hives.

4.3.1 *Nosema* (*ceranae* and *apis*)

There are two species of Nosema that can be damaging to European bees. *N. ceranae* Is believed to be more damaging because it is likely an introduced fungi from the Asian honeybee *Apis cerana*, and European bees have fewer ways to combat it. These spores can be picked up in the environment and multiply in the gut lining of bees. It is spread through bee faeces (poop) and when infected combs are cleaned by workers. There are almost always low levels of these fungal pathogens in colonies, but weaker colonies and long periods of cold, wet weather may permit outbreaks which can kill bees. Nosema cannot be seen with the naked eye, it is diagnosed with a microscope, and the symptoms are not a definitive way to diagnose but can help. Symptoms are most noticeable in autumn and during the first spring inspection. These fungi can cause dysentery in bees, and they often defecate in their hive, leaving brown faecal stains on comb, frames and the entrance to the hive. Certain types of honey (like honeydew or forest honey) can also produce dysentery in hives, which looks similar to a Nosema infection. Infected young bees can have difficulty digesting food, and often are unable to produce enough brood food for larvae, effectively reducing the number of functional nurse bees in the hive. This is very important in spring, when young bees are reared to grow a colony. Heavily infected queens can stop egg production entirely. Look for a declining population in a hive that seems to have no other issues, lower brood production or honey production.

Most ways to combat Nosema are preventative: Maintaining good health in all your hives is key, replacing old queens, cleaning your tools and limiting frame transfer from colonies you suspect may have a problem. If a colony seems weak for an unknown reason, you can add bees from a known healthy colony (always fewer bees than what is in the hive) and changing out the queen. If your climate is colder, placing bees in a sunny area protected by the wind will allow them to take cleansing flights more regularly when temperatures dip, and reduce the amount of faeces in the hive and limit spread. Frames from deadout hives in spring, especially ones with a large amount of dark, faecal staining should be melted down, not reused and all tools should be disinfected before their use in healthy hives.

4.3.2 Chalkbrood

Chalkbrood (*Ascosphaera apis*) is usually not a serious pathogen in hives, though it can be a symptom of a more serious problem. It is a fungus that infects larvae only through feeding and prevents the larvae from taking up nutrients. When the larva dies it becomes shrunken, hard, brittle and white and the pathogen can then transmit its spores to the bees who clean the dead larvae out.

Symptoms include white “mummified” larvae in the cells and often scattered on the bottom board or under the colony. These signs are most frequently observed in spring when older bees are building the new spring workforce and may have a weaker immune response than fresh bees. This pathogen can reduce the work force in spring, but it may be a sign the colony is struggling with a different problem.

Maintaining strong hives is the best defence, however, infected comb can be removed to limit the spread of this fungus and replaced with fresh wax foundation or clean, built comb. You can also add bees from a known healthy colony and replace the queen if the problem persists. It is very important to clean your tools after managing a hive with clear signs of chalkbrood, so you do not spread it to your other hives.

4.4 Viral diseases

There are a great many viruses that can affect your bees, and most cannot be treated directly, but rather, curbing the parasite that spreads them or else providing them with new, healthy bees to boost immunity are likely the best methods to prevent damage.

4.4.1 Deformed wing virus (DWV) (previously known as the Egypt bee virus) is a virus that can cause honeybee wing deformities and eventual mortality when infection levels are high. Prior to the introduction of varroa, DWV was benign, transmitted orally and existing at low levels. This virus adapted to use varroa as a vector when it was introduced, and now the mite and the virus together are quite often fatal to entire colonies if left unchecked. When deformed wings can be seen in a honeybee colony, it means the colony may be close to collapse (19). The virus can be controlled by controlling varroa mites in the colony (20).

4.4.2 Black Queen Cell Virus (BQCV) The main symptom of BQCV is the mortality of honeybee queen larvae. The cells turn black as the larvae dies and decays. Adult bees can become infected as well, but often asymptomatically. BQCV is distributed in various ways, from nurse bees to larvae, when infected

queens are introduced to other hives and possibly from external sources like flowers, visited by bees and other insects. BQCV is generally a very low threat to colonies as a whole and there are no known vaccines or treatments to fight against BQCV and the best ting to do is make sure equipment is clean, and heavily-affected colonies receive a new queen(21). This disease can affect queen rearing operations, and the disease is most damaging early in the season. Infections tend to lapse in mid to late summer.

4.4.3 Sacbrood Virus (SBV) is a larval disease that exists throughout the world. SBV is a brood disease that results in larval death. Interestingly, SBV is prevalent in many honeybee colonies that do not show clinical symptoms, because adult honeybees remove infected larvae during the early stage of infection. SBV can be detected more frequently in spring or in early summer when there is a lack of younger bees. Symptoms can look similar to American or European foulbrood (Patchy brood pattern and brown-black rotting larvae), but there is a lack of the sour, rotting smell. This skin of the larvae forms a fluid-filled sac around the body, giving the virus its name. There are no chemical controls to treat the SBV. It is recommended to make sure your colonies are strong and healthy going into winter, and combining or requeening weaker colonies in your apiaries (22). Pests and pathogens will always be present and pose problems for your apiaries. It is imperative that you are well-informed on the threats to your bees, know how to recognize the signs and apply the correct treatment. The most important message from this section, is to maintain healthy colonies and treat or remove sick and diseased hives as soon as you find an issue.

To help solve some of the problems of pests and diseases, many beekeepers are developing lines of hygienic bees. Buying these queens or selecting the most hygienic queens from your own stock is a good way to help reduce risk. Hygienic bees will not prevent all problems, but they may give you more time to intervene when serious ones occur, and they can take care of minor issues quickly, so they have fewer chances to spread.

4.5 Predators

Wherever your operation is, honeybees must share their environment with other animals, and some of these animals can pose a threat to your bees. Some predators are natural enemies of your bees, but some have been introduced, and usually, the introduced species pose the largest problems. It is important for you to be aware of the different kinds of predators in your area to avoid costly damage to your operation.

4.5.1 Vespa velutina

The yellow-legged hornet (*Vespa velutina*) or Asian hornet (not to be confused with the Asian giant hornet, a different species) is a honeybee specialist predator. It is endemic to Asia but was accidentally introduced to Europe (France) in 2004. After the introduction *V. velutina* numbers increased (23) preying on the many domestic bee colonies available and the species quickly became invasive. This predator has completely invaded Southern Europe (Spain, Portugal, Italy) and has now spread to Great-Britain and Germany (24).

V. velutina nests are located at the top of the trees and in early season, hidden in lower places like bushes or sheds. A velutina colony consists of one queen, drones and workers. Virgin queens mate in autumn. Only the queen overwinters, both the worker hornets and the drones die before that.

Though the Asian honeybees have some defence, European honeybee colonies (*Apis mellifera*) have little, and velutina may cause severe damage. Velutina workers start to hunt honeybees in summer during the colony growth and continue to hunt until late autumn. Vespa workers hunt honeybees directly in flight or at the hive entrances (25). When the hornet predation pressure is intense, honeybees will not fly out to forage and this can harm development and honey production, especially if the attacks happen during a honeyflow.

Identification and treatment

There is a native species of hornet in Europe (*Vespa crabro*) that may be confused with this invasive pest. It is important to identify the species you find therefore, as there may be no cause for alarm, *V. crabro*, though it will take the occasional bee, does not stalk hives and prevent foraging. The European hornet is acorn-brown with a yellow head and several yellow bands on the abdomen. Velutina's head and thorax are very dark brown to black, and it has only one thick yellow band on the end of its abdomen, and two thinner stripes above that.

Several options have been evaluated to treat velutina. If whole nests are found, they can be destroyed with sulphur dioxide or another chemical. If the nest can be reached, it can be bagged and frozen. For the method to be effective, the queen at least must not be allowed to escape. Taking the nest at night may provide better results, though these hornets are large and may be able to penetrate a bee suit with their stingers, so caution is advised. The second method involves catching individual hunting hornets using lure traps, but this is time-consuming and probably not the most effective way (queens are in nests producing more hunters). The third option is to find and kill velutina queens in spring or in autumn when they are out flying and easier to spot (25). Special hive entrances are being designed to help the bees fly out in a manner that lets them escape most hornets' attention. Since this threat is relatively new, it is very important to keep informed on the methods of control and how to identify it, especially if you live in or near a place where it has been confirmed by local authorities.

4.5.2 Ants

Ant attacks usually occur in early spring when overwintered ants are starting to build their nests and gather food. Small black ants (*Lasius niger*) do not damage honeybee colonies substantially, though they can be a nuisance when working hives. Beekeepers have noted that they can be beneficial insects because in addition to a little robbing, they clean dead bees and other debris from underneath the hive. These small black ants can invade deadouts for the sugar left within, and in colder climates, they place their pupae underneath hive covers to take advantage of the warmth produced by the bees. There are several species of ant present in any environment, no matter where you are in Europe, and some can cause severe damage to honeybee colonies. Some larger species will target a colony in a strategic way, spraying formic acid (an acid that most ants use in defense and attack) as they invade and forcing the bees against the walls or killing them outright.

Identification and treatment

It is very difficult to identify specific ant species that can harm your bees and distinguish them from harmless ones. Ants are everywhere, and they provide crucial ecosystem services that maintain many of the flowering plants bees need. Species vary across Europe, but fortunately, the methods to take care of pest ants are the same in every environment. If your hives have a serious, recurring problem with spring ants, building a moat stand can help, this is simply elevating your hive stands on four or more legs and placing each leg in a plastic container filled with water, effectively creating a moat around each leg. In order to save water-foraging bees, you can place a stick against the outer edge of your moats, so anything that falls in can crawl about out back into the environment, but not up to your hives. It is ill-advised to use chemical insecticides to treat for ants, as it can target many other beneficial species, and can harm your bees. Generally, ants are not a serious problem in most areas, and strong colonies have the ability to defend themselves against them.

4.5.3 Mice

Mice can be a serious pest for beekeepers. They cause severe damage to bee colonies in winter by consuming stored food, eating bees and destroying the wax in frames. Mouse attacks usually start in late autumn when the weather gets colder, and food becomes scarce. A heated honeybee colony is the ideal place to nest in winter. Mice can spend the whole winter inside the hive and leave again in spring when bees and beekeepers become more active. The constant disturbance in winter may lead to honeybee colony death, and in years when mouse populations boom, the damage can be extensive. The easiest way to keep the mice out of hives is to make sure your boxes are sealed, and close down the entrances to spaces too small for mice to squeeze through. Mice can fit through openings the width of their own skull, so it is important to reduce entrances to a height only your bees can fit through.

4.5.4 Shrews

These little mouse-like animals are actually not rodents, but carnivores, more closely related to moles and weasels than mice. They are tiny, some only four to five centimeters long and they are voracious insectivores. These pests also come in winter, more often in hives placed close to running water like rivers or streams, where the shrews hunt during summer. They can decimate a bee population by feeding on the bees all winter. They leave distinctive evidence in the form of hundreds of bee abdomens scattered under the hive or on bottom boards, as they eat the head and thorax of the bee but leave the rest. Standard mouse guards will not keep these pests out, they are too small. Adding a tight, mesh screen to entrances will help, but it is imperative that workers be able to leave the colony on warm days for cleansing flights, so the mesh must allow bees to pass through, and be removed the moment the weather gets warm enough for bees to fly en mass. Shrews are only a problem for the northern-most areas of Europe, and it is rare for shrews to become a problem for countries without a distinct winter season.

4.5.5 Pine marten

Pine marten (*Martes martes*) is a cat-sized predator from the weasel family. It has reddish-brown fur and a white underbelly. The pine marten is a serious pest for hives in winter. In spring and summer

when the bees are active, the marten normally does not bother the hives and no measures need to be taken against them. Pine martens eat honey and will take advantage of the bees' lower defense in the cold winter months. Fairly often, a marten attack ends with a colony's death. They are not strong enough to topple hives like bears, but their sharp claws can tear holes in material and their tracks and spoor (poop) will likely be found nearby. The easiest way to get rid off martens is to connect with local hunter who will place traps in your area (Figure 1). Generally, it will only be one animal at a time that discovers your hives, so taking care of that individual will solve your problem.

Figure 1. Pine marten trap. Source: jaanikese.ee

4.5.6 Bear

Brown bear (*Ursus arctos*) is a very rare but serious enemy for honeybee colonies. Despite popular thought, the bears are not after your honey, but the brood, which is high in protein and a very good food on which to store fat for the winter. Once the bear has started visiting the apiary, it will likely not stop until all the hives are destroyed (Figure 2). There is no need to take precautionary measures against bears unless they are common in your area. Often, bears are protected by laws, so you will not be legally permitted to shoot them. Building an electric bear fence is your best option if you have trouble with bears, or you can move your hives to an area much less visited by bears, like a rural or agricultural space.

Figure 2. An apiary destroyed by bear. Source: pinterest.com

For many honeybee predators, a good preventative step is to keep your apiaries very clean. Do not throw bur comb or extra wax on the ground as it can attract martens and mice, have a bucket you can toss it into to take back to your honey house. Never leave frames outside of boxes, especially if filled with honey and during a flow; honey has a very attractive scent to many animals. Make sure to remove the honey in a timely manner and do not leave the harvest until late in the season. This next section will cover the basic practices to help keep your operation pest, pathogen and predator-free.

4.6 Apiary/honey house/storage hygiene

4.6.1 Apiary hygiene

The first thing in spring is to clean and disinfect overwintered beehive bottom boards. The disinfection is done using soapstone or fire scoring (depending on the hive material). Often you can bring clean boards from your storage and replace the dirty ones so they can be taken back and cleaned. If you do not have extra material, the bottom boards can be cleaned on site, but must be replaced under the same colony to avoid disease spread. The debris and dead bees should be burned or at least removed far from any active hives. Secondly, it is crucial to monitor colony health in spring (presence of queen, signs of nosema etc). Replacing the old or sick queens as soon as possible. Depending on your colonies' health status and varroa counts, perform a spring varroa treatment may save your hives. When the weather becomes warmer and the first pollen or nectar sources appear it is time to start expanding your colonies. It is crucial to disinfect your hive tool(s) while visiting different apiaries and clearing dead out

hives. Replacing old, dark comb with fresh wax foundation is one of the best ways to avoid pathogen outbreaks. Normally, the frames from an overwintered box are rotated to honey supers during the summer and after the honey harvest, they are melted and new wax foundations can be made, either by your own operation or by a local wax producer. After the last honey harvest, it is usually time to treat against varroa to make sure this pest does not cause winter losses and create more dead outs for you in spring.

4.6.2 Honey house hygiene

Before building your honey house, consider what you need to keep your material clean and pest-free. Honey is a food product, and your production house must probably meet several food safety regulations in your country. Production house walls and floors must be washable, and the floors at least should be waterproof, or else easily lined with plastic sheeting that can be collected and washed after the harvest. Always plan for easy access to your storage area and honey house by vehicle, paved roads help reduce the amount of dirt that gets into your production area. Invest in quality detergents to keep your production house clean. During the honey harvesting season the bees are often in robbing mode and will be very tempted to break into your honey house – so, you must ensure that the honey house is properly sealed, to keep bees and pests out, and your honey clean.

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5.0

Self-Sustained Beekeeping

In the beekeeping industry you can save a lot of money if you make your operation self-sustaining. Producing your own queens and swarms allows you to grow the number of your hives inexpensively, control the traits of your bees and even produce some extra bees to sell to other beekeepers.

There is a lot to think about when making your operation provide for itself and in this chapter, we will discuss most of what you will need to make it happen.

5.1 Apiary establishment

The right location

There might be many different areas available to you when you are looking to place your bees, but the bees have very specific needs to keep them at their healthiest and sometimes small details can make large differences. Here are some questions to think about when choosing a good location for your bees:

1. Is the area protected?

From wind, bad weather, interference from large farm equipment, theft; there are a lot of things that can be detrimental to your hives, often the area you have to place bees will not be immediately close to your home, and you will not be able to visit them every day to check on them. Ideally, it should be sheltered from strong wind and storms, close to trees or behind a structure. It should be out of the way of large throughfares for cars and tractors, especially if you have snow, the colonies can be buried and therefore hard to see. If the area in which you live has had recorded hive thefts, it is good to place them off major roads and out of plain sight.

2. Is it close to floral resources?

The next most important thing is honey. Is the area close enough to flowering crops or wild plants that the bees can forage nectar to produce honey for themselves and for you? How many kinds of flowers are there? When do these flowers bloom? Sometimes an area can be great at one time of year, and very poor at another, so you must feed your bees when the nectar isn't flowing. A good area will have access to an early crop, a large summer crop (your honey crop) and a modest fall crop to augment your winter feeding and provide enough pollen for the next year. Depending on the area you may also be able to harvest from the spring or fall crops too.

3. How far must you drive from home?

Beekeeping equipment is large and heavy, and it is imperative that you have the resources to transport a large volume and weight too and from the hives. Ten hives can produce hundreds of kilos of honey during a flow, and you must bring enough bee feed to them in fall to help them overwinter safely. The apiary you choose must be close enough to you that you can drive there to run general beekeeping work at least every month and have the capacity to transport everything you need. Oftentimes beekeepers will drive their hives to a flower bloom like a fruit crop and these locations are often very far away, but

the home apiary where the colonies are kept outside of large migratory operations should be easily accessible from your home.

4. What sort of agriculture is close by?

Most areas that are suitable for keeping bees also have a lot of other agricultural activities. It is very important to know how the surrounding land is managed, so you can make good decisions for your bees. Cutting verges and roadside grass can deprive your bees of a lot of good nectar and pollen, and many crops grown don't produce any nectar at all, effectively making food deserts across a large area. A lot of crops are sprayed with chemicals: fertilizers, fungicides, herbicides, and pesticides and many of these can be toxic to your bees if they are exposed to high concentrations. Even if the crops are non-flowering crops like cereals and the bees do not fly on them directly, the pesticide runoff can still affect your bees by getting into the ground water they drink or being blown onto nearby flowers by dry winds. When placing your bees, it is important to ask about local regimes for crop care, the rotations, chemicals used and harvest and spraying periods. Non-intensive grazing pastureland is usually the best form of agricultural land for bees to use.

5. Private or public land?

Some countries permit beekeepers to place hives on public land, with the right permits but most contracts will be private, between you the beekeeper, and the landowner. Contracts can be written or verbal and are basically agreements between the two parties for permission of land use for the temporary or permanent placement of your hives. Oftentimes the landowner will ask for a small amount in compensation but sometimes, especially if the crop they work requires bees for pollination, they are not likely to charge and may even pay to rent colonies during the flowering season. It is generally recommended to obtain a written contract detailing the use of land, the number of colonies permitted, a promise to keep the area clean and free of surplus and debris, a period of notification for hive removal etc. This list is by no means exhaustive, and conditions may vary between countries. It is a good idea to do research in your local area and investigate the best contract templates to use.

5.2 Government registration and organic certification

Government permits and registration

Most countries have a local or national registration process for new beekeepers and/or the hives they are responsible for. Sometimes this may come with a hive inspection from a local authority, or a request to submit samples for disease testing. Many of the registration forms are online now, and you should consult your local beekeeping association for information on the process where you live. Not registering your hives could result in a fine, or the seizure of your hives by authorities, it is very important you know the rules and regulations around keeping bees in your country.

Making your operation organic

Organic beekeeping means that the products you offer from your own hives are almost completely free from chemical residues. You achieve this quality by adhering to a specific set of regulations in your beekeeping practices that are usually defined by country. Having an organic certification can allow for higher sale prices and niche marketing to turn a better profit, however these conditions are often hard to meet if the land use in your area is dominated by intense, industrial-scale agriculture. Generally, there must be a set radius around your hives where nothing but organic practices are applied to the land, and this area must also be free of major pollution sources. Though it is different for every country, generally the radius is approximately 5km ($80km^2$). In choosing your apiary location for an organic certification you must be aware of the practices not just on private land, but also the government approved regulation of things like weeds and invasive species on roadsides and public spaces that could be counted as sources of pollutants.

It is not just the surrounding land use that must be organic in nature, the equipment and practices in the apiary must also adhere to these rules: hives must be made from natural material, free of chemical treatments like varnish or fungicide, wax foundation and bee feed must also be from a certified organic source, no synthetic treatments such as antibiotics or miticides can be used (organic acids like formic and oxalic acids for Varroa mites are acceptable). In some cases, honey must be kept below a certain temperature.

Operations that meet these requirements can apply for a certification, where their hives and products are appraised by an official body. If the assessment is successfully passed, the beekeeper may apply an official certification seal on the labels of their products for that assessment period, which is generally one year.

Regulations for this certification vary widely between countries and regions and it is important to do thorough research before attempting to apply for it.

5.3 Honeybee nutrition

A good beekeeper will keep bees much like other animals, maintaining good health through careful monitoring and action. The basis for healthy bees is a good diet and being aware of what your bees are foraging for themselves and what they lack. This will help you keep your hives alive and productive.

5.3.1 bee feed, honey, pollen, supplements

What do bees need?

Bees need a steady diet of nectar and pollen, and tree resins for the making of propolis. Nectar acts as the central energy source for bees and is necessary for wax production. Pollen is processed to feed the queen and developing larvae and contributes to the making of more bees. Tree resins are mixed with wax to form propolis, the main anti-microbial agent in a colony and their first line of defense against bacteria, fungi,

and viruses. Most often, bees can collect all these resources for themselves and require very little additions from the beekeeper, but with an increase of intense agriculture, and more volatile weather patterns due to climate change, these resources are decreasing in many areas, and it may become necessary for beekeepers to put more care into how their bees are fed.

Floral diversity and natural nutrition

Bees are burst crop pollinators, and this means they collect most of their resources from only a few very general species, but that does not mean they never harvest from others, and, a diversity of flowers often generates the best nutrition, and presents a much longer time where resources are made available to the bees. Some crop flowers offer sugar ratios that are not as beneficial to bees, and their pollen can be protein and nutrient poor, or contain too much or too little fat. It is a good idea to read up on the latest research on the crop plants your bees will be getting and try to find out if your bees are missing anything that could be supplemented.

Bee feed and other supplements

Feeding your bees is necessary at several times in the year, new splits in spring benefit from feeding, and during dearths when there are no natural resources, and of course, after the honey harvest, to replace the honey you have taken. This feed is very simply: sugar and water in various combinations. Bees need 3 major types of sugar: sucrose, glucose, and fructose and these are the three most common sugars found in natural nectar. In terms of supplements, sucrose is by far the best option for your bees, and this can be found in the normal, table sugar you use in your home. Bee feed is never fully solid, and usually is mixed into a paste or a syrup with a good quantity of water. The ratios of sugar to water in bee feed also vary with season if you want to maintain the health of your bees: in cold autumns, bees may not have the space or time to take a lot of water away from the sugar to store it properly, so a 66% sugar solution might be ideal, whereas in spring, the bees consume resources quickly, and more water (50-40% solution) helps them process the food faster. In some circles it is believed that adding an acidifying agent to the sugars to invert the sucrose into glucose and fructose is better for the bees as it reduces the need for expensive metabolic processes. No scientific confirmation has been given to this, and if used inappropriately, acids in bee feed can be detrimental to their health.

Pollen supplements

There are hundreds of nutritional supplements on the market for bees and many of them are sensationalized to be much more than what they really are. Many of them are also more expensive than they need to be. Fundamentally, science does not know a large amount about honeybee nutrition beyond the fundamental protein and some crucial minerals, vitamins and fats, so most commercial supplements are built around this. The differences come in the source of protein used. Ideally, the best protein for your bees is pollen. It is the source they have evolved to digest and process, but if your operation is large, pollen can be expensive to purchase, and if you are applying for an organic certification, it can be nearly impossible to buy. Many supplements use other protein sources, like those form soy, seaweed, or yeasts.

Bees need a pollen or supplement containing over 20% protein, anything below this is not considered sufficient for good bee health. Most pollens contain between 20 and 30% protein, but not all pollens. A protein supplement quality with a high protein content means you can provide your bees with less

supplement for the same effect: Giving your bees 3kg of a 20% protein supplement is the same as giving them 2kg of a supplement with 30% protein. The type of protein will also play a role in how it affects your bees, the amino acid profile is important to look at and compare with natural pollen, and the fat content will aid with palatability. If a supplement is not appetizing, the bees will not take it. There may be a risk of an excess of sodium in pollen substitutes and if you opt for this strategy, it is important to monitor your bees and try to provide pollen whenever it is affordable.

5.3.2 Organic aspects of nutrition

If going for an organic certification, natural food is all the more important. It if the best way to assure the organic origin. Outside of this, if/when supplements need to be fed, organically certified products might be the only option in many countries to keep your own certification on your bee products. If purchasing wax foundation, the wax must also have an organic certification, or you risk contaminating your own wax.

5.4 Colony propagation

One of the most important skills you can learn as a beekeeper is how to split your hives. Splitting allows you to control swarming, replace lost hives, control Varroa mites and grow your operation without spending money buying bees. Propagating your own colonies allows you to select from your own stock and control traits like gentleness and honey production. Splitting hives successfully means you may also be able to make a surplus to sell to other beekeepers. The process is theoretically simple but comes with several requirements and conditions to do it safely and effectively.

5.4.1 timing

Splitting a hive can only be done when the colonies are strong enough to survive the operation and have the spring and summer nectars to grow back. Generally, when colonies begin to produce drones, this is an indication they are fit enough to swarm, in which case, they are strong enough to be split. The other element of creating splits are the queens. Drones must be available to mate with the new queens produced to take control of the split hive. You can allow a colony to replace the queen themselves if you provide the new, queenless split with eggs from the mother queen, but generally it is a good idea to choose the queens yourself, whether from your stock or a breeder, to maintain gentleness and other desirable traits in your lines.

5.4.2 How to split a colony

There are many ways to split a colony, and the basic principle is to divide the number of bees, so you end up with two smaller colonies. In the height of summer each split should recover quite quickly and be strong enough to produce honey latest the following year. If your central business is to sell splits and swarms and not collect honey, you can start as soon as the colonies are strong enough to begin making drones.

In a natural swarm, a virgin queen is made and flies out to mate, once she returns, the old queen leaves with a swarm of adult worker bees to start the new hive while the new queen takes over the brood-filled colony. This process is essentially what you are trying to recreate. You should normally never try to split a colony into more than two each year, or you risk losing all of the colonies because they are too small.

You can begin by placing a new box in place of the colony you want to split. This is very important because if you shake bees into a new box and move it, the bees will simply fly out and return to the original place where their old hive was standing. You want bees to fly into the new box, so this new box must stand where your old hive was. The brood (with the bees sitting on it) and the old box you can move to a new location, because the nurse bees are enticed to stay with the developing brood. Make sure this box has enough bees to keep the brood warm and healthy, and check it afterwards to make sure they stay there. Distance between the old and new hives can be tricky, the ideal is to move it at least 2km away, so the bees cannot fly out and return to their original hive, however a lot of people do not have the option for this, so it is imperative you collect the majority of the nurse bees (found on open brood frames) and make sure they move with the brood.

Now you have an old box with brood in a new location, and a new box with only bees in the old location. Creating a broodless split is a good way to get a new colony with a low number of Varroa mites, and 70% of the mite population is found in the brood at any given time. Make sure both colonies have a honey frame with pollen or, if there is no honey in the colony, feed them right away so they have the resources to recover from the process. Each box should also have 1 or 2 new wax foundation frames, so you can track their willingness to build new comb, a good indication of queen status. Giving them a little pollen too helps them rear brood right away. These two colonies won't be able to collect much honey for you until likely the next year.

At this point, you have one queen which, depending on the method, will go into the old colony with the brood (this might not prevent colony swarming) or into the new colony with no brood. We will discuss the method closest to natural swarming, with the old queen being put into the broodless split. The old queen will generally always be accepted back into the colony right away. Then you will either need to buy or breed a new queen for the second box, or, allow the bees to create their own queen by giving them a frame full of eggs. Allowing the bees to make their own queen is the slowest but surest way to get an accepted queen, taking 2-4 weeks for the entire process.

Once the old, brood-filled colony has been queenless for several days, go back into this box and look for any queen cells they may have tried to start themselves. If you do not want them to make their own queen, remove these cells and make sure there is no brood left young enough for them to start making more, only then are they likely to accept a queen of your choosing.

It is also possible to split the brood between the old and new box as well, this provides the new colony with a cohort of younger bees to keep the colony processes consistent. The colony you are aiming to introduce a queen too should ideally have only capped brood, this makes it much easier and faster to introduce the queen, because there will be much less brood on the frames that the bees can create their own new queen from (it is always a good idea to wait and check just to make sure there are no eggs or young larvae left on the frames.

If making colonies to sell, generally you make smaller splits called nucs. These splits are generally in a 6-frame box, have 2-3 frames of brood and one frame of honey, with enough bees to cover each frame. Normally you will introduce a mated queen to the box before selling it. Making smaller splits allows you to make and sell more of them, but nucs must have the time to grow throughout summer or they will not overwinter well. There are many resources to cover the different ways of creating a split, and it is very beneficial to do research on the method that works best for your region, operation size and time restraints.

5.4.3 Split colony care and troubleshooting

Once you have your successful splits, it is a good idea to check up on them once a week for the first month and make sure they are happy with their new queen and not trying to replace her.

Check if they have enough food and are collecting more. New comb is a good sign that the queen is healthy and if she has not started laying eggs yet, she will start soon. Sometimes, for many reasons a split doesn't grow as quickly as it needs too. Check to see if the queen is laying well, a queen will not lay if the colony has very little honey or pollen and providing that may help. Queens will also stop laying in dearths, when there is no nectar flow, so liquid food might stimulate egg laying.

If the brood pattern is small and patchy, the queen may not have been mated well, but usually the bees will catch problems with the queen and they will begin making queen cells. If there are not enough bees in the split, its growth will be very slow. Adding a frame of brood or two, and enough bees to cover them might give your split the strength it needs, but you should never add more than the number of bees that are already in the colony at once. If there are too many bees added from a foreign colony, they may try to kill the queen. After a few weeks, if nothing goes wrong you should have two healthy colonies prepared to overwinter, and in the spring, they will be strong enough to start producing honey, or, be split again.

5.5 Queen breeding

Breeding your own queens is a long process, it is time-consuming and difficult, but this is a good trade-off for the strength it lends to your operation if you can master it. Breeding your own queens gives you access to as many queens as you need to grow your amount of hives at precisely the times you need. It allows you to track and keep the traits in your own population consistent, it can permit you to select for special traits like Varroa resistance. If your stock is healthy and productive, you can sell virgin and mated queens for a very good price, stock your own nucs and run courses on queen breeding for other

beekeepers. Queen breeding is a highly coveted skill. To get started you will need a few things: A large enough population to keep the genetics of your bees clean and healthy (you can work together with other beekeepers in your area for this), several extra colonies not used for splits or honey production (these will be your queen breeder colonies and provide bees for the mating nucs), queen cell frames and cups, cages, grafting tools (the Chinese grafting tool or a paintbrush are good choices), marking paint and a way to incubate your queens in separate cages, most beekeepers use an incubator indoors in a closed off room. You will also need time. Queen breeding usually requires some sleepless nights during the days the queens emerge. If all of this seems possible, this next section will outline the basic process.

5.5.1 Creating a queen breeder colony

Timing for queen breeding begins when your strongest colonies begin making drones in mid to late spring. To have your bees ready to make queens, you will need to create a queenless colony. This can be done by creating a split with bees, capped brood and, simply not adding a queen to it. Before you can use this colony for queen breeding it is very important you look through it 4-5 days after making it, to take away any queen cells they may have created themselves. If there are queen cells in your breeder colony they will not build the queen cells you will graft into them. Create this colony by taking at least two frames of capped brood from another colony (or two colonies depending on strength) and take some bees to care for it. This queen breeder colony must be taken far enough from the parent colonies that the bees cannot fly back, and must stay queenless, with the capped brood. You must also make sure they have pollen and honey (or liquid bee feed) so they do not starve and have the resources to make your queens. Rearing queens takes a lot of protein, and they cannot do it without a good source of pollen. When you are ready to graft, leave 1-2 frame spaces open at the back of the hive. This is the space for the queen cell starter frames. Each colony should only be given 1-2 queen frames at a time. Generally, these colonies will forage for themselves, but it is always good to keep an eye on their resources to make sure they have what they need. If you are doing multiple rounds of breeding, adding more capped brood to replace the brood that emerges will keep the bees primed for queen rearing.

5.5.2 Queen breeding (grafting and incubation)[1]

Keeping detailed records on performance is always good when you are trying to breed from your own stock. Once you have your breeder colony or colonies, and they are *definitely* queenless, it is time to begin grafting.

Prepare all your equipment beforehand so you can do the grafting quickly. The larvae you graft with will not be able to tolerate being out of a colony for more than a few hours depending on the climate in your grafting room. Queen cell starter frames are made from the top bar of a normal frame, with rows of plastic or rubber queen cell starter cups fixed to it approximately 2-3 cm apart. Cups can also be made directly from melted beeswax, but they are delicate and take time to make. These cups are open on the bottom and open downwards which is the correct orientation for a queen cell and will tell the bees that the larva inside must become a queen. You can have a frame with 2 bars, the second fixed halfway down the frame. If rubber or plastic, the cups should be carefully coated in beeswax before grafting day, this is not necessary but often increases the acceptance rate of the larvae. To prepare the cups, it helps to have some queen jelly, warmed to room temperature, or collected fresh from an unwanted queen cell in your breeder colony. Some beekeepers mix the jelly with a small amount of honey to entice the bees to investigate the cells more closely. You do not have to provision the cells, but some find it makes a large difference. Dip the end of a matchstick in the queen jelly mix and just touch the bottom of each cup. This provides the young larva with moisture and food which will keep it healthier for longer. Make sure you have your grafting tool on hand, this is a thin metal stick with a sculpted tip to make collecting the young larvae out of their cells easy.

Choose a frame of young brood (1-3 days after hatching) from the colony you wish to breed from. Generally, one of your top-performing, healthiest colonies, so you can ensure the best of your bees are providing the genetic background for your new queens. The larvae should not be more than 3mm long. The younger the larvae, the more likely the bees will build out the queen cell and rear them. Do not take eggs. Take these frames of brood to a warm room with good light and keep them covered in a box with a damp towel to prevent them from drying out.

[1] The method of queen breeding discussed here has been recorded from the breeder Terje Reinertsen in the Oslo region of Norway. There are many adaptations to the techniques, but this course will discuss only the basics, using the Reinertsen method as an example.

Take the first frame of brood and prop it up on your table with a block of wood under the top bar so it is tilted toward you. Using a box cutter knife, gently scrape the tops of the cells away, so the larvae at the bottom are more accessible. It is important to take larvae of the same age, this will narrow the time window when they emerge, the step which requires the most regular (and overnight) attention. Select a larva and very gently slip your tool under it, picking it up without changing its orientation. The larva will be lying on its side in the cell, looking like a tiny croissant. It is very important that the larvae be placed in the queen cup on the exact same side it was lying on. Once in the cell, rotate the tool or brush gently to slip it back out from under the larva without disturbing it. Once all cells on the bar contain a larva, turn it so the cells point down again (the larvae will not fall out) and put them back in the box covered in the damp towel. Be careful not to jog or shake the frame, or the larvae might get bumped out of position and be removed by the bees. Once all the frames are filled with your chosen larvae, bring them back to your breeder colony and place them gently in the center of the colony, between brood frames. If you have more than one queen frame, space them with a frame of brood in between. The origin of the nurse bees will not matter much for queen production. The genes from the colonies that provided the larvae will be the ones to provide the traits for your next generation.

For the next six days, the bees in your queen breeder colonies will feed and raise the larvae in your queen cups as queens. They build out the cells and will eventually cap them. Once a cell is capped it can be removed from the colony, caged with a specialized queen cage that fits over the queen cup, and transferred to an incubator. Having the incubator for the second part of the queen cell rearing is so that you can check on the queen cells without having to open your hives, which is difficult and takes a lot of time if you must check them regularly. A queen will emerge from her cell after 14 days from the egg being laid, which is about 10-12 days after the grafting. Incubators can be quite expensive, but the incubator does not need to be specially made for queen bees. Chicken egg incubators are often cheaper, can be bought second hand, and have all the temperature and humidity controls you need to raise your queens safely. Some incubators require a pan of water to be placed on the bottom of the cabin, it is important you know how to use your model properly. Once the deadline for emergence comes close, it is a good idea to begin checking your cells in the incubator every 4-6 hours. A queen must be fed and cared for hours after she emerges from her cell or she will die shortly after. Some beekeepers put a small cup of honey at the bottom of the cell cage, to prolong the life of the queen and lengthen the time between checking, but this has mixed results.

When you begin to check the cells, it is a good idea to make up a number of queen cages, provisioned with queen candy and 6-10 worker bees (the origin colony does not matter). These cages will provide a temporary home for your queens and allow you time to prepare the mating nucs.

Once a queen has emerged, she will be easy to handle for a time, gently take her out of the cage and place her onto a flat surface like a table, using foam or soft material to handle her. This prevents injury and an injured queen will not be able to fly out and mate properly. Pin her down using a queen capture tool or soft material and paint a mark on the back of her thorax using queen paint of the colour that is

used for that year. Most countries cycle between 5 colours in an international marking scheme. It is very easy to find out what colour is needed for the year you are breeding. Once the virgin queen is marked, place her gently in one of the prepared queen cages with the worker bees and keep the cages at room temperature. The queen will be given everything she needs by the workers in her cage and you can keep them like this for several days. Longer than that is possible, but the cages should be sprayed with water once a day. Generally, it is recommended to transfer them into mating nucs within 2-5 days of emergence.

5.5.3 Mating (Nuc making, free-mating and mating stations)

Nuc making

It takes a lot of bees to create the mating nucs needed to get your queens mated. A mating nuc is used to provide the queen with a miniature colony setting so natural behaviours can take place. It requires bees, small frames, a provision of sugar paste and an open entrance so workers can forage, and the queen can go on mating flights. Again, the bees used for these nucs must be kept away from the parent colonies, or they will fly back to them and leave your queen stranded and alone. Many beekeepers use commercially available miniature boxes made of polystyrene, or wood if you are an organic beekeeper) with three easily movable frames primed with a small sheet of wax foundation. Once the nuc is prepared with food and wax, choose a colony that can spare the bees. If it is close to the end of your queen breeding operation for that year, you can use the bees from your breeder to fill the nucs. Shake a large volume of bees into a colony top or a bucket and spray them with a bit of water to keep them grounded. Then take about a cup and a half of the bees and pour them into a closed nuc box. Make sure there is ventilation in the box or the bees might suffocate. Once the box is placed in the mating area and the bees have had 24 hrs to settle, introduce one of your virgin queens. You can place the cage, or tip the queen straight in, both methods are effective. Then, you must wait until the queen mates and her ovaries develop so she begins to put eggs in the nuc frames built out by her worker cohort. Once a queen is laying well, she is ready to be sold and can be put back into a small cage with workers and candy, or sold with the small mating nuc itself, else, she can be introduced to a split you have made and kept or sold with a larger nuc or full colony.

If you do not have the means to start your own queen breeding operation, it is still good to experiment. Queens can be incubated above a working colony in separate cages, so you do not need an incubator. Or, once the queen cells are capped, you can introduce them into a mating nuc and the bees will rear them out for you. There are many ways to experiment. The method described above is the most efficient way to rear a lot of queens, using resources as wisely as possible.

Free mating and mating stations

The goal of queen breeding is to control the genetics of your stock, and queens are only half of this problem. The other half are the drones, which also play a big role in the quality of your bees. For some

beekeepers, their stock may be the only stock in the area, or else, controlling the queens is sufficient for them, and they allow their queens to fly among whatever drones are in the area, a process called “free-mating”. Some operations haver far too many mixed stocks in their area or else they are looking for a very specific list of traits or one specific race and want to choose the origin of the drones too. This requires a mating station.

A mating station is a communally used area where beekeeping is prohibited, so only drones from selected colonies placed there will be available for mating. These drone colonies are placed in the center of the area, generally about 15-20km away from any other colonies, and breeders can bring their virgin queens in mating nucs to mate with them. Mating stations are often run by a beekeeping organization or privately and will require a verbal contract or written registration. Rules and regulations around mating stations are different for every region so it is important to do local research.

The expense and time of breeding queens is not small, but you can reduce the burden by working together with beekeepers in your community, sharing the cost of equipment, pooling colony resources for breeding and nuc-making or simply sharing knowledge and experience. Within a group of beekeepers, it is almost always worth the effort to learn a bit about queen breeding.

6.0

Starting a Business in Beekeeping

6.1.1 Regional & national regulations on production, food safety, organic certification and taxation

Whether you already own a piece of land with an apiary or not, in order to grow your business and position your products on the market, you have to form an entity (as a legal or natural person) through which you can market and sell your products.

In Croatia, there are several types of entities, such as a d.o.o., j.d.o.o., craft and a family farm (obiteljsko poljoprivredno gospodarstvo). In this course, we will focus mostly on opening a family farm, which is the most common organisational form for beekeepers as it does not require you to invest an initial capital and have specific professional qualifications, and the registration costs are also low.

Family farm

A family farm is an organisational form of an economic operator as a natural person farmer who, in order to generate income, independently and permanently performs an agricultural activity and related ancillary activities using own and/or leased production resources based on the work, knowledge and skills of family members. A family farm is intended for natural persons only. Produced products and/or services are placed on the market, i.e., the production takes place with the aim of generating income.

Before you start a business, you should get in touch with a commissioner of a beekeeping association active in the area in which you want to set up your apiary. The commissioner visits the apiary and registers your beekeeping operation in the Apiary Cadastre and a national Register of Beekeepers. You will then receive a certificate with the registration number.

Depending on the residence of the holder of the family farm, you should visit a regional office of the Paying Agency for Agriculture, Fisheries and Rural Development (PAAFRD). The PAAFRD issues a Decision on the registration in the Farmers Register/ Family Farm Register and assigns the identification number of

Do not forget to provide the name of the accounting firm keeping financial records to the Tax Administration. You can choose to keep financial records for yourself, but it is highly recommended to hire an expert.

Establishing a family farm in Croatia

Registration in the Farmers Register - Regional Office of The Paying Agency for Agriculture, Fisheries and Rural Development (PAAFRD)
Giro account opening – a bank of your choice
Registration in the register of taxpayers liable to income tax – Tax Administration regional office
Application to the pension insurance institute - regional office of The Croatian Pension Insurance Institute (HZMO)
Registration for compulsory health insurance - regional office of the Croatian Health Insurance Institute (HZZO)
Bookkeeping

In accordance with the Rules on the registration in the Family Farm Register, the holder of the family farm must record the services in the Record of services provided on the family farm in the AGRONET application.

the family farm (MIBPG).

To be able to sell your products at fairs, shows and farmers' markets, you have to be registered in the Farmers Register and fill in a Request for the registration of an object in the food business of animal origin (primary production). With the Request, you have to enclose a copy of the Decision on the registration in the Farmers Register and pay the administrative fee in the amount of HRK 35.00 and send it by post to the Ministry of Agriculture.

This guide is of informative character and written based on the current requirements. Before starting a business, make sure to consult with competent institutions, such as the Paying Agency for Agriculture, Fisheries and Rural Development (PAAFRD) and the Ministry of Agriculture.

For more detailed information about starting a beekeeping business in Croatia and the list of the required documentation, check out a detailed guidebook published by the Ministry of Agriculture.

Make sure you get some practical beekeeping experience before starting a business.

You can take up beekeeping courses, learn from more experienced beekeepers and eventually acquire one or two hives to learn how to keep and provide for your bees. You need to know how to protect them from disease, predators and elements and know the area in which they forage.

It is very important that you familiarise yourself with all the laws governing apiculture in your country before starting a business. Depending on the country, there might be special permits required or restrictions put in place. Also, when it comes to product packaging and labelling, make sure that your label contains everything required by the national legislation. In Croatia, you can find all the information about food labelling and food quality standards on the websites of the Ministry of Agriculture.

Furthermore, it is recommended to join your local beekeeping association and the national umbrella organisation, such as the Croatian Beekeepers' Association, to have access to all the latest information and support.

6.1.2 Food safety specifications for your business and organic certification

According to the publication "Steps to register a family farm for the processing of raw materials of plant origin" of the Directorate for Professional Support to the Development of Agriculture at the Ministry of Agriculture of the Republic of Croatia, a family farm that wants to process primary agricultural products and put them on the market as processed products or food products, should be entered in the Family Farms Register. In the aforementioned Register, a family farm must enter its production resources that will be the subject of the processing, and when family farm decides to process, it must arrange a facility for that purpose and register as a subject in the food business with the registration of that facility or processing. The State

Inspectorate carries out the registration of the subject in the food business and the registration of the facility for the processing of products of plant origin, and the control of meeting the minimum technical conditions in the facility. Application forms and instructions are available on the website of the State Inspectorate.

The facility is regulated in accordance with the directives of Regulation (EC) No 852/2004 of 29 April 2004 on the hygiene of foodstuffs, which lays down general rules for food business operators on the hygiene of foodstuffs. The Regulation shall apply to all stages of production, processing and distribution of food and to exports, and without prejudice to more specific requirements for food hygiene. According to the aforementioned Regulation, the general implementation of procedures based on the Hazard Analysis and Critical Control Point (HACCP) system is emphasised, which includes a whole series of preventive procedures aiming to ensure healthy food.

HACCP certification is an international standard defining the requirements for effective control of food safety. It is built around seven principles: Conduct Hazard Analysis of biological, chemical or physical food hazards; Determine critical control points, Establish critical control limits, for example, minimum cooking temperature and time; Establish a system to monitor control of Critical Control Points; Establish corrective actions; Establish a procedure for verification to confirm that the HACCP system is working effectively; Establish documentation and record-keeping.

HACCP certification instantly demonstrates to customers your commitment to producing or trading in safe food. This evidence-based approach can be particularly beneficial when you are subject to inspection by regulatory authorities or stakeholders. Demonstrating a real commitment to food safety through HACCP compliance can also transform your brand and act as an effective entry-to-market tool, opening up new business opportunities around the world.

ORGANIC FARMING

Organic farming is an agricultural method that aims to produce food using natural substances and processes. This means that organic farming tends to have a limited environmental impact as it encourages:

1. the responsible use of energy and natural resources
2. the maintenance of biodiversity
3. preservation of regional ecological balances
4. enhancement of soil fertility
5. maintenance of water quality

EU regulations on organic farming are designed to provide a clear structure for the production of organic goods across the entire EU. This is to satisfy consumer demand for trustworthy organic products whilst providing a fair marketplace for producers, distributors and marketers.

To market food products in the EU as organic, farmers need to implement organic farming techniques and have their facilities audited by an accredited certifier. These requirements are specified in the Regulation (EU) 2018/848 of the European Parliament and of the Council of 30

May 2018 on organic production and labelling of organic products. According to the Annex II of this document, the core requirements for organic beekeeping are as follows:

1. the siting of the apiaries shall be such that, within a radius of 3 km from the apiary site, nectar and pollen sources consist essentially of organically produced crops or spontaneous vegetation or crops treated with low environmental impact methods equivalent to those provided for in Articles 28 and 30 of Regulation (EU) No 1305/2013 of the European Parliament and of the Council of 17 December 2013 which cannot affect the qualification of beekeeping production as being organic
2. crops on which the bees feed must not have been chemically treated
3. artificial feed must carry organic certification
4. diseases must not be treated with veterinary medicines, only with approved organic substances
5. bees must not be stupefied while the honey is harvested
6. the hives should be made of natural materials

All the other relevant regulations on the organic sector in the EU can be found at the following links: Legislation for the organics sector, Committee on organic production, The organic logo.

QUALITY SYSTEMS AND MAIN STANDARDS

Organic production

If you wish to become an organic beekeeper, you must be certificated through a control body. That involves a yearly inspection and a set of checks to make sure you comply with the rules on organic production. To produce organically, one has to undergo a process known as 'conversion'. During this period, organic production methods need to be used, but the resulting product cannot be sold as organic. The length of the conversion period depends on the type of organic product being produced:

- 3 years for orchards of perennial soft, top and vine fruits,
- 12 months for pig and poultry grazing,
- 2 years for land ruminant grazing annual crops.

ISO STANDARDS

ISO 9000ff is the fundamental generic quality system.

ISO 14000ff quality management system establishes regulations and work procedures in the field of environment protection. Its aims are: reducing a negative impact on the environment, harmonising the business with relevant legal and sublegal acts, and continuously improving the previous two aims.

EMAS (ECO MANAGEMENT AND AUDIT SCHEME)

By entering the EU, entrepreneurs from the Member States have received new possibilities and obligations when it comes to quality management and environmental impact systems. The EMAS regulation was introduced by the European Commission in 1993. The regulation defines

an efficient and usable tool for managing the organisation's environmental impact. It requires annual improvements, as well as the influence on suppliers and subcontractors. The ISO 14001 requirements are an integral part of the EU EMAS standard – Eco-Management and Audit Scheme.

6.1.3 How to obtain financial support in beekeeping

Each EU country may draw up a National Apiculture Programme covering a three-year period, which is then supported by the EU. The National Apiculture Programme, which is continuously implemented, aims to create better conditions for beekeeping in Croatia and increase competitiveness in the beekeeping sector. The implementation of the National Apiculture Programme is co-financed by the European Union. Recognising the importance of the beekeeping sector at the global level, the EU has proposed increasing its contribution to beekeeping support programmes for all Member States during the transition periods of 2021 and 2022 and under the new Strategic Plan of the Common Agricultural Policy (CAP) 2023-2027.

Under the Croatian National Apiculture Programme 2020-2022, beekeepers and beekeeping organisations may apply for funding within eight specific measures: Technical assistance to beekeepers and beekeepers' organisations, Suppression of bee pests and diseases, especially varroosis, rationalisation of the costs of migratory beekeeping, Measures to support laboratories for the analysis of bee products with the aim of supporting beekeepers to market their products and increase their value, Measures supporting the restoration of bee stocks in the Union, Cooperation with specialised bodies for the implementation of applied research programmes in the field of beekeeping and beekeeping, Market monitoring, Improving product quality with the aim of exploiting the product's potential on the market.

Keep in mind that to be eligible to apply for the Croatian National Apiculture Programme measures, you must be registered in the Beekeepers Register, managed by the Croatian Beekeeping Federation.

The measures are announced by the Ministry of Agriculture, so make sure to follow the announcements to be able to apply for funding before the deadline. If necessary, contact your local beekeepers' association or business support organisations to find some assistance with the application. More information about the measures is available at this link.

6.2 Introduction to small business planning and entrepreneurship

An entrepreneurial idea is the foundation of a future business, and it can significantly depend on motivation and the way we set the business up. To some people, a business venture is a replacement for an existing or lost job, and to others, it is a way of changing their lifestyle or earning more money.

Check out the mission and vision statement by the company named Leeco Honey, situated in Lexington, Texas.

"Our mission is to grow bees ethically and naturally in order to

SETTING THE COMPANY MISSION, VISION, GOALS AND OBJECTIVES

As a first step in planning your beekeeping business, you should set your mission and vision. The mission defines the purpose and the goal of your business, and it is more present-oriented. The vision focuses on the future, and not only on the future of your company but also on the future of the sector or the society as a whole, which you wish to improve with your operations.

A good mission includes:

- Your company's purpose and values
- What do you want your company to be (product, service or market), and who the main stakeholders and key accounts are
- Your responsibilities towards your customers
- Main goals that support the implementation of your mission

Before starting a business, it is highly recommended to write a business plan, which will help you analyse, estimate and keep track of the costs and your business goals. It is especially important to write a good business plan if you need a loan for your business or are applying for grants because you will need to demonstrate that you have thought about every detail. For business plan writing, you can use an online application developed by TERA Tehnopolis from Osijek, Croatia, that will guide you through the entire process and greatly facilitate the financial part of your business plan with built-in automatic calculation tools.

Think about what you will sell!

When it comes to your product range, try to think outside the box. Are you planning to sell only honey, or can you stand out among the competition and offer multiple or innovative products that will help you build your income? Besides honey, you can sell beeswax, propolis, swarms or queens, as well as beekeeping supplies. Maybe you can offer apitherapy, pollination services or grow crops that are suitable for bees but also for sales. If you have a lot of knowledge and experience, you can offer practical courses for amateur beekeepers. Furthermore, you can make and sell a variety of products based on honey, such as food and drinks or even candles made from your own beeswax. If you put your creativity to work, the possibilities are endless. Make sure to explore different opportunities for income. Note that you can always expand your product range based on new ideas, knowledge and market demand.

Now that you have decided on your initial product range, it is time to determine the budget necessary to make your beekeeping venture a reality.

To determine the costs of your operation, you should first identify your business needs.

- Write down all the expenses you might have already incurred but do not forget to add the expenses necessary to launch a business. Those might include business registration fees, licences, insurance, taxes costs of purchasing or renting land for your apiary, beekeeping truck if you are planning to be a migratory beekeeper, accountant, marketing, website, salaries (if applicable) and, of course, all the equipment and supplies for your beekeeping operation. Do not forget to include honey jars and labels.

- Now do some research and note the average prices of all the items on your list. You can visit the government offices or find the information on their websites to determine the business registration costs, and you can find the prices of equipment and supplies by browsing through web shops or requesting quotes from the vendors. It is a good idea to set aside around 10% of your budget for marketing.
- Now divide the list into one-time (e.g., business registration and license fees, equipment, website development) and ongoing expenses (e.g., supplies, marketing, website maintenance, taxes, accounting, insurance, etc.). The ongoing expenses should reflect a monthly price, and you can multiply them by the number of months and add the one-time costs to get the estimated expenses of your business.

Keep in mind that there are two different types of ongoing costs: **fixed** and **variable costs**. The calculation of variable and fixed costs will help you establish the prices of your products and/or services. Also, include those costs in your business plan to be able to estimate when your business will become profitable.

> **Variable costs** are those that change based on how much you produce and sell. They increase as production rises and decrease as production falls. Some of the most common types of variable costs include labour, utility expenses,

When you have calculated the costs of your beekeeping operation, you can check out the available national and EU funding opportunities, as well as funding options and loans offered by banks and government agencies to help you set off your business. It is always a good idea to set some money aside for unforeseen expenses and complications that might arise when starting and managing a business, e.g., late payments, as well as risks connected with beekeeping, such as unfavourable weather conditions, predators, low honey yield and bee diseases.

When you launch your business, it is important to keep track of your earnings and expenditure to create a balance. In some countries, it is mandatory for family farms to keep track of and report their income and expenses to competent bodies. However, it is highly recommended to do that regardless, to be able to financially manage your business and find out where you can cut the expenses if necessary.

The best way to do that is to create a spreadsheet and list down all your expenses, noting where, when and how much money you spend. Update the list regularly with both the expenses and income. At the end of the month, subtract your total expenses from your income. If the result is negative, that means you have to cut some expenses and revise your budget. If the result is positive, you might be able to invest in the development of new products or services or expand your capacities. To better plan your finances, try to revise your budget at least once every six months.

Local market research

Ask yourself: “How far will people come to buy my products or services?”

The answer depends on the type of product or service you are providing and other similar businesses that provide the same product or services in the area, i.e., your competitors. If there

are not many beekeepers in and around your area who offer the same products, people might come from farther away to buy your products.

1) Identify the profile of your customers.

   Ask yourself:
   - What age are my potential customers?
   - What is their purchasing power?
   - What are their needs and preferences regarding packaging and the product itself (in terms of the general public, retailers, and wholesalers)?
   - How do they want to be approached and buy the products (on the doorstep, in stores, web shops)?

2) Identify your competitors.

   You will have to find out how many competitors there are in your market area. You can do this with the help of Google Maps ("find businesses"). Also, in some countries, there are publicly available digital databases that can be filtered by region, city and activity.

   Use all the information you have acquired to better plan your sales and marketing strategy.

Selling your products

There are many cost-effective ways to sell your beekeeping products.

You can start by selling directly to the customers at your doorstep or at the local farmers' market. Also, always be on the lookout for fairs and festivals or other local events and try to get a stand to promote and sell your products. It is important that you find out the cost of renting a stand and how many people are expected to attend to learn if it would be cost-effective.

You can also sell your products at local privately-owned retail stores, as well as restaurants or cafes. In some countries, beekeepers supply honey to local schools and kindergartens, so it might be worth exploring that option as well.

Furthermore, an online presence is very important nowadays, so think about setting up your webshop if you have enough products and varieties of the same product for it to be cost-effective. Of course, if you do not have enough capacity to run your webshop, you can create a website that will include your contact information or a form for customers to be able to order your products online. You can also join one or a few online food shops available to expand your market and reach a greater number of customers all over the country. You can send your products to the customers via local courier companies for a small fee.

If your products are organic and of premium quality, it is a good idea to sell them at specialised organic or delicatessen food stores. You can also sell via specialist networks or brand owners who already have established sales channels. However, be aware that such companies may purchase your honey and apply their own label to your product.

Finally, as in every business, it is important to utilise and expand your contact network. Get help from your friends, family and relatives in getting out the word about your business and find local partners that might help you sell and promote your products.

6.3 The power of the brand: Marketing & promotion

The basis on which you build your brand is, of course, your product. Whether you sell in the local or other markets, word of mouth remains the fundamental way to promote your product. Nowadays, it is very simple to go online and write a review of a product or a business, which will be seen by other potential customers. Thus, both negative and positive reviews can create a significant impact on your business.

Due to the rise of fake or low-quality honey on the market, consumers are getting more aware and careful when buying honey. They will sooner pay more than risk buying cheap, fake honey. One jar of inferior honey can bring you a lot of negative PR and sink your business. Therefore, it is important that you ensure the quality of every jar you sell and do not deceive your customers for short-term benefits. As long as you can guarantee the quality of your honey, your product will stand out, and you will be able to reach more customers and grow your business.

To start, you can gift a few jars of honey or your other products to your friends and neighbours, who will likely recommend them to their friends as well. It is also a good idea to give out free samples at the farmers' market or fairs to let people taste your products and encourage them to buy and come back for more.

However, before you start promoting your beekeeping business, you should create a visual identity that will make your products visually stand out and be recognisable among other similar products. Put a lot of thought and research into designing a logotype for your brand. It is recommended to hire a professional to design the visual identity of your company, and there are many crafts run by talented people who might charge much less for those services than large companies.

Connect with your customers

When you are selling your products directly to the customers, tell them your story. Tell them about your passion for beekeeping, how you started and what you love about it. Romanticise your products. Educate them on how to use the product and include it in their everyday lives. For example, let them know which type of honey they can use in cooking, which one goes best with tea or coffee and why. Enthusiastically suggest a few recipes to inform your customer about different uses of honey as a condiment or an ingredient to enrich various meals. Try to paint a picture of your love for bees and your and your bees' hard work to create the product. With that picture in mind, the customer will surely want to support you and your work.

Moreover, post such stories on social media and regularly write engaging content on your website or blog. Publish photos of your apiary to let your customers see from where your products come. If you put effort into connecting with your customers and are transparent about your operations, you will gain their trust, and they will always come back to buy from you.

Work with the designer to create a logotype that shows the customers what you stand for and make your brand stand out through the use of colour and shape. Let your visual identity tell the story of your brand.

Packaging and label design are just as important to make your products stand out from the competition. When choosing, for instance, honey jars, you should take into consideration the cost, shelf presence, size and the practicalities, such as how easy they are to fill, how the lid fits and attaches, and how easy it is to apply a label and how durable they are. Similarly, you can opt for cheaper, ready-designed labels, which will not do much for your product in terms of standing out among other honey jars on the shelf, or you can use online tools to design your label yourself or hire a professional. You should also think about the characteristics of the label. You might want to check if it is easy to peel if it can be wiped clean, if it is partially or fully bespoke or if it is biodegradable. Depending on the product and the target market, you might need a transparent label or one that does not fade when displayed in direct sun.

You should always adapt the packaging and labels to the market you are targeting, e.g., unusual and more attractive jars and labels for the gift market. Make sure that the labels fit the jars before the purchase - you could cut out pieces of paper to see which size and shape look the best.

Do not forget to check national requirements for the mandatory information on the label at the back of the jar!

It might also be a good idea to check out other products on the shelves to check the prices and assess if your product would attract attention. Also, when displaying your products at the farmers' market or fairs, try to arrange them in a creative way to make them look more attractive or ‘rustic’.

Now that you have a good visual identity and a market-ready product, social media is a great way to promote your business, which you can use without any cost. You can increase your visibility by regularly posting new and engaging content, networking with like-minded beekeepers, commenting on others’ posts and sharing content from reputable sources. Of course, you can periodically invest a small amount of money into paid ads, which can help you reach a larger pool of potential customers.

It is also highly recommended to create a website on which you can promote and sell your products. There are free website builders or those that charge a small fee and do not require you to possess web design or coding skills to use them. Again, if you have the budget, it is recommended to hire a professional to create a unique website that will surely attract attention.

Moreover, never miss the opportunity for promotion in local or national television or newspapers to share your story with a greater number of people and increase the chances of scaling up your business.

In essence, neither a brand nor a successful business can be created overnight. It is a long but achievable process in which you will face both success and failure. However, be patient and do not give up. With a lot of hard work and a bit of creativity, the sky is the limit.

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Co-funded by the
Erasmus+ Programme
of European Union

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Proj No: 2019-1-PT01-KA202-60782
beeB - Foster for beekeeping bridges through innovative and participative training